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Automated bus services – To whom are they appealing in their early stages?

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ABSTRACT

Amidst a period of operational and financial challenges for the bus industry, the advent of Automated Buses (ABs) could be an opportunity to boost the attractiveness of public transport. This paper examines the determinants of changes in bus use after automated buses have been deployed. Given that any impact of automation on bus use is highly subject to the public acceptance of ABs, we also investigate the determinants of eagerness to use ABs. As part of the CAVForth project, which aims to deploy the first AB pilot service in the UK, an online questionnaire was completed by 1,054 bus passengers in Scotland who were asked about their attitudes and expectations towards ABs operating with a trained human safety driver onboard. To identify the factors that shape expectations about ABs and future bus use, random parameter ordered probit and binary logit models with heterogeneity in the means were estimated. The results suggest a high prevalence of people who would be eager to use ABs, and a slight prevalence of people who intend to use buses more often because of automation. Five major categories of factors were identified as influential including exposure to AVs, system evaluation, travel behaviour and attitudes, personality, and socio-demographic profile of the potential users. Factors relating to current bus use, satisfaction, and car dependency induced mixed effect on respondents' expectations. Our findings are relevant for service providers and can inform the development of policies aimed at operational issues that could potentially impede the deployment of ABs and the recovery of the bus industry, especially in the fragile aftermath of COVID-19.

1. Introduction and background

In Scotland, bus use has been declining over time and the evidence suggests that the COVID-19 pandemic, has further contributed to this decline (Downey et al., 2022). 127 million Scottish journeys were made by bus in 2020–21. This was a reduction of 65 per cent since 2019–2020 and a 74 per cent decrease since 2007–08 (Transport Scotland, 2020a). Along with this decrease in bus use, there are indications that the Scottish bus industry is contracting, with the number of buses in the operators' fleet decreasing by 13% over the previous 5 years since 2015–16, along with a 23% fall in the number of staff employed in the industry over the same period (Transport Scotland, 2020a). A reduced bus network combined with a shift away from public transport may have implications regarding achieving the overall aim to reduce private car use, as outlined in the National Transport Strategy of Scotland (Transport Scotland, 2020b). To reverse this negative trend, it is vital that the bus industry adopts measures that will increase bus patronage. In this context, the current research examines whether bus automation could encourage the public to use buses more often. Given that any impact of automation on bus use is highly subject to the public acceptance of Automated Buses (ABs), we also investigate the determinants of eagerness to use ABs. The research was undertaken as part of the CAVForth project (CAVForth Partners, 2022) which involves a trial service of a fleet of full size, single deck, ABs operating on a 22 km inter-urban route on the Scottish public road network.

The potential benefits of fully Automated Vehicles (AVs) have been well documented and could include enhanced safety/collision avoidance (through eliminating human driver error), travel time savings, more productive use of travel time and increased highway capacity. Autonomous mobility also has the potential to benefit people who currently have to rely on others for transportation, such as the elderly, disabled, or those without a driver's license. Studies looking at the impact of AVs on the environment suggest a reduction in congestion, less idling, improved fuel efficiency due to more eco-driving styles, fewer emissions, decreased tyre and brake wear and a reduction in the number of vehicles. However, environmental benefits may not be achieved if

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there is reduced public transport use, reduced active travel and an increase in vehicle miles travelled (due to lower associated costs and higher demand) and urban expansion/sprawl (Nenseth, et al., 2019; Mouratidis et al., 2021).

The deployment of autonomous vehicle technology has the potential to improve sustainable mobility if used to support public transport rather than private vehicles or individual AV cars. Automated Buses (ABs) could contribute towards promoting public transport use, offer greater network efficiency through transporting a larger number of passengers and reduce the demand for private vehicles. ABs could also offer advantages such as improved efficiency of bus terminal operations, increased precision of curb-side docking, better comfort, and improved reliability. ABs operating without staff onboard, could offer additional benefits including reduced labour costs for operation and maintenance, expanding service hours and more frequent services (as a result of lower operating costs), greater flexibility of changing routes and timetables, optimizing the spatial and temporal allocation of the bus fleet and mitigation against the effects of staff shortages that the industry is currently experiencing. In the UK, the Confederation of Passenger Transport (2020) publish a Cost Index, which shows that driver wages account for 47% of total bus operating costs and, as a consequence, even a small employee reduction could have a substantial impact on bus operations.

Despite the potential benefits, it is too early to guarantee the widespread uptake of ABs. There are many challenges that have yet to be addressed including policy and regulatory requirements, safety requirements, unemployment amongst bus drivers, potential non-payment of tickets, data privacy, security of the systems, high upfront costs, and investment in infrastructure. Although the contribution of ABs is move positive for the environment when compared to AV cars, it may be that these benefits are no better than those achieved by non-automated buses (Mouratidis and Cobeña Serrano, 2021).

Potentially the biggest barrier to the adoption of ABs may well be acceptance of the technology (Shariff et al., 2017). Public perception of, and attitudes to, ABs will determine the extent to which people will accept and use such systems and will also be a key factor in the bus industry's ability to adopt automated technology. The Scottish Government's CAV Roadmap for Scotland (Transport Scotland, 2019) highlights consumer acceptance and uptake as a challenge for automated vehicle deployment in Scotland. If there is not broad consumer acceptance and willingness to use the technology, then it will be difficult to develop a commercially sustainable market, even if the technology and infrastructure are mature.

Public acceptance acts as a prerequisite for ABs to have any impact on overall bus use. Hence, it is important to understand what might drive that acceptance. Models such as the Technology Acceptance Model (TAM) (Venkatesh and Bala, 2008), and the Unified Theory of Acceptance and Use of Technology UTAUT (Venkatesh et al., 2016) were developed to explain technology acceptance and use. Complimentary to the UTAUT framework, the Diffusion of Innovation Theory, DOI (Rogers, 2003) seeks to explain how, why and at what rate new technology will spread. Rogers (2003) considers the characteristics of both the innovation and the potential adopters that affect adoption rates. He suggests a total of five categories of adopters: innovators, early adopters, early majority, late majority, and laggards, with the majority of the general population tending to fall in the middle categories.

More recently, theories have been developed (e.g., Hewitt et al., 2019; Acheampong and Cugurullo, 2019; Nordhoff et al., 2019a, Nordhoff et al., 2019b) that specifically address autonomous vehicle acceptance. Nordhoff et al. (2019a,b) proposed MAVA, a multi-level model on automated vehicle acceptance that is based on a systematic review of 124 empirical studies. They found that acceptance was determined by twenty-eight factors. The acceptance factors are divided into two levels, which the authors describe as 'micro' and 'meso'. Factors at the meso level constitute exposure to and systematic evaluation of AVs, including performance expectancy, effort expectancy, facilitating conditions, safety, service and vehicle characteristics, social influence, hedonic motivation, and perceptions of risks and benefits. The micro-level includes individual differences (socio-demographics, personality, and travel behaviour). Individual differences influence the intention to use AVs by moderating the meso-level factors but can also have a direct effect on the intention to use AVs. Diffusion of Innovation and the MAVA framework serve as the theoretical foundation for this paper. MAVA is used to examine the system evaluation, experience and individual difference factors that determine the rate of adoption or "eagerness" to use ABs.

Previous research examining factors that influence intention to use automated public transport suggested that knowledge and experience plays a key role in acceptance of Automated Shuttles (AS) (Moták et al., 2017; Wicki et al., 2019). Several studies found that exposure increases passengers' trust and safety perceptions (Dong et al, 2019; Eden et al 2017; Salonen and Haavisto, 2019; Xu et al, 2018). Wicki et al. (2019) investigated the support for, willingness to use, and fears and concerns regarding the introduction of an automated shuttle service on public roads. He found that after using the shuttle, support for it increased significantly.

Hedonic motivation has also been correlated with intention to use. For example, Moták et al. (2017) observed that positive affective attitudes (measured by the extent that an individual found using AS a pleasurable experience) improved the predictability of AS behavioural intentions. Madigan et al. (2016) and Nordhoff et al. (2018) found that there was a positive relationship between expected performance of an AS system when compared to existing modes, and intention to use such a system. Facilitating conditions such as perceived behavioural control, helpfulness, technical support, self-efficacy, conceptual compatibility, lifestyle fit, and technology support have been found to influence intention to use an AS (Madigan et al., 2016; Moták et al., 2017; Nordhoff et al., 2019a).

Travel behaviour has the potential to influence automated public transport use. However, the results of recent investigations are mixed. Liljamo et al. (2018) found that those who currently use public transport were more positive towards automated shuttles systems than other mode users. Furthermore, highly multi-modal people (i.e., three or more modes used per week) had the highest intention to use autonomous minibuses, while car drivers had the lowest (Kostorz et al., 2019). Paddeu et al. (2020) found that car drivers initially rated AV comfort and trust expectations lower than who travelled by other modes. However, after using an AV they rated them higher that the non-driver group. In contrast, Nordhoff et al. (2018) found no differences between public transport users and car drivers in terms of their intention to use automated public transport. Wien (2019) and Kassens-Noor et al. (2020) found no significant differences between daily or weekly public transport users and occasional public transport users and preferences for ABs. With regards to socio-demographic characteristics that affect willingness to use automated public transport, previous studies indicate that age, gender, existing travel behaviour, income and residing in a rural area were found to be significant (Chee et al., 2020; Dong et al., 2019; Esterwood et al., 2021; Guo et al., 2021; Herrenkind et al., 2019; Kyriakidis et al., 2015; Wicki et al., 2019; Winter et al., 2018).

Studies relating to the intention to use automated public transport have shown the importance of quality of service and vehicle characteristics. Specifically, the impact of factors such as travel cost, travel time, comfort, performance of other modes, vehicle speed, route type (fixed route or segregated), level of automation, reliability, and vehicle occupancy on willingness to use automated public transport has been widely investigated (Alessandrini et al., 2014; Eden et al., 2017; Herrenkind et al., 2019; Hoff and Bashir, 2015; Nordhoff et al., 2019b; Paddeu et al., 2020; Piao et al., 2016; Rehrl and Zankl, 2018; Schoettle and Sivak, 2014; Wicki et al., 2019; Wien, 2019). Earlier studies (Nordhoff et al., 2018) have indicated that a drawback cited by users of a pilot shuttle bus was a lack of space and storage for carry-on items.

For AB passengers, there is a trade-off between the feeling that a slow vehicle takes too long and increased safety concerns if the vehicle travels faster. Low vehicle speeds have been linked to unfavourable perceptions in prior studies (Mouratidis and Cobeña Serrano, 2021) employing autonomous shuttles in an urban setting. According to a study by Eden et al. (2017), the introduction of large-sized ABs travelling on a scheduled route at regular speed would raise additional user safety concerns. This is likely because any collision would have more severe consequences given the larger vehicle size and more participants involved.

Much of the reported research carried out to assess the potential uptake of automated public transport has utilised the perceptions and experiences of those using shared automated shuttle buses or 'pods' (usually with 4 to 12 seats). Many studies considered autonomous shuttle buses operating either as first-last mile or on fixed routes within urban environments or away from the public road network (e.g., University campuses, airports etc). The use of large mass transit buses, which could replace conventional public transport, has not been researched as extensively. Research (Chng and Cheah, 2022) found that there are differences in receptiveness toward the introduction of automated shuttles and full-sized ABs. Shuttles had higher acceptance levels than larger capacity buses and there were expectations that full-sized buses would not perform as well or be as easy to use as other shared AV services. The authors attributed these findings to the fact that AV buses are still in their early stages of development which means that they are less known and visible to the public.

Existing literature (Piao et al., 2016; Dong et al., 2019), confirmed by initial consultation activities in this project involving more than 450 bus passengers, suggests that operating services with no staff onboard would be less acceptable to the public. Research undertaken by Dong et al. (2019) and Rehrl and Zankl (2018) found that presence and responsibilities of onboard staff influence users' initial willingness to ride in ABs. The absence of a human bus driver raised concerns from passengers regarding safety, in-vehicle security, lack of assistance for disabled passengers and the quality of customer service in general. Given that people are weary of the technology and the range of issues with travelling on an unstaffed bus, Stagecoach (UKs largest bus operator) envisage that a future AB service will still need human staff onboard (Stagecoach, 2019). They also highlight the potential benefits to future services if the staff member can leave the driving seat and assist passengers but can still be ready and able to drive if needed.

In 2019, the UK Government published a Code of Practice (Department for Transport, 2019) for the testing of automated vehicles on public roads. Trialling any level of automated vehicle technology is possible on any UK road if carried out in line with UK law. As part of complying with the law, they will need to ensure that they have a driver or operator who is ready, able, and willing to resume control of the vehicle. Litman (2023) considers predictions regarding timescales for implementing AVs and concludes that level 5 autonomy (vehicles able to operate without a driver under all normal conditions) will require many more years of development, testing and approval. However, he acknowledges that because of predictable routes and high labour costs, autonomous operation is most appropriate for long-haul HGVs and buses and that self-driving buses may become common in the 2030s and 2040s. Given the predicted length of this transition period, it is appropriate for research to consider peoples responses towards these vehicles operating during the intermediate stage, when trained safety drivers are required onboard.

Risk management, particularly risk mitigation, is critical for avoiding incidents that delay deployment or even lead to the withdrawal of potentially beneficial technologies and services as proven for the instance of automated elevators. By 1900, completely automated elevators were available, but it took around 50 years for the public to adopt them and feel comfortable using them. People's confidence in safety and reliability increased as lift technology advanced and safety features were introduced. However, it was not until the 1970s that most elevators functioned without human operators. Similarly, automated bus operations with safety drivers appears to be an unavoidable and important step towards the deployment of unmanned ABs. It is crucial to allow the public to gain the exposure to the technology needed to become familiar with it and develop trust it. Exposure to ABs with a safety driver onboard could encourage consumers to try unmanned services. Ariza-Álvarez et al., (2023) investigated public acceptance of large, mass transit ABs with capacity for sixty passengers circulating in real-life traffic conditions. A high percentage of passengers (71.4%) who experienced the bus in automated mode while a safety operator was present said they would still be prepared to use the bus if it was fully automated (i.e., with no safety operator). Therefore, in the journey towards the implementation of unmanned ABs, initial and possibly long deployments (including test trials) with safety drivers are necessary to improve public's confidence and acceptance of the technology. A thorough understanding of the attitudes of potential users at initial stages is as important as the knowledge concerning more mature deployments, and potentially more urgent.

One of the main conclusions from the literature is that the majority of research concentrates on evaluating slowly moving, small-capacity vehicles (e.g., autonomous shuttle with up to 12 passengers) often operating on private roads. Thus, it is imperative to investigate passengers' perceptions towards large mass transit vehicles travelling on the public road network at the same speeds as traditional buses. Furthermore, a clear understanding of the public's attitudes towards vehicles supervised by safety drivers is important and urgent given that they may soon be present on UK roads.

The objective of the research is to gain a deeper understanding of the role of full-size ABs, operating with a human safety operator onboard in attracting new passengers to bus services. To understand the characteristics that potentially make ABs appealing to the public, we first explore the determinants of eagerness to use full-sized ABs. The findings of this two-fold endeavour can lay the groundwork for policy measures to be implemented in the bus industry, during and after the large-scale launch of ABs, with the aim of making public transport more attractive.

2. Method

2.1. Data collection

To identify the factors that shape passengers' eagerness to use ABs and the potential of ABs to attract new passengers, questionnaire data was collected through the project CAVForth (CAVForth Partners, 2022) which launched the first full-size level 4 (Society of Automotive Engineering, 2021) automated bus service in the UK. As part of the project, an investigation was undertaken to assess bus passengers' attitudes and eagerness to use ABs operating with a trained human safety driver onboard before the onset of the trial bus service. An online survey was administered through the Qualtrics platform (Qualtrics, 2005) and distributed to Scottish bus passengers, included on the most recent Stagecoach online mailing list. Stagecoach is the UK's largest bus operator and responsible for the operation of the CAVForth pilot service. The mailing list is made up of customers who 'opted in' while buying tickets online or using onboard Wi-Fi and who were engaged customers (i.e., they have opened emails from Stagecoach in the previous 12 months). As an incentive to complete the online questionnaire each respondent was offered an entry into a prize draw with an opportunity to win £100 worth of Amazon vouchers. A pilot study was initially conducted on 23rd September 2021, where members of the CAV Forth Co-Design Panel were invited to test run the survey and share feedback.

The questionnaire was developed as a series of largely closed-ended items covering topics related to general perceptions towards technology and vehicle automation (e.g., eagerness to use any new technology, familiarity with Automated Driver Assistance Systems – ADAS), expectations and attitudes towards bus automation (e.g., eagerness to use ABs, willingness to use buses less or more when automated; attitudes and feelings towards various aspects of ABs, perceived comfort while traveling with ABs under different roadway circumstances, expected

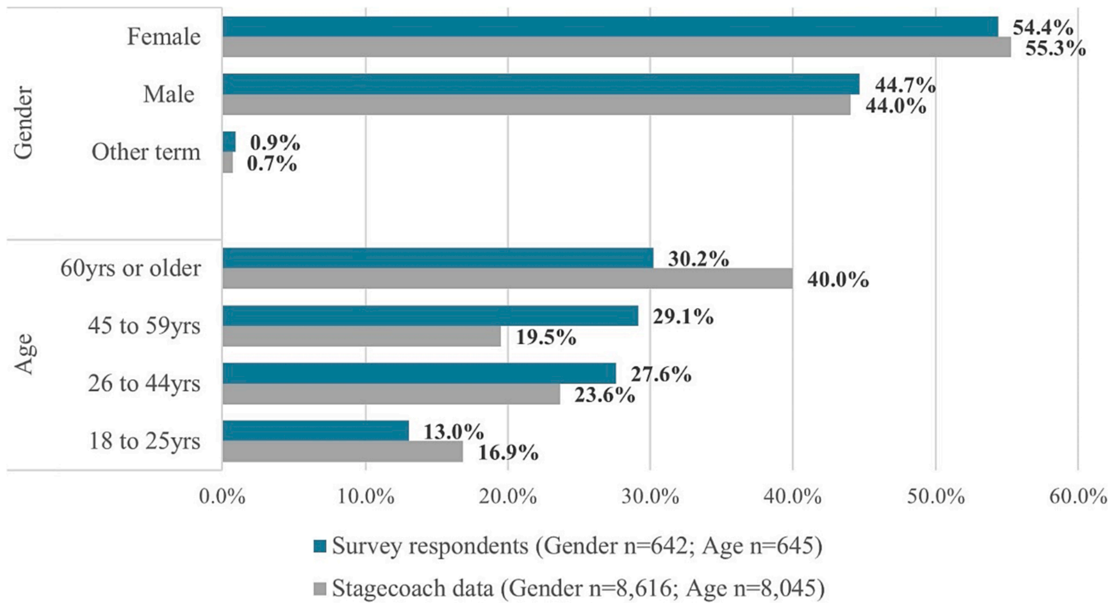

Fig. 2.1. Distribution of survey respondents and Stagecoach passengers for gender and age.

benefits and concerns around ABs, importance of benefits of ABs); travel behaviour and transport related life choices and attitudes (e.g., mode choice before and during the COVID-19 pandemic, perceived ease of life without a car, satisfaction with bus services, areas of improvement for bus services, ticket type used in public transport) and socio-demographic and household characteristics of the respondents (e.g., age, gender, employment status, educational attainment, health status, financial concerns, household income, car availability, household type).

At the beginning of the questionnaire, the respondents were briefed about the CAVForth project (CAVForth Partners, 2022) and the operational characteristics of the AB trial as follows:

"The project will include a trial service of a fleet of full size, single deck, buses travelling on public roads between Edinburgh and Fife and carrying passengers at the same speed as traditional buses. During the CAV Forth autonomous bus trial the buses will have computer systems designed to carry out all the driving functions (such as steering, accelerating or braking) without direct driver input; all trial buses will have trained human drivers behind the wheel at all times. Their role will be to monitor the roadway and vehicle during the entire journey and be available to take control of the vehicle if required."

To ensure alignment with the General Data Protection Regulation, a privacy notice detailing the scope and objectives of the project and how the data will be managed was provided to the potential respondents, who had to assert their informed consent before starting the survey. Approval for compliance of the survey with the institutional data governance and research ethics standards was also granted by Edinburgh Napier University.

A total of 1,054 responses were collected between the 15th of October and 5th of November 2021. Some of the responses were discarded in the following stages of data analysis due to partial or missing information. Fig. 2.1 show details of the gender split and age distribution of the survey respondents, respectively. The Figure also provides details of the equivalent distribution, for Stagecoach passengers in Scotland as a whole, which were derived from the Transport Focus survey (2019). The survey sample was representative of Stagecoach passengers in terms of gender. However, there were slightly fewer older (65 + years) respondents among the survey sample when compared to the Stagecoach customer data. Previous studies suggest demographic factors influence the likelihood of completing a web-based survey. Millar et al. (2009) found that online respondents were younger than mail respondents, had higher levels of income and higher levels of education. The current research considers differences between groups rather than making broad assertions about all bus users. Consequently, weighting was not applied to the survey data. The Stagecoach mailing list does have a bias towards people who buy tickets online or use on bus Wi-Fi. It is therefore possible that the people on the Stagecoach database are more 'tech savvy' than the population of Stagecoach bus passengers as a whole.

2.2. Statistical analysis

The survey-collected data were analysed through discrete outcome models. Details of all the independent variables trialled in the models are provided in the Appendix. First, a Random Parameter Ordered Probit model with Heterogeneity in the Means (RPOPHM) of the random parameters was estimated to provide insights into the socio-demographic, behavioural and perceptual factors, which shape participants' eagerness to use ABs operating with a trained safety driver onboard. The dependent variable chosen for the current study includes a measure of the rate of adoption or "eagerness" to use that was adapted from the Diffusion of Innovation Theory, as opposed to a binary "yes" or "no" response that is utilised in many AB acceptance studies. This enables the creation of distinct categories of adopters (e.g., innovators, early adopters, early majority, late majority, and laggards). The question capturing respondents' eagerness to use ABs was originally framed in the survey as a six-point Likert scale question (further details about this question are provided in the sub-section 3.1). For the statistical analysis, the six-point eagerness-scale variable was reduced to three ordered alternatives: 'never or last to use an AB' (coded as 0, 23.5%); 'wait a while' (coded as 1, 27.2%); 'one of the first or soon after they are available' (coded as 2, 49.3%). The merge of conceptually similar outcomes for statistical modelling facilitates drawing clear insights into the characteristics that shape the early adopters, late adopters, and laggards of bus automation, without adding considerable aggregation bias in the analysis (Eker et al., 2020). The ordered probit model is formulated (Washington et al., 2020):

$$k_i^* = \beta \mathbf{X}_i + \varepsilon \quad (1)$$

where, for each respondent, k^* is an unobserved (latent) variable, $\mathbf{X}$ is a vector of factors affecting the eagerness to use ABs, $\boldsymbol{\beta}$ indicates a vector of estimable parameters corresponding to $\mathbf{X}$, and ε indicates a disturbance term specified to follow the standard normal distribution (i.e.,

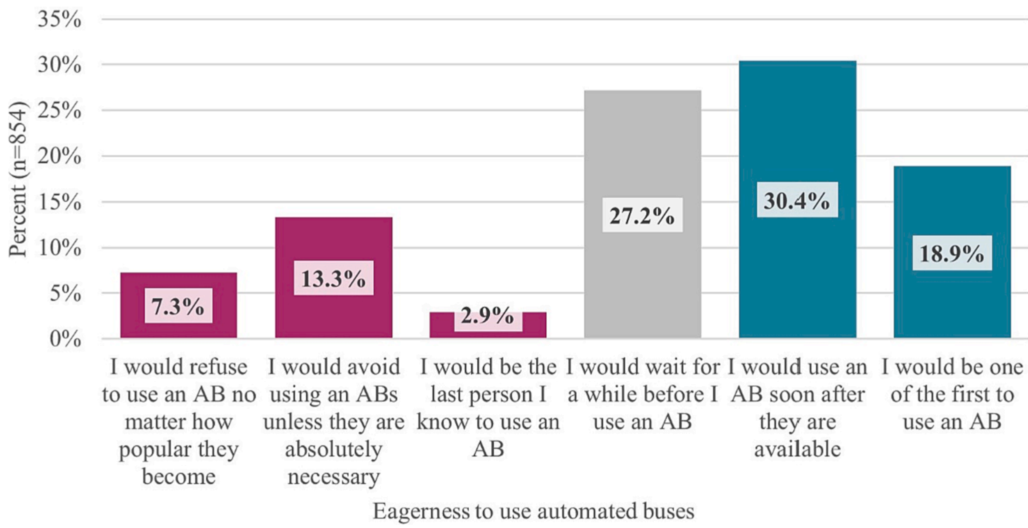

Fig. 3.1. Eagerness to use automated buses (with staff onboard).

zero mean and standard deviation equal to one). The unobserved (latent) variable k_i* is linked with the self-reported preference of each respondent, through an integer k_i according to the following formula:

$$k_i = \begin{cases} 0 if k_i^* \leq \mu_0 = 0 \\ j if \mu_{j-1} < k_i^* \leq \mu_j, \text{for} 1 \leq j < J \\ J if k_i^* > \mu_{J-1} \end{cases} \quad (2)$$

where, j is an integer denoting the possible outcome of the dependent variable (i.e., the actual response in the eagerness-to-use question) with, j taking values from 0 to J and μ denotes the generic estimable threshold defining the probability ranges between the alternatives 'wait a while' and 'one of the first or soon after they are available'; without loss of generality, it is assumed that the first threshold (μ_0) has zero value, hence only a single threshold is ultimately estimated (Washington et al., 2020).

To identify the factors that determine respondents' intentions to use buses more frequently as a result of automation, a Random Parameter Binary Logit model with Heterogeneity in the Means (RPBLHM) was estimated. To gain more clear insights, the variable measuring intentions for future bus use was reduced to two discrete alternatives: 'use buses more' (coded as 1, 23.84%) or 'use buses same amount or less' (coded as 0, 76.16%). The utility function, *U,* which determines the respondents' intentions for each respondent *i*, is formulated as:

$$U_i = \boldsymbol{\beta}_i \boldsymbol{\Omega}_i + \zeta_i \quad (3)$$

where $\boldsymbol{\Omega}$ is a vector of independent variables affecting the intentions to use buses more, $\boldsymbol{\beta}$ indicates a vector of estimable parameters corresponding to $\boldsymbol{\Omega}$, and ζ is a disturbance term.

For both models, random parameters were introduced to account for the impact of unobserved heterogeneity. The inclusion of random parameters enables the identification of possible varying effects of a subset of factors on users' perceptions and intentions, thus controlling for the impact of potential unobserved characteristics, preferences, or taste (Anastasopoulos et al., 2017; Mannering et al., 2016). The random parameters are formulated as (Semple et al., 2021):

$$\boldsymbol{\beta}_i = \beta + \boldsymbol{\lambda}\boldsymbol{\Theta}_i + \delta_i \quad (4)$$

where β denotes the mean of the random parameter distribution, $\boldsymbol{\Theta}$ constitutes a vector of exogenous factors that influence the mean of the random parameter, with the corresponding vector of estimable parameters being $\boldsymbol{\lambda}$, and δ is a disturbance term. With the employed formulation, the heterogeneity encapsulated in the means of the random parameters can be further decomposed, thus allowing to explain an additional part of the variations induced by factors with random parameters. We also strived to address possible unobserved effects in the variance of the random parameters (i.e., heterogeneity in variance), by examining exogenous variables potentially affecting their standard deviations (Pang et al., 2022), but these trials resulted in statistically insignificant outputs. The normal distribution was used to fit the random parameters. For estimation of both RPOPHM and RPBLHM models, we utilised the Simulated Maximum Likelihood Estimation technique, while for estimation of the random parameters, we used a Halton draws-based approach, with 1,000 draws found to be the optimal setting for ensuring parameter stability.

To quantify the specific impact of independent variables on the likelihood for each outcome of the dependent variables, marginal effects were also calculated. The marginal effects show the impact of one-unit change of the value of each independent variable on the likelihood of each discrete outcome. Their calculation is particularly important for the RPOPHM model, as the coefficients of the ordered models can only show the impact of the independent variables on the extreme outcomes (lowest and highest ranked) and cannot illustrate their effect on the intermediate outcomes of the dependent variables (Washington et al., 2020).

3. Results

3.1. Overview of the survey results

With reference to eagerness to use ABs, respondents were asked how quickly they might take up the opportunity (if at all) to use ABs operating with a trained human safety driver behind the wheel to monitor the roadway and vehicle and intervene only if required. The participants were asked to respond to statements regarding their eagerness to use the service (how early they are likely to adopt) when it becomes available to the public. The eagerness to use ABs was measured on the following scale:

- I would be one of the first to use an autonomous bus (1)
- I would use an autonomous bus soon after they are available (2)
- I would wait for a while before I use an autonomous bus (3)
- I would be the last person I know to use an autonomous bus (4)
- I would avoid using an autonomous bus unless they are absolutely necessary (5)
- I would refuse to use an autonomous bus no matter how popular they become (6)

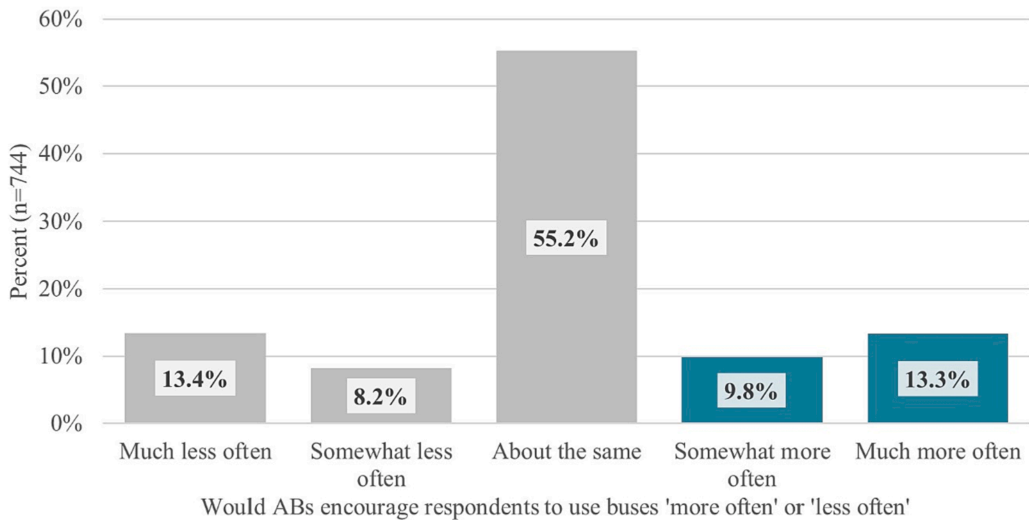

Fig. 3.2. Intentions to use buses in the future as a result of automation.

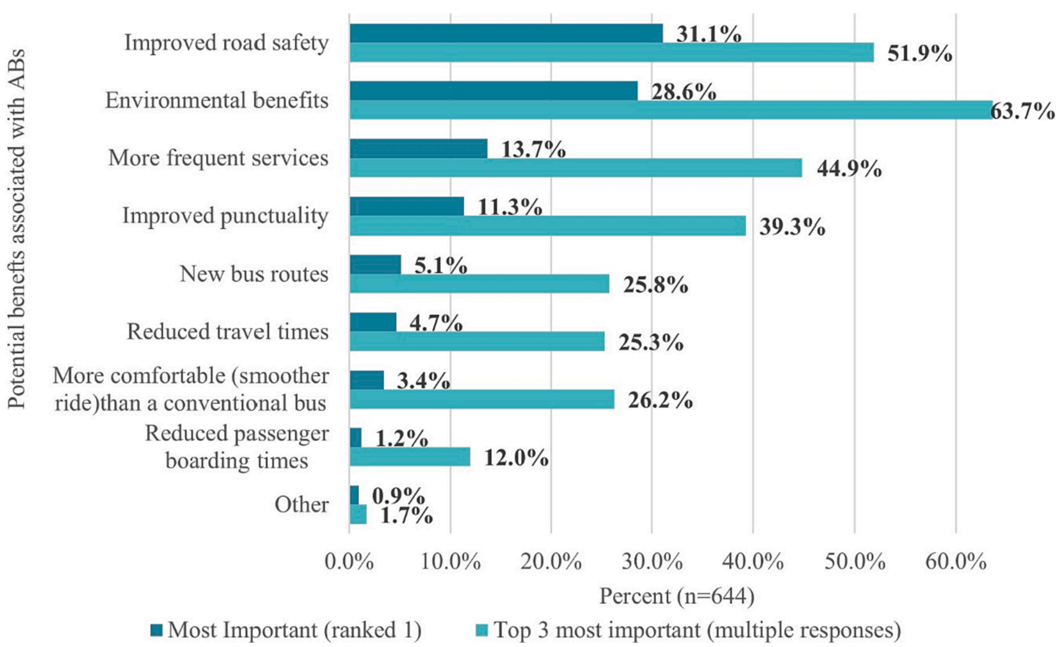

Fig. 3.3. Ranking of importance of potential benefits associated with ABs.

Fig. 3.1 shows that almost half of the respondents would use ABs at the time of their introduction or shortly afterwards. In keeping with Roger's theory, intention to use ABs in the study follows a bell-shaped, normally distributed curve with categories of adopters ranging from innovators, early adopters, early majority, late majority, and laggards, with the majority of the general population tending to fall in the middle categories.

Respondents were asked whether ABs, operating with a trained human safety driver onboard would encourage them to use buses more often or less often if possible. Almost a quarter of respondents anticipated using buses more frequently because of ABs, as shown in Fig. 3.2.

The online survey revealed moderate levels of interest (51.0% interested) and excitement (55.3%) associated with ABs. Less than a quarter of respondents (24.2%) considered themselves well informed about them. Over two-fifths (41.5%) thought ABs were fear inducing and almost a third viewed them as unsafe (31.8%) or untrustworthy (31.8%). Participants were asked whether they thought there would be benefits in introducing ABs. More respondents thought that it would be more beneficial to introduce ABs than not with regard to the environment (58.6% agreed; 15.9% disagreed), increased frequency and new routes (43.7% agreed; 31.3% disagreed), bus punctuality (35.1% agreed; 27.8% disagreed) and increased comfort (32.8% agreed; 26.8% disagreed). However, there was no clear majority amongst respondents who thought that the introduction of ABs would lead to greater safety (34.0% agreed it would be beneficial; 34.2% disagreed).

Survey participants were asked which potential benefits that could be associated with ABs, were most important to them. Fig. 3.3 shows that almost a third (31.1%) of respondents rated improved road safety as the most important benefit associated with ABs. Environmental benefits, more frequent services and improved punctuality were rated as most important by 28.6%, 13.7% and 11.7% of respondents, respectively. Over a quarter (26.2%) ranked comfort ('smoothness' of ride) as one of their three most important benefits. A small number of respondents (n = 32) indicated that they did not think there would be any benefits associated with ABs.

Our research found that the presence and responsibilities of onboard

Table 3.1
Estimation results of the RPOPHM model for eagerness to use ABs (summary statistics of variables in parentheses).

Variable description	Coefficient	t-stat	p-value
VARIABLES WITH FIXED PARAMETERS			
Constant	−1.046	−3.97	0.000
Familiarity with ADAS (1 if the respondent has seen or used a Driver Assistance Autonomous System, 51.66%; 0 no)	0.401	2.88	0.004
Comfort of ride with autonomous buses compared to conventional buses (1 if this is among the top-3 most important benefits, 25.93%; 0 otherwise)	0.413	2.56	0.011
Perceived trustworthiness of autonomous buses (1: No trustworthy at all,…7: Trustworthy, mean 4.34)	0.578	13.83	0.000
Gender (1 female, 53.94%; 0 male)	−0.569	−4.01	0.000
Age (1 if 45 years or older, 57.88%; 0 otherwise)	−0.489	−3.58	0.000
Area type (1 if rural, 17.22%; 0 otherwise)	0.569	3.02	0.003
MARGINAL EFFECTS OF VARIABLES WITH FIXED PARAMETERS			
	Never or last	**Wait a while**	**One of the first**
Familiarity with ADAS (1 if the respondent has seen or used a Driver Assistance Autonomous System, 0 no)	−0.042	−0.112	0.154
Comfort of ride with autonomous buses compared to conventional buses (1 if this is among the top-3 most important benefits, 0 otherwise)	−0.036	−0.117	0.153
Gender (1 female, 0 male)	0.058	0.158	−0.216
Age (1 if 45 years or older, 0 otherwise)	0.048	0.137	−0.185
Area type (1 if rural, 0 otherwise)	−0.044	−0.159	0.203
Perceived trustworthiness of autonomous buses (1: No trustworthy at all…,7: Trustworthy)	−0.070	−0.153	0.223
VARIABLES WITH RANDOM PARAMETERS			
	Coefficient	**t-stat**	**p-value**
New bus routes with autonomous buses (1 if this is among the top-3 most important benefits, 25.52%; 0 otherwise)	−0.173	−1.10	0.269
Standard deviation of parameter density function	0.890	6.44	0.000
Satisfaction with bus service (1 if satisfied, 58.09%; 0 otherwise)	0.417	3.07	0.002
Standard deviation of parameter density function	0.690	7.20	0.000
Driving a car during COVID (1 if more than before, 12.03%; 0 otherwise)	−0.294	−0.98	0.326
Standard deviation of parameter density function	0.459	2.49	0.013
Car free lifestyle (1 if the respondent can structure life well without a car, 57.26%; 0 otherwise)	0.553	3	0.003
Standard deviation of parameter density function	0.495	5.27	0.000
Reluctance to use new technologies (1 if last to use, 5.81%; 0 otherwise)	−2.017	−4.69	0.000
Standard deviation of parameter density function	1.040	3.17	0.002
HETEROGENEITY IN THE MEANS OF THE RANDOM PARAMETERS (Variable resulting in a random parameter: variable affecting the mean of the random parameter)			
Driving a car during COVID: employment status (1 if full or part time employed, 53.11%; 0 otherwise)	1.043	2.69	0.007
Car free lifestyle: employment status (1 if full or part time employed, 53.11%; 0 otherwise)	−0.474	−2.42	0.016
Reluctance to use new technologies: employment status (1 if full or part time employed, 53.11%; 0 otherwise)	2.194	3.34	0.001
μ	1.384	12.24	0.000
MARGINAL EFFECTS OF VARIABLES WITH RANDOM PARAMETERS			

Table 3.1 (*continued*)

Variable description	Coefficient	t-stat	p-value
	Never or last	**Wait a while**	**One of the first**
Satisfaction with bus service (1 if satisfied, 0 otherwise)	−0.046	−0.115	0.161
Driving a car during COVID (1 if more than before, 0 otherwise)	0.036	0.079	−0.116
Car free lifestyle (1 if the respondent can structure life well without a car, 0 otherwise)	−0.062	−0.151	0.213
New bus routes with autonomous buses (1 if this is among the top-3 most important benefits, 0 otherwise)	0.019	0.048	−0.067
Reluctance to use new technologies (1 if last to use, 0 otherwise)	0.562	0.034	−0.596
DISTRIBUTIONAL CHARACTERISTICS OF VARIABLES WITH RANDOM PARAMETERS			
	Positive effect	Negative effect	
New bus routes with autonomous buses (1 if this is among the top-3 most important benefits; 0 otherwise)	42.29%	57.71%	
Satisfaction with bus service (1 if satisfied; 0 otherwise)	72.72%	27.28%	
Driving a car during COVID (1 if more than before; 0 otherwise)	26.09%	73.91%	
Car free lifestyle (1 if the respondent can structure life well without a car; 0 otherwise)	86.80%	13.20%	
Reluctance to use new technologies (1 if last to use; 0 otherwise)	2.62%	97.38%	
MODEL FIT STATISTICS			
Number of observations	482		
Log-likelihood at zero, LL (0)	−481.48		
Log-likelihood at convergence, LL($\boldsymbol{\beta}$)	−348.36		
ρ^2 [1- LL($\boldsymbol{\beta}$)/LL(0)]	0.276		

staff influences users' initial willingness to ride in ABs. As part of the questionnaire, respondents were asked about the likelihood of them using ABs with distinct levels of employee involvement under four scenarios:

- a trained safety driver behind the wheel to monitor vehicle operations and a steward to provide customer care;
- a transit employee onboard to provide customer service, but not to monitor the vehicle operations;
- a transit employee onboard to monitor the vehicle operations, but not to provide customer care; and
- no transit employees onboard the vehicle.

It was found that over three quarters (76.5%) of survey participants expressed a willingness to ride (either 'definitely yes' or 'probably yes') in an AB when a member of staff is on board to monitor vehicle operations and another to provide customer service. Almost two-thirds (62.2%) were willing to ride in an AB if the staff onboard monitored the AB but did not provide customer care. A third (32.9%) were willing to ride when onboard staff only provided customer service and no monitoring. This suggests that if a member of staff is present onboard the AB, survey respondents would much prefer a safety driver to the steward. Less than a fifth (18.2%) would agree to ride in an AB without any staff on board.

3.2. *Eagerness to use automated buses with a trained human safety driver onboard*

The results of the RPOPHM model estimated to understand the determinants of eagerness to use ABs with a trained human safety driver onboard are presented in Table 3.1. It should be noted that a positive coefficient in the RPOPHM model indicates an increase in the likelihood of the highest outcome (i.e., one of the first to use ABs), whereas a

Table 3.2
Estimation results of the RPBLHM model for intentions to use buses more often because of automation (summary statistics of variables in parentheses).

Variable description	Coefficient	t-stat	p-value	Marginal effect
VARIABLES WITH FIXED PARAMETERS				
Constant	−4.132	−4.21	0.000	–
Reluctance to use new technologies (1 if last to use, 5.79%; 0 otherwise)	−3.128	−1.98	0.048	−0.020
Knowledge about ABs (1 if well-informed, 24.54%; 0 if the respondent does not know much or neutral)	1.517	2.70	0.007	0.010
Expected benefit of ABs (1 if the respondent agrees that ABs will offer a smoother ride than conventional buses, 40.05%; 0 otherwise)	5.785	4.96	0.000	0.037
Using active travel means (walking or cycling) during COVID-19 (1 if more than before, 13.89%; 0 otherwise)	1.278	1.79	0.074	0.008
Age (1 if 45 years or older, 60.42%; 0 otherwise)	−3.068	−4.31	0.000	−0.020
Employment status (1 if employed either full-time or part-time, 53.24%; 0 otherwise)	−1.847	−3.37	0.001	−0.012
Financial situation (1 if the respondent has financial concerns, 11.11%; 0 no financial struggle)	4.796	4.41	0.000	0.031
VARIABLES WITH RANDOM PARAMETERS				
Low frequency of bus use (1 if less than once a month, 21.99%; 0 otherwise)	−5.786	−1.79	0.073	−0.037
Standard deviation of parameter density function	16.047	4.71	0.000	–
Satisfaction with bus service (1 if satisfied, 60.19% 0 otherwise)	1.634	2.48	0.013	0.010
Standard deviation of parameter density function	8.715	5.25	0.000	–
Car free lifestyle (1 if the respondent can structure life well without a car, 58.56%; 0 otherwise)	−10.209	−4.58	0.000	−0.065
Standard deviation of parameter density function	10.158	5.26	0.000	–
HETROGENEITY IN THE MEANS OF THE RANDOM PARAMETERS (Variable resulting in a random parameter: variable affecting the mean of the random parameter)				
Low frequency of bus use: gender (1 if female, 53.24%; 0 otherwise)	−10.716	−3.94	0.000	–
Low frequency of bus use: perceived trustworthiness of autonomous buses (1: No trustworthy at all…,7: Trustworthy, mean: 4.37)	1.098	1.85	0.064	–
Satisfaction with bus service: area type (1 if rural, 17.13%; 0 otherwise)	−7.447	−4.09	0.000	–
Satisfaction with bus service: gender (1 if female, 53.24%; 0 otherwise)	−3.590	−3.86	0.000	–
Car free lifestyle: area type (1 If rural, 17.13%; 0 otherwise)	3.519	2.92	0.004	–
Car free lifestyle: perceived trustworthiness of autonomous buses (1: No trustworthy at all…,7: Trustworthy, mean:4.37)	1.473	4.33	0.000	–
DISTRIBUTIONAL CHARACTERISTICS OF VARIABLES WITH RANDOM PARAMETERS				
	Positive effect		Negative effect	
Low frequency of bus use (1 if less than once a month; 0 otherwise)	35.92%		64.08%	
Satisfaction with bus service (1 if satisfied; 0 otherwise)	57.44%		42.56%	
Car free lifestyle (1 if the respondent can structure life well without a car; 0 otherwise)	15.74%		84.26%	
MODEL FIT STATISTICS				
Number of observations	432			
Log-likelihood at zero, LL (0)	−237.552			
Log-likelihood at convergence LL (**β**)	−182.071			
ρ^2 [1- LL(**β**)/LL(0)]	0.234			

negative coefficient implies an increase in the likelihood of the lowest outcome (i.e., never, or last to use ABs). Several factors concerning knowledge and expectation about technology, travel behaviour and socio-demographics of the respondents were found to affect the eagerness to use ABs significantly. Due to partial or missing information for some of the variables identified as statistically significant in the RPOPHM model, 482 responses (with full information) were used for model estimation.

Those who had used or seen at least one Automated Driver Assistance System (ADAS) were more eager to use ABs than those who had not seen or used an ADAS. Respondents who perceived comfort as an important benefit of ABs were more likely to report that they were eager to use ABs. Younger respondents (less than 45 years old) were more likely than older ones to be eager to use ABs; males were more eager to use ABs than females; and those living in rural areas were more eager to use ABs than those from urban areas. The variable representing respondents from rural areas is also associated with the largest (in magnitude) decrease of the likelihood of "wait a while," as shown in Table 3.1. Participants who viewed ABs as trustworthy were more eager to use them than those who considered them untrustworthy.

Several independent variables, including, expectation that ABs will improve bus network coverage, satisfaction with bus services, car use since COVID-19, car dependency and reluctance to use new technologies in general, resulted in statistically significant random parameters. Interestingly, the reluctance to use new technologies triggered the most pronounced impacts on the extreme outcomes of the model; Table 3.1 shows that it increases the likelihood of "never or last to use" by 0.562, and at the same time, it decreases the likelihood of "one of the first to use or soon after they are available" by 0.596. However, there was a low prevalence (5.81%) of respondents who were 'last to use' new technologies. Among the variables yielding random parameters, three instances of heterogeneity in the means of random parameters were found. Among those who were reluctant to use new technologies, those who were employed (either full or part-time) were significantly more eager to use ABs than those in other employment categories. Among those who drove their car more often than they did before COVID-19, those who were employed were significantly more eager to use ABs. Among those who could structure life well without a car, those who were employed were significantly less eager to use ABs.

3.3. *Future intentions to use buses as a result of automation*

The results of the RPBLHM model for future intentions to use buses as a result of automation as well as the relevant marginal effects are provided in Table 3.2. A positive coefficient in the RPBLHM model suggests an increase in the likelihood of using buses more, whereas a negative coefficient indicates a decrease of the same likelihood (and, in turn, an increase in the likelihood of using buses the same amount or less). Likelihood Ratio Tests (LRTs) were conducted to ensure the inclusion of random parameters with heterogeneity in their means significantly improves the fit of the models compared to lower order counterparts (i.

Table 4.1
MAVA acceptance factors and results of the RPOPHM and RPBLHM models.

MAVA (Nordhoff et al., 2019a, Nordhoff et al., 2019b)			Estimated models	
Level	Factor Class	Acceptance Factors	Eagerness to use ABs with a trained human safety driver onboard	Intentions to use buses more often because of automation
Meso	Exposure to AVs	Experience with and knowledge about AVs	Familiarity with ADAS	Knowledge about ABs
	System Evaluation	Performance expectancy, Effort expectancy, Facilitation conditions, Safety, Service and vehicle characteristics, Hedonic motivation, social influence, Perceived benefits, Perceived risks	Important that AB ride is more comfortable than conventional buses Important that there will be new bus routes with ABs	Perceived benefit: ABs will offer a smoother ride than conventional buses
Micro	Socio-demographic	Age, Gender, Household structure, Education, Income, Employment, Residential situation	Gender (Male) Age (less than 45yrs) Area type (Rural)	Financial situation Age (less than 45yrs) Employment status
	Travel Behaviour	Access to mobility, Travel purpose, Attitude towards using transport modes, Frequency of travel mode use, medical condition/ disability, Accident involvement, Driving mileage	Satisfaction with bus service Driving a car more often during COVID Ability to adopt a car free lifestyle	Satisfaction with bus service Walking or cycling more often during COVID Ability to adopt a car free lifestyle Frequency of bus use
	Personality	Trust, Technology savviness, Control, Sharing AV with stranger	Technology savviness Perceived trustworthiness of ABs	Technology savviness

e., fixed parameters models, and random parameters models with fixed means of random parameters). Due to partial or missing information for some of the variables identified as statistically significant in the RPBLHM model, 432 responses (with full information) were used for model estimation.

Several factors were identified to shape participants' intentions to use buses more or less frequently as a result of automation, as shown in Table 3.2. Similar with the findings from the eagerness-to-use model, those who are reluctant to use any kind of new technology and older respondents (older than 45 years) are less likely to increase the frequency bus use, whereas respondents who are well-informed about ABs and those expecting smoother rides with ABs are more likely to use buses. Respondents who struggle with their financial situation are also more likely to use buses more often compared to those who do not have financial concerns. Participants who increased their amount of active travel (e.g., walking or cycling) during COVID-19 also exhibit a tendency to use buses more often. The opposite trend is observed for full-time or part-time employees, for whom the prospect of bus automation does not seem to increase their level of bus use in the future.

Mixed effects relating to future intentions to use buses stem from infrequent (i.e., those who use buses less than once a month) and satisfied bus users, and respondents who are not dependent on the car and can structure life well without a car. The variables representing these groups of respondents resulted in statistically significant random parameters. The effect of the car dependency variable is notable, as it yields the largest (in magnitude), yet negative impact on the likelihood to use buses more often, as shown by the relevant marginal effect provided in Table 3.2.

Among the variables producing random parameters, six instances of heterogeneity in the means of random parameters were detected. Among the infrequent bus users, females were significantly less likely to use buses more often, whereas those who consider ABs as trustworthy are more inclined to use buses more often. Among the users who are satisfied with the bus service in their area, rural dwellers and female participants exhibit a propensity to use buses the same amount or less often. On the opposite end, among the respondents who can structure their life well without a car, those who live in rural areas and those who value the trustworthiness of ABs are inclined to use buses more often.

4. Discussion

The results of the RPOPHM and RPBLHM models showed that the determinants of eagerness to use ABs with a trained human safety driver onboard and of future intentions to use buses fall within five major categories, which have been long seen as dimensions of acceptance for automation in transport: exposure to AVs, system evaluation, travel behaviour and attitudes, personality, and socio-demographic profile of the potential users. Table 4.1 details the factors identified from both models and the corresponding MAVA acceptance factors (Nordhoff et al., 2019a,b).

4.1. Experience with and knowledge about AVs

Participants who consider themselves well informed about ABs were significantly more likely to anticipate travelling on buses more often. Sanbonmatsu et al. (2018) found that as knowledge of fully automated vehicles increased, beliefs about automated vehicles became more positive. According to Du et al. (2019a), increasing the level of information about AVs can reduce potential users' anxiety, increase their trust in AVs and increase the likelihood that they will exhibit positive attitudes towards AVs. Dong et al. (2019) found that people with prior knowledge of automated vehicles expressed higher willingness to take an AB. Our results, therefore, confirm that bus operators should ensure their customers are well informed about ABs. In addition, the result in the RPOPHM model that those who are familiar with ADAS were more eager to use ABs suggests that increasing use of ADAS in the future may help reduce diffidence towards ABs and encourage uptake. Higher performing ADAS may function as a pathway to mass AB adoption.

4.2. System evaluation

Respondents who agreed that ABs would be more comfortable because they will offer a smoother ride than conventional buses were significantly more likely to report that AB technology would encourage them to use buses more often. The results of the related model also confirmed that comfort of the ride is important with regards to encouraging passengers to use AB services at an earlier stage. Previous research (Nordhoff et al., 2018; Paddeu et al., 2020) also identified comfort as a key factor in the acceptance and adoption of automated shuttles. This suggests that it is important to ensure that high levels of in-vehicle comfort are considered during the development of AB technology. Abrupt and frequent braking onboard automated public transport was assessed negatively in some research studies (Eden et al., 2017; Nordhoff et al., 2019a; Wicki and Bernauer, 2018). In contrast to evidence obtained from trials, our research found that over a quarter of respondents (26.2%) stated ‘more comfortable (smoother ride) than a conventional bus’ as one of the top three most important benefits that could be associated with ABs. It is possible that participants expect the design of the vehicle and software to be able to offer a ride that is smoother than traditional buses. There is evidence to suggest that some passengers using traditional bus services find the driving style uncomfortable. The Transport Focus survey (2019) found that 9% of Scottish bus passengers were dissatisfied with the ‘smoothness/freedom from jolting’’ of the ride. Previous studies indicate that comfort, in terms of magnitudes of acceleration and jerk of the vehicle motion will need to be improved onboard ABs (Bae et al., 2019). Like all new technology, ABs are going through a period of development and refinement and early designs may not have been optimised for smoothness of travel. However, as AB technology continues to improve, it is likely that the smoothness of travel will continue to improve as well. Alessandrini et al. (2015) argues that automatic driving could offer better riding comfort to passengers due to smoother acceleration and jerk. Piao et al (2016) also suggest that AVs will be able to control a vehicle more accurately than humans and this should help improve comfort. However, driving at higher speed and minimising abrupt breaking without compromising safety is a challenge for autonomous buses and autonomous vehicles in general (Mouratidis and Cobeña Serrano, 2021).

Societal benefits such as increased road safety and environment were ranked by respondents as the most important benefits that could be associated with ABs. However, these factors did not significantly affect either eagerness to use ABs or anticipated use in the future. Our findings are in line with previous research (Herrenkind et al., 2019), which also found that attitudes towards the environment did not influence intention to use ABs. Pro-environmental motivation may not be enough for many people to engage in behaviour that benefits sustainable travel modes (Bouscasse et al., 2018). In contrast, other research (Acheampong and Cugurullo, 2019; Haboucha et al., 2017) observed that attitudes towards the environment were positively associated with intention to use automated public transport. Similarly, concerns about safety of the vehicle were found to decrease willingness to use an AB (Dong et al., 2019).

4.3. Socio-demographic factors

The RPBLHM model results suggested that younger individuals (less than 45 years old) were significantly more likely than older ones to be encouraged to use buses more often. A similar finding was also drawn from the RPOPHM, where older individuals are shown to be among the most likely candidates for late or non-adopters of ABs. The demographic cohort of millennials (born between 1965 and 1980) have shown different behaviour compared to their older generations in various domains such as technology acceptance, perceived benefits, and inclination towards early adoption of AVs (Rahimi et al., 2020). Dong et al. (2019) found that ‘millennials’ who have greater exposure to automated technologies than the older generations are more accepting towards ABs. The group of older individuals may require additional support and consideration when introducing an AB fleet. However, other research (Nordhoff et al., 2019a) suggested that the impact of age on AV behavioural intentions either reduces significantly or vanishes when considered in conjunction with other variables. A number of studies found no significant relationship between age and willingness to use automated shuttles (Kostorz et al., 2019; Madigan et al., 2016; Moták et al., 2017).

The RPBLHM model showed that those in employment (either part/full time) were significantly more likely than those in other employment categories to indicate that ABs would not encourage them to use buses more often. In the RPOPHM model, the employment status was found to explain the heterogeneity associated with several groups of respondents, thus highlighting its mixed role on eagerness to use ABs, as for some respondents it increases intentions to use ABs and for others it decreases intentions. The result that those in employment, who have recently increased their car driving are more eager to use ABs is positive for encouraging more sustainable travel choices amongst this group. However, it would be desirable to undertake additional studies to fully understand the role of employment in the acceptance mechanism of automated public transport.

Respondents living in Scottish rural areas were more eager to use ABs than those in urban areas. Rural communities have unique challenges in terms of lack of accessibility, car dependency, social isolation, and road safety issues. Much of rural Scotland continues to rely on subsidised local bus services, and rural communities are suffering with the reduction and demise of many routes in their areas (Hitrans Rural Bus Service Support and Funding, 2021). Deployment of automated public transport could help address some of these issues. Hence, rural priorities should be considered in future AB policy, developments, and trials. Furthermore, it might be easier to first deploy ABs in rural areas, where residents may be more receptive than those living in urban areas. However, if early deployment is disproportionately focused on rural areas, rural residents may feel aggrieved about being the subject of unproven technology deployment, compared to urban dwellers. Therefore, the deployment should be adequately balanced to reduce the possibility of discontent arising from the sense of being a ‘low-risk test bed.’ The use of ABs in rural areas may be perceived as easier or safer than in urban contexts because of fewer interactions with pedestrians and other vehicles. However, rural routes may pose additional challenges for vehicle automation, such as the effectiveness of the technology operating in rural road environments and funding additional infrastructure requirements.

Participants who indicated that they had financial concerns were significantly more likely to anticipate traveling more by bus in the future. This is a positive finding due to its potentially favourable impact on transport equity and accessibility. However, it should be noted that the sample size for those with financial concerns was small.

4.4. Travel behaviour and attitudes

Respondents who were using active travel modes more than they did before the COVID-19 pandemic were significantly more likely to indicate that ABs would encourage them to travel more often by bus. These respondents may highly value the public health benefits provided by both active travel and public transport (NIHCR, 2022). Also, there may be synergetic effects in terms of sustainable mobility from greater familiarity with walking and cycling and deployment of bus automation (Mouratidis and Cobeña Serrano, 2021). Furthermore, those who used active travel modes more often since COVID-19 may be more open to changing their travel habits.

Those who rarely use buses (less than once a month) were significantly less likely than frequent users to indicate that ABs would encourage them to use buses more often. Two variables related to gender and perceived trustworthiness of ABs significantly affected the mean of the random parameter drawn from the variable reflecting current frequency of bus use. Females were less likely than males to be encouraged by ABs to use buses more often. Earlier studies have also identified that females are less willing to use unstaffed automated public transport (Winter et al., 2018), especially when they ride alone (Rosell and Allen, 2020). According to previous evidence, the reluctance to use unstaffed ABs becomes even more pronounced for infrequent, female bus users (Rosell and Allen, 2020). Our research found that infrequent, females bus users were more reluctant to use ABs with a safety driver onboard. It may be that they are unwilling, or unable to, use public transport, so automation would make no difference to their frequency of bus use.

Users who were satisfied with bus services in their area were significantly more likely to use buses more often. Among those who were satisfied with bus services, two instances of heterogeneity in the means of random parameters were found. Specifically, those who lived in rural areas were less likely to use buses more often compared to those who lived in urban areas. This may reflect rural inequities in public transport provision. Although rural residents are eager to use ABs, they might not believe that the technology will enhance bus services provision in their area by for example, providing more frequent services or additional routes. Similarly, females were less likely than males to use buses more often. This suggests that, for women who are dissatisfied with bus services, increasing their public transport use in general, may not be an option. Previous research indicates a positive attitude towards public transport has been associated with willingness to use an AS (Acheampong and Cugurullo, 2019; Kostorz et al., 2019). An earlier study (Yap et al., 2016) has identified that higher levels of satisfaction with conventional bus services pave the way for positive ride experience with ABs, which could, in turn, encourage passengers to use buses more often.

The RPBLHM shows that those who can structure life well without a car are more likely to anticipate using buses less often or the same. Furthermore, for employed respondents, a car-free lifestyle is associated with higher propensity to use ABs. A possible explanation is that this group are open to technologies that will improve their public transport experience, but they do not expect to use buses more often, as their everyday activities are already reliant on public transport. Among those who could adopt a car-free lifestyle, two instances of heterogeneity in the means of random parameters were found. Those who live in rural areas were more likely than those in urban areas to increase their bus use. This may reflect those rural residents, who enjoy a car-free lifestyle, are already well served by public transport. Trustworthiness was also found to affect the random parameter associated with infrequent bus users; in particular, those who perceived ABs as trustworthy, were significantly more likely to use buses more often in the future. The RPBLHM results suggest that measures that improve perceived AB trustworthiness, such as those identified in the next sub-section, would encourage infrequent bus users and those who can adopt a car free lifestyle to travel more often by bus.

4.5. Trust and technology savviness

Respondents who are eager to use new technologies were significantly more likely to be among the early adopters of ABs and to use buses more often as a result of automation. Other research (Wicki et al., 2019; Wien, 2019) also identified acceptance of new technology as a robust indicator for predicting intention to use as well as actual automated public transport use behaviour. Wicki et al. (2019) suggests that potential AS users are mainly technology enthusiasts, who would be defined as either 'innovators' or 'early adopters' in the technology adoption lifecycle (Rogers, 2003). To encourage diffusion of the new 'disruptive' technology, the benefits need to be communicated to the 'laggards' or technophobic, who may also require additional support to encourage AB usage. Asmussen et al. (2020) suggest that campaigns to enhance tech-savviness levels, especially targeted toward women, older adults, and individuals with low education levels and low income, should be used as part of strategies to increase AV uptake. Furthermore, they advise that such campaigns should emphasise AV technology and use in the context of the current lifestyles and habits of the target audience.

The RPOPHM model shows that participants who viewed ABs as trustworthy were significantly more eager to use ABs than those who considered them untrustworthy. Trust is an issue frequently cited in technology adoption literature and has been included as factor in modelling acceptance of AVs (Wien, 2019; Yap et al., 2016). A high level of trust has been associated with the intention to use an AS and preference for an AB over a traditional bus (Herrenkind et al., 2019; Wien, 2019; Winter et al., 2018). The literature suggests a number of factors that could positively affect people's trust in the technology such as having a steward onboard who monitors the vehicle (Dong et al., 2019; Piao et al., 2016), introducing legislation that allows industry to safely operate and test ABs on public roads (Goldbach et al., 2022), and increasing the availability of information about AVs (Du et al., 2019). Shariff et al. (2017) also suggest certain strategies to foster public trust in AVs; these include addressing the ethical and social dilemmas, addressing over reactions to accidents and increasing the transparency in decision-making processes related to AVs and enhancing public beliefs on reliability, usability and understanding of AV technology. Not only should legislation be passed that allows industry to safely operate and test ABs on public roads, but public awareness of such legislation should also be heightened together with an awareness of available contingency actions if something goes wrong. Furthermore, to foster trust, bus operators should continue to have staff onboard to monitor the vehicle as this provides a visible back-up, in the unlikely event of system failure.

5. Conclusions and future work

The goal of this study was to investigate the role and potential of automation technology in attracting more passengers in bus services. To inform technology development, bus operators and policy initiatives for making ABs appealing, not only to captive users but also to car users, it is important to fully understand what could encourage people to use ABs. Hence, this study focused on two dimensions of acceptance and expectations relating to ABs: (i) eagerness to use ABs with a trained human safety driver onboard; and (ii) intentions to use buses more often because of automation. To that end, survey data was collected from a sample of bus users in Scotland, and it was statistically analysed to identify the determinants of these two dimensions. To account for several layers of unobserved heterogeneity being potentially present in the collected data, random parameter models with heterogeneity in the means were estimated.

Overall, our study shows a significantly higher prevalence of people who would be eager to use ABs with a trained human safety driver onboard as opposed to those who are more sceptical towards automation in buses. In addition, a slightly higher prevalence of people who would be encouraged to use buses more often because of automated technology onboard was also observed. This is good for both the bus industry and the sustainable mobility strategies of public authorities. However, much of the population would not be affected, as mode choice, typically is a function of many factors other than bus technology.

Factors associated with the technology itself discriminate more than other variables. Therefore, these are the ones that the transport industry should focus a greater proportion of their resources on in order to encourage AB usage. The results of both RPBLHM and RPOPHM models suggest that AB technology development should focus on ensuring high levels of in-vehicle comfort, especially with regard to reducing sudden braking or sudden acceleration. If ABs offer a more comfortable, smoother ride than traditional buses, this should be emphasised through marketing campaigns. Such campaigns should be targeted towards specific groups of users with a higher level of scepticism towards ABs. Future AB trials should consider monitoring onboard comfort such as measuring vehicle lateral acceleration.

The finding that those who have increased their post pandemic active mobility also expect to use buses more because of automation is encouraging. There might be synergistic effects in terms of sustainable mobility from greater familiarity with walking and cycling and deployment of bus automation. Bus automation on its own does not seem able to attract infrequent bus users. Individuals who can structure their life well without a car, while they belong among the keenest adopters of ABs, they do not expect to increase the amount of their bus use upon the launch of ABs. However, both these factors resulted in random parameters in the statistical models so, there are people within those categories who would behave differently. Overall, the fact that all bus-related variables generated random parameters may be a sign that the influence of actual bus use may not be so direct and requires further investigation.

Focusing on the socio-demographic characteristics, older and female passengers are significantly less likely to be early adopters of ABs with a trained safety driver onboard and to use buses more often because of automation. These groups may require additional support and tailor-made considerations when introducing automation on buses. Furthermore, understanding the role of the rural attribute requires further consideration. Only for respondents who are not dependent on the car for everyday activities, location in a rural area increases intentions of using buses more often. However, all respondents who are in rural areas have a favourable tendency towards using ABs.

Janatabadi and Ermagun (2022) found evidence that studies investigating acceptance of autonomous vehicles tend to be biased. Therefore, it should be acknowledged that potential bias may be present in survey data and as such, the findings of the analysis should be interpreted with caution. The study estimated advanced heterogeneity models (i.e., the random parameter models), which can account, to some extent, for the impact of some sources of bias on parameter estimates, according to Mannering et al. (2016).

While considering the findings of this study, it should be factored in that the participants were requested to assume that there is a trained human safety driver behind the wheel to intervene if required which might positively influence perceptions of safety and overall travel experience. Very few (18.2%) respondents would agree to ride in a bus without an employee on board. Many of the anticipated benefits associated with ABs, such as reduced vehicle operating costs, would only be achieved once safety drivers are no longer required. The purpose of the study was to assess the acceptance of an automated bus service with a safety driver onboard prior to a trial service operating on public roads in Scotland. Although, for the longer term, perception towards bus services without staff onboard is essential (considering the potential for reduced operational costs and more services in remote rural areas) there is still merit in investigating perceptions towards ABs with staff onboard. What happens in the immediate future is important as staffed ABs are an intermediate step on the journey towards full automation. There is a substantial number of respondents who would be unwilling to ride in an AB bus even when a safety driver is present (37.8% either 'probably not' or 'definitely not' or 'might/might not'). The perspectives of these individuals are of interest and warrant further investigation because they are important for operators who may wish to consider trialling a pilot AB service or integrating automated features into their current fleet. It may also be that the presence of a driver generates additional concerns. For example, our research suggested that almost three fifths (57.6%) agreed it would be difficult for the bus driver monitoring an AB, to maintain attention throughout the working day. Further research should be carried out to understand the impact of staff presence on eagerness to use ABs.

Lastly, the findings of this study are valid for Scottish bus passengers from a selected population. Further studies should investigate the general population considering varying levels of bus use. The current study is reliant on expectations about future AB travel of the respondents participating in the study. This may not reflect actual behaviour in the future. Actual behaviour depends on an individual's own ability to adapt them together with external factors, such as employment and the characteristics of a particular AB service. Petty and Cacioppo (1986) propose that exposure to information and direct experience would produce different results in attitude formation. They suggest that direct experience results in participants engaging more carefully and with greater effort leading to greater consistency in beliefs, affects, and behaviours. However, experiencing autonomous bus services has been found to positively impact the propensity to use services in the future (Weschke et al., 2021). In this context, more research on AB acceptance would be desirable after the deployment of ABs on the Scottish public road network under the CAVforth project.

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Table A1
Independent variables and their distribution in sample.

Variable	Description
Eagerness to use any kind of new technology	Q2.2 If you think about any kind of new technology, please select the statement, which describes you best?I refuse to use new technologies no matter how popular they become (1.6%); I avoid using or purchasing new technologies unless they are absolutely necessary (7.4%); I am usually the last person I know to use new technologies (4.7%); I usually wait for a while before I use new technologies (41.2%); I like to use new technologies soon after they are available (31.7%); I am always one of the first to use new technologies (13.3%)
Driver assistance system (used or seen)	Q2.3 Which of the following driver assistance systems have you used (as a driver) or seen (as a passenger)? Please tick ALL that apply. Lane Departure Warning - Warns the driver when the vehicle unintentionally drifts (moves out of its lane). (28.6% have seen or used LDW); Lane Keep Assist - Advanced lane departure warning system. Keeps the car in its lane without driver input. (17.1%); Adaptive Cruise Control - Automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead without driver input. (31.6%); Traffic Jam Assist - This is essentially a low-speed version of Adaptive Cruise Control. (8.6%) Autonomous Emergency Braking - Detects a potential collision ahead and applies the brakes automatically without driver input (19.5%);) Parking Assistance Warning Systems - Uses parking sensors fitted to the front, back and side of the car, which detect spaces and obstacles and warns the driver (51.0%). Autonomous Parking Assistance Systems - Uses parking sensors fitted to the front, back and side of the car, which detect spaces and obstacles and automatically steers the vehicle into the parking space without driver input. (19.5%). I have not used or seen any of any of the above automated driver assistance systems (34.1%);
Knowledge and perceptions towards ABs	Q3.2 Assume that there will be a trained human safety driver behind the wheel to monitor the roadway and autonomous bus and intervene only if required. Autonomous buses are………?7-point scale: Do not know much about (1,2,3) (58.3%); neutral (4) (17.5%); very well informed about (5,6,7) (24.2%)7-point scale: Something I am not very interested in (1,2,3) (29.0%); neutral (4) (20.0%); Something I am not very interested in (5,6,7) (51.0%)7-point scale: Very boring (1,2,3) (18.6%); neutral (4) (26.1%); Very exciting (5,6,7) (55.3%)7-point scale: Fear inducing (1,2,3) (41.5%); neutral (4) (19.4%); Not fear inducing (5,6,7) (39.0%)7-point scale: Not trustworthy at all (1,2,3) (31.8%); neutral (4) (29.0%); Trustworthy (5,6,7) (39.2%)7-point scale: Not safe for me to use (1,2,3) (31.8%); neutral (4) (24.9%); Safe for me to use (5,6,7) (43.2%)
Eagerness to use ABs	Q3.3 Assume that there will be a trained human safety driver behind the wheel to monitor the roadway and autonomous bus and intervene only if required. If you think about autonomous buses, which statement describes you best?I would be one of the first to use an autonomous bus (7.3%)I would use an autonomous bus soon after they are available

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Table A1 (*continued*)

Variable	Description
	(13.3%)I would wait for a while before I use an autonomous bus (2.9%)I would be the last person I know to use an autonomous bus (27.2%)I would avoid using an autonomous bus unless they are absolutely necessary (30.4%)I would refuse to use an autonomous bus no matter how popular they become (18.9%)
Frequency of AB use	Q3.4 Assume that there will be a trained human safety driver behind the wheel to monitor the roadway and autonomous bus and intervene only if required. Would autonomous buses encourage you to use buses 'more often' or 'less often'?Much more often (13.3%)Somewhat more often (9.8%)About the same (55.2%)Somewhat less often (8.2%)Much less often (13.4%)
Concerns about ABs	Q3.6 Assume that there will be a trained human safety driver behind the wheel to monitor the roadway and autonomous bus and intervene only if required. Please indicate your level of agreement with the following statements about potential concerns associated with autonomous buses. Strongly agree (1) Somewhat agree (2) Neither agree nor disagree (3) Somewhat disagree (4) Strongly disagree (5) Don't know (6)Autonomous buses would require too much public investment (e.g., infrastructure and maintenance) (56.3% agree)It would be difficult for the bus driver monitoring an autonomous bus, to maintain attention throughout the working day (57.6%)An autonomous bus would not 'sense' all that is happening around it (62.7%)An autonomous bus could be made unsafe through a computer virus or hacking just like any other computer system (%74.1) Autonomous bus technology will not be reliable (38.0%)
Benefits associated with ABs (level of agreement)	Q3.7 Assume that there will be a trained human safety driver behind the wheel to monitor the roadway and autonomous bus and intervene only if required. Please indicate your level of agreement with the following statements about the potential benefits of autonomous buses. Strongly agree (1) Somewhat agree (2) Neither agree nor disagree (3) Somewhat disagree (4) Strongly disagree (5) Don't know (6) Autonomous buses will improve road safety overall (34.0% agree)Autonomous buses will be more comfortable (through a 'smoother' ride) than a conventional bus (32.8% agree)Autonomous buses will reduce bus travel times (24.4% agree)Autonomous buses will increase bus punctuality (35.1% agree)Autonomous buses will have environmental benefits (e.g., through reduced bus emissions, more efficient driving styles etc.) (58.6% agree)Autonomous buses will encourage more people to use the buses (21.0% agree)Autonomous buses will encourage bus operators to introduce more frequent services and/or new bus routes (43.7% agree)
Most important benefits	Q3.8 Assume that there will be a trained human safety driver behind the wheel to monitor the roadway and autonomous bus and intervene only if required. Thinking about benefits (if any) that could be associated with autonomous buses, which are the most important to you? Please select up to 3 benefits and rank them by typing '1′ (most important benefit), '2′ (second most important) and '3′ (third most important)____Improved road safety (1) Most Important (31.1%)____More comfortable (smoother ride) than a conventional bus (2) Most Important (3.4%)____Environmental benefits (reduced bus emissions, more efficient driving styles etc) (3) Most Important (28.5%)____Reduced bus travel times (4) Most Important (4.7%)____Improved bus punctuality (5) Most Important (11.3%)____Reduced passenger boarding times (6) Most Important (1.2%)____More frequent services (7) Most Important (13.7%)____New bus routes (8) Most Important (5.1%)____Other (PLEASE WRITE) (0.9%)I do not think there will be any benefits associated with autonomous buses (5%)
Staffing levels onboard AB	Q4.1 FUTURE SERVICES WITH AUTONOMOUS BUSES In the future, consideration might be given to using fully autonomous buses without a driver in the cab (this does NOT apply to the CAV Forth trial). In such circumstances, some operators may consider having a steward on board to provide customer care. They would be able to move around the bus and offer passengers support and assistance when both boarding and in transit, sell/check tickets as well as acting as an authority figure in an emergency or when there is disorder.Q4.2 Would you be likely to ride in an autonomous bus WITH a human driver available to intervene and WITH a steward to provide customer care? (76.4% yes)Q4.3 Would you be likely to ride in an autonomous bus WITH a human driver available to intervene and WITHOUT a steward to provide customer care? (62.2% yes)Q4.4 Would you be likely to ride in an autonomous bus WITHOUT a human driver available to intervene and WITH a steward to provide customer care? 32.9% yesQ4.5 Would you be likely to ride in an autonomous bus WITHOUT a human driver available to intervene and WITHOUT a steward to provide customer care? (18.2% yes)
Current mode of travel (frequency):	Q5.3 Currently, how often do you usually travel using EACH of the following types of transport? Car driver (46.1% at least once per month; 53.9% less than once per month)Car passenger (67.0% at least once per month; 33.0% less than once per month)Bus (78.1% at least once per month; 21.9% less than once per month)Train (27.8% at least once per month; 72.2% less than once per month) Walking or cycling (87.9% at least once per month; 12.1% less than once per month)
Change in frequency of travel since COVID-19 (by mode)	Q5.2 Before the COVID-19 pandemic (i.e., BEFORE 11th MARCH 2020), how often did you usually travel using the following types of transport?Car driver (19.3% decreased since COVID; 69.4% no change; 11.3% increased)Car passenger (22.5% decreased since COVID; 58.2% no change; 19.3% increased)Bus (31.1% decreased since COVID; 54.6% no change; 14.3% increased)Train (22.4% decreased since COVID; 68.1% no change; 9.5% increased)Walking or cycling

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Table A1 (*continued*)

Variable	Description
	(15.9% decreased since COVID; 70.3% no change; 13.7% increased)
Structure everyday life very well without a car	Q5.4_1 Please indicate whether the following statements apply to you? - I can structure my everyday life very well without a carDefinitely does not apply (14.6%); Rather does not apply (8.4%); Applies in part / Does not apply in part (20.4%); Rather applies (16.0%); Definitely applies (40.7%)
Difficult for me to travel by public transport instead of by car	Q5.4_2 Please indicate whether the following statements apply to you? - It is difficult for me to travel the ways I need to go in everyday life with public transport instead of by carDefinitely does not apply (26.8%); Rather does not apply (13.6%); Applies in part / Does not apply in part (21.7%); Rather applies (17.0%); Definitely applies (20.9%)
Overall satisfaction with bus service	Q5.5 Overall, how satisfied are you with the bus service in your area?Very dissatisfied (9.5%); Fairly dissatisfied (19.1%); Neither satisfied nor dissatisfied (12.9%); Fairly satisfied (40.9%); Very satisfied (17.6%)
Age	Q6.2 Which age group are you in? 18–24(13.0%), 25–34(12.1%), 35–44(15.5%), 45–54(18.4%), 55–64, (10.7%) 65–74(10.7%), 75+(3.1%)
Gender	Q6.3 How would you describe your gender? Male*(44.7%)*, Female*(54.4%)*, Non-binary / prefer to self describe / Other*(0.9%)*
Employment status	Q6.4 Which, if any, of the following describes your current situation?Currently employed full time (38.7%), Currently employed part time (13.3%), Self-employed (3.5%), In full-time education (9.1%), Unemployed and seeking work (2.9%), Permanently retired from work (19.3%), Full time career (3.5%), Looking after the household (3.2%), Long term sick or disabled and unable to work (6.2%), On paid leave from employment (e.g., maternity leave, long-term sick leave) (0.3%).
Highest education level	Q6.5 What is the highest educational qualifications you have?No qualifications (0.7%), Standard Grades or equivalent (24.9%), Higher Grades or equivalent (12.5%), HNC; HND or equivalent (23.4%), First degree level or equivalent (15.7%), Higher degree or postgraduate qualifications or professional qualification (22.9%)
Concessionary travel pass	Q6.6 Do you currently have a concessionary travel pass which allows you to travel free of charge on scheduled bus services?Yes (37.2%); No (62.8%)
Stagecoach ticket type	Q6.7 Which bus ticket type will you use most often now (over the next few months) when travelling on Stagecoach buses?Concessions (34.0%), Single (23.8%), Weekly (14.9%), Return (12.4%), Day ticket (11.3%), Other (3.5%)
Long standing illness that limits travel choices	Q6.9 Do you have any long standing (i.e., lasts or expected to last at least 12 months) illness, health issue or disability that limits your travel choices?Yes, physical health issue (14.9%); Yes, mental health issue (6.0%); Yes, both mental and physical health issues (5.1%); No (73.9%)
Income concern	Q6.10 Which of the following best describes you?Paying bills is a constant struggle and worry (11.0%); Paying bills is tough and on my mind, but I get by (35.7%); My monthly bills are affordable, and I don't worry too much about paying them (37.7%); I never worry about my monthly bills (15.6%)
Region of Scotland	Q7.2 Which region of Scotland do you live in? Ayrshire and Arran (18.2%); Borders, Dumfries and Galloway (3,3%); Fife (24.6%); Forth Valley (2,0%); Grampian (15.1%); Greater Glasgow and Clyde (5.5%); Highland), Orkney

Table A1 (*continued*)

Variable	Description
	(%), Shetland, Western Isles (6.2%); Lanarkshire (4.0%); Lothian (4.7%); Tayside (16.4%)
Urban Rural Classification	Derived from postcode.Urban (82.8%); Rural (17.2%)
Household car availability	Q7.4 In total, how many cars or vans are owned, or are available for use, by members of your households?no car (37.7%), one car (39.5%), two or more cars (22.8%)
Household size (number of adults)	Q7.5 How many adults (18 years or older) are there in your household (including yourself)? One (32.1%), two (28.1%), three (14.7%), four or more adults (5.0%)
Children per household	Q7.6 How many children (17 years or younger) are there in your household?None (73.2%), one (12.9%), two (10.1%), three (2.2%), four or more children (1.6%)
Household income (GBP)	Q7.7 What is your total household income per year from all sources, before tax and other deductions? 0–10,000 (14.7%), 10,001–20,000 (30.1%), 20,001–30,000 (18.5%), 30,001–40,000 (13.5%), 40,001–50,000 (6.6%), 50,001–60,000 (6.0%), 60,001–70,000 (3.8%), 70,001–80,000 (2.4%), Over 80,000 (4.4%)

CRediT authorship contribution statement

Achille Fonzone: Conceptualization, Methodology, Formal analysis, Investigation, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Grigorios Fountas:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. **Lucy Downey:** Conceptualization, Methodology, Investigation, Writing – original draft, Visualization, Project administration, Funding acquisition.

Declaration of Competing Interest

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

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Appendix

Table A1

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