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ScienceDirect

Transportation Research Procedia 72 (2023) 957–964

Transportation Research Procedia

www.elsevier.com/locate/procedia

Transport Research Arena (TRA) Conference

Automation as an enabler: Passengers' experience of travelling with a full-length automated bus and their expectations of a future public transport system

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Abstract

Twenty-two frequent public transport users experienced travelling with a fully automated, full-length bus on a test course that included nine simulated everyday traffic situations. Most participants experienced the journey as very positive and their trust in the automated system was high. In general, they were positive about using automated buses in the future but believed that this would not improve their travelling experience or change their travel behaviour without additional modifications to the system, such as dedicated public transport lanes etc. Many believed that the introduction of automated buses could create conditions for increased access to transport in rural areas and that the automated technology might enable new services that would have a great impact on public transport development, contributing a more individual, efficient and flexible public transport system.

Keywords: automated bus; full-length bus; automated vehicle; automated mass transit; user acceptance; behaviour and mobility patterns

1. Introduction

The interest in automated vehicles (AVs) has increased considerably in recent decades, as well as a concern about how the introduction of AVs will affect the transportation network (e.g., Azad et al., 2019). An important issue for a successful introduction of AVs is to what extent people will accept and use automated transport solutions. This has led to extensive research, primarily with focus on autonomous cars (private or shared) (see e.g. Acheampong and

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10.1016/j.trpro.2023.11.523

Cugurullo, 2019; Weigl et al., 2022), while less attention has been devoted to driverless vehicles in public transport (PT) (for overviews, see Becker and Axhausen, 2017; Gkartzonikas and Gkritza, 2019) even though integrating AVs into the PT system has been considered to provide more environment-friendly and cost-efficient mobility solutions (e.g. Meyer et al., 2017). At the same time, investigations into people's acceptance (or the acceptability) of, as well as their intention to use, such AVs for shared PT have either been based on descriptions and images of the phenomenon (e.g., Detjen et al., 2021; Goldbach et al., 2017) and/or focused on automated minibuses and shuttles (e.g., Bellone et al., 2021; Bernhard et al., 2020; Nordhoff et al., 2019; Soe and Müür, 2020). There are few investigations of PT users' perceptions and experiences of travelling with full-length automated busses although such insights are important for understanding the preconditions for these vehicles in an urban PT context, for example how they are perceived and experienced by different categories of users, and whether and in what ways they can be used.

The aim of the study was to investigate how frequent PT users perceive and experience travelling with a full-length, fully automated bus and their expectations of how an AV-based PT system would affect their commuting.

2. Method

The study was designed to comply with Swedish Covid restrictions (spring 2021) and the conditions that had to be fulfilled when testing a prototype system. It was conducted over two days on a test course with a route involving nine everyday situations often encountered in everyday traffic (see also Ekman et al., 2019). Twenty-two frequent PT users, recruited from two cities (one larger, one smaller) in Sweden, took part in the study; twelve men and ten women, aged between 21 and 70 years (M=40.5, SD=16.5). Overall, they had a relatively positive attitude to PT; a deliberate choice in order to reduce the potential negative bias towards PT in general influencing their feedback on automated buses.

The participants travelled in an automated bus (SAE Lvl 4), more specifically a Volvo 7900 electric-diesel hybrid bus, the interior and exterior of which resembled a conventional bus (Fig. 1; Fig. 2). The bus incorporated a self-driving system comprising five lidar sensors with which a three-dimensional map of the test course had been created prior to the study. The system navigated by comparing the data from the sensors with the map and the predefined route. As the bus dealt with all situations (in that specific traffic environment) without any driver involvement, the participants experienced it as a fully automated bus.

Fig. 1. Volvo electric-hybrid bus using a self-driving system. Photo from actual experiment.

The route driven on the test course encompassed a simulated city area with some longer stretches of road, where the bus reached speeds of around 35 km/h. The city area consisted of one building, a four-way intersection including road signs and a zebra crossing, covering an area of around 8 000 square meters. The building was designed to

simulate a bus terminal from which the participants embarked and disembarked from the bus. The city area had normal road standards for bi-directional (right-hand) traffic. The route driven, for two laps, included nine everyday traffic situations (e.g., reversing the bus out of the bus terminal; stopping at an intersection for a pedestrian with baby stroller; picking up a passenger; and stopping for a car at an intersection) designed specifically for the experiment and supported by extras acting as road users. The route measured 3.3 km, and it took approximately 15 minutes to drive through all nine traffic situations.

During the experiment there were three test leaders in the bus; one to monitor the self-driving system; one to serve as a driver in the case of an emergency; and one to observe any noteworthy behaviours and/or comments related to the experience, but none sat in the driver's seat (Fig. 2).

Fig. 2. The driver's seat. Photo from actual experiment.

Data on participants' perceptions and experiences were collected in different ways. When the participants had disembarked, they completed two questionnaires; the first one comprised a semantic differential scale on which they rated their experience of travelling on the bus and evaluated the vehicle's driving behaviour (e.g., "comfortable" – "uncomfortable" or "safe" – "unsafe"). The second was a Likert-type scale designed to measure different aspects of trust. In this case the participants indicated their agreement with different statements, such as "I think that the self-driving bus drove in a competent way" (see also Ekman et al., 2021). Finally, the participants were interviewed, using a semi-structured interview guide on how they perceived the bus (e.g., driving style and appearance), how they had experienced the journey and what they believed would be the effects on commuting if automated buses were introduced in the PT system in the future.

A descriptive statistical analysis of the questionnaire data was performed (i.e., median, max, and min values were calculated for each rating/item, etc.) The semi-interviews, which were recorded with the participants' written consent, were transcribed and a content analysis conducted based on the themes addressed.

3. Findings

3.1. Users' experiences of travelling on the automated bus

Overall, the participants experienced the journey in the automated bus as very positive (Fig. 3). At the end of the trip, they described it as the same as traveling with a human driver operated bus, as quite ordinary, and a few even thought it was slightly boring – which was not necessarily a bad thing – "The *bus trip itself was quite boring and that is what I expect a bus trip to be like. I do not travel by public transport because I expect something fun to happen, but rather the opposite. In that sense, it lived up to my expectations."* (P20).

Fig. 3. Inside the bus. Photo from actual experiment.

According to the trust questionnaire, a majority of the participants had a high level of trust in the automated bus. They trusted the bus to function as intended (median=6 of 7), to be safe to travel with (median= 6 of 7), it was perceived to drive in a competent way (median=6 of 7) and to have the ability to cope with the different traffic situations (median=7 of 7). Those participants who had concerns were worried that the bus would not manage, for example really tough or very varying weather conditions – *"If we had a really bad snowfall, then I probably would trust a human driver more. /.../ There are so many, very different scenarios."* (P25). However, the participants' trust in the bus was not only a matter of the vehicle's design and behaviour; it was also influenced by their trust in the developers / manufacturers of the bus

Regarding driving behaviour, the automated bus was perceived as very "*cautious*", as its driving was described as "*slow*" and "*calm*", and because it braked well ahead of the upcoming traffic situations and then waited before continuing to drive. However, some participants thought that the stops were sometimes too long – [*It was good] that the distance was maintained to the cyclists and pedestrians, I am just thinking if it would have been me on the street. But if I am sitting in the bus, I do not want it to stop for too long." (P9).* The traffic situations that the participants considered the bus to managed best were manoeuvring into and out of the bus terminal and stopping for the pedestrian and the cyclist. Driving the bus at the terminal was considered to require complicated manoeuvres in a

tight space that the bus handled smoothly. In the situations with the pedestrian and cyclist, the bus braked early, which was experienced as the bus having good foresight and being 'considerate' by clearly indicating that it had detected the other road user.

However, there were other situations which the participants thought that the bus did not handle equally well. A frequently mentioned one was when the bus stopped to pick up a passenger at a bus stop. Its behaviour was here perceived as "*jerky*" and "*slow*" before coming to a halt, something that was interpreted as the bus being "*indecisive*". Another situation was when the bus navigated a roundabout. Some participants were concerned about its position, stating that it took a short cut and drove into the wrong lane when exiting the roundabout – *"Is it not able to manage the roundabout? Is it too big? /.../ Maybe it was driving too fast, I do not know." (P14).*

3.2. Anticipated future travel behaviour in an Automated Public Transport System

Although most participants had a positive experience of traveling on the bus; believing that an automated bus would perform at least as well as a human driver and trusting automated buses to complete the journey in a safe and reliable way, they nevertheless stated that such buses would not drastically change their own PT travel behaviour. Merely introducing automated buses would not fulfil their travel needs to any greater extent than existing solutions – *"I do not think it would affect how I travel from A to B. If it is with a driver or automated, I would still take the bus or tram in a similar way." (P3).* The mode of transport per se was not considered to affect how their travel needs were fulfilled as much as for example, other design elements of a PT system, such as the frequency of departures and the distribution of PT stops.

Another reason why participants believed that the introduction of automated buses would not change their travel behaviour was because they supposed that any positive effects of automated buses would be counteracted by other factors. Many anticipated difficulties with a mixed traffic system, i.e., a system with both manually driven vehicles and automated buses. For example, even if the automated bus drove more efficiently than a manually operated one, the positive effect would be lost due to queues caused by manually driven vehicles. If it was not possible to separate automated buses from other traffic, the participants expected that this would initially slow down the introduction of automated buses. They argued though those automated buses could have an impact on their PT use if the automated buses could have dedicated lanes, without any interference from other road users – *"In a scenario where public transport is king of the road*." (P20) – or if the entire transportation system became automated.

3.3. Expectations of a future Automated Public Transport System

Irrespective of the participants' own use of PT, when discussing the potential effects that the introduction of automated buses could have, several positive effects were mentioned. One of the most discussed, as well as the one considered most important, was **efficiency**. Public transport was expected to become more efficient due to better traffic flow, more accurate departure times and improved punctuality which would make travelling by PT more predictable – *"It [the bus] will keep the timetable better than a driver, [it has) a computer that plans [the driving). /.../ It can plan better than a driver.* (P14). However, as the bus used in the trial was considered somewhat slow and cautious in certain situations, a few participants were concerned that the PT system could in fact become less efficient.

Another anticipated positive effect was increased traffic **safety**. Automated buses were expected to reduce the number of accidents compared to today – *"It will be safer [when automated buses are introduced], there is always a risk when people are involved. /.../ "The vehicles communicate with each other and there will be a different traffic flow."* (P19).

Some participants believed that automated buses would also make travelling more **comfortable** due to the calm and smooth driving behaviour, which in turn could lead to improved fuel efficiency and a positive impact on the environment.

Furthermore, the participants anticipated that the introduction of automated buses could lead to **economic** benefits for service providers, as driver labour costs would be reduced. This would lower costs, but the introduction of automated buses could also help alleviate problems such as replacing drivers who report sick as well as bus driver

recruitment problems in general. In addition, the precision of the automated buses' driving behaviour could lead to less wear and tear on the buses. These savings could in turn lead to "…more public transport for the same money" (P1). At the same time, some participants thought that a system with automated buses would be more sensitive to issues such as power failures. Having no personnel onboard would mean that no one was available to sort out issues such as doors not opening/closing properly, which could lead to delays, seeing to it if someone becomes ill onboard, or reducing the feeling of insecurity when travelling alone at night. – *"[It is important to consider] how people feel, the security when travelling is not the security related to how the bus drives but interpersonal security. /.../ Even more at night /.../ when you have a driver compared to only other passengers. /.../ How will this affect the feeling of security among the people in the bus?* (P25). Thus, the discussion also revealed possible negative effects. A few participants also worried that the implementation of automated buses would lead to "a good job" (as bus driver) disappearing but most participants argued that this development would not necessarily be the case as automation would most probably also create new types of professions.

In addition, many participants were of the opinion that the introduction of an automated bus system could improve the **accessibility** of PT, for example, in rural areas. As the buses would no longer need drivers, a more dynamic system could be introduced, that would adapt to meet the actual need for transfers. – *"I was thinking about resources. You would not need such a large bus in rural areas, if there were smaller self-driving buses without the bus drivers who now sit in big empty buses that just drive back and forth." (P9)*

Automated technology was also considered to be a possible **enabler of new services** that could radically improve public transport overall. The technology that comes with automated buses (e.g., improved sensory capabilities) might lead to new functions and services that could create a more adaptable and efficient PT system. The most common type of service mentioned by the participants was on-demand services where the bus lines could become more flexible in terms of the frequency of departures at different times of the day or the route served by the buses, for example, only considering bus stops where there are passengers would make public transport more efficient – *"... floating bus stops where you can say that I want to go from here and it plans [the journey] in a more advanced way. But I do not think that has to do with the physical bus but the technology behind it. ... that would better meet my needs, because today public transport is going from one place where you are not to a place where you are not going, and that is something that one wants to change." (P10)*. Another service mentioned was bus trains, where several buses could be connected during peak hour to increase efficiency. As the buses would be able to provide more detailed and accurate information to passengers, several participants also expected improved information services – *"The bus will know exactly where it is /.../ and I believe that this information could be sent to a travel app which could tell you that the bus will be here in 42 seconds" (P20).*

4. Discussion and conclusions

In summary, most participants were positive in their assessment of the automated bus as well as the idea of automated PT. However, they also had concerns and their comments emphasize that it may not be enough with merely exchanging manually driven buses with automated ones in order for automation to have positive effects on PT and PT usage,

A substantial number of studies have concluded that people's intention to use AVs, including automated buses, is highly influenced by trust (e.g., Herrenkind et al., 2019; Nordhoff et al., 2019; Winter et al., 2019). At the same time most of these studies focused people's trust in the technology. However, trust is a complex concept and in the case of automated buses there are several aspects to consider. In this study, two aspects of trust were investigated: (a) trust in the bus's ability to manoeuvre (i.e., the technology) and (b) trust in the bus's ability to drive to the passengers' destination (i.e., the transport task). Even though there were individual differences, most participants' ratings revealed a high level of trust in both aspects; in fact, based on comments made in the interviews, most thought that an automated PT system may become safer as well as more reliable than existing PT systems – although with certain prerequisites.

Another trust-related aspect to consider when introducing automated buses is security. Even though someone trusts the technology, they may not be inclined to use driverless, unsupervised buses for fear of being disturbed or harassed by other passengers. Previous research draws contradictory conclusions. For example, while Dong et al.

(2017) and Piao et al. (2016) found security to be an important issue, especially during evening/night-time services, Winter et al. (2019) concluded that the participants preferred no extra surveillance. Dolins et al. (2021) suggest, based on focus groups on shared autonomous mobility services, that the driver's role in a future automated PT may not primarily be that of a surveyor of vehicle navigation, but as an authority figure in the case of an emergency as well as a social representative of the PT service. The issue of security was not a frequently mentioned theme in the present study but given the ambiguous results, there is a need to understand more in depth how passengers anticipate or experience travelling with a bus with no driver onboard and in what way this influences their perception of risks associated with using an automated PT system.

The driving behaviour of AVs has been shown to play an important role in users' trust in automated cars (e.g., Ekman et al., 2019), but is a less investigated item in automated buses. The driving behaviour of the bus tested in this study was commented on by the participants, mostly in positive terms but their comments also revealed concerns about specific driving behaviours in specific situations. However, knowledge is lacking on how the vehicle's driving behaviour influences trust, acceptance and overall travel experience with automated buses in a short and long term, why further research is needed on how to design the driving behaviour of automated buses (i.e., speed, acceleration and deceleration patterns, curve driving, obstacle avoidance, vehicle following, etc.)

Several benefits could be envisioned by the participants as a result of an introduction of automated buses; increased efficiency, safety, flexibility, accessibility, but at the same time they emphasized that merely replacing manually driven buses with automated ones would not necessarily lead to these positive effects, or any change in their use of PT. Such positive effects would require consideration also of other PT system elements such as information services, frequency of services, allocation of bus stops, etc. The importance of ensuring that these 'basic' PT qualities pertain is emphasized also by Zhao et al. (2022). They conclude based on a long-term evaluation of an automated minibus-service that even though people were attracted to use the service if they found information on the service to be sufficient, they were demotivated to continue using it "if the comfort was worse, frequency was lower, or travel time was longer than expected."

When interpreting the results, the settings must be considered; the journey took place in daylight, on a test track, and the people onboard comprised a limited number of passengers as well as what was understood by most participants as some kind of surveillance personnel (i.e., the test leaders). At the same time, the results are based on passengers actually experiencing an automated bus, not merely responding to a description, and considerable effort was made to increase the realism of the bus journey; the participants did not travel alone but with other passengers and the bus did not drive on a road/street with no other vehicles or obstacles but the participants experienced the bus in different traffic situations which required interaction between the vehicle and other road users (pedestrian, cyclist, and car).

Therefore, how the participants expected that an automated full-length bus would affect their commuting contributes to the research on users' acceptance of AVs in general and of automated full-length buses in particular. Furthermore, the findings provide insights for stakeholders within the PT system, in particular the interdependencies between automation, the automated PT vehicles and other design elements of the PT system. Further work is needed to confirm these findings and explore the issues further; in addition to further insights into the importance of surveillance and how to design driving behaviour, this involves investigating passengers' experiences and assessments of full-length automated buses in a real, dynamic traffic environment, in a real PT system context, and over time.

Acknowledgements

This study was initiated and financed by Volvo Bus Corporation and conducted by researchers at Division Design & Human Factors at Chalmers University of Technology, Gothenburg, Sweden. The research project is part of Drive Sweden's project KRABAT, which is partly financed by Vinnova, Sweden's Innovation Agency. The technical solution has also been supported by the Strategic Vehicle Research and Innovation Programme (FFI). The authors would like to thank Mr. Kent Karlsson and Mr. Christer Ryberg from Volvo Bus Corporation for providing technical support for the study.

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