User acceptance of mixed-traffic autonomous shuttles in Gothenburg, Sweden

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Abstract. A user acceptance questionnaire study was carried out during the first phase of the Shared Shuttle Services (S3) pilot project in Gothenburg Sweden. Autonomous vehicles in the form of shuttle buses (AV shuttles) embody three major developments in transportation: mobility solutions that are electrified, shared, and automated. The adoption of these three developments is closely connected to the UN SDG (11) Sustainable cities and communities and in order to achieve any broader societal benefits, it is crucial to understand and address user acceptance and adoption of these services in real-life settings. The questionnaire included attitudinal and context specific questions, resulting in overall high ratings except for perceived speed and comfort. Still, the main reasons for not wanting to use the AV shuttle services could be linked to performance expectancy, route reasons and effort expectancy. Future implementations of AV shuttles will need to address this in order to expect any widespread adoption.

1. Introduction
Autonomous vehicles in the form of shuttle buses (AV shuttles) embody three major developments in transportation: mobility solutions that are electrified, shared, and automated.

Electrification of vehicles is one of the most promising ways to address local CO₂- and particle emissions, and to reduce noise levels from traffic.

Increased sharing of transportation resources is crucial at a time when many cities and roads have reached maximum capacity, especially during peak hours of the day. Sharing of vehicles and trips is thereby connected to reducing congestion and increased resource utilization.

Increased automation of the transportation system is expected to have positive impacts on traffic safety and efficiency [1]. It can also lead to a greater mobility access for groups of people who cannot, are not allowed, or do not want to drive themselves (e.g. elderly, children, people with visual impairment). In the context of public transportation, it could result in new lines and services that are not economically viable today, including on-demand services during off-peak hours in both urban and rural settings.

The adoption of these three developments is therefore closely connected to the UN SDG:s (11) Sustainable cities and communities, and (3) Good health and well-being. Being able to combine these three enablers within specific mobility solutions is so far largely limited to first/last-mile use-cases. This is mainly due to the current maturity and availability of higher levels of autonomous vehicle technology [2]. In order to achieve any broader societal benefits, it is crucial to understand and address user acceptance and adoption of these services in real-life settings.
1.1. Research context
The present study was carried out during the first phase of the Shared Shuttle Services (S3) pilot project in Gothenburg Sweden, a project under the cross-functional collaboration platform Drive Sweden’s “KRABAT” initiative funded in part by the Swedish Government’s innovation partnership program, “The next generation’s travel and transport”.

In the project, first/last-mile AV shuttle services were tested during four months at the Chalmers University of Technology campus (May - October 2018), and during six months at Lindholmen Science Park (May - November 2019). The trials were carried out with 11-seated NAVYA AV shuttles along approximately one-kilometer routes on public roads, within mixed traffic, and with a maximum operating speed of 18km/h (see figure 1). A safety steward was on board the vehicle at all times to monitor the operations and intervene if necessary.

![Figure 1. The AV shuttles used in the pilot project (Photo: Holo).](image)

1.2. Research on acceptance of AV shuttles
During the recent years, research has intensified when it comes to understanding user acceptance of AVs in general, but it is still far from being standardized. A recent review-based study found a total of twenty-eight acceptance factors identified in the literature [5].

The research on AV shuttles has largely been based on the social-psychological models previously developed to explain and predict technology acceptance and use, including the Technology Acceptance Model (TAM) [3], and the Unified Theory of Acceptance and Use of Technology (UTAUT) [4]. Here it has been indicated that an individual’s decision to use AV shuttle services can be connected to a number of attitudinal dimensions including performance expectancy, effort expectancy, social influence, hedonic motivations, facilitating conditions, price value, habits, safety and security, trust and vehicle and service attributes [6,7,8]. This is partly in line with Roger’s Diffusion of Innovation Theory [9] suggesting that an individual’s adoption decision is influenced by the following six characteristics relative advantage, image, compatibility, observability, complexity and trialability.

There has also been context specific research on users’ preferences towards innovative public transport indicating that the attributes with the highest potential to influence the choices of travelers between walking and motorized public transport include weather, illumination, on-board comfort, and distance travelled on foot [10].

2. Method
The methodology was based on a questionnaire created to evaluate the AV shuttle services. However, only questions and responses related to the user acceptance are reported here.
2.1. Measure of user acceptance and questionnaire content
Previous research points to a multitude of factors and dimensions for fully explaining AV shuttle acceptance. With this being said, there are indications that performance expectancy (i.e. Relative advantage) and hedonic motivation are two important factors for predicting user acceptance (or behavioral intention to use a system) at an early stage [6,7,8]. With this background, one deductive data collection approach was chosen based on the van der Laan acceptance scale [11] with the two attitudinal dimensions of system Usefulness (connected to performance expectancy) and Satisfaction (connected to hedonic motivation). The first dimension contains evaluations of the categories useful, good, effective, assisting and raising alertness, and the second dimension contains evaluations of the categories pleasant, nice, likeable and desirable. This method was complemented with an inductive data collection approach with two open questions gathering motivating reasons to use (or not to use) the specific service.

In addition, the questionnaire included context specific questions on perceived comfort, speed and safety in traffic, stated on a 5-point Likert scale (including antonyms) matching the van der Laan acceptance scale. There were also questions about participant demographics along with aspects relating to previous experience, including the number of times respondents had used the shuttles, how many days a week they used any other form of public transport in the area, and their general attitude towards new technology.

2.2. Data collection procedure
For each of the two routes, responses were collected from both potential users just before the services started (targeting pre-service expectations), and from actual riders of the shuttles. For the Chalmers campus route, pre-service questionnaires were collected on the campus area in the beginning of May 2018, and user questionnaires were collected continuously until the end of operations in October 2018 (excluding a service intermission in July). For the Lindholmen route, pre-service questionnaires were collected at the Lindholmen Science Park area at the end of May 2019, and user questionnaires were collected continuously until the end of operations in late November 2019 (excluding a service intermission in July).

The questionnaires were administered using the survey tool SurveyMonkey and were distributed by the safety stewards and project members as a link and QR-code on physical cards (to be accessed on personal devices) and on tablets in the shuttles. The pre-service collection also made use of social media channels targeting potential users of the services (e.g. campus students, staff and parking permit holders). The questionnaires were available in Swedish or English and took on average four and a half minutes to complete. The information was recorded anonymously, and no financial compensation was offered to respondents.

2.3. Analysis of responses
The responses to the van der Laan acceptance scale and context specific questions were analysed using Microsoft Excel and IBM SPSS, generating descriptive- and comparative statistics (alpha value for statistical testing was set to .05). The statements from the open questions on motivating reasons to use (and not use) the services were coded manually and grouped in a thematic analysis process [12].

3. Results
3.1. Respondents
A total of 434 valid responses were collected, of which 211 were collected just before the services started and 223 from actual riders of the shuttles. Table 1 provides an overview of demographic results for the two locations. For gender, no statistically significant difference between the locations was found ($\chi^2(1)=2.799$, $p=0.094$). For technology adoption, the two multinomial probability distributions were not equal in the population ($\chi^2(3)=8.944$, $p=0.030$). Observed percentages of technology adoption categories for each location are presented in Table 1. The difference in technology adoption is however small and of little practical relevance.
Table 1. Demographic and travel behavior information.

|                          | Chalmers campus | Lindholm |        |
|--------------------------|-----------------|----------|--------|
| Gender                   | Male            | 60.4%    | 54.2%  |
|                          | Female          | 39.6%    | 45.8%  |
| Number of times          |                 |          |        |
| using the shuttle service| 0 times        | 60.4%    | 31.8%  |
|                          | Up to 5 times   | 39.6%    | 66.3%  |
|                          | > 5 times       | 0%       | 1.9%   |
| Days a week              |                 |          |        |
| using public             |                 |          |        |
| transport in the area    | 0 days          | 8.6%     | 41.1%  |
|                          | 1 - 2 days      | 21.3%    | 12.8%  |
|                          | 3 - 5 days      | 41.2%    | 37.5%  |
|                          | 6 - 7 days      | 28.9%    | 8.6%   |
| When it comes to         |                 |          |        |
| trying new technology    |                 |          |        |
| generally…               | Among the first | 37.3%    | 35.7%  |
|                          | In the middle   | 55.2%    | 46.8%  |
|                          | Among the last  | 3.0%     | 7.8%   |
|                          | Do not know     | 4.5%     | 9.7%   |

Distributions of the number of times having used the AV shuttle service and number of days using public transport were not similar between the locations, as assessed by visual inspection. Median number of times having used the shuttle service was statistically significantly higher at Lindholmen (1 time) than at Chalmers (0 times), \(U = 12659, z=-7.618, p < .001\). Median number of days using public transport was statistically significantly higher at Chalmers (5 days) than at Lindholmen (1 day), \(U = 8279.5, z = -8.462, p < .001\). Distributions of the participants’ age between Chalmers and Lindholmen were not similar (Figure 2). There was a statistically significant difference, where participants at Lindholmen were older (median=40-49 years) as compared to Chalmers (median=20-29 years), \(U = 29878.5, z = 7.002, p < .001\).

Figure 2. Comparison of age groups across the two routes.

3.2. Ratings of attitudinal questions

Table 2 presents the results from the van der Laan acceptance scale and context specific questions on perceived comfort level, safety in traffic and speed. In figure 3, the average scores have been mapped along two dimensions showing results from pre-service expectations and user evaluations at the two routes.
Table 2. Attitudinal ratings of the two AV shuttle services.

|                                | Chalmers campus route | Lindholmen route |
|--------------------------------|-----------------------|------------------|
|                                | Expectations Users    | Expectations Users |
| Usefulness^a                   | M: 1.29 SD: 1.00      | M: 0.96 SD: 1.35 |
| Satisfaction^b                 | M: 1.31 SD: 0.90      | M: 0.93 SD: 1.15 |
| Comfortable                    | M: 1.10 SD: 0.99      | M: 0.25 SD: 1.10 |
| Safe in traffic                | M: -2.00 SD: 1.18     | M: -0.40 SD: 1.17|
| Fast                           | M: -2.00 SD: 1.18     | M: -0.40 SD: 1.17|

^a Combined from the sub-categories useful, good, effective, assisting and raising alertness.

^b Combined from the sub-categories pleasant, nice, likeable and desirable.

Figure 3. Two-dimensional representations of the attitudinal scores including pre-service expectations (white markings).

The difference between expectation and actual use within each location seems to be small (Table 2 and Figure 3). Looking at the combined ratings for each route (expectation and use together) we found that there were statistically significant differences in usefulness (U = 15334.5, z=-5.016, p < .001), satisfaction (U = 14187, z=-5.969, p < .001) and perceived safety in traffic (U = 16044, z=-4.675, p < .001), when comparing between the locations.

3.3. Motivating reasons to use
The following section provides an overview of respondents’ motivating reasons to use, or not to use, the specific AV shuttle services provided in the pilot project (see tables 3 and 4). During analysis, it was possible to group similar statements according to some of the user acceptance dimensions found in the literature, while some statements were coded into more context specific motivating themes (e.g. “route reasons”, “weather protection”, “prefer walking/biking” and “save jobs”).
Table 3. Motivating reasons to use the AV shuttle services listed by frequency (N=533).

| #  | Theme                  | Expectations | Users | Example                                      |
|----|------------------------|--------------|-------|----------------------------------------------|
| 1  | Hedonic motivations    | 40%          | 40%   | “It’s fun/exciting to try”                   |
| 2  | Performance expectancy | 20%          | 20%   | “It’s better/more practical”                 |
| 3  | Effort expectancy      | 10%          | 16%   | “It takes less effort”                       |
| 4  | Weather protection     | 9%           | 6%    | “It shields me from bad weather”             |
| 5  | Environmental concerns | 4%           | 7%    | “It is environmentally friendly”             |
| 6  | Support development    | 7%           | 4%    | “I want to support the development”          |
| 7  | Safety reasons         | 2%           | 4%    | “It will be safer than what we have today”   |
| 8  | Price value            | 5%           | 2%    | “It is free to use”                          |
| 9  | Social influence       | 2%           | 1%    | “Because my friend wanted to try”            |

Table 4. Motivating reasons to not use the AV shuttle services listed by frequency (N=447).

| #  | Theme                  | Expectations | Users | Example                                      |
|----|------------------------|--------------|-------|----------------------------------------------|
| 1  | Performance expectancy | 38%          | 44%   | “It is not practical enough”                 |
| 2  | Route reasons          | 19%          | 12%   | “The route is not for me”                    |
| 3  | Effort expectancy      | 8%           | 17%   | “It is crowded and requires timing”          |
| 4  | Safety/security reasons| 14%          | 5%    | “Something could go wrong”                   |
| 5  | Prefer walking/biking  | 8%           | 5%    | “It is better to walk or bike”               |
| 6  | Facilitating conditions| 5%           | 9%    | “There is no timetable”                      |
| 7  | Weather reasons        | -            | 3%    | “If it is nice outside”                      |
| 8  | Save jobs              | 2%           | -     | “What about the bus drivers?”                |
| 9  | Social influence       | 1%           | 2%    | “Would have to be social during the trip”    |
| 10 | Price value            | 1%           | -     | “If it would cost money”                     |

4. Discussion and conclusions

Researchers have applied, combined and extended different methods and models of technology acceptance to suit the context of first/last-mile AV shuttle services. While this ongoing detailed methodological work is highly needed to come up with more accurate acceptance models, there is also a need for bridging the gap between research and practice in order to ensure the applicability of theory in real-life settings. The current study design practically captures an indication of user acceptance in the S3 pilot project. It was a priority not to include any hypothetical or future scenarios and only evaluate the specific AV shuttle services offered in the project. Even so, it cannot be excluded that respondents imagined future use-cases and evolved functionality when rating their expectations and experiences.

Our results show similar pre-service and user ratings when it comes to stated usefulness and satisfaction related to the AV shuttle services, with the Chalmers campus route resulting in overall higher scores. In conclusion, there is little difference in rated expectations and experiences, at least after the still limited amount of AV shuttle experience acquired from the users. The samples from the two routes were similar when it comes to gender and attitude towards trying new technology, but differed in age groups and frequency of use of public transport in the area. Prior research has downplayed the effects of demographic variables such as age and gender when it comes to AV acceptance [5], but a higher tendency of using public transport in general would explain a higher acceptance of using shared AV shuttle services.
Besides socio-demographic aspects, any differences between samples would most likely be related to the characteristics of the routes and quality of the provided services. In our case, the Lindholmen route presented a more challenging setting adding more traffic (including a lot of pedestrians) and difficult obstacles (i.e. roundabouts and narrow roads).

Tables 3 and 4 present a number of factors that motivate and hinder the use of the AV shuttle services. Even if the answers are based on the specific services and contexts within the project, they should serve as an indication for similar first/last-mile services using AV shuttles. Both expectations and early use show that what is most attractive is the novelty factor, and that there is an expectation that it will be more practical and less strenuous to use than competing transport alternatives. However, there is a contradiction in the fact that the factors performance expectancy (including route reasons) and effort expectancy also motivate to not use the services. This suggests that the AV technology and services as a whole are not yet considered to be practically competitive and that the utility of the first/last-mile use cases in the tests is limited. At the same time, it is our view that most people interpret the exploratory nature of the tests and realize that a safety-critical approach is guiding the design of use-cases. However, this attitude cannot be expected to last over time, suggesting that the maturity level must quickly improve as people become more accustomed to (and less curious of) the technology.

The pilot project was created to test the first/last-mile AV shuttles and allow the public to start to familiarize with this novel type of mobility service. The mixed-traffic routes were very challenging for the current generation of AV shuttles, causing fundamental service parameters such as speed, comfort and efficiency to be low. Even if the usefulness was rated relatively high, it was clear that not many people were using the services on a regular basis in their daily commute.

Figure 4 illustrates how any AV shuttle service aiming at providing a competitive transportation alternative will need to deliver on a range of important adoption criteria. For now, the AV shuttles could be viewed to have acceptance in terms of attracting curious riders, but not necessarily as a competitive first/last-mile mobility solution. As the AV technology matures, different stakeholders will need to take these factors into account since any societal gains acquired through the combination of shared, electrified and automated mobility solutions rely on their widespread acceptance and adoption.

![Figure 4. Overview of AV shuttle service adoption adapted from Roger’s Diffusion of Innovation Theory (1995, 2003).](image)

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References
[1] NHTSA Automated Vehicles for Safety Accessed at https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety on 05/01/2020
[2] SAE J3016 2014 Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems Accessed at https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic on 18/12/2019
[3] Davis F D 1989 Perceived Usefulness, Perceived Ease of Use and User Acceptance of Information Technology MIS Quarterly 13 pp 319–340
[4] Venkatesh V Thong J Y L and Xu X 2012 Consumer Acceptance and Use of Information Technology Extending the Unified Theory of Acceptance and Use of Technology MIS Quarterly 36(1) pp 157–178
[5] Nordhoff S Kyriakidis M van Arem B and Happee R 2019 A multi-level model on automated vehicle acceptance (MAVA): a review-based study Theoretical Issues in Ergonomics Science 20:6 pp 682-710
[6] Madigan R Louw T Dziennus M Graindorge T Ortega E Graindorge M and Merat N 2016 Acceptance of Automated Road Transport Systems (ARTS): An adaptation of the UTAUT model In Proceedings of the 6th Transport Research Arena April 18-21 Warsaw Poland
[7] Madigan R Louw T Wilbrink M Schieben A and Merat N 2017 What influences the decision to use automated public transport? Using UTAUT to understand public acceptance of automated road transport systems Transportation Research Part F: Traffic Psychology and Behavior 50 pp 55–64.
[8] Nordhoff S De Winter J Madigan R Merat N Van Arem B and Happee R 2018a User acceptance of AVs in Berlin-Schöneberg: A questionnaire study Transportation Research Part F: Traffic Psychology and Behavior 58 pp 843–854.
[9] Rogers E M 2003 Diffusion of innovations New York Free Press
[10] Delle Site P Filippi F and Giusiniani G 2011 Users’ Preferences Towards Innovative and Conventional Public Transport Procedia Social and Behavioural Sciences 20 pp 906–915
[11] Van der Laan J D Heino A and De Waard D 1997 A simple procedure for the assessment of acceptance of advanced transport telematics Transportation Research - Part C: Emerging Technologies 5 pp 1-10
[12] Braun V and Clarke V 2012 Thematic analysis In Cooper H Camic P M Long D L Panter A T Rindskopf D and Sher K J (Eds.) APA handbooks in psychology® APA handbook of research methods in psychology Vol. 2 Research designs: Quantitative, qualitative, neuropsychological, and biological (American Psychological Association) pp 57–71