On the Attitudes towards Automation in Determining the Intention to Use Automated Buses in Scotland

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ABSTRACT

The vehicle automation technology is expected to bring significant benefits to transit systems. In order for public transportation to continue being a viable mobility alternative to private modes, automated technologies are anticipated to be actively utilized in the future. Investigating public perceptions and their determinants at an early stage is important to inform policies that will support the acceptance and future adoption of automated buses. The objective of this study is to investigate the factors that affect intentions to use automated buses using an extended version of Technology Acceptance model. To that end, survey data were collected from bus users in Scotland. An Exploratory Factor Analysis was conducted to identify latent attitudinal constructs potentially influencing intentions to use automated buses. Considering the ordinal nature of the dependent variable, ordered models were estimated using SPSS. Age, gender, and experience with automated vehicle technologies were found to be crucial factors in the absence of attitudinal constructs. Young males with experience of using or seeing automated vehicle technologies are more likely to use automated buses at the early stage. The fear regarding their navigation on roads, the perceived usefulness, enjoyment of using the system, trust, perceived safety, and security influence how early one will adopt automated buses. Unlike the expectations, perceived ease of use (PEU) did not emerge as significant. The socio-demographic variables lost their predictive power when used along with attitudinal latent variables. The findings of this study highlight the importance for policy interventions to increase public awareness about automated buses.

Keywords: Automated Buses, Technology Acceptance, Intentions**,** Ordered Model; Attitudes

INTRODUCTION

In recent years, the field of Automated Vehicle (AV) technology has been rapidly growing. The potential benefits of fully automated private vehicles have been largely investigated over the last decade; these include improved safety (through eliminating human driving errors), decreased traffic congestion, improved accessibility through a wide palette of mobility solutions, reduced emissions, more productive use of travel time (*1*), increased effective road capacity and reduced fuel consumption (*2*). However, the wider societal benefits such as reduced traffic congestion, reduced need for parking spaces, mobility alternative for people with lower income, improved safety, and environmental benefits will be prominent only when AVs become common and affordable. At the beginning of the AV transition, issues due to high costs and limited performance are expected to happen *(3)*. Reliable operations in mixed traffic and unfavourable weather conditions, regulatory approval and acceptance among public are some of the potential barriers. Some long-term negative outcomes of AVs may be related to the increased number of vehicles on road and subsequent congestion (due to the increase in number of private vehicles with low occupancy rates), job losses, and workplace shifts for those currently in driving-related occupations (*4*).

Transportation agencies need to leverage the benefits of emerging automated and connected technologies to transform public transportation services so they can operate in the traffic networks as competitive mobility alternative to private modes (*5*). The implementation of partial or full automation technology in bus transit offers similar benefits as previously discussed (apart from more productive times in case of bus passengers). These benefits could be materialized without the risk of exacerbating traffic congestion, as with private AVs. In particular, automated buses (ABs) are expected to lower bus fares due to reduction in operating costs (*2*).

Public transportation authorities are advised to implement suitable pilots as a starting point if they are planning to introduce ABs in their public transit systems (*6*). The CAVForth project in Scotland, UK is considered one of the world's most ambitious automated vehicle pilot (www.cavforth.com). A fleet of five Level 4 automated (fully automated vehicle operation with a safety driver onboard) full sized buses will operate a scheduled service with Stagecoach East Scotland for six months, carrying up to 10,000 paying passengers per week. The buses will drive along a 14-mile (22.5 km) route between Ferrytoll Park and Ride facility in Fife and Edinburgh Park across the Forth Road Bridge in Edinburgh (See **Figure 1** for the route map), in mixed traffic conditions on public roads at speeds up to 50 mph (*7*).

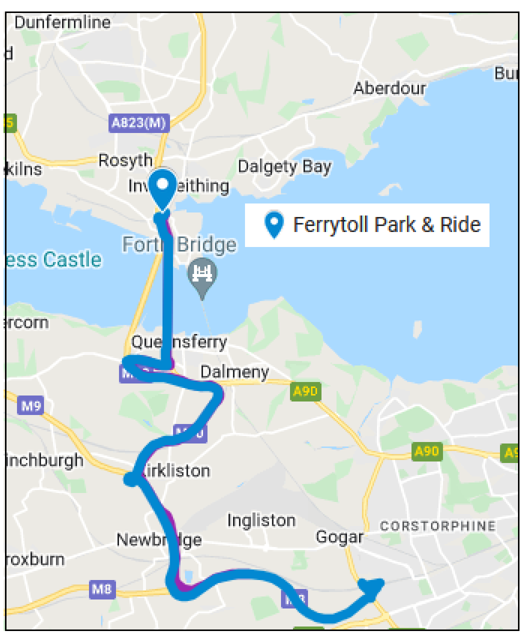

Figure 1 Route map of CAVForth Project

Public involvement in the planning process is crucial for developing the services as well as for measuring the public feedback after the project implementation. The expected benefits of automation in public transit depend on passenger attitudes and acceptance (*8*). Hence, investigating the public perceptions and factors affecting the decisions of users is fundamental to understand the future appeal of ABs to the commuting population. The main objective of this study is to identify the factors that shape the acceptance and intentions to use the proposed automated bus service in Scotland. The study features an extended version of the Technology Acceptance Model, by investigating the impact of attitudinal variables on usage intentions, when used along with socio-demographic characteristics and experience with automated vehicle technologies. The level of significance placed by potential AB users on facilitating conditions, hedonic motivation, personality traits like trust, scepticism, which have not been explored in the context of full-sized Level 4 automated public transport in the past to the best of our knowledge, is investigated using a latent variable approach and ordered probit models.The findings of the study can inform future policies of transit authorities and operators targeted at boosting the awareness of public of the operation of automated buses.

LITERATURE REVIEW

A significant amount of research has been conducted in the field of private AVs in the past decade. Men, highly educated individuals, residents of densely populated areas, members of households without a car and owners of vehicles with automated features overall have more positive attitudes towards AVs than others (*4*, *9*, *10*). Several socio-psychological models have also been used in the past to study and explain user acceptance of emerging technologies. Technology Acceptance Model (TAM) is popular in the field of transportation research. (*11*) postulates in TAM that Perceived Ease of Use (PEU) and Perceived Usefulness (PU) are the two fundamental constructs underpinning the attitudes towards a technology, which in turn, predict behavioral intention and actual usage. Many researchers have used this framework and have extended the core constructs of TAM to include additional variables, relevant in particular contexts (12). The flexibility of its structure, which can be readily tailored to the characteristics of the study context, is one of the useful aspects of TAM. Adaptations of TAM have been used to explain technology acceptance in many studies in the transportation field – concerning, for instance, intentions to switch to public transport, eco-driving interfaces, navigational systems as well as intention to use AVs (10, 12, 13). The consideration of attitudes has been proven capable of increasing the explanatory power of TAM (14).

Nordhoff *et al* in (*15*) studied the determinants of acceptance of driverless shuttles in large cross-national samples using core constructs of TAM. Transportation-related attitudes, pleasure, and personality related attributes were also considered. A Principal Component Analysis (PCA) was conducted on all items in the questionnaire, measured on a Likert scale, finding that domain-specific attitudes were more important determinants than socio-demographic characteristics (*15*). Perceived use, fear, trust, hedonic motivation and perceived safety were found to be steady predictors of both behavioral intention to use and willingness to pay in studies considering automated cars (*10*, *16*, *17*). The results of the studies that investigated the role of socio-demographic characteristics and psychological factors in influencing the intention to use ABs provide heterogeneous indications (*8*, *9*, *18*). For example, although many studies found that younger people were more likely to use AVs than older people, others found that the effect of age varies with the level of automation, or non-significant effects of age (*9*) or older people were more likely to intend to use AVs (*19*, *20*). Similarly, PEU was found to be non-significant by (*10*) and (*14*). A better understanding of the effect of PEU is important to design the bus services that suit the needs of the targeted population

Previous research in the area of public transit automation has been limited compared to private or shared AVs, especially studies about attitude and intentions (*20*). Azad *et al* in (*18*) reviewed the literature on the studies on fully automated buses, acknowledging that pilots and associated research in automation of public transit in the last few years have been mostly about automated shuttles operating on demand on short route lengths, either in closed environments or as first/last mile solutions. The majority of studies considered private vehicle drivers to be the target population, because of the general belief that AVs will replace conventional vehicles. However, automation technology could also be used in buses or trains, hence, the perceptions of public transport users are of great importance as well (*21*). Moreover, previous acceptance studies tended to focus on automation levels lower than SAE Level 4, except a very few studies like the CityMobil2 project running pilot services across Europe with Level 4 automated vehicles, but with lower capacity (2 to 10 persons) and lower speeds (approx.12mph) (*10*). Little is known about the perceptions of bus users towards highly automated larger AVs like buses. Furthermore, the factors affecting the acceptance vary significantly in the literature; hence, the findings of previous studies cannot be simply transferred to encourage the use of new systems. To address this gap and supplement the existing knowledge, this study focuses on understanding the public attitudes, specifically towards full-sized ABs operating scheduled services on public roads. This is achieved by developing discrete choice models to investigate the public acceptance of ABs by using an extended version of TAM, which considers several socio-demographic and behavioral factors.

DATA

A questionnaire-based survey targeting Scottish bus passengers was used to collect data about perceptions and attitudes towards ABs. The survey was disseminated to the Stagecoach passenger mailing list. The survey was administered through the online platform Qualtrics. A total of 1,054 responses were received between October the 15th and November the 5th 2021. The CAVForth automated bus trial was briefly introduced during the survey.

The questionnaire was composed of a wide range of questions around the following topics: socio-demographic characteristics, household characteristics, travel characteristics (current modes of travel and frequency of use, modes of travel and their frequency of use before pandemic), general acceptance of technology, experience with current Automated Driver Assistance Systems (ADAS), attitudes towards ABs as well as intentions to use them. Many determinants of acceptance of AVs identified by previous studies, namely (*8-10*, *15*, *16*, *19-22*), were introduced in the questionnaire. These include PU and PEU along with hedonic motivation/perceived enjoyment of the system, personality-related attributes, such as trust in driverless vehicles, anxiety regarding operation in demanding situations and interaction of automated buses on road, perceived safety and security, facilitating conditions (knowledge about ABs, infrastructure and maintenance required for ABs), transportation-related attitudes (such as satisfaction with bus services, and car dependency). These factors were measured by questions, which required responses on a 5- point Likert scale.

The acceptance of a new system can be measured through the intention to use it, which is a predictor of the actual usage. The participants were asked to respond to statements regarding their readiness to use the service (how early they are likely to adopt), and intended frequency of use of the proposed automated bus service when it becomes available to the public. The two variables are considered indicators of acceptance (*19*). The readiness to use ABs was measured on the scale:

i. I would be the first one to use
ii. I would use it soon after they are available
iii. I usually wait for a while
iv. I am usually the last person to use
v. I avoid using it unless they are absolutely necessary
vi. I refuse to use no matter how popular they become

In the analysis, respondents were classified into three categories: early adopters (people who chose i or ii), late adopters (iii and iv), reluctant/non-users (v and vi).

METHODOLOGY

Exploratory Factor Analysis

An Exploratory Factor Analysis (EFA) was carried out to reduce the dimensionality of variables defining the attitudes towards ABs. An extended version of Technology Acceptance Model (TAM) was used as an underlying theory for categorizing attitudinal items in the questionnaire under different constructs as shown in **Table 1**. When used as an exploratory tool, factor analysis does not require any statistical assumptions, except that the variables measuring the same underlying factor are significantly correlated to each other (*23*). EFA is frequently used in studies involving attitudes and behaviour, such as response of users to new arrivals in the market and studies of how environment-friendly attitudes affect behavioral intentions (*24*). EFA has been widely adopted in studies of travel intentions and behaviour, e.g., (*10*, *25*, *26*), to name a few.

TABLE 1 Attitudinal Variables Categorized into Different Constructs

Constructs	**Items**
Perceived Usefulness (PU)	ABs will be more comfortable than conventional buses (PU1)
	ABs will reduce bus travel times (PU2)
	ABs will increase bus punctuality (PU3)
	ABs will encourage bus operators to introduce more frequent services and/or new bus routes (PU4)
	ABs will have environmental benefits e.g., through reduced bus emissions, more efficient driving styles etc. (PU5)
	ABs will improve road safety overall (PU6)
Perceived Ease of Use (PEU)	I do not feel a steward on board is important for practical support like assistance with accessibility, luggage etc. (PEU1)
	I do not feel a steward on board is important for information (PEU2)
	I do not feel a steward on board is important for personal safety (PEU3)
	I do not feel a steward on board is important for faster boarding (PEU4)
Facilitating Conditions (FC)	ABs are something I do not know much about (FC1)
	ABs require too much public investment (e.g., infrastructure and maintenance) (FC2)
Hedonic Motivation (HM)	ABs are something I am very interested in (HM1)
	ABs are not boring (HM2)
	ABs are not fear inducing (HM3)
Transportation Related Attitude (TA)	I am satisfied with the bus service in my area (TA1)
	I can structure my everyday life very well without a car (TA2)
	It is not difficult for me to travel the ways I need to go in everyday life with public transportation instead of by car (TA3)
Trust (TR)	ABs are trustworthy (TR1)
	ABs are be safe for me to use (TR2)
	AB technology will be reliable (TR3)
Anxiety in Demanding Situations (AN)	Not comfortable with ABs driving itself at night (AN1)
	Not comfortable with ABs driving itself in bad weather(AN2)
	Not comfortable with ABs driving itself on public roads with other vehicles (AN3)
	Not comfortable with ABs driving itself on public roads with cyclists and pedestrians (AN4)

Constructs	**Items**
	Not comfortable with ABs navigating roundabouts by itself (AN5)
	Not comfortable with ABs stopping and departing from bus stops by itself (AN6)
	Not comfortable with ABs stopping at red traffic lights by itself (AN7)
	Not comfortable with ABs opening and closing doors automatically by itself (AN8)
Perceived Safety and Security (PS)	It would be difficult for the bus driver monitoring an automated bus to maintain attention throughout the day (PS1)
	Automated bus would not sense all that is happening around it (PS2)
	An AB could be made unsafe through a computer virus or hacking just like any other computer system (PS3)

The EFA was carried out by means of a Principal Component Analysis (PCA) with Varimax rotation on the attitudinal items measured on Likert scale. Although the aggregation of the originally observed variables might result in loss of some information, PCA helps interpret data sets with large number of variables, by reducing their dimensionality. PCA is widely used as an exploratory method to reveal underlying structures in datasets, by explaining the variance-covariance structure by means of linear combinations of the originally measured variables (*27*). PCA has been extensively employed to examine the sources of variation in perceptual data relating to attitudes and acceptance of AVs, as for example, in the studies of Nordhoff et al. (*15*, *19*) and Madigan et al. (*28*). The formulation of the PCA is in accordance with (*27*). If n observations, each characterised by the measurements on P variables (a set of correlated variables), are expressed in an n × P matrix X, with each cell representing the individual observation of a variable:

$$X_{nxP} = \begin{bmatrix} x11 & \cdots & x1P \\ \vdots & \ddots & \vdots \\ xn1 & \dots & xnP \end{bmatrix} \quad (1)$$

Then, the PCA extracts principal components using the variance-covariance matrix X. The components are expressed as a linear combination of originally observed variables, say, first principal component:

$$Z_1 = a_{11}x_1 + a_{12}x_2 + \dots + a_{1p}x_p \quad (2)$$

that maximizes the variance of all variables, subject to the constraint:

$$a_{11}^2 + a_{12}^2 + \dots + a_{1p}^2 = 1 \quad (3)$$

All the extracted prinicipal components should be uncorrelated with each other. Eigenvalues of the sample variance-covariance matrix X are the variances of the principal componentsand the corresponding Eigenvector provides the coefficients to satisfy the constraint in Equation (*3*). In the end, any components that account for relatively small proportion of variation in data are discarded (*27*).Thus, the outputs of the PCA are the components/factors, which consist of uncorrelated latent attitudinal constructs representing groups of correlated observed variables. We used the factor scores (composite scores obtained from the average of all variables forming a particular factor) as predictor variables in modeling the intention to use ABs. The SPSS software was used to identify the minimum number of factors, which explains the maximum variance across all variables.

Ordered Logit Modeling

Considering the ordinal nature of the dependent variable ‘intention to use ABs’, an ordered logit model is estimated using SPSS. Ordered models are defined by an unobserved variable, z* that is specified as a linear function for each observation *n*, as:

$$z_n^* = \boldsymbol{\beta}\mathbf{X}_n + \varepsilon_n \quad (4)$$

where **X** is a vector of explanatory variables determining the discrete ordering for observation *n*, **β** is a vector of estimable parameters, and *ε* is a random disturbance (*27*). Using the Equation (4), each outcome of the observed dependent variable, *y* is linked with the unobserved variable z*, as follows:

$$y_n = 1 \text{ if } z_n^* \leq \mu_0$$

$$y_n = 2 \text{ if } \mu_0 < z_n^* \leq \mu_1$$

$$\ldots\ldots\ldots\ldots$$

$$y_n = I \text{ if } z_n^* \geq \mu_{I-1} \quad (5)$$

where μ are thresholds of the ordered logit process that define *y*, and I is the highest integer ordered response. The thresholds also constitute estimable parameters of the model.

Initially, a model is run to predict the intention to use ABs, considering only the non-attitudinal variables. The PCA components capturing the attitudes towards ABs are then added as independent variables along with the non-attitudinal variables. The change in the coefficients and significance of the variables are noted to understand how the predictive power of non-attitudinal variables change with the introduction of latent attitudinal constructs in the model.

RESULTS

Profile of Respondents

The sample drawn from the survey was representative of Stagecoach passengers in terms of gender, but it included slightly fewer respondents in the 65+ years age group data. Thus, the sample could be more tech savvy and might not be representative of the whole Stagecoach bus passenger population. The sample has a slight over-representation of full time employed people (39.2%). This is not surprising since commuters are the major group of public transit users in Scotland, and especially bus users. The mailing list consists of passengers who purchase online tickets or those who use Wi-Fi on-board.

Acceptance of the Automated Buses

Figure 2 compares the distributions of the readiness to use any new technology in general with the readiness to use automated buses. The figure shows that the percentage of early adopters of ABs is high (52%), proving a general trust in the technology. However, the percentage of reluctant/non-users is larger for ABs (19%) when compared to technology in general (8%), hinting at the fear of automated driving for a significant proportion of respondents.

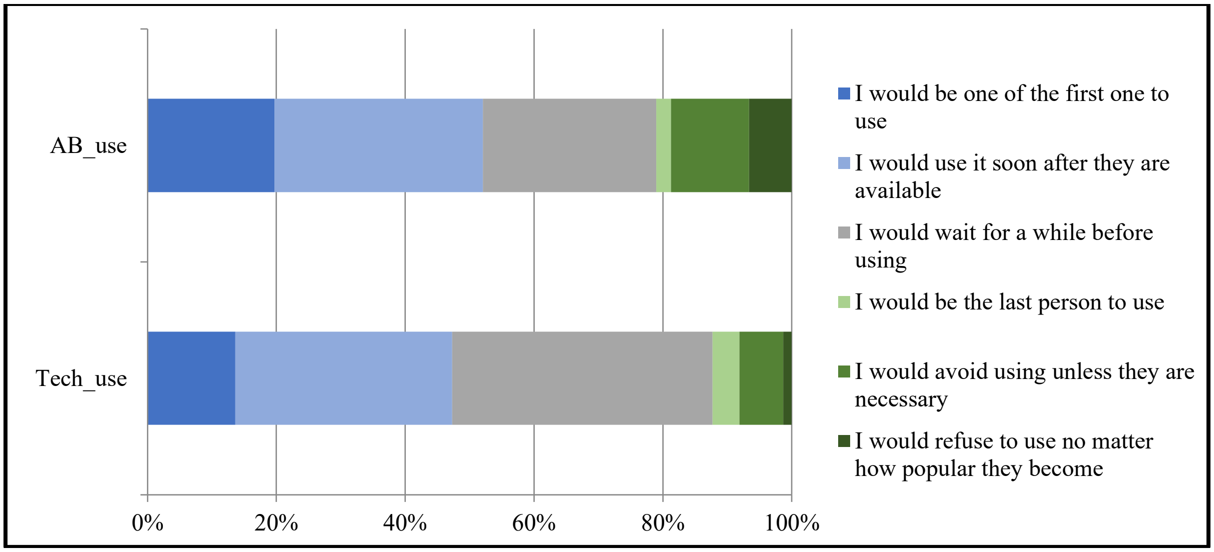

Figure 2 Readiness to Use Technology in General Vs Readiness to Use ABs

Figure 3 presents the percentage distribution of expected change of bus use after the introduction of ABs. 59.5% of respondents expect their frequency of bus use to be about the same even after the introduction of ABs in service, i.e., the vast majority of respondents feel that the advent of automation technology would not significantly affect their choices for bus travel; this is an expected finding considering the complexity of the mode choice mechanism. The distributions are almost symmetrical, with the proportion of people expecting to use buses if automated (21.7%) being similar to that of respondents who state that they would use buses less often after the introduction of automation (18.8%).

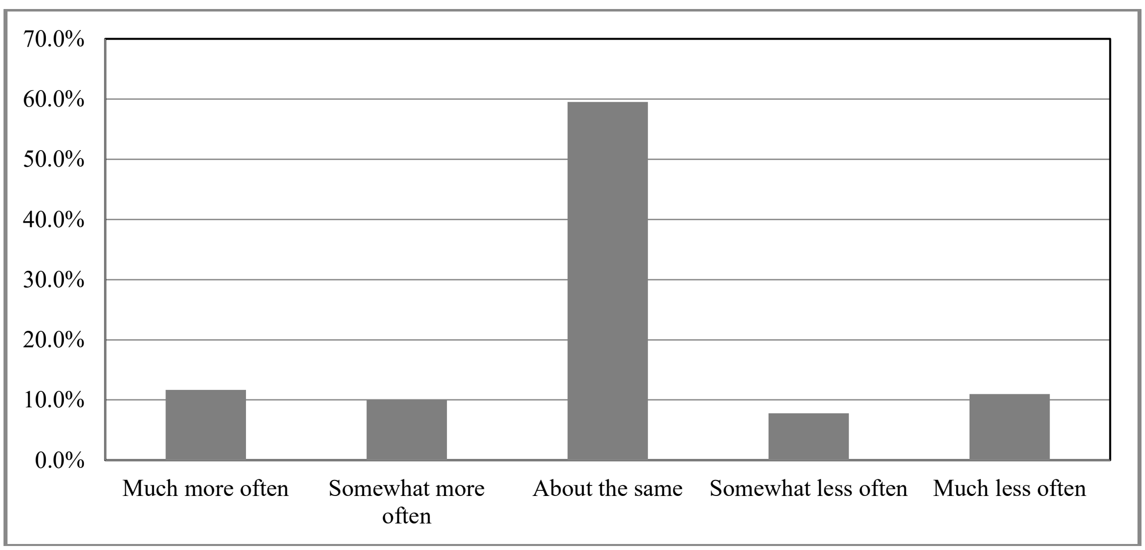

Figure 3 Frequency of bus use after introduction of ABs

Technology Acceptance Model Attitudinal Variables

The criteria for extracting the factors/constructs from observed attitudinal variables using PCA are: (i) the Eigenvalue should be greater than 1; and (ii) the factorial loads must present values above 0.5 (*29*). The Cronbach alpha values, Kaiser-Meyer-Olkin (KMO) statistics and Bartlett's spherical hypothesis tests were adopted to assess the reliability and validity of the constructs prior to factor analysis. Some variables were gradually removed to improve alpha values, if the communality (percentage variance that can be explained by the high loading factors) were low, or the factor loadings were smaller than 0.5, or if the variables had large cross loadings (one variable loads highly on two or more factors), a procedure similar to previous studies (*10*). The factors and factor loadings obtained after PCA are given in **Table 2**.

TABLE 2 Results of Principal Component Analysis

Variables	**Components/Factors**					
	Factor_1	Factor_2	Factor_3	Factor_4	Factor_5	Factor_6
PU1		0.720				
PU2		0.781				
PU3		0.741				
PU4		0.665				
PU5		0.744				
PEU1				0.720		
PEU2				0.793		
PEU3				0.769		
PEU4				0.696		
HM1			0.647			
HM2			0.686			
TA2						0.838
TA3						0.838
TR1			0.785			
TR2			0.729			
AN1	0.776					
AN2	0.773					
AN3	0.780					
AN4	0.772					
AN5	0.812					
AN6	0.776					
AN7	0.796					
PS1					0.737	
PS2					0.646	
PS3					0.656	

It is clear from **Table 2** that the variables can be grouped in six underlying latent constructs, which explain 69% of the variance among all variables. The results indicate that variables were loaded on factors as expected apart from variables relating to hedonic motivation (HM) and Trust (TR), which were associated in a single factor. The FC variables were removed due to the low reliability of the variables. Thus, the six components drawn from the PCA and their interpretations (given in **Table 3**) are used in modeling intention to use ABs as described in the following section.

Determinants of the Intention to Use Automated Buses

The dependent variable of the ordered logit models is the "intention to use automated buses" (AB_use), measured using three ordered categories: early adopter (coded 2; 52.0%), late adopter (coded 1; 29.2%) and reluctant/non-user (coded 0; 18.7%). The predictor variables are grouped in two sets for the ease of understanding and are given in **Table 3**:

TABLE 3 All Variables Tested in the Model

No.	Description
Set 1: Non-attitudinal variables	
1	**Gender:** Male (coded 1), Female (coded 0), Non-binary
2	**Age**:18-25, 26-34, 35-44, 45-54, 55-59, 60-64, 65-74, 74+
3	**Employment status**: Employed full time, Employed part time, Self employed, In full time education, Unemployed and seeking work, Full time carer, Permanently retired from work, Looking after household, Sick or disabled and unable to work
4	**Educational qualification**: O grade, Standard Grade; Higher Grade/Advanced Higher; HNC,HNC; First Degree; Post Graduate; Professional qualification
5	**Total Household Income** (GBP): 0-10,000, 10,001-20,000, 20,001-30,000, 30,001-40,000, 40,001-50,000, 50,001-60,000, 60,001-70,000, 70,001-80,000, Over 80,000
6	**Household type**: Number of adults, Number of Children, Number of cars available for use
7	**Concessionary travel pass** (free of charge travel on bus): Yes (pass holder); No
8	**Driving license:** Full UK license; Provisional UK license; Overseas license; Disqualified from driving; License surrendered on medical grounds; Did not reapply for license at age 70; Surrendered license-given up driving, Never held a UK license
9	**Long standing illness/disability affecting travel choices:** Physical health issue, Mental health issue, Both physical and mental issues, No health issues
10	**Financial concerns:** Paying bills is a constant struggle; Paying bills is tough but I get by; My monthly bills are affordable and I don't worry about it too much; I never worry about monthly bills
11	**Frequency of travel using each mode of transportation** (Car as a driver, Car as a passenger, Bus, Train, Walking or Cycling): Before Covid-19 pandemic and Current
12	**Experience with automated vehicle technologies:** Yes (have seen or used before) or No
Set 2: Latent attitudinal variables obtained after PCA	
13	**Anxiety in demanding situations** (Factor_1)
14	**Perceived usefulness** (Factor_2)
15	**Hedonic motivation and trust** (Factor_3)
16	**Perceived ease of use** (Factor_4)
17	**Perceived safety and security** (Factor_5)
18	**Transportation related attitudes** (Factor_6)

In the final models, we retained the variables that were statistically significant at a 95% level of confidence or higher. The model results are presented in **Table 4**. Throughout the model estimation process, we monitored the model statistical significance (i.e., whether the final model has a significant improvement over the intercept-only model), and goodness-of-fit measures to assess the overall explanatory performance of the model. We also conducted tests of parallel lines to ensure that the assumption of proportional odds has been met. The results of all tests and measures were satisfactory.

TABLE 4 Ordered Logit Model Results

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Model 1 (without latent attitudinal variables)								
% Correctly Predicted = 54.9%								
Threshold	[AB_use = 0]	-2.662	0.298	79.809	1	0.000	-3.246	-2.078
	[AB_use = 1]	-1.256	0.275	20.906	1	0.000	-0.717	-1.794
Location	Age	-0.176	0.088	4.031	1	0.045	-0.347	-0.004
	[Experience with automated vehicle technologies =0]	-0.714	0.188	14.388	1	0.000	-1.082	-0.345
	[Experience with automated vehicle technologies =1]	0[a]	.	.	0	.	.	.
	[Gender=0]	-0.708	0.189	14.100	1	0.000	-1.078	-0.338
	[Gender=1]	0[a]	.	.	0	.	.	.
a. This parameter is set to zero because it is redundant.								
Model 2 (with latent attitudinal variables)								
% Correctly Predicted = 79.6%								
Threshold	[AB_use = 0]	-4.288	0.408	110.418	1	0.000	-5.088	-3.489
	[AB_use = 1]	-0.286	0.189	2.278	1	0.131	-0.657	0.085
Location	Anxiety in demanding situations	-2.864	0.272	110.667	1	0.000	-3.398	-2.331
	Perceived usefulness	1.205	0.184	42.886	1	0.000	0.844	1.565
	Hedonic motivation and trust	1.658	0.197	70.511	1	0.000	1.271	2.045
	Perceived safety and security	-0.695	0.174	15.999	1	0.000	-1.036	-0.355

Model 1 (without latent attitudinal variables

The coefficient for the variable indicating experience with automated vehicle technologies is negative implying that those without experience of automated assistance systems in vehicles are associated with lower scores of intention to use ABs. Similarly, females are less likely to be encouraged to use automated buses compared to males. The odds of females to be reluctant to use ABs is exp (0.708) = 2.03 times that of males. The respondent's age is measured on an ordinal scale. Age is a statistically significant factor and yields a negative coefficient, suggesting that older people tend to be more reluctant to use ABs when compared to younger people.

Model 2 (with latent attitudinal variables)

Another ordinal model is run with 'AB_use' as dependent variable after adding the attitudinal constructs to the previous set of independent variables. The parameter estimates for Model 2 are also given in the **Table 4**. Out of the six attitudinal variables, four were found to be significant with $p<0.0005$. The latent constructs, which were found to be significant, are:

Factor_1: Anxiety in demanding situations

Factor_2: Perceived use

Factor_3: Hedonic motivation and trust
Factor_5: Perceived safety and security

Perceived ease of use (Factor_4) and transportation related attitudes (Factor_6) were not found to significantly affect the intention to use of ABs. Variables from the Set1 group were no longer significant when the attitudinal variables were added in the model. The coefficients for 'anxiety in demanding situations'and 'perceived safety and secuirty' are negative, which implies that as the anxiety regarding the operation of ABs and perceived safety and security concerns increase, the odds of using ABs decrease. In other words, fear and safety and security concerns about the operation of ABs are associated with decrease in the odds of using ABs at an early stage. This is an intuitive finding, as people skeptical about ABs are more likely to be reluctant to use them. The coefficients for Factor_2 and Factor_3 are positive, which suggest that as the perceived use and hedonic motivation and trust increase, the odds of scoring higher for intention to use ABs increases. Thus, as the perceived benefits, pleasure, and trust on the system increase, automation is more effective in attracting people to buses. The proportion of correctly predicted observations by the model is 79.6 %. That is a notable improvement compared to 54.9%, which is the corresponding proportion in the model with Set1 variables. Thus, the inclusion of the latent behavioral constructs results in a significant increase in the predictive power of the model. **Figure 4** represents the dependent variable, latent factors, observed variables and the corresponding coefficients obtained from PCA and ordered logit modeling results for Model 2.

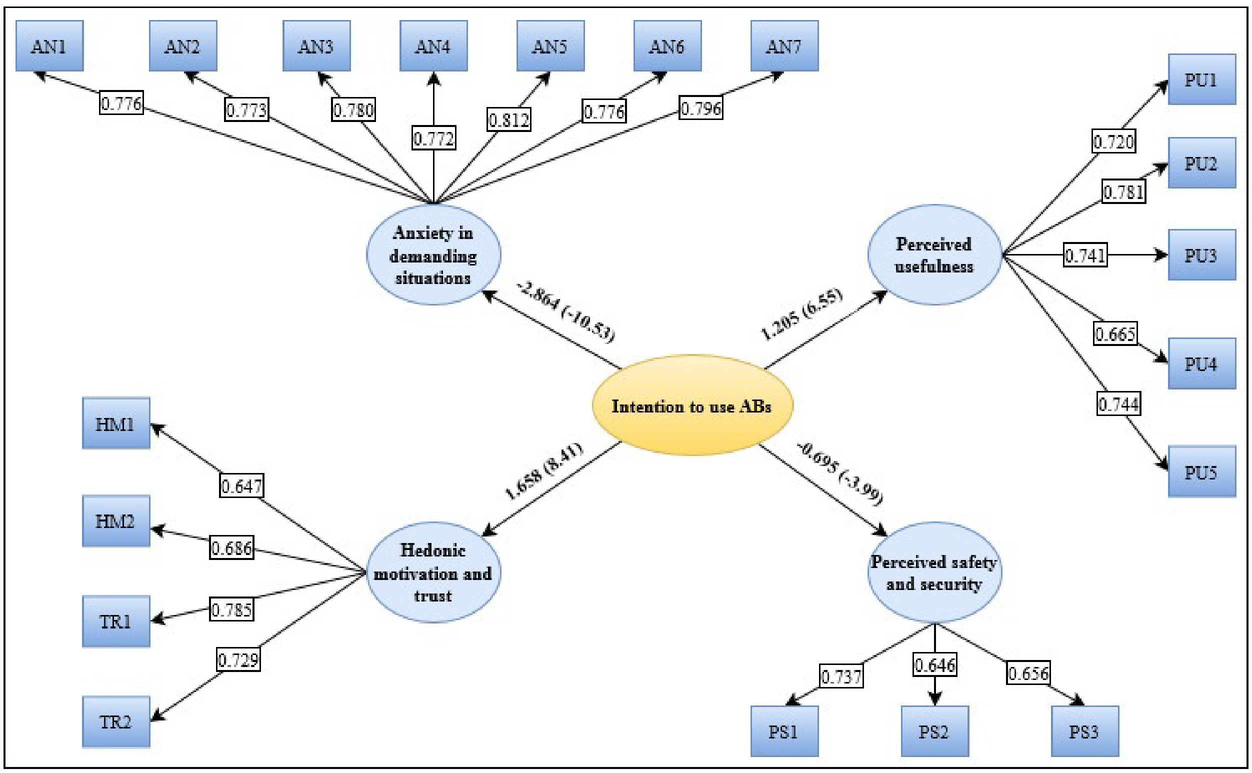

Figure 4 Relationship between dependent variable, latent factors and observed variables

DISCUSSION OF RESULTS

In the model, without the latent attitudinal constructs, gender, age and experience with automated vehicle technologies were found to affect intentions to use ABs. Gender is found to be the strongest predictor with b= -0.708, followed by the variable experience with b= -0.714. Age is found to be the least strong predictor with b= -0.176. The coefficient for the gender shows that men are more favourable towards ABs than women. This finding is in line with many of the acceptance studies in the field of automated vehicle technology (*4*, *21*, *30*). The results also indicate that older people are less likely to use ABs at an early stage. This might be because they are more concerned about the safety of these vehicles and more worried about using them on their own. Younger people were found to be more likely to use automated vehicle technology as compared to their older counterparts in previous studies as well (*4*, *30*). Another factor that affects the readiness to use ABs is the experience or familiarity with any automation vehicle technologies. This result is in accordance with the findings of (*31*), who found that people who have used or seen adaptive cruise control in vehicles are more willing to pay for automated vehicles since they might be more comfortable with the removal of driving controls from humans (*31*). (*17*) also found that familiarity affected the willingness to pay for AV technology in China.

When the latent attitudinal constructs were considered as explanatory variables, anxiety regarding operation in demanding situations became the strongest predictor of intention to use ABs (b=-2.864,), followed by hedonic motivation and trust (b=1.658), perceived usefulness (b=1.205), and perceived safety and security (b=-0.695). However, one of the fundamental constructs of TAM, PEU was statistically insignificant (p=.446). The effect of general transportation related attitudes on intentions to use ABs was also statistically insignificant. In the second model, none of the non-attitudinal variables were significant, thus indicating that the impact of the gender, age and experience variables (which were significant in the first model) disappears. The results suggest that the intention to use ABs depend mainly on attitudinal factors. This effect was previously observed in (*10*), where the acceptance of automated public transit in Trikala, Greece was studied.

Hedonic motivation and trust is one of the strongest predictors of intentions to use ABs. This factor was found to be the strongest predictor influencing intentions to use low capacity automated transport systems (*10*). The extent of pleasure and joy that people expect to obtain from ABs has a strong influence on the intention to use them. Hence, operators should focus on users' needs and expectations about their on-board experience, which would be different for car users and conventional bus users. This is because there may not be evident changes for bus users in time value, deprivation of driving pleasure or stress relief due to non-driving as a result of automation (*32*), whereas the opposite would be expected for car users. Trust is a common thread in acceptance studies about automated technologies, with higher perceived trust typically leading to more favorable expectations about their use. Even though trust can be affected, to some extent, by attitudes towards and interest in technology in general, when it comes to automated buses, trust can be determined by the perceived safety and reliability of their operation, as suggested by the components of the latent trust variable, as well as the overall ease that individuals expect to feel when using the ABs (*13*). Anxiety regarding the operation of ABs in different circumstances, such as at night time, under inclement weather conditions, during boarding and alighting at bus stops, and in mixed traffic environment, is found to be important in determining people's intention to use ABs. People do have concerns about cyber-security aspects of ABs, and especially whether they could be hacked or attacked by computer virus. Safety risks like system failures and terrorist attacks were found to be one of the most important negative factors influencing acceptability of ABs in the focus group discussions conducted in Spain (32). In the context of data security, privacy too could be a source of anxiety for potential users, and particularly, whether their privacy could be invaded through data breaching or surveillance, thus potentially affecting their intentions. Perceived quality of service is another significant and positive determinant of intentions, in line with previous studies (*10*, *28*). The finding implies that those with positive perceptions of how well ABs will perform in terms of travel times, on-board comfort, service frequency, environmental and road safety impact are more likely to use ABs at an early stage. This is an anticipated outcome, given that previous research focusing on automated vehicles in general has highlighted the correlation of positive perceptions and tendency of early adoption (*33*).

PEU was not identified as a significant factor, which possibly suggests that either people are ready to put effort to use such new promising technologies or they expect that the use of automated buses does not require effort or skills from their part. The results of this study validate the recommendations proposed by (*10*), when they studied the user acceptance of automated road transit system using the Unified Theory of Acceptance and Use of Technoloy (UTAUT) framework. They concluded that effort expectancy (similar to perceived ease of use in TAM) is not a significant factor influencing intentions to use automated transit systems and it should not be considered in future studies in this field (*10*). In a general context of technology adoption, a similar observation was made by (*34*). Perceived usefulness has been consistently a significant factor affecting behavioral intention in majority of studies. But they stated that PEU has no direct influence on intentions, but an indirect influence that operates through PU.

It was also found that the predictive power of the models improved significantly with the inclusion of the latent attitudinal constructs. The results of this study emphasize the previous findings of (*9*, *15*, *31*) , that psychological and attitudinal factors are better predictors of the acceptance and use of any new technology than the socio-demographic characteristics. Exploring further the effects of such factors could provide more granular insights into the acceptance of ABs. However, age and gender were found to be significant only in the absence of the attitudinal variables. Data collection from more disaggregate and stratified samples could help further investigate the effects of socio-demographic characteristics on adoption of ABs and understand whether campaigns targeted at specific groups (based on the socio-demographic characteristics) are warranted or not. This is important, as (*8*) found socio-demographic variable like age to be significant even when latent constructs like trust and perceived safety were considered, suggesting that the impact of age on acceptance of ABs is heterogeneous.

CONCLUSIONS

The main objective of this study was to investigate the factors affecting the users' acceptance of automated buses using an adapted version of the Technology Acceptance Model (TAM). For this purpose, data from a survey carried out among the prospective users of an automated bus pilot service in Scotland was used. We examined the potential impact of personal attributes and attitudinal variables along with the conventional set of socio-demographic variables to explain the acceptance of automated bus technology. The results of the statistical analysis showed that the socio-demographic variables lost their predictive power in explaining intentions to use automated buses when used along with the behavioral constructs measuring the attitudes of potential users towards automated buses. The model with attitudinal variables also showed better predicting capacity than that with only non-attitudinal variables.

The attitudes of potential users to automated buses influenced how early they would adopt them. The fear and anxiety regarding the operation and navigation of automated buses on roads was found to be a crucial factor. The perceived usefulness of the system, the enjoyment or motivation to use the system (referred to as hedonic motivation), trust, perceived safety and security also significantly affected intention of respondents to use the automated buses. The study results, thus, provide evidence of usefulness of considering these potential influencing factors. Hence, attitude and behavioral intention factors need to be consistently included in studies on public acceptance of automated buses by future researchers. The findings of this study also corroborated previous evidence about the weak impact of 'perceived ease of use' on behavioural intentions to use automated road transport and it is recommended to rigorously evaluate the relative merit of considering this factor while investigating the determinants of public acceptance of vehicle automation.

The results re-iterate the need for potential users to be informed about the technology and vehicle capabilities of automated buses. Designing AB systems that could ubiquitously inform users about the operational status and anticipated manoeuvres of the ABs (21) can increase trust and reduce fear and concerns of the passengers. The policy-makers and governmental bodies should provide explicit certification processes and regulations, accounting not only for the technology performance, but also for the user attitudes and perceptions (35). Regulating the operation of ABs as well as the practices employed by the service operators through relevant laws could help to build confidence among public. Confidence and trust are particularly important for cyber security, which should be strong enough to safeguard the operating systems and software. The issue is especially critical in the case of buses, given the size of the vehicles – which may cause more damage than automated cars if hijacked – and the number of people on board. Policies and measures should be transparent and widely communicated so as to shape more informed public attitudes towards ABs, and to eliminate lack of trust and anxiety issues related to their operation. Perceived use also has a strong impact on the intention to use ABs. Thus, it is important for service providers to align the service provision and performance of ABs with passengers' priorities such as reliability, comfort etc., and general transportation goals such as sustainability, road safety and so on. Age, gender and experience with current automated vehicle technologies were found to be significant factors only in the absence of behavioral constructs. The specific segments of the population which are more inclined to adopt automated buses early could help foster a positive word of mouth as early as possible. This could help reduce the apprehensions and concerns regarding the system and gain trust among other segments of the population, which are more skeptical towards bus automation. Policy makers with the help of service providers should roll out pilot projects with incentives to the public to use the buses, as familiarity and experience with automation were found to shape intentions to use automated buses. Attitudes of people towards automated buses were found to improve after taking a ride in these vehicles (10), and more positive attitudes could highly influence usage intentions as suggested by our results. During these rides, "automation champions" could actively reach out to the passengers explaining them in plain terms the use of sensors, control and navigation systems, thus contributing to the improvement of public understanding of the technology.

The data may be subject to limited self-selection bias, as information was collected from the members of the mailing list of Stagecoach who voluntarily chose to respond. These people might be more interested in new technologies than the rest of population, or more positively inclined towards the use of buses. Hence, the findings of this study may not be transferable to the whole population. Biases due to the online survey administration are also expected. For example, responses could mostly be from people with higher online engagement. The findings of the study are subjected to perceptions about hypothetical scenarios, as the participants did not have any actual experience on ABs, and their responses were driven from general beliefs and information about automated bus that were provided during the survey. Surveying people without prior AV experience could lead to inaccurate mental models of AVs (*16*), hence, more studies need to be conducted after people experience riding in AVs. This is of particular relevance, as research has shown that there is a shift in acceptance of transportation systems before and after their actual use *(10).* Longitudinal studies to understand potentially changing trends over time are also important in the context of acceptance of any new technology. The effect of other factors, such as the cost of service and social pressure and norms, which were not considered in this study, could be also explored in future endeavors.

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AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: A. Fonzone, A. Rahim, G. Fountas and L. Downey; data collection A. Fonzone, G. Fountas and L. Downey; analysis and interpretation of results: A. Fonzone and A. Rahim; draft manuscript preparation: A. Fonzone, A. Rahim, and G. Fountas. All authors reviewed the results and approved the final version of the manuscript.

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