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HOW AUTONOMOUS BUS TRIALS AFFECT PASSENGERS' VIEWS: EXPLORING THE GAP BETWEEN PRE-RIDE EXPECTATIONS AND REAL WORD EXPERIENCE

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ABSTRACT

The study investigates passengers' perceptions of a real-world trial involving a level 4 full-sized Automated Bus (AB) operating as a commercial service on a 22 km inter-urban route along public roads in East Scotland. By focusing on a trial, where the AB navigates mixed traffic, different road types (including motorways) and operates at speeds of up to 80 km/h, this research fills a significant gap in the existing literature, which has offered limited exploration of passenger AB experiences in such complex and realistic operational environments. The contribution of this study lies in providing a comprehensive analysis of passenger expectations and satisfaction, considering both the automated driving technology and the service in all its aspects, while also taking into account their interactions. Results (n = 490) revealed generally positive views from passengers with 61.7 % indicating that the AB technology exceeded their expectations and 71.1 % expressing a high likelihood of recommending the service to others. A binary probit model with random parameters showed satisfaction with ride smoothness and vehicle noise, low pre-ride expectations, and a willingness to use unstaffed ABs were key determinants of post-trial evaluation. In addition, frequency of bus use and gender were found to have mixed effects. A second binary probit model found that high pre-trial expectations, infrequent car use, and frequent bus use influenced the net promoter score, with satisfaction with AB driving style and with service characteristics having heterogeneous effects. These findings offer valuable insights for the transport industry, guiding their future developments and strategies for the successful implementation of AB technology.

1. INTRODUCTION

Mass transportation will continue to be an essential element of future mobility systems. The digital revolution and automation have enabled the development of new services that should be designed to complement and work together with public transport, rather than replacing mass services (Department for Transport, 2019). Buses play an important role as a form of mass transit, as they offer greater

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flexibility and adaptability in terms of route options at much lower infrastructure costs than rail-based services. They are especially effective in areas with lower population density or where demand varies, providing crucial connectivity in these regions. Increased bus shares can contribute to healthier lifestyles, less congested roads, more liveable cities, and more environmentally friendly movement of people. The possibility of attracting more people to buses depends on the quality of the service provided. The deployment of automation on bus services can contribute to their quality in several ways: enhanced safety and more efficient and less polluting driving styles can be expected even when technology level, legislation or customers still require the presence of staff on board. In addition, unstaffed services can lead to reduced operational costs, greater flexibility, wider coverage, and increased frequencies. While it can be expected that operating fully automated, unstaffed vehicles in the future will increase the offer of on-demand, shared taxi-like services (Almaskati et al., 2024; Tu et al., 2024), timetabled and fixed route bus services will still be necessary to efficiently serve high-density routes.

Although it can be anticipated that automated services may not be perceived as a barrier to bus use once the technology becomes mature and the services widely available, low levels of acceptance in the initial stages of deployment can hinder their adoption. A lack of early passenger acceptance and willingness to use Automated Buses (ABs) can make it challenging to establish a sustainable market (Transport Scotland, 2019) and it may even discourage the use of buses, thus leading to an increased reliance on private cars. Therefore, understanding the attitudes and motivations of early adopters is critical, as it allows for a better alignment between user expectations and their experiences with the service, a crucial factor for success of innovation (Venkatesh & Davis, 2000). Conducting trials is particularly valuable for gathering insights especially when they closely mimic real-world use cases.

Mode choice is a complex decision, the motivations for which extend beyond the way a bus is driven. It is influenced by factors including overall satisfaction with the bus journey and the availability and accessibility of other transportation options. Satisfaction with a bus journey can be shaped by multiple factors, including those directly related to the driving experience and those that are not, such as seating comfort, cleanliness, or cost to mention a few (Hansson et al., 2019; Redman et al., 2013). These factors often interact with one another. For example, the comfort of seats may influence passengers' perceptions of the driving style. A higher fare may lead to expectations of better service quality, thereby influencing satisfaction levels. Additionally, the journey experience depends on the trip characteristics, such as the length and frequency. A longer trip may heighten the importance of comfort and convenience. Moreover, passengers' preferences are not uniform and can vary based on individual characteristics, such as age, mobility needs, or past experiences with public transport. Some of these characteristics may not be observable. Therefore, when assessing the impact of autonomous driving on mode choice, it is important to control for these various aspects and to account for unobserved heterogeneity to isolate the specific influence of automation on user preferences.

This paper studies passengers' views of SAE (Society of Automotive Engineers (SAE), 2018) level 4 AB services making several contributions. First, it addresses an understudied context by focusing on inter-urban bus trips using automated buses. The case study is particularly realistic, as the bus operates in mixed traffic, on different types of roads (including motorways, A-roads, and bus lanes) while maintains typical cruising speeds. Questionnaire data was collected from passengers following their direct experience of the AB service. Second, the study offers a comprehensive analysis of passenger expectations and satisfaction, considering both the automated driving technology and the service in all its aspects, while also taking into account their interactions. Third, the analysis employs advanced statistical methodologies that effectively account for unobserved heterogeneity, providing a deeper understanding of variations in passenger preferences and behaviors, as well as offering a more accurate estimate of the importance of the determinants of their experience.

2. LITERATURE REVIEW

2.1. Theoretical background

For Automated Buses (ABs) to gain public acceptance, it is essential to understand the factors determining this acceptance. To provide an explanation for the acceptance of emerging technologies by users, several socio-psychological models have been established. The Technology Acceptance Model (TAM) (Davis, 1989) suggests that perceived usefulness combined with ease-of-use determine attitudes towards a technology, which then predict behavioral intention and actual use. In the context of Automated Public Transport Vehicles (APTV), studies have demonstrated the influence of TAM components (Herrenkind et al., 2019; Moták et al., 2017) on acceptance. The Unified Theory of Acceptance and Use of Technology (UTUAT) (Venkatesh et al., 2012) identifies four key constructs of acceptance: performance expectancy (extent that the technology will provide benefits), effort expectancy (how easy the system is to use), social influence (perceptions of others' attitudes towards the technology), and facilitating conditions (having adequate resources and knowledge available). In UTAUT2 (Venkatesh et al., 2012) three additional constructs were introduced: hedonic motivation (enjoyment derived from technology use), price value (overall value derived relative to costs incurred), and habit (integration into the users' routine). Research (Madigan et al., 2016, 2017; Nordhoff et al., 2018) has shown that the components of UTUAT2 significantly influence APTV acceptance.

In order to develop a more comprehensive theoretical framework, TAM and UTUAT2 constructs have been incorporated into the Model on Automated Vehicle Acceptance (MAVA) (Nordhoff, Kyriakidis, et al., 2019). MAVA acceptance factors are categorized into 'meso' and 'micro' levels covering experience and system evaluation, and individual differences (such as socio-demographics, personality, and travel behavior), respectively. Individual differences influence the intention to use AVs either directly or by moderating the *meso*-level factors. Although MAVA contains up to 70 factors (Pigeon et al., 2021), which could potentially make it too unwieldly for practical applications by researchers, the robust and systematic foundation in empirical research makes it highly valuable for studies on APTV acceptance.

Existing literature often relies on findings from individuals without direct experience. Research (Petty & Cacioppo, 1986) suggests that direct exposure to technology leads to stronger more consistent attitudes, affects, and actions, particularly as participants may be more likely to engage with the technology in a more careful manner and with greater effort. Expectation-Confirmation Theory (ECT) provides a theoretical framework for understanding the relationship between expectations, satisfaction and experience (Oliver, 1977, 1980) suggesting that user satisfaction arises when actual experiences meet or exceed initial expectations. Cognitive Dissonance Theory (Festinger, 1957) is highly relevant in the context of ECT, particularly when post-use experiences do not align with pre-use expectations, leading individuals to adjust their beliefs, attitudes, or perceptions to resolve the conflict. Oliver (1980) highlights the 'halo' effect, where individuals who begin with positive expectations tend to evaluate their overall experience more favorably, even if minor negative incidents occur. However, high initial expectations can lead to greater dissatisfaction if the experience falls short (Bhattacherjee & Premkumar, 2004). In the field of technology acceptance, post-use satisfaction and expectation confirmation serve as crucial indicators for continued use and positive word-of-mouth recommendations (Bhattacherjee, 2001; Venkatesh & Davis, 2000). Word-of-mouth communication not only serves as a strong indicator of consumer satisfaction, but it is also recognized as one of the most powerful marketing tools available (Chevalier & Mayzlin, 2006). Therefore, word-of-mouth functions as a highly influential source of information shaping perceptions and facilitating adoption.

Overall, the MAVA framework and Expectation-Confirmation Theory contribute to the theoretical foundations for this paper exploring the factors influencing the relationship between AB user expectations and real-word experiences. Additionally, given the importance of word-of-mouth communication, the study explores the factors that affect the likelihood of recommending AB services to others.

2.2. Meso level factors

MAVA instrumental domain-specific constructs (performance expectancy, effort expectancy and facilitating conditions, service and vehicle characteristics, and safety) and symbolic-affective constructs (social influence and hedonic motivation) have been well established as factors influencing APTV and AV acceptance, with performance expectancy being widely recognized as the most influential (Bellet & Banet, 2023; Bernhard et al., 2020; Dirsehan & Can, 2020; Herrenkind et al., 2019; Madigan et al., 2016; Maghrour Zefreh et al., 2023; Moták et al., 2017). Service and vehicle characteristics (such as ticket prices, level of service, journey times) and safety (such as road safety and security on board) have been identified as the most frequently mentioned factors in the literature (Pigeon et al., 2021). Studies have shown the importance of level of automation, fixed or flexible routes, provision of dedicated lanes, vehicle occupancy, or the presence of human staff on board (Dong et al., 2019; Piao et al., 2016; Rehrl & Zankl, 2018). Research also suggests a greater acceptance towards Automated Shuttles (AS) compared to full-sized buses, with expectations that full-sized vehicles would not function as well or be as easy to use (Chng et al., 2022). The authors suggest that these perceptions are associated with ABs remaining in their early phase of development, so they remain less familiar and visible to the public.

Knowledge and experience have been shown to play a key role in the intention to use APTV. Individuals who considered themselves well informed about AVs indicated greater willingness to use ABs (Dong et al., 2019). Furthermore, those who are familiar with automated driver assistance systems exhibited greater eagerness to use ABs and those who were knowledgeable about ABs were more likely to anticipate using them more frequently (Fonzone et al., 2024).

2.3. Micro level factors

When examining sociodemographic factors, the impact of age on acceptance varies across the research. Research has suggested that younger individuals are more open to APTV than older adults (Guo et al., 2020; Kassens-Noor et al., 2020). However, many studies (Kostorz et al., 2019; Madigan et al., 2016, 2017; Moták et al., 2017; Pakusch & Bossauer, 2017) report no significant age effect on willingness to use APTVs. Additionally, age has been shown to moderate factors such as perceived ease of use and trust. For example, older adults tend to place greater value on ease of use (Chen, 2019) whereas trust plays a more significant role in younger individuals' acceptance (Nordhoff et al., 2017).

Gender also influences APTV acceptance, though findings remain mixed. Some studies (Dong et al., 2019; Winter et al., 2018) found that men are generally more willing to use ABs, whereas other studies (Madigan et al., 2017; Pakusch & Bossauer, 2017; Winter et al., 2018) reported no significant gender differences. Chen (2019) found that gender may moderate perceived usefulness. The likelihood of adopting an AS also appears to vary by location, with residents of large cities showing a greater willingness to use AS compared to those living in less densely populated areas (Bellet & Banet, 2023). In contrast, other research found that rural inhabitants exhibited a greater eagerness to use ABs than those in more densely populated regions (Fonzone et al., 2024).

Individuals' travel behavior can also influence the intention to use APTV. A recent study found that satisfaction with current primary mode of transport influences AS acceptance and that car drivers generally exhibit lower intentions to use AS compared to regular public transport users (Bellet & Banet, 2023). However, other research has found no significant differences in the intention to use APTV between car and public transport users (Pakusch & Bossauer, 2017). Individuals also consider value-for-money of AS relative to their current transport modes (Bellet & Banet, 2023). Occasional bus users showed reduced eagerness for using ABs compared to frequent bus users (Fonzone et al., 2024; Nordhoff et al., 2018). Conversely, some studies (Kassens-Noor et al., 2020; Wien, 2019) report no difference in preferences for ABs between frequent and occasional public transport users. Lastly, familiarity with information and communication technologies and interest and confidence with new technologies have been found to influence likelihood of using APTV (Bellet & Banet, 2023; Herrenkind et al., 2019; Moták et al., 2017; Wicki et al., 2019).

2.4. Experience

Recent research on APTVs, including both automated buses (ABs) and automated shuttles (ASs), has increasingly focused on understanding users' direct experiences, their satisfaction, and the factors that shape their continued use. Table 1 summarises recent

Table 1
Overview of studies involving passenger experience in APTV trials.

Study	APTV Description	Findings
(Ariza-Álvarez et al., 2023)	**AB (Spain).** The SAE level 3 tourist bus operated along a 5 km fixed route in mixed traffic at speeds of 11 km/h. The AB was the same size as a traditional bus, with capacity for up to 60 passengers.	Passengers who were older, female, employed, private vehicle users, environmentally conscious, and open to new technologies reported higher satisfaction on board. Those more open to new technologies and environmentally conscious also showed a greater willingness to adopt ABs. Pre-pilot (n = 300); Post-pilot (n = 105).
(Bellone et al., 2021)	**AS (Finland, Estonia, Norway, and Poland)** The vehicles, either EasyMile or Navya, operated at speeds of up to 20 km/h (capped at 12 km/h for some trials). These small shuttles, with a capacity of up to 8 seats, ran in mixed traffic, and passengers were offered free journeys.	Users (n = 837) across cities reported strong feelings of safety and security on AS, with women rating experiences more positively than men. However, issues like slow speed, abrupt maneuvers, and high pedestrian interactions were noted as drawbacks.
(Chee et al., 2021)	**AS (Sweden)** The small EasyMile EZ10 shuttles, with a capacity of up to 6 seats, operated on an 800-meter route as first/last-mile transport, traveling at speeds of around 12 km/h.	Initial evaluations (n = 483) of AS were shaped by user expectations about technology and service. With more experience, comfort overtook safety and travel time as the most influential factor in continued use.
(Guo et al., 2025)	**AS (Sweden).** The vehicle operated on a 2.5 km route in a mixed-traffic urban environment on public roads, traveling at speeds of 12–15 km/h.	Comfort and convenience were key to users (n = 363) satisfaction and continued use of ASs. However, behavioral intentions alone did not strongly predict actual usage, emphasizing the role of direct experience.
(Herrenkind et al., 2019)	**AS (Germany)** The small EasyMile EZ10 shuttles, with a capacity of up to 6 seats, traveled at a speed of 15 km/h on a 1 km route along public roads. While there was no driver onboard (with no steering wheel or accelerator pedal), a safety operator was present to intervene if needed.	Younger users (n = 268) appreciated the simplicity and convenience of AS, while older individuals valued usefulness. Acceptance was shaped by environmental attitudes, social context, and personal well-being.
(Johansson et al., 2023)	**AB (Sweden)** Operating on a 3.3 km test route, the vehicle achieved SAE Level 4 autonomy, traveling at speeds of up to 35 km/h. The Volvo 7900 electric-diesel hybrid bus was the same size as a conventional bus.	Users (n = 22) expressed high trust in ABs and optimism about their future, with most reporting a very positive experience on board.
(Madigan et al., 2017)	**AS (Greece)** The AS operated along a 2.5 km urban route in mixed traffic with an average speed of 13 km/h and a capacity of up to 10 passengers.	Hedonic motivation (i.e., enjoyment) was the strongest driver of intention to use AS (n = 315). Performance, social influence, and ease of use also played key roles.
(Mouratidis & Cobeña Serrano, 2021)	**AS (Norway)** The AS operated on a fixed 1.5 km urban route in mixed traffic, with a capacity of 8 passengers and an average speed of 18 km/h.	AS users generally felt safe, but were dissatisfied with low speed and abrupt braking, affecting their overall experience. Before use (n = 117). After use (n = 25)
(Nordhoff et al., 2018)	**AS (Germany)** The AS operated on a 700-meter route within an office campus, carrying up to 8 passengers at speeds of up to 8 km/h	Using the UTAUT framework. Passengers (n = 384) showed generally positive attitudes toward AS for first/last-mile travel but found them slower and less effective than traditional options.
(Nordhoff, de Winter, et al., 2019)	**AS (Germany)** The AS operated on a 700-meter route within an office campus, traveling at speeds of up to 10 km/h on a shared road used by pedestrians, cyclists, and occasional cars.	Applying the UTUAT model, identified six factors relevant for AS passengers (n = 30 interviews) – expectations about capabilities, performance, service quality, risk perception, travel purpose, and trust
(Paddeu et al., 2020)	**AS (United Kingdon)** The AS operated on a test track in the United Kingdom, with a maximum speed of approximately 16 km/h and a capacity of up to 4 passengers.	Trust in autonomous shuttle technology is an important predictor of passengers' perceived comfort (n = 55).
(Rosell & Allen, 2020)	**AS (Spain)** The EZ10 EasyMile vehicle operated in designated test zones, primarily within pedestrianized areas such as university campuses. It did not run in mixed traffic, had a maximum speed of 11 km/h, and accommodated up to five seated passengers.	Satisfaction with conventional buses positively influenced perceptions of safety and overall satisfaction with AS (n = 1062). Women were more satisfied but more hesitant to ride alone
(Weschke et al., 2021)	**AS (Germany)** A conventional manually driven shuttle was used for first/last mile transport, but the vehicle was modified for the experiment so that the driver was not visible to passengers.	Passengers (n = 65) are generally satisfied with AS, preferring to ride alone. Direct experience increases the likelihood of choosing AV in stated preference studies.
(Yan et al., 2022)	**AB (China)** In China, large 12-meter electric ABs were used, featuring 19 standard seats and one space for a wheelchair. They operated in mixed traffic at a speed of 20 km/h.	Bus characteristics, such as perceived in-vehicle safety, service quality, and overall attitudes toward buses, positively influenced the intention to continue using (n = 576). Past riding habits and dependence on drivers influenced ongoing use intentions. Perceived road safety affected usefulness but not direct use intention.

studies involving passengers' experience with APTV vehicles that were reviewed as part of the current study. As may be seen from the Table, most of the studies involved passengers experience with small automated shuttles that travelled at slow speeds on short, fixed routes.

The impact of APTV exposure depends on whether it is positive or negative. Positive media coverage of AVs can create unrealistically high expectations, which may reduce positive perceptions during real world APTV trials (Nordhoff, de Winter, et al., 2019). Research (Bernhard et al., 2020; Sweet et al., 2023) highlights the influence of prior experience, suggesting that negative initial impressions or subjective emotional experience can have enduring impacts on the adoption of the technology. In AS trials, participants have reported negative impressions of slow driving speed, unpredictable maneuvers and routes that required more interaction with other traffic, especially in areas with high volumes of pedestrians (Bellone et al., 2021; Wintersberger & Riener, 2022). Users' adverse APTV experiences have been shown to generate negative perceptions, reducing their likelihood of using such vehicles in the future (Pigeon et al., 2021).

The importance of safety and security perceptions of passengers have been investigated in several studies. For example, a study (Guo et al., 2021) investigating public perceptions of an AS in Stockholm revealed that individuals who had used the shuttle held a more favorable view of its safety and driving speed compared to those with no experience. Eden et al., (2017) found that after riding in an AS, safety concerns reduced. Bellone et al., (2021), examining AS trials across Finland, Estonia, Norway, and Poland, reported on passengers' positive feelings of personal safety and security onboard. Additionally, research involving a full-length AB (Johansson et al., 2023) operating on a test route found that most users reported a highly favorable experience and expressed a strong sense of trust in the automated system. They also expressed a sense of optimism regarding the future of ABs. Furthermore, research suggests that being exposed to ABs when a human safety operator is present encourages users to try unstaffed services (Ariza-Álvarez et al., 2023).

Comfort emerged as a determinant of user satisfaction and continued use. Chee et al., (2021), studying an AS operating on a short first-/last-mile route in Sweden, found that when participants decided to take an AS for the first time, their evaluations were predominantly influenced by their initial expectations regarding the service and the technology's capabilities. Initially, users' evaluations were influenced by their satisfaction with safety and travel time. However, as their ride experiences increased, ride comfort emerged as the dominant factor in their ongoing evaluations. A study (Guo et al., 2025) investigating users' experience with an AS found that comfort and convenience are the most significant determinants of user satisfaction which positively affects individuals continued use as well as encouraging positive word-of-mouth behavior. Furthermore, the study found that individuals' behavioral intentions did not significantly predict their actual usage. The authors emphasize the importance of understanding real-world user behavior, as intentions based on hypothetical scenarios may not align with actual usage patterns once users experience the service.

Passenger satisfaction is influenced by a range of individual differences such as sociodemographic factors, personality, and travel behavior. A Spanish AB trial ((Ariza-Álvarez et al., 2023) found that users who were older, female, employed, environmentally conscious, private car users, and open to new technologies reported higher levels of satisfaction. Openness to innovation and environmental concern also correlated with a greater willingness to adopt ABs. Similarly, Rosell & Allen, (2020) found that satisfaction with conventional bus services positively influenced users' perceptions of safety and overall satisfaction during an AS trial. Female users were generally more satisfied than males, though more reluctant to use the service alone, particularly due to concerns about in-vehicle security in the absence of transit personnel. A German AS study (Herrenkind et al., 2019) found that younger users valued simplicity and convenience, while older users valued usefulness. The authors also reported other factors such as ecological attitudes, residential location, and financial status, also shaped acceptance. Bellone et al. (2021) found that males had significantly lower overall experience scores compared to females, which the authors suggested could be explained by higher pre-ride expectations among males, particularly concerning vehicle speed.

Finally, prior attitudes toward conventional public transport can influence perceptions of APTVs. Yan et al., (2022) found that a positive view of traditional buses significantly shaped perceptions of ABs' usefulness and ease of use. Satisfaction with in-vehicle safety and service quality contributed to the intention to continue using ABs. While perceived road safety had a significant impact on perceived usefulness, it did not directly influence the intention to continue using ABs. The study also identified two moderating variables, past bus-riding habits and reliance on human drivers, which influenced ongoing use intentions.

2.5. Limitations of the existing research and relevance of the present study

The majority of APTV research has primarily concentrated on the use of AS, which typically carry up to 12 passengers. These vehicles are often designed to operate on-demand services, covering short distances, operating at slow speeds in closed environments or as first/last mile services (Azad et al., 2019). Of the thirty-nine studies included in a literature review on the acceptance of APTV (Pigeon et al., 2021), only four specifically focus on ABs. Moreover, many consider only APTV knowledge and expectations rather than direct experience. As summarized in Table 1, studies exploring passengers' actual experiences with APTVs have largely involved small shuttles on short, urban routes at low speeds, often in closed settings. There is a lack of research on passenger experiences with full-sized ABs operating in mixed traffic at speeds comparable to traditional buses on interurban routes. This study aims to address this gap. In contrast to previous research, the present study focuses on passengers' real-world experience using a full-length, staffed, AB service that operates at SAE level 4 and reaches speeds of up to 80 km/h on the public road network. The primary aim is to investigate the determinants of the extent to which passengers' real word experiences with AB technology aligned with their initial expectations before riding. By identifying the key factors affecting this alignment, as well as establishing which groups are most influenced by participation in an AB trial, the study provides valuable insights into user satisfaction and perceptions. Specifically, the research also explores the likelihood of passengers recommending AB services to others, offering a potentially powerful tool for assessing its marketability. The findings will give valuable guidance for bus manufacturers, service providers, and transport authorities in their future planning and implementation efforts.

3. METHODOLOGY

As part of Project CAVForth (CAVForth Partners, 2022), the UKs first full-length level 4 AB service was launched on May 15, 2023. The trial was a new commercial service using buses with a capacity of 36 passengers, operating on a 22-kilometer inter-urban route connecting a public transport hub located on the outskirts of Edinburgh to a park and ride site north of the city, in Fife, UK. The bus travels at speeds of up to 80 km/h on the public road network, navigating through a combination of A-roads, motorways, bus lanes and private land. The route offers the opportunity for the AB to carry out a range of complex traffic maneuvers such as navigating traffic lights and motorway lane changes. During the CAVForth trial all buses have a human safety driver positioned behind the steering wheel. Their responsibility is to continuously monitor the road environment and the performance of the vehicle throughout the whole trip and be ready to take control of the vehicle if necessary. Furthermore, an additional staff member is present inside the vehicle during the journey to provide customer support.

Self-completion questionnaires were distributed to bus passengers immediately after they used the CAVForth service in May and June 2023. The majority (82.8 %) of respondents chose to complete a paper-based version of the survey, while 17.2 % opted for an online version, accessed through scanning a QR code linked to the Qualtrics survey platform (Qualtrics, 2005). To encourage bus passengers to complete the questionnaire, they were offered the chance to take part in a prize draw for £100 worth of vouchers. To adhere to UK General Data Protection Regulations (Information Commissioner's Office, 2024), prospective respondents were given a privacy notice and were required to provide informed consent before they could participate. The research design was granted governance and ethical approval from Edinburgh Napier University.

The questionnaire was organized into a series of short and predominantly multiple-choice questions that addressed the following subjects: journey details (e.g., weather conditions, ticket type, journey purpose etc.); travel behavior (e.g., frequency of using different transport modes); and socio-demographic characteristics. Several facets of their experience, such as comfort, satisfaction with the vehicle and service, safety perceptions and attitudes towards the vehicles' driving style were measured on Likert scales. Participants were also asked about both their expectations prior to using the service and the extent that their experience aligned with these expectations. The survey also covered perceptions of services that may operate in the future with different levels of staffing on board.

An Exploratory Factor Analysis (EFA) was conducted to reduce the dimensionality of the variables assessing passengers' attitudes towards the service through Principal Component Analysis (PCA) with Varimax rotation. PCA reduces the dimensionality of a dataset **X** composed of correlated variables by identifying a set of linearly uncorrelated components (principal components), which capture the maximum possible variance of the original dataset while minimizing the number of components and maintaining orthogonality. Mathematically, this process is described as (Rahim et al., 2023)

$$\boldsymbol{Z} = \widehat{\boldsymbol{X}}\boldsymbol{W} \quad (1)$$

where **Z** is the matrix of principal components, $\widehat{\boldsymbol{X}}$ is the centered data matrix, **W** the matrix of eigenvectors of the covariance matrix $\frac{1}{n-1}\widehat{\boldsymbol{X}}^{\boldsymbol{T}}\widehat{\boldsymbol{X}}$ with n indicating number of observations.

Two separate discrete outcome models were estimated using NLOGIT (Econometric Software Inc, 2016) to identify the factors affecting the post-ride evaluation of AB users and their willingness to recommend the AB services to others. The two dependent variables evaluate different aspects of the user experience and the linkage with prior expectations, thus providing complementary insights. For example, a person may appreciate the technology but not recommend AB services due to factors unrelated to the technology itself such as fares, crowding or customer support. For both models, the Binary Probit approach with Random Parameters was leveraged taking into account the binary formulation of the dependent variables. The first dependent variable captures the post-ride evaluation (1 if the ride with the AB was 'better than expected', 0 otherwise). The second dependent variable represents the net promoter score in a binary form. In the questionnaire of the study, the net promoter score was measured on a 0–10 Likert scale, with 0 indicating that the respondent was very unlikely to recommend the service, and 10 very likely to recommend it. Following standard practice (Owen, 2019), those who provided very high scores (9 or 10) were classified as "promoters" of the service, those who responded with a score of 7 or 8 as "passives", whereas those who responded with score equal or lower to 6 as "detractors" of the service. Due to the distribution of the responses, the net promoter score was eventually formulated as a binary dependent variable, where a value of 1 reflects the "promoters" of the service, and a value of 0 collectively represents the "passives" and "detractors".

The binary probit model can be expressed as follows (Washington et al., 2011):

$$Y_i = \begin{cases} 1, & \text{if } Y^* > 0 \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

With

$$Y_i^* = \beta_i \mathrm{X}_{\boldsymbol{i}} + \varepsilon_i, \ with\ \varepsilon\ \mathscr{N}(0,1), \quad (3)$$

where Y is the observed binary outcome, Y^* is a continuous latent variable assumed to determine the outcome, $\mathbf{X_i}$ represents the vector of explanatory variables for each respondent i, β represents the vector of estimable parameters relating to X (some of which can vary across the observations as random parameters), and ε denotes the error term following a standard normal distribution. The factors derived by EFA, in addition to sociodemographic and travel behavior characteristics, were utilized as explanatory variables in both models.

To account for unobserved heterogeneity (i.e., the impact of unobserved factors on the dependent variable), random parameters were incorporated into the model estimation process. As noted by Washington et al., (2011), the incorporation of random parameters in the model enables the estimation of a separate vector of coefficients, β for each individual response i, as follows:

$$\beta_i = \beta + \omega\Delta_i + \zeta_i \tag{4}$$

where β represents the mean of the random parameter distribution, Δ indicates a vector of independent variables that capture heterogeneity in the mean of βi, ω represents a vector of heterogeneity-in-means parameters to be estimated for Δ, and ζ denotes a random term with a mean of 0 and variance of 1. The unrestricted formulation of the random parameters in Eq. (4) allows for the identification of variables determining the mean of the random parameter distribution. These variables help capture the effect of unobserved heterogeneity in a more nuanced way by tracking the systematic variations that concern the means of the random parameters. While the random parameters allow for the coefficients (betas) to vary across the respondents, the heterogeneity-in means variables shed light on the patterns of such variations. The normal distribution was used to model the random parameters in the binary logit models, consistent with previous studies (Fonzone et al., 2024).

For the estimation of the Binary Probit Random Parameter models, a simulated maximum likelihood estimation technique was employed (Washington et al., 2011). Numerical integrations necessary for model estimation were performed using Halton sequence draws, with 500 Halton draws used to generate stable model coefficients (Fonzone et al., 2024). Furthermore, marginal effects were also computed to quantify the impact of a one-unit change of the explanatory variables of both models to the dependent variables (Fountas et al., 2022).

4. RESULTS

A total of 490[1] responses from CAVForth AB passengers were collected between 15th May and 14th July 2023. Almost three-quarters (72.5 %) of respondents live in the local authority region where the service operates (City of Edinburgh 30.2 %; Fife 42.3 %). 15.7 % have either physical or mental health issues or disability that could limit their travel choices, 41.5 % are employed (either full or part time), 40.3 % have a university qualification, and 29.5 % have a household income below £20,000. In terms of their travel behavior, 31.8 % frequently drive their car (5 or more days a week) and 26.0 % used a bus most days. Summary descriptive statistics of sociodemographic and other variables used at different stages of the modelling process are given in the Appendix.

When compared to the Scottish population (Office for National Statistics, 2021), the study passenger sample included more individuals older than 65 years (Scottish population: 24.7 %; Survey sample: 34.9 %) and more males (Scottish population: 41.0 %; Survey sample: 66.1 %). The observed demographics reflect those who chose to participate in the trial rather than the general Scottish population, which provides valuable insights into the perceptions of early adopters, who often play a critical role in shaping public acceptance and influencing the diffusion of emerging technologies. The primary aim of this study was to explore the perceptions and experiences of individuals who actively interacted with the AB during the pilot study. Importantly, the study achieved a high response rate of 80 %, suggesting the sample is highly representative of those who experienced the service first-hand. Our analysis focused on examining variability in responses among different user subgroups rather than generalizing across the population, which is crucial when considering how future services can serve different needs.

The majority of survey respondents (85.3 %) were using the AB service for the first time. Most (83.1 %) were motivated by wanting to ‘try out’ the technology. A small percentage used the service for commuting (5.7 %) and accessing leisure activities (4.2 %). Most (91.0 %) travelled during favorable weather conditions, characterized by the absence of rain, wind or fog. Only 2.1 % reported experiencing symptoms of motion sickness during their journey.

The outcome of the attitudinal survey on passengers’ perceptions revealed that the majority of respondents held favorable views of the service. Most were satisfied with their trip overall (95.3 %), 94.2 % felt that the AB was driven well and 95.0 % felt it was driven safely. In terms of the way the AB was driven, 86.2 % of passengers were satisfied with the smoothness of the driving, but around a quarter (26.4 %) reported that the braking was too abrupt and 15.2 % agreed that the bus drove too slowly given the conditions. Regarding the CAVForth AB fleet, participants were asked to assess their satisfaction level using statements related to the vehicles used in the trial. Many respondents were satisfied (rated either ‘somewhat satisfied’ or ‘very satisfied’) with the cleanliness and condition inside the bus (80.8 %), the temperature (75.3 %) and the comfort of the seats (71.8 %). Fewer individuals were satisfied with vehicle noises (62.7 %) and vibrations (56.9 %).

A high percentage showed a strong likelihood (71.1 % rated 9 or 10 on a scale of 0–10) of recommending AB services to others and were classified as ’promoters’ of the service as shown in Fig. 1. Additionally, 21.6 % were ‘passives’ (7 or 8), while 7.3 % ‘detractors’, scoring 6 or below. Pre-ride expectations were measured using a 5-point Likert scale item that asked: “What were your expectations about the autonomous bus technology before you had a chance to experience it?” (Response options: Very Low, Low, Moderate, High, Very High). Prior to experiencing the trial, 93.8 % of questionnaire respondents had moderate to high expectations for AB technology. After experiencing AB technology first-hand, the vast majority (94.5 %) indicated that it met or exceeded their expectations (Fig. 2).

[1] The minimum required sample size, calculated using Cochran’s formula (Cochran, 1977), was 370. The final study sample included 490 participants, thereby exceeds the minimum threshold.

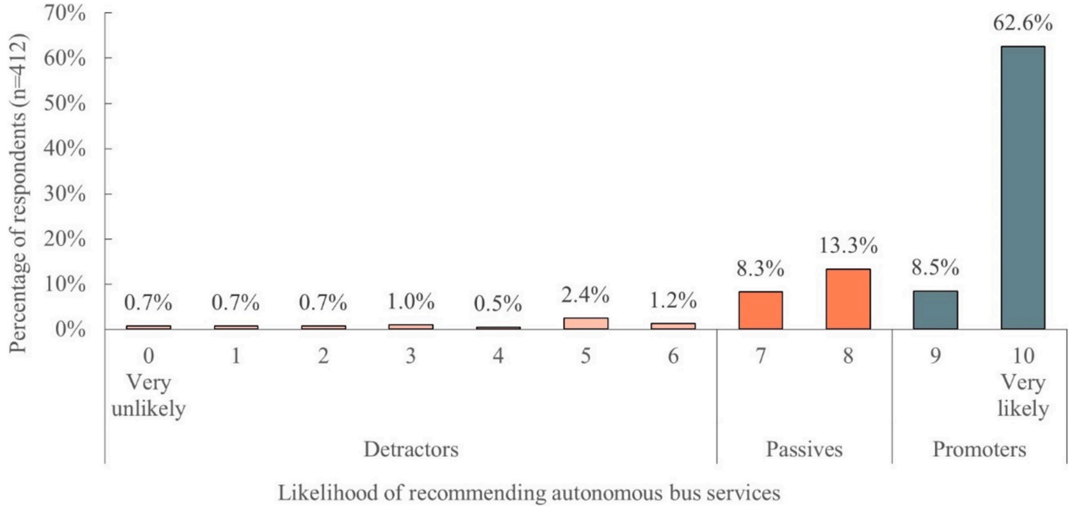

Fig. 1. Likelihood of recommending ABs to others.

Only 38.1 % (n = 415) indicated that they would feel either somewhat or very comfortable if there had been no staff onboard during their journey.

SPSS (IBM, 2022) was used for the EFA. The minimal factor loading criterion was set at 0.50. Bartlett's Test of Sphericity yielded significant results (df = 171, Chi-Square = 4640.718, $p < 0.001$) indicating that the data is suitable for factor analysis. Additionally, the Kaiser–Meyer–Olkin measure of sampling adequacy was 0.884, which is above the recommended threshold of 0.800 (Field, 2018), further supporting the suitability of the data for factor analysis. The EFA identified three factors with total initial eigenvalues greater than 1 and they explained 68.16 % of the variation in the data. These were characterized as "satisfaction with AB1 fleet"; "satisfaction with AB1 journey"; and "satisfaction with AB1 driving style". Their components and factor loadings are provided in Table 2. Cronbach's alpha was used to evaluate internal consistency. As per the guidelines (Nunnally & Bernstein, 2007), the Cronbach alpha values for each construct in the study exceeded the minimum threshold of 0.70. Additionally, the average variance extracted (AVE) was employed to measure convergent validity, with all values exceeding the 0.50 threshold (Fornell & Larcker, 1981). The factor scores of all construct items are shown along with the mean, standard deviations, and sample sizes for each item. The factor scores were used as predictor variables in model estimations.

A Binary Probit model with Random Parameters (BPRP) model was estimated to ascertain the elements that affect the relationship between expectations and experience. The binary dependent variable reflects the evaluation of the trial experience from the respondents (1= 'better than expected' (61.4 %); 0 = other (38.6 %). The results are detailed in Table 3. A positive coefficient sign indicates an increase in the likelihood of evaluating the AB service as better than expected, whereas a negative sign indicates a reduction in the same likelihood. The model with the best statistical fit showed that satisfaction with smoothness of the ride and satisfaction with vehicle noise, whether pre-ride expectations were high and willingness to use unstaffed ABs were identified as statistically significant determinants of post-trial evaluation. Frequent bus users and female users were observed to have mixed associations with post-ride evaluation as their corresponding coefficients were found to vary as random parameters.

A Binary Probit model with Random Parameters and Heterogeneity in the Means (BPRPHM) model was estimated for the net promoter score, i.e., the likelihood of recommending AB services to other people. The service includes the presence of a safety driver and a bus steward on board to provide customer support. As previously stated, the binary dependent variable takes the value 1 if the respondent is a promoter of the AB service dependent variable, and 0 for non-promoters. The results are presented in Table 4. A positive coefficient sign indicates an increase in the net promoter score, and, in turn, in the likelihood of recommending the AB service to others, whereas a negative sign indicates the opposite. The best model fit comprised two of the factors identified during EFA: 'satisfied with AB1 driving style' and 'satisfied with AB1 service'; both factors were found to have varying impacts on the net promoter score resulting in random parameters. In addition, the model showed that pre-trial expectations, infrequent car use and frequent bus use were also significant factors affecting the likelihood that AB passengers would recommend the service to others. The age of the respondent was found to decompose the heterogeneity stemming from the means of the random parameters, thus providing further insights into the mixed effects of the two satisfaction-related latent factors on the net promoter score.

5. DISCUSSION

This study provides valuable insights into the factors influencing the adoption and diffusion of AB technology in Scotland, with a specific focus on AB passengers' real-world experiences. The results from the attitudinal survey indicate that users generally held positive perceptions of the AB service. After firsthand experience with AB technology, 61.7 % of respondents reported that it exceeded their expectations and 71.1 % had a high likelihood of recommending the service to others. The findings from the BPRP and BPRPHM

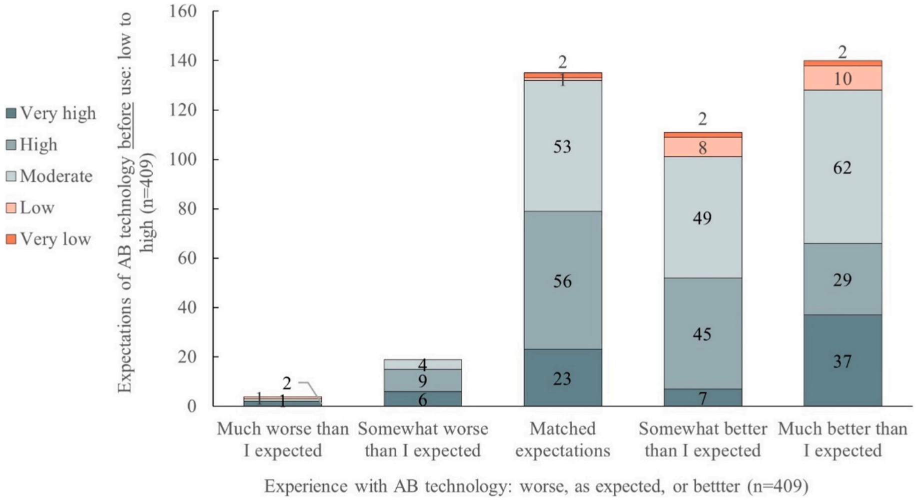

Fig. 2. Respondents' expectations before using AB technology and their evaluation after the experience.

Table 2
Three-factor model obtained after EFA.

Construct	Internal consistency & AVE	Items	Score mean	Score standard deviation	Factor loading
Satisfied with AB1 fleet	Cronbach's Alpha: 0.940 AVE:0.925 n = 405	Temperature inside the bus	4.38	1.004	0.817
		Available leg space and arm space	4.25	1.124	0.838
		Comfort of the seats	4.32	1.011	0.899
		Vehicle noises (engine, wheels etc.)	4.05	1.105	0.838
		Vibrations	4.00	1.128	0.844
		Air quality/ventilation	4.37	0.988	0.909
		Cleanliness and condition of the inside of the bus	4.71	0.856	0.842
Satisfied with AB1 driving style	Cronbach's Alpha: 0.906 AVE:0.903 n = 377	The bus drove to slow for the conditions	2.11	1.257	0.760
		The bus drove too fast for the conditions	1.86	1.113	0.843
		The bus braked too suddenly	2.43	1.291	0.644
		The bus accelerated too quickly	1.86	1.103	0.903
		The bus took corners/curves in a way that made me feel uncomfortable	1.71	1.074	0.901
		It required effort to maintain posture/balance during the rides	1.70	1.103	0.857
Satisfied with AB service	Cronbach's Alpha: 0.855 AVE:0.858 n = 415	Value for money of your ticket	4.39	0.954	0.618
		Punctuality of the bus	4.65	0.756	0.725
		Time taken to complete the bus journey	4.72	0.677	0.836
		Number of passengers on board (i.e. how crowded the bus felt)	4.71	0.712	0.677
		The helpfulness of the staff on board	4.88	0.496	0.792
		Overall, how satisfied are you with the bus journey	4.78	0.618	0.778

models indicated that the factors influencing post-ride evaluation and net promoter score can be categorized into dimensions historically recognized as determinants of acceptance of automated vehicles (Table 5), thus proving the validity of the MAVA approach to study acceptance of autonomous bus technology and service acceptance. The Table also shows that there are differences between the determinants of the two analyzed dimensions of user acceptance, highlighting the differences between achieving satisfaction with driving technology and gaining support for AB services.

5.1. *Meso level factors*

The model outcomes highlight the significant role that pre-trial expectations play in shaping how passengers perceive their experience with AB technology and their likelihood of recommending AB services to others. According to Expectation-Confirmation Theory (ECT), user satisfaction occurs when actual experiences meet or exceed initial expectations. In this study, those with high expectations were significantly less likely to view the experience as better than expected. This can be attributed to the fact that setting expectations at an elevated level makes it less likely for the actual experience to surpass them. It must be noted that for most respondents whose experience did not exceed expectations, the experience still met their high initial expectations (Fig. 2). Therefore, it

Table 3
BPRP model of post-ride evaluation.

Variable description	Coefficient	T-stat	Marginal effect
Variables with fixed parameters			
Constant	0.436	0.95	–
Satisfied with AB smoothness (1 if user agreed, strongly agreed driving was smooth – 85.92 %, 0 otherwise)	0.856	3.36	0.3006
Satisfied with vehicle noises (1 if user somewhat, very satisfied with vehicle noise – 73.24 %, 0 otherwise)	0.488	2.60	0.1714
Ride without safety driver/operator availability (1 if the user will ride is Yes – 14.37 %, 0 otherwise)	−0.139	−2.08	−0.0488
Expectations (1 if the user has high expectations – 46.48 %, 0 otherwise)	−0.667	−4.03	−0.2342
Variables with random parameters			
Frequent bus use (1 if using the bus 5 + days a week – 25.63 %, 0 otherwise)	0.668	2.97	0.2346
Standard deviation of Frequent bus use parameter density function	*1.192*	*4.88*	–
Gender of the user (1 if the user was Female – 31.83 %, 0 otherwise)	0.747	3.74	0.2622
Standard deviation of Gender of the user parameter density function	*1.152*	*5.33*	–
Number of observations	351		
Log-likelihood at zero	−207.472		
Log-likelihood at convergence	−232.900		
McFadden pseudo-R2	0.109		
Akaike Information Criterion (AIC)	432.90		

Table 4
BPRPHM model of net promoter score.

Variable description	Coefficient	T-stat	Marginal effect
Variables with fixed parameters			
Constant	1.366	5.41	–
Pre-trial expectations (1 if very low, low or moderate – 48.20 %, 0 otherwise)	−0.708	−2.54	−0.166
Frequent bus user (1 if use bus 5 or more days a week – 26.26 %, 0 otherwise)	1.362	3.41	0.319
Frequent car user (1 if use car 5 or more days a week – 35.25 %, 0 otherwise)	−1.071	−3.57	−0.251
Variables with random parameters			
Satisfied with AB1 service (mean: 0.027; standard deviation: 0.983)	2.136	5.75	0.500
Standard deviation of Satisfied with AB1 service parameter density function	*5.162*	*6.90*	
Satisfied with AB1 driving style (mean: −0.030; standard deviation: 1.116) *	−0.096	−0.40	−0.023
Standard deviation of AB1 driving style parameter density function	*0.361*	*2.21*	–
Heterogeneity in the means variables			
Old user (1 if 60 years or older – 48.9 %, 0 otherwise): Satisfied with AB1 service	−0.970	−2.78	–
Number of observations	277		
Log-likelihood at zero	−167.392		
Log-likelihood at convergence	−139.709		
McFadden pseudo-R2	0.165		
Akaike Information Criterion (AIC)	297.42		

*Following the standard practice with random parameter estimation (Econometric Software Inc, 2016), a Likelihood Ratio Test (LRT) was carried out to further evaluate the significance of this variable and the LRT results showed the inclusion of the specific variable as a random parameter led to a statistically significant improvement of the model fit at a > 95 % level of confidence.

Table 5
Acceptance factors of MAVA and outcomes of the BRP and BPRPHM models.

MAVA Level	Factor class	Acceptance factors	Dependent variable: Post ride evaluation – whether AB technology performed better than expected	Net promoter score – likelihood of recommending AB services
Meso	Exposure to AVs and system evaluation	Experience & knowledge; System evaluation (domain-specific, symbolic-affective and moral-normative)	Low pre-ride expectations Satisfied with smoothness of AB driving Satisfied with vehicle noises	High pre-ride expectations Satisfied with AB driving style Satisfied with AB service
Micro	Socio-demographics	Age, gender, education, income, etc.	Gender (Female)	Age (60 + years)
	User profiling	Travel behavior and technology savviness	Frequent bus use (5 + days a week) Tech savviness (willingness to ride without human staff on board)	Frequent bus use (5 + days a week) Infrequent car use (<5 days a week)

can be concluded that most respondents were satisfied. Still, these findings emphasize the importance of managing user expectations, particularly in the context of AB trials. Marketing campaigns promoting AB technology should focus on providing a realistic portrayal of the service. This is crucial for users who may have inflated pre-ride expectations, as these may lead to disappointment if not properly aligned with the actual service experience. For instance, many users did not anticipate that the CAVForth service would be manually operated on certain segments of the route. Early communication of such limitations can help set more realistic expectations and mitigate potential dissatisfaction. At the same time, the BPRPHM model suggests that individuals with high pre-ride expectations about the AB technology report higher net promoter scores. Therefore, individuals who are already optimistic about AB technology prior to use are more likely to generate positive word-of-mouth behaviors, which is widely recognized as one of the most effective marketing strategies available (Chevalier & Mayzlin, 2006).

Two factors identified in the EFA were found to significantly influence net promoter score: Satisfaction with the AB service and satisfaction with AB driving style. The AB service factor includes aspects such as ticket prices, punctuality, journey time, crowding and helpfulness of staff on board.[2] While none of these factors directly relate to AB technology itself, they nonetheless have a positive impact on the extent that passengers would recommend AB services to others. Therefore, bus operators intending to introduce an AB service should prioritize enhancing the overall quality of their service. Other research has highlighted these factors as important for transit users' willingness to recommend conventional bus services (Diab et al., 2017). APTV acceptance studies have consistently shown the importance of service characteristics such as fares that are good value for money or lower than other means of transport, lower vehicle occupancy rates and satisfaction with journey times (Bellet & Banet, 2023; Dekker, 2017; Pigeon et al., 2021). Chee et al., (2021) found that following AS passengers first ride, their evaluations were influenced by their satisfaction with travel time. Research on passenger acceptance and satisfaction with AB technology must take into account service characteristics beyond the driving technology to avoid misestimating the importance of the latter.

The driving style factor identified in the EFA incorporates elements such as braking abruptness, speed, acceleration responsiveness, and cornering ability. The BPRPHM model suggests that the effect of the factor varies across the respondents, with some being less likely to be promoters although they are satisfied with the driving style. As indicated by the distribution of the specific random parameter, approximately 60 % of the respondents satisfied with the driving style are less likely to recommend the service to others, while for the remaining 40 %, the driving style satisfaction increases the likelihood of being a promoter. To further examine this mixed effect, we calculated respondent-specific parameter estimates for the specific random parameter following the methodology described by Fountas et al., (2018). The analysis of these estimates revealed that the majority of respondents whose satisfaction with driving style reduces the likelihood of recommending AB services (i.e., the aforementioned 60 %) are categorized as "passives" (responding 7 or 8 on the net promoter question). These "passives" were grouped with "detractors" in a single outcome category for modeling purposes, thus the negative sign of the coefficient. Therefore, the distribution of the random parameter underscores a notable trend: most users who are satisfied with the driving style are more likely to fall into either the "passive" category or "promoter" category. Without the random parameter estimation, this trend could not be easily unveiled. Overall, the mixed effects of this variable suggest that satisfaction alone, without the excitement of experiences exceeding expectations, may not be enough to encourage people to recommend the service. Therefore, operators trialing AB services should aim to generate public attention by not only providing a high-quality experience but also by making passengers aware of the exceptional results achieved. Our findings are consistent with other APTV studies, which revealed that some passengers negatively assessed slow vehicle speeds, abrupt and frequent braking, and unpredictable maneuvers, indicating that these negative perceptions may reduce the likelihood of future use (Bellone et al., 2021; Pigeon et al., 2021; Wintersberger & Riener, 2022). A study (Guo et al., 2025) involving APTV users emphasizes the importance of an individual's overall comfort during the ride, as well as whether the service is perceived as more comfortable than traditional public transport. These factors were found to influence both satisfaction with service quality and the likelihood of continued use and positive word-of-mouth recommendations. In comparison, our findings highlight the impact of driving style, rather than the broader comfort factors that may affect the experience. Autonomous driving has the potential to improve passenger comfort by enabling smoother, more consistent acceleration and minimizing abrupt changes in speed (Alessandrini et al., 2014). As with any emerging technology, ABs are still in the development phase and as the technology matures, ABs are likely to be designed with more sophisticated sensors, improved predictive software, and more precise control mechanisms to enhance ride quality. By optimizing these driving style elements along with AB service characteristics, operators can increase the likelihood of positive recommendations, thus facilitating the broader diffusion of AB technology.

The BPRP model identified two statistically significant random parameters affecting post-ride evaluation: satisfaction with AB smoothness and satisfaction with vehicle noise. Prior studies (Fonzone et al., 2024) have indicated that the degree of comfort in terms of smoothness of the ride plays a crucial role in motivating passengers to adopt AB services earlier. Our findings further highlight the importance of continuing to develop AB technology optimized for smoothness of travel. Although the vehicle noises are not inherently connected to the performance of the technology, the current research found they exert an influence on the degree to which some users experience surpasses expectations in relation to AB technology. Given that 73.24 % of users reported being somewhat or very satisfied with vehicle noise, there is an opportunity to further optimize vehicle design to enhance the acoustic environment. Since the CAVForth vehicles used diesel engines, this finding supports the potential benefits of using electric vehicles in future trials of ABs. Electric buses have been shown to be significantly quieter than diesel buses, both internally and externally, which has been shown to contribute to decreased noise pollution and improved passenger comfort (Mathes et al., 2022).

[2] The "satisfaction with the AB service" factor primarily emphasizes the characteristics of the service (e.g., affordability, travel time), as detailed in Table 2, rather than the overall satisfaction with the autonomous bus service. Therefore, this variable is evidently exogenous to the dependent variable, which is derived from the net promoter score.

5.2. Sociodemographic variables

The BPRP model identified gender of the user as a statistically significant random parameter, with females on average being more likely to rate the technology as better than expected. The finding aligns with the general conclusion of the literature review that basic sociodemographic characteristics are not consistently linked to attitudes toward vehicle automation. Interestingly, according to the distribution of the relevant random parameter, more than 74 % of females are more likely to rate the AB trial better than expected. This implies that providing women with the chance to experience riding in an AB may entail a more pronounced beneficial effect compared to men. Other studies also report that females provided higher positive feedback scores than males after experiencing an APTV service. Bellone et al., (2021) conducted a study involving shared and automated urban transport across multiple pilot sites in Finland, Poland, Norway and Estonia. In line with our findings, they found females provided significantly higher overall experience scores compared to males. Rosell & Allen, (2020) also found that female users of an AS operating on test tracks in Spain were more satisfied overall than males and were only reluctant to use the service when travelling alone.

Chee et al., (2021), in a study involving passengers who had used a first-last mile AS in Sweden found that male adopter reported higher trust in the safety of the AB service and also expressed higher willingness to continue using the service. Some items in the CAVForth passenger questionnaire included aspects of trust and perceptions of risk. Comparative descriptive analyses and inferential tests, specifically two proportion Z-tests (see Appendix Table A2) were conducted to examine gender-based differences in perceptions of AB safety and comfort. There results revealed no significant differences between males and females regarding the perception that the bus was driven safely or in reported comfort levels across different situations, including operations at night or in poor weather conditions. However, female respondents were significantly less likely to report feeling comfortable if there were no staff onboard. This finding may reflect concerns around personal safety (e.g., absence of an authority figure to intervene in the event of anti-social behaviour) rather than concerns about trust in the AB technology. For example, Rosell & Allen, (2020) also found that females had lower intention to ride without transit support personnel because concerns related to in-vehicle security in unstaffed vehicle were greater for women.

The results of the BPRPHM model revealed that amongst those who were satisfied with AB service aspects (e.g., fares, punctuality, journey time, crowding etc.), older users had a lower net promoter score compared to younger users. This suggests that for older individuals, these service characteristics may have less impact on their likelihood to recommend the service to others. One possible reason is that the older participants in this study benefit from free concessionary travel passes. Further research should evaluate the differences in factors that influence service satisfaction and recommendation likelihood among passengers of different age groups.

5.3. User profiling factors

The BPRP identified frequency of bus use as a statistically significant random parameter with frequent bus users (5 days a week or more) on average, being more inclined to view the AB technology as better than expected. This may be due to a bias towards interventions expected to improve bus services. On the other hand, exposure to human-driven buses might lead some passengers to recognize aspects where autonomous driving has not yet reached the level of human driving, which could negatively impact their perception of AB technology.

The BPRPHM model highlights the importance of the individuals' travel behavior and their current choice of transportation mode. Participants who use the bus frequently (at least 5 days a week) are more likely to have a high net promoter score, as opposed to those who use the bus infrequently. Conversely, those who drive cars frequently (5 + days a week) were more likely to have a lower net promoter score than those who drive infrequently. The result highlights that it can be difficult to overcome ingrained mode choice habits and attitudes just by improving one mode. Our findings are corroborated by previous research (Haboucha et al., 2017; Liljamo et al., 2018) which suggested that regular public transport users or those who rarely drive had more favorable attitudes towards AVs and were more inclined to use shared AV. In contrast, other studies (Pakusch & Bossauer, 2017) found no differences in intentions to use APTV between individuals who use public transport and car drivers. However, these were based on expectations rather than real-world experience. Furthermore, a recent study discovered that regular public transport users expressed lower levels of satisfaction with an AS (Ariza-Álvarez et al., 2023) after using it. However, this finding was linked to passengers perceiving the vehicle as not fast enough, which was not a concern for CAVForth passengers, as only 15 % suggested the vehicle was too slow.

While it might be assumed that frequent bus users have lower expectations of traditional bus services and therefore may perceive a greater improvement when experiencing ABs our previous pre-trial research suggests this may not be the case. In the CAVForth pre-trial survey (Downey & Fonzone, 2025) (n = 422), frequent bus users (defined as those using buses three or more times per week) reported higher satisfaction with their bus services than less frequent users, with 64.3 % of frequent users indicating satisfaction compared to 57.8 % of less frequent users. The available literature supports the view that those who are satisfied with traditional buses are more satisfied after experiencing AB trial. Rosell & Allen, (2020) found that the perceptions of AS operating on test tracks in Spain found that satisfaction with regular buses positively affected their perceptions of safety and overall satisfaction with the trial. Yan et al., (2022). as part of trial involving electric AV mini-buses in China, also found that a positive general attitude toward traditional buses encourages respondents to believe that APTV are more useful and easier to use and promotes continuance use intention.

The BPRP model indicates that individuals who are willing to ride in an unstaffed AB were significantly less likely to view AB technology as better than expected. One possible explanation is that people who are open to riding in an unstaffed AB are more tech-savvy and thus more accepting of emerging technologies, which could lead them to expect more from the AB trial. The questionnaire did not enquire about participants' level of technology savviness, thus leaving the variable about willingness to use unstaffed ABs to potentially serve as a substitute. Research has identified technology savviness as an indicator for APTV acceptance (Fonzone et al., 2024; Wicki, 2021; Wien, 2019). These individuals may also have a better awareness and understanding of the capabilities, limitations and challenges of AB technology. This could make them more critical when evaluating the technology's performance, focusing on areas where the system falls short. Consequently, this could make it harder for the AB trial to exceed their expectations.

A recent study (Ariza-Álvarez et al., 2023) revealed that a large majority of passengers who experienced a full-length AB operating in real-life traffic conditions while a safety operator was present expressed willingness to use the bus even if there was no safety operator. However, for our study to confirm that exposure to ABs with a safety driver on board could have the potential to help pave the way for public acceptance of future services operating without any staff on board, it would be necessary to ask passengers about their intent to use unstaffed services both prior to and following their ride, which was not possible in our case. The potential for unmanned ABs to increase acceptance of staffed ABs is positive given that many of the benefits linked to ABs such as reducing the costs of labor and increasing frequency and network coverage will only be achieved when human staff are no longer required (Fonzone et al., 2024; Wicki, 2021; Wien, 2019).

5.4. Recommendations, limitations and further research

This findings from the current study, which showed that perceived performance of the technology including smoothness of ride and driving style, significantly influenced whether passengers viewed the technology as better than expected and whether they would recommend the service to others. To address these public acceptance and technology challenges, we suggest that transport authorities approach to AB deployment includes ongoing public engagement and education, developing technology that performs well especially with regard to smoothness, noise and driving style, investment in technology performance monitoring and evaluation. In the short term, the continued presence of a safety operator may also be beneficial in supporting user comfort and providing reassurance during the early stages of deployment. One critical step is to support the development and funding of more real-world trials involving ABs. These trials are essential not only for advancing the technology but also for providing the public with direct exposure to automated transport. As our research suggests, firsthand experience plays a role in shaping perceptions: The majority of AB users in our study reported that the experience exceeded their expectations and indicated they would be likely to recommend the service to others.

There are a number of limitations in the current research. During the trial, some portions of the route were designated for manual driving, and there were times when safety drivers had to assume control, such as when the bus lanes were closed or when it rained heavily. The validity of the survey results is diminished by the absence of precise information regarding the instances in which the bus was manually driven.

The questions regarding pre-trial expectations relied upon the respondents' recollection of these expectations at the end of their journey. The questionnaire aimed to capture general expectations, with the primary focus on post-ride perceptions after experiencing the AB. A detailed pre-ride and post-ride comparison was not included due to the real-world nature of the trial. The bus operated as a public transport service and passengers completed a brief voluntary survey after their journey and there were concerns that longer questionnaires could reduce response rates. Requesting participants to complete a form about their expectations before they boarded the vehicle may have produced more accurate results. However, it also risks unintentionally priming participants to focus on specific aspects they might not have otherwise noticed.

The questionnaire did not assess participants' level of technology savviness directly, leaving the variable about willingness to use unstaffed ABs to potentially serve as a substitute. Future research should include a more direct measure of technology savviness such as the Technology Readiness Index (Parasuraman, 2000).

The study sample consisted of individuals who opted to participate in the trial and were early adopters of the technology. Broader adoption will require understanding perceptions among the general population, including potentially reluctant user groups. Therefore, future AB trial research should include passenger samples that are representative of the general population.

A further limitation with the current study was that it was not possible to confirm whether experience with AB services with staff onboard would affect willingness to use unstaffed services. In the pre-trial survey (Downey & Fonzone, 2025) ($n = 450$), which targeted bus users before the CAVForth service launched, only 20.2 % of respondents indicated they would be willing to use an unstaffed AB. In contrast, in the onboard survey conducted during the trial ($n = 420$), 35.7 % of respondents who had just completed a journey on an AB with staff present indicated they would probably or definitely be willing to use an unstaffed service in the future. We acknowledge that there may be an element of self-selection bias with individuals who chose to participate in the trial may have already held more favourable attitudes toward automation than the bus user population. Future research should involve a pre-ride and post-ride design with the same participants to assess how trial experiences influence the willingness to adopt unstaffed services. Given that future trials are likely to involve unstaffed services, it is of crucial importance to understand the public response to these services and explore potential measures that could alleviate concerns. For example, possible mitigation measures could include having a large screen at the front of the bus where passengers can see a 'live' remote operator who can hear and see all activity onboard.

The purpose of the CAVForth trial was to develop the driving technology and consequently the technology continued to be improved as the trial progressed. Therefore, if the research was conducted a few months after the launch, it is probable that passengers would have shown an even greater appreciation of the driving style. The CAVForth service operated on an inter-urban route in East Scotland, navigating primarily motorways and A roads during daylight hours. Future research should extend this work by examining operations across a broader range of road types, traffic environments, and lighting conditions, and weather scenarios.

Future research could also explore the opinions and experiences of individuals who have been using the service for a longer period. This would provide valuable insights into how acceptance and satisfaction levels evolve over time, particularly as exposure to ABs increases with more real world trials. Additionally, examining the reasons why people continue to use the service beyond the initial trial phase will help identify potential areas for improvement and shed light on its long-term viability.

CRediT authorship contribution statement

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

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
Socio-demographics and other key variables.

Variable	Categories	Count	Percentage
Gender	Male	263	66.1 %
	Female	135	33.9 %
	Total	398	100.0 %
	Prefer not to say	17	
	Missing	101	
Age	18 to 21yrs	39	9.6 %
	22 to 24yrs	27	6.6 %
	25 to 34yrs	39	9.6 %
	35 to 44yrs	51	12.5 %
	45 to 54yrs	32	7.9 %
	55 to 59yrs	26	6.4 %
	60 to 64yrs	51	12.5 %
	65 to 74yrs	104	25.6 %
	Older than 74yrs	38	9.3 %
	Total	407	100.0 %
	Prefer not to say	10	
	Missing	73	
Household income	£0 – £10,000	21	7.7 %
	£10,001-£20,000	59	21.8 %
	£20,001-£30,000	53	19.6 %
	£30,001-£40,000	42	15.5 %
	£40,001-£50,000	31	11.4 %
	£50,001-£60,000	21	7.7 %
	£60,001-£70,000	14	5.2 %
	£70,001-£80,000	4	1.5 %
	Over £80,000	26	9.6 %
	Total	271	100.0 %
	Prefer not to say	132	
	Missing	87	
Highest education level	No educational qualifications	26	7.2 %
	Secondary school up to 16 years	56	15.6 %
	Secondary school up to 18 years	47	13.1 %
	College	86	23.9 %
	University (first degree)	84	23.3 %
	University (postgraduate)	61	16.9 %
	Total	360	100.0 %
	Missing	130	
Residential location	Kirkcaldy	171	42.3 %
	Edinburgh	122	30.2 %
	Glasgow	20	5.0 %
	Dundee	14	3.5 %
	Falkirk	11	2.7 %

(*continued on next page*)

Table A1 (*continued*)

Variable	Categories	Count	Percentage
	Motherwell	7	1.7 %
	Kilmarnock	4	1.0 %
	Perth	4	1.0 %
	Aberdeen	3	0.7 %
	Other (Scotland)	5	1.2 %
	Other (England)	39	9.7 %
	Other (Non-UK)	4	1.0 %
	Total	404	100.0 %
	Missing	86	
Health issue or disability	Yes	59	15.7 %
	No	317	84.3 %
	Total	376	100.0 %
	Don’t know or prefer not to say	27	
	Missing	87	
Car use (as a driver)	Less than once a year or never	121	30.3 %
	less than once a month	21	5.3 %
	1 to 3 days a week	18	4.5 %
	1 or 2 days a week	54	13.5 %
	3 or 4 days a week	58	14.5 %
	5 or more days a week	127	31.8 %
	Total	399	100.0 %
	Missing	91	
Bus use	Less than once a year or never	21	5.2 %
	less than once a month	46	11.4 %
	1 to 3 days a week	82	20.3 %
	1 or 2 days a week	78	19.3 %
	3 or 4 days a week	72	17.8 %
	5 or more days a week	105	26.0 %
	Total	404	100.0 %
	Missing	86	
Employment status	Employed full time (30 + hours per week)	126	31.1 %
	Employed part time (<30 h per week)	30	7.4 %
	In full-time education	37	9.1 %
	Long term sick or disabled and unable to work	27	6.7 %
	Permanently retired from work	151	37.3 %
	Full time carer	6	1.5 %
	Self employed	12	3.0 %
	Looking after the household	4	1.0 %
	Unemployed and / not seeking work	12	3.0 %
	Total	418	100.0 %
	Prefer not to say	14	
	Missing	71	
Motion sickness during journey	None	421	97.9 %
	Slight	9	2.1 %
	Total	430	100.0 %
	Missing	60	
Journey purpose	To try out an autonomous bus	379	83.5 %
	Travelling to/from work	26	5.7 %
	Leisure	19	4.2 %
	Visiting friends or relatives	11	2.4 %
	To/from shopping	8	1.8 %
	Personal business	7	1.5 %
	Employer’s business	2	0.4 %
	Travelling to/from school/education	2	0.4 %
	Total	454	100.0 %
	Missing	36	
Weather (n = 448) Multiple Responses	Dry	401	92.8 %
	Light rain	25	5.8 %
	Heavy rain	5	1.2 %
	Fog	3	0.7 %
	Strong winds	8	1.9 %
Boarding location	Ferrytoll Park and Ride	222	48.9 %
	Edinburgh Park	177	39.0 %
	South Queensferry Bus Stop (to Edinburgh Park)	37	8.1 %
	South Queensferry Bus Stop (to Ferrytoll)	18	4.0 %
	Total	454	100.0 %
	Missing	36	
Ticket type	A free bus pass or free journey	308	67.8 %
	Single/return/multi tickets/day pass	122	26.9 %
	A pass/season ticket for longer period	24	5.3 %

(*continued on next page*)

Table A1 (*continued*)

Variable	Categories	Count	Percentage
	Total	454	100.0 %
	Missing	35	
Expectations before use	Very low	6	1.4 %
	Low	20	4.8 %
	Moderate	174	41.8 %
	High	140	33.7 %
	Very high	76	18.3 %
	Total	416	100.0 %
	Missing	74	
Experience compared to expectations	Much worse than I expected	4	1.0 %
	Somewhat worse than I expected	19	4.6 %
	Matched expectations	136	32.8 %
	Somewhat better than I expected	113	27.2 %
	Much better than I expected	143	34.5 %
	Total	415	100.0 %
	Missing	75	
Future AB1 use	Much less often	5	1.2 %
	Somewhat less often	13	3.1 %
	About the same	283	67.2 %
	Somewhat more often	52	12.4 %
	Much more often	68	16.2 %
	Total	421	100.0 %
	Missing	69	
No Staff on AB1	Very uncomfortable	55	13.3 %
	Somewhat uncomfortable	132	31.8 %
	Neither comfortable nor uncomfortable	70	16.9 %
	Somewhat comfortable	78	18.8 %
	Very comfortable	80	19.3 %
	Total	415	100.0 %
	Missing	75	
Use of AB with safety driver and without captain	Definitely Yes	169	39.9 %
	Probably Yes	172	40.6 %
	Might or might not	54	12.7 %
	Probably No	15	3.5 %
	Definitely No	14	3.3 %
	Total	424	
	Missing	66	
Use of AB without safety driver and with captain	Definitely Yes	90	21.5 %
	Probably Yes	104	24.9 %
	Might or might not	112	26.8 %
	Probably No	73	17.5 %
	Definitely No	39	9.3 %
	Total	418	100.0 %
	Missing	72	
Use of AB without any staff	Definitely Yes	67	16.0 %
	Probably Yes	83	19.8 %
	Might or might not	104	24.8 %
	Probably No	82	19.5 %
	Definitely No	84	20.0 %
	Total	420	100.0 %
	Missing	70	
Preferred staffing option	Safety driver	255	65.7 %
	Bus captain	97	25.0 %
	No staff	36	9.3 %
	Total	388	100.0 %
	Missing	102	

Table A2
Perceptions of AB comfort and safety for males and females.

Questionnaire item	Percentage either 'somewhat comfortable' or 'very comfortable'				Two proportions Z −test	
	Male		Female			
	%	n	%	n	Z	p
Comfort with AB driving itself on roads with other vehicles	89.20 %	287	85.82 %	134	1.00	0.32
Comfort with AB driving itself on roads with cyclists & pedestrians	78.21 %	234	75.68 %	111	0.52	0.60
Comfort with AB driving itself on bus lanes	89.33 %	253	89.84 %	128	0.16	0.88
Comfort with AB driving at speeds greater than 80kph	85.02 %	247	78.15 %	119	1.63	0.10

(*continued on next page*)

Table A2 (*continued*)

Questionnaire item	Percentage either 'somewhat comfortable' or 'very comfortable'				Two proportions Z −test	
	Male		Female			
	%	n	%	n	Z	p
Comfort with AB driving at speeds less than 32kph	88.35 %	249	81.36 %	118	1.81	0.70
Comfort with AB stopping at red traffic lights by itself	80.56 %	216	82.65 %	98	0.44	0.66
Comfort with AB navigating roundabouts by itself	80.36 %	224	76.53 %	98	0.78	0.44
Comfort with AB navigating priority junctions	77.48 %	222	71.70 %	106	1.14	0.25
Comfort with AB stopping and departing from bus stops	81.11 %	217	77.67 %	103	0.72	0.47
Comfort with AB opening and closing doors automatically	82.18 %	202	83.96 %	106	0.39	0.69
Comfort with AB merging and changing lanes on motorways	83.60 %	250	81.30 %	123	0.55	0.58
Comfort with AB driving itself at night-time/darkness	73.29 %	161	60.29 %	68	1.95	0.51
Comfort with AB driving itself in bad weather	67.31 %	156	58.82 %	68	1.22	0.22
Comfortable with sharing the road with the CAVForth AB, assuming you are in another vehicle	78.02 %	273	69.34 %	137	1.92	0.055*
Comfortable with sharing the road with the CAVForth AB, assuming you are on a bicycle or on foot	61.54 %	273	53.68 %	136	1.52	0.13
Comfortable with no staff onboard the CAVForth AB service	43.12 %	269	30.83 %	133	2.38	0.02*
	Percentage either 'somewhat agree' or 'strongly agree'				Two proportions Z −test	
	Male		Female			
	%	n	%	n	Z	p
The bus was driven in a safe manner	95.26 %	274	96.32 %	136	0.50	0.62
Overall, the bus was driven well	94.07 %	270	94.81 %	135	0.30	0.76

Data availability

The authors do not have permission to share data.

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