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User Acceptance of Automated Shuttles in Berlin-Schöneberg: A Questionnaire Study

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Abstract

Automated shuttles are now in a prototyping phase in several research projects. However, there is still a paucity of knowledge on the acceptance of these shuttles. This paper presents the results of a questionnaire study among individuals (n = 384) who physically experienced an automated shuttle on an office campus in Berlin-Schöneberg. The findings indicate that the respondents were positive towards automated shuttles and could envision their use as feeders to public transport systems, in both urban and rural areas. The respondents were less satisfied with the effectiveness of the shuttle compared to their existing form of travel, the speed of the shuttle, and the space for luggage. A principal component analysis resulted in the retention of three components: 1) intention to use, 2) shuttle and service characteristics, and 3) shuttle effectiveness compared to existing transport. Older respondents expressed a higher intention to use, but found the shuttle less effective than their existing travel. We argue that automated shuttles are a valued concept, but speed and efficiency have to improve, in order for automated shuttles to become viable on a wide scale. Future research should use more objective measures and establish long-term effects in larger, more representative samples.

1. Introduction

1.1. Automated Shuttles

Since the DARPA Challenges in 2004–2007 and the initiation of Google's self-driving car project in 2009, automated driving has seen a marked upsurge (Shladover, 2017). Current developments in the field of automated driving can be assigned to an evolutionary, revolutionary, or transformatory path of vehicle automation (Fraedrich et al., 2015). The evolutionary path is pursued by various automotive manufacturers, combining driver assistance systems such as adaptive cruise control, automated emergency braking, and automated lane keeping. The revolutionary path to vehicle automation, which is pursued by several ICT companies, targets the deployment of fully automated vehicles, enabling hands-free and eyes-off-the-road driving under every possible driving and traffic situation. The transformatory path includes automated shuttles that deliver on-demand transport and may serve as (last mile) feeders to public transport systems (Fraedrich et al., 2015).

Automated trams and metros that operate without a driver already exist in various cities worldwide (e.g., Fraszczyk & Mulley, 2017). The difference between existing automated public transport and automated shuttle projects is that the latter aim for operation in a mixed traffic environment without relying on specialized infrastructure. Shuttles that drive automatically in restricted conditions, on specified routes, may be released within three years (Shladover, 2017). Full 'revolutionary' automation, on the other hand, will probably not be commercialized anytime soon (Kyriakidis et al., in press; Shladover, 2016), and SAE Level 2–4 'evolutionary' automation may need to overcome human factors challenges associated with transitions between manual and automated control in order to be safe and accepted (Kyriakidis et al., in press).

Automated shuttles are now in a prototyping phase in various projects around the world (e.g., STIMULATE, 2018; Drive Sweden, 2018). Current shuttles run on specified routes at limited speeds, typically provide space for about 8 to 10 passengers, and require some level of supervision by a steward on board the vehicle or by an external control room. The CityMobil1 (2006–2011) and CityMobil2 (2012–2016) projects implemented automated shuttles in urban environments in several European cities with the aim to identify and remove barriers to deployment. More recent projects include WePods in the Netherlands (Liang et al., 2016; Van der Wiel, 2017) and Smartshuttle in Switzerland (Eden et al., 2017).

The EUREF demonstrator project in Berlin-Schöneberg, which is the topic of the present study, involves an automated shuttle ‘Olli’ developed by Local Motors, driving on the EUREF office campus in Berlin-Schöneberg.

1.2. Previous Studies on the Acceptance of Automated Shuttles

The vision of a multimodal mobility system with automated shuttles as feeders to public transport can only become a reality if the shuttles are accepted by their target users. A large number of survey studies exist in which people were asked to imagine and give their opinion on various types of automated driving concepts (e.g., Bansal et al., 2016; Bazilinskyy et al., 2015; European Commission, 2015, 2017; Hohenberger et al., 2016; Schoettle & Sivak, 2016). However, as summarized below, only a few studies have asked respondents to reflect on automated shuttles after having physically experienced a ride in the shuttle.

An evaluation of user acceptance across six demonstrations (Trondheim, Vantaa, La Rochelle, Daventry, Orta San Guilio, Castellon) of the CityMobil1 project showed that the most highly rated indicator was ‘ease of use’ with an average of 3.7 on a scale from 1 (completely dissatisfied) to 5 (completely satisfied), followed by usefulness (3.5), reliability, integration with other systems, perception of safety, perceived level of privacy, and perceived cleanliness (3.4), and comfort (3.3) (Gorris et al., 2011).

The results of interviews with over 1,500 users of automated shuttles of the CityMobil2 project showed general user acceptance regarding the performance of the shuttles, with high ratings on comfort and safety. Users were willing to pay for ticket fares, but the price should be comparable to the conventional transport (e.g., bus) (Alessandrini, 2016).

Another CityMobil2 questionnaire study examined user acceptance with 349 respondents who had used an automated shuttle along a popular tourist route in La Rochelle (France), and as a link between a metro station and key working sites/campuses in the district in Lausanne, Switzerland (Madigan et al., 2016). The means for the key constructs ‘performance expectancy’, ‘effort expectancy’, and ‘behavioral intention’ were 3.08, 3.89, and 3.59 from 1 (strongly disagree) to 5 (strongly agree). A consecutive study surveyed 315 passengers who experienced a CityMobil2 automated shuttle on a dedicated lane in the center of Trikala (Greece) and found that the means for ‘performance expectancy’, ‘effort expectancy’, and ‘behavioral intention’ were 3.62, 3.92, and 3.74. Thus, people found automated shuttles useful, easy to use, and expressed an intention to use them again in the future (Madigan et al., 2017).

Portouli et al. (2017) asked 200 respondents about their satisfaction with automated shuttles that run in Trikala as part of the CityMobil2 project. Their results showed that passengers rated the usefulness and comfort as 1.29 and 0.95 respectively, on a scale from -2 (very poor) to 2 (very good). Ratings of the service quality in terms of waiting time and onboard time (0.59) and the integration with other modes (0.57) were considerably lower. 182 people (91%) responded that permanent operation of the shuttle in the city would be useful; only 18 respondents (9%) responded that this would not be useful.

Finally, results from interviews with local residents of Sion (Switzerland) who experienced an automated shuttle as part of the SmartShuttle project in Sion’s Old Town district of the city, also showed that opinions towards the shuttle were positive overall. However, many participants felt that the shuttle slows down other traffic because of its low maximum speed of 20 km/h (Eden et al., 2017).

1.3. Objectives of the Present Study

The surveys reviewed above indicate that substantial progress has been made in the understanding of attitudes of users towards automated shuttles. However, whether participants are positive about the shuttle as a replacement of their current transport is a question that has received relatively little attention so far. The aim of the present study was to investigate how users rate the shuttle itself, its potential as a feeder to transport systems in urban and rural areas, and its advantages in comparison to respondents' existing form of travel.

We have included items from the Unified Theory of Acceptance and Use of Technology (UTAUT) constructs 'performance expectancy', 'effort expectancy', and 'social influence', which have been found to be predictive of the intention to use technologies across a variety of domains (Venkatesh et al., 2003). Additionally, we investigated respondents' perceptions with regard to perceived safety, perceived enjoyment, desired level of control, and environmental attitudes, because these variables have been identified as potentially critical determinants of the acceptance of automated vehicles in previous studies (e.g., Gorris et al., 2011, Moták et al., 2017; Nordhoff et al., 2018). Finally, the present 68-item survey study includes information on respondents' ratings of the acceptance of automated shuttles, using Van der Laan et al.'s (1997) acceptance scale, in addition to other indicators of acceptance, including respondents' intended frequency to use, willingness to pay, and behavioral intention to use shuttles as feeders in public transport.

A principal component analysis (PCA) was conducted on respondents' ratings to investigate the major sources of variation in the attitudes towards automated shuttles. To date, there has been little exploration of how the attitudes of various demographic groups towards automated shuttles might differ. Therefore, the component scores were correlated with personal characteristics (e.g., age, gender, employment on the EUREF campus) in order to assess individual differences.

It can be assumed that the acceptance ratings as measured in the current study are generalizable to other types of automated shuttles, because current shuttle prototypes worldwide have similar forms and sizes and are deployed in similar settings (e.g., university and office campuses, near public transport). This similarity renders the knowledge obtained in this study relevant beyond the trial in Berlin-Schöneberg.

2. Methods

2.1. Shuttle and Route

During the period of the survey from December 2016 to April 2017, the automated shuttle drove on a 700 m route on the EUREF office campus in Berlin-Schöneberg. This route took on average 8 to 12 minutes per trip at an average speed of 8 km/h, and a maximum campus speed of 10 km/h. The shuttle operated on the basis of 3 fixed stops along the route from 09:00 to 17:00 to provide a transport option for the EUREF campus employees. The stopping and continuing to drive at the stops was done manually by the steward. The shuttle was also used by national and international guests, as well as interested persons who visited the EUREF campus to experience a ride in the shuttle. At the end of the shuttle ride, the steward handed out tablet computers with a questionnaire to passengers (see Figure 1, left, for an image of the shuttle).

The shuttle was fully electric, had a driving range of 80 km at a speed of 8 km/h. It was charged at night and during the lunch break (45 minutes) of the stewards to integrate the charging process into the daily operations. The shuttle operated on 'virtual tracks' using Lidar (Light Detection and Ranging), radar, and geopositioning technology for localization, mapping, and navigation.

As the shuttle was still in a prototype phase, a steward was on-board to supervise its operations and to intervene when requested by the system (see Figure 1, right). For example, given that the shuttle only had obstacle detection sensors in the front, obstacles that were on the path of the shuttle (e.g., parked cars) had to be passed manually by the steward using a joystick. As shown by Figure 2, the shuttle shared the road with pedestrians and cyclists, and occasional cars and trucks. It stopped for road users (e.g., pedestrians, cyclists) that crossed its trajectory within a distance of about 4 meters. Campus visitors were informed via a sign at the campus entrance of the shuttle operation and that the shuttle has right of way and should not be overtaken. The sign also stated that road users should maintain a distance of 10 meters from the shuttle.

Figure 1. Left: Automated shuttle Olli by Local Motors at the EUREF campus, Right: Inside view, with passenger and steward

Figure 2. Left: Part of the route. Right: View on shared space on the EUREF campus and entrance to the campus

2.2. Respondent Recruitment and Procedure

To bring the research to the attention of potential shuttle users, social media accounts (e.g., Twitter, Facebook) of the Innovation Centre for Mobility and Societal Change (InnoZ) were used in addition to publishing the project on the InnoZ website. An invitation for a test ride and participation in an online study was also sent to the Geography department of the Humboldt University in Berlin. The invitation to participate in our questionnaire study was also offered to delegations or other groups who performed around 20% of all test rides.

A maximum of 12 passengers was accepted (8 seated and 4 standing), with an average occupancy rate of around 3. The stewards explained the shuttle's functionality before the ride, by showing users the technology behind Olli, including the location of the sensors, the Lidar system, and the position of the touchpad that is used by the stewards to intervene. The shuttle's functionality was also explained during the ride inside the shuttle while making sure that passengers could also experience the ride. The respondents were told that the shuttle was a prototype and in a continuous state of development.

Furthermore, the respondents were informed that the use of the shuttle on a semi-public domain, such as the EUREF campus, was a first step in the deployment of automated shuttles as feeders to public transport systems on public roads. Taking a ride in the shuttle was free of charge, and no financial compensation was offered for the participation in the test ride and the questionnaire study.

2.3. Questionnaire Content

2.3.1. Demographics and Shuttle and Service Characteristics

The questionnaire asked for personal details, namely whether the respondents completed the questionnaire for the first time (Q1), gender (Q2), age (Q3), whether they worked on the EUREF campus (Q4), in which field they worked (Q5), which transport mode they used on the EUREF campus (Q6; multiple responses possible), whether they have used the shuttle before (Q7), and if so, how many times (Q8).

The next section asked the respondents to rate the service, including the attractiveness of the shuttle service (Q9), its reliability (Q10), and its usability/comfort for the daily commute (Q11).

Next, questions were presented about the shuttle itself, including the attractiveness of the automated shuttle (Q12), the size of the shuttle (Q13), the perceived quality of the exterior of the shuttle (Q14), the design of the exterior of the shuttle (Q15), the speed (Q16), the comfort of entry and exit (Q17), the spaciousness of the shuttle (Q18), the number of seats (Q19), the seating comfort (if having taken a seat) (Q20), the number of standing positions (Q21), the handholds in the bus (Q22), the space for luggage (Q23), the brightness (Q24), the quality of the shuttle interior (Q25), the design of the interior of the shuttle (Q26), the atmosphere (Q27), and the safety (Q28).

2.3.2. Attitudinal Questions

Next, eleven questions (Q29, Q34, Q36–Q42, Q44, Q45) were presented to assess respondents' level of agreement with items pertaining to the perceived enjoyment of taking a ride in the shuttle, perceived usefulness (performance expectancy), as well as the ease of use (effort expectancy) of the automated shuttle.

In particular, the respondents were asked how they liked the trip with the automated shuttle (Q29), whether taking a ride in the shuttle was fun and enjoyable (Q34), and whether the respondents found the trip in the shuttle boring (Q37).

The respondents were asked whether the driverless shuttle is useful (Q36), whether they would use an automated shuttle for their day-to-day commuting as it is better and more convenient than their existing form of travel (Q38), whether they think that the automated shuttle will become an important part of the existing public transport system (Q39), whether using the automated shuttle is similar to using existing public transport systems (e.g., busses, trains, and trams) (Q41), and whether the automated shuttle is more efficient/faster than their existing form of travel (Q44).

The respondents were also asked whether using the automated shuttle is easier for them than using their existing form of travel (Q40), whether the automated shuttle is easy to understand how to use (Q42), and whether it would not take long to learn how to use an automated shuttle (Q45).

Thirteen questions (Q43, Q46, Q53–Q62, Q67) were presented about the respondents' perceived level of safety and desired level of control in an automated shuttle, their environmental attitudes, as well as their reliance on the opinion of others (social influence).

The respondents were asked whether they like it that the driverless shuttle drives at a low speed (Q43), whether they felt safe in the automated shuttle throughout the whole trip (Q46), whether they felt comfortable in a vehicle without steering wheel, gas or brake pedal (Q56), whether people who are important to them would like it if the respondent used an automated shuttle (Q57), whether they would prefer the automated shuttle to drive without a steward on board (Q58), whether they would like to manually steer the automated shuttle when they want to (Q59), whether they would like to have a button inside the automated shuttle which they can press to stop it (Q60), whether they would like to have their friends or family or other important people to them adopt the automated shuttle before they themselves do (Q61), and whether the automated shuttle is safe and reliable under severe weather conditions, such as snow, heavy rain, or fog (Q62). Question Q67 asked respondents to provide their level of agreement with "Driverless vehicles can operate without human supervision. Would you still prefer having some level of supervision?", on a scale ranging from no human supervision, remote supervision from a control room, to supervision by a steward on board.

Specifically, the respondents were asked about their agreement with the statement that the protection of the environment is crucial for the choice of the automated shuttle (Q53), whether they like it to use a 100% electric automated shuttle from the train station to their final destination (Q54), and whether they would like to choose the automated shuttle as a more ecological form of travel even if it were more expensive (Q55).

2.3.3. Indicators of Acceptance

Fifteen questions (Q30–Q33, Q35, Q47–Q52, Q63–Q66) asked the respondents to indicate their level of acceptance of automated shuttles. The respondents were asked how they liked the idea of using automated shuttles for public transport (Q30), and whether they would use automated shuttles as mobility offer in the city (Q31) and in rural areas (Q32). Question Q33 asked the respondents to what extent the service of automated shuttles fits existing railway facilities. The respondents were further asked whether they would be willing to share the shuttle with other travelers having the same destination (Q35), whether they dislike it that they might have to share the automated shuttle with unknown passengers (Q47), whether they would use an electric automated shuttle from the train station or some other public transport stop to their final destination or vice versa (Q48), whether they would use the automated shuttle with another 6 to 8 passengers having the same destination as themselves (Q49), whether they plan to use automated shuttles when they are available on the market (Q50), and whether they intend to use an automated shuttle for their daily trips (Q51), or to replace their current form of transport with an automated shuttle (Q52). The respondents were asked whether they would use an automated shuttle as mobility offer in rural areas (Q63) or in urban areas (Q64), and how often they intend to use automated shuttles on their daily trips (Q65). Question Q66 asked the respondents to rate the usefulness of and satisfaction with the automated shuttle, using Van der Laan's usefulness and satisfaction scale (Van der Laan et al., 1997). With the final question Q68, the respondents were asked how much they would be willing to pay for a 10-minute use of an automated shuttle.

The respondents indicated their level of agreement for Q9 to Q28 on a scale from 1 (very good) to 6 (very bad), while questions Q34 to Q64 were measured on a six-point Likert scale from strongly disagree to strongly agree. Responses to the response option 'I don't know' in Q34 to Q64 were excluded from the analysis. Responses were gathered between December 01, 2016 and April 2017. The questionnaire was offered in German and English, depending on the preference of the respondent.

2.4. Analysis of Responses

Responses were included only if the survey was completed for the first time (Q1). Descriptive statistics (means, 95% confidence intervals) were calculated per questionnaire item. A principal component analysis (PCA) was conducted on all questions (except for the demographic questions Q1–Q8) to investigate the major sources of variation in the attitudes towards automated shuttles. Correlations were computed between the PCA scores and personal characteristics (i.e., age, gender, employment on the EUREF campus). The number of components to be retained was decided based on the percentage variance explained (scree plot) as well as the interpretability of the components. The loadings were rotated using the Promax rotation procedure with a power of 4 (Hendrickson & White, 1964). For the PCA, the respondents who had 20% or more missing items (e.g., due to not completing the questionnaire or because the questionnaire was extended later, by adding Q34 to Q68) were excluded from the analysis. Missing data were imputed using the 'nearest neighbor' participant on that item (Euclidean distance). Pearson product-moment correlations between respondents' personal details measured by Q2-Q8 and the PCA scores were calculated. All analyses were conducted in MATLAB 2016a.

3. Results

3.1. Respondents

From the around 1,600 passengers that were transported from December 2016 to April 2017, 384 participated in our questionnaire study (mean age = 35.5, SD = 14.4; 227 were male, 135 were female, and 22 did not specify their gender). 274 respondents were included in the PCA (mean age = 34.9, SD = 14.2; 169 were male, 102 were female, and 3 did not specify their gender). Regarding their common mode of transport on the EUREF campus (Q6), 3 reported using an electric scooter, 9 an electric vehicle, 45 a bike, 16 a conventional vehicle with a combustion engine, 202 walked, 23 used another type of transport, and no one used a truck. 211 respondents indicated to not work at the EUREF campus, 59 did work at the EUREF campus, and 4 did not specify whether they worked at the campus.

3.2. Ratings of Shuttle and Service Characteristics

As shown in Figure 3, the respondents indicated that they liked the trip in the shuttle (Q29), with a mean (M) of 5.17 on the scale from 1 (strongly disagree) to 6 (strongly agree). They found the service of the shuttle (Q9) and the shuttle itself (Q12) attractive. The shuttle was also regarded as bright (Q24), spacious (Q13, Q18, Q19), and comfortable in terms of seating (Q20). The respondents also liked the atmosphere (Q27), especially the quality (Q14) and design of the shuttle exterior (Q15) and interior (Q25, Q26).

The respondents liked the idea of using automated shuttles in public transport systems (Q30, with a mean of 5.18 on the scale from 1 (strongly disagree) to 6 (strongly agree). They were less satisfied with the practicalities of the shuttle, such as the availability of handholds (Q22), and standing positions (Q21). The lowest ratings were obtained for vehicle speed (Q16; M = 3.38), and space for luggage (Q23, M = 3.49).

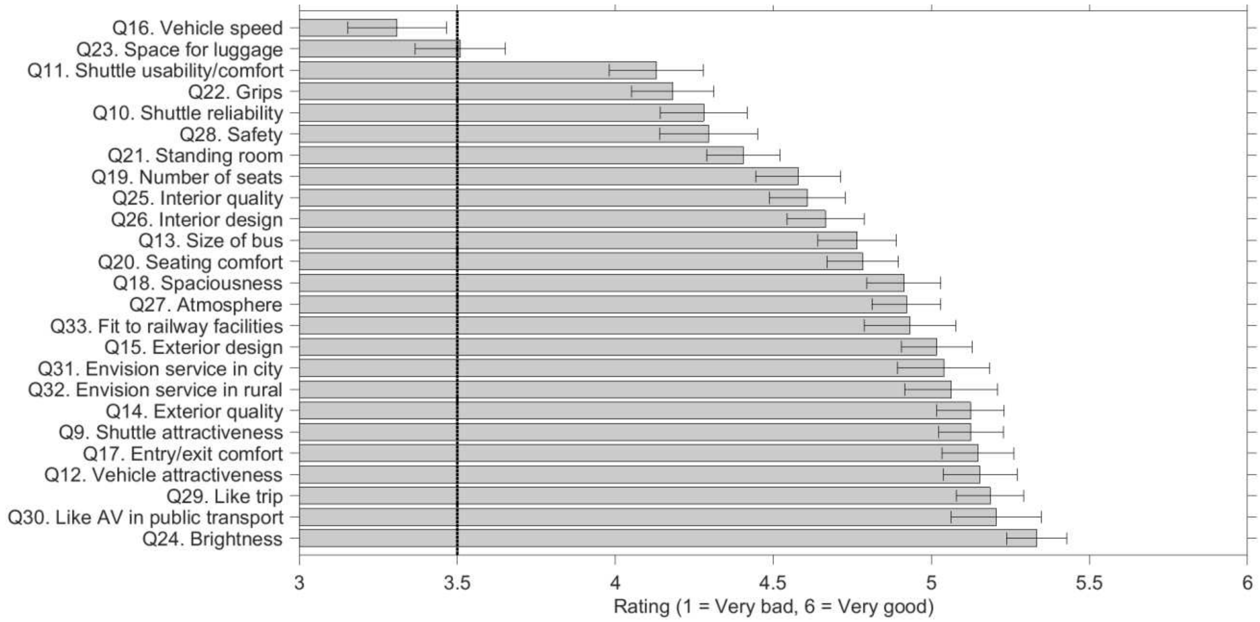

Figure 3. Shuttle and service characteristics, mean and 95% confidence intervals. The items are sorted by mean rating. The vertical line at 3.5 indicates a score in the middle of the range from 1 to 6.

3.3. Ratings of Attitudinal Questions

Figure 4 shows that the respondents gave high ratings to generic questions about the shuttle's usefulness and importance and their own affective state. For example, the respondents considered the shuttle to be useful (Q36, M = 5.13), and believed that the shuttle would become an important part of the existing public transport system (Q39, M = 4.77). They considered taking a ride in the automated shuttle to be fun and enjoyable (Q34, M = 5.40), and disagreed that the trip was boring (Q37, M = 2.30).

The respondents liked the idea that a 100% electric driverless shuttle will transport them from the train station to their final destination (Q54, M = 5.04), and agreed with the statement that the protection of the environment is crucial for their choice of transportation (Q53, M = 4.71). They were inclined to choose a driverless shuttle as a more ecological form of transport, even if it were more expensive than their current travel (Q55, M = 4.02). The respondents gave high ratings for sharing the shuttle together with 6–8 passengers having the same destination as them (Q49, M = 5.34).

When the respondents were asked to compare automated shuttles to their current travel, their ratings were low. In particular, the respondents did not think that the shuttle was more efficient/faster (Q44), or easier to use (Q40) than their existing form of travel, with means of 2.50 and 2.96 respectively on the six-point scale.

A majority liked the idea of a button inside the shuttle which they could use to stop it (Q60, M = 5.23). In terms of vehicle supervision, the most preferred option was supervision from an external control room, followed by having a steward on board, with no human supervision receiving the lowest ratings (51.6%, 33.5%, and 14.9% of respondents, respectively, Q67).

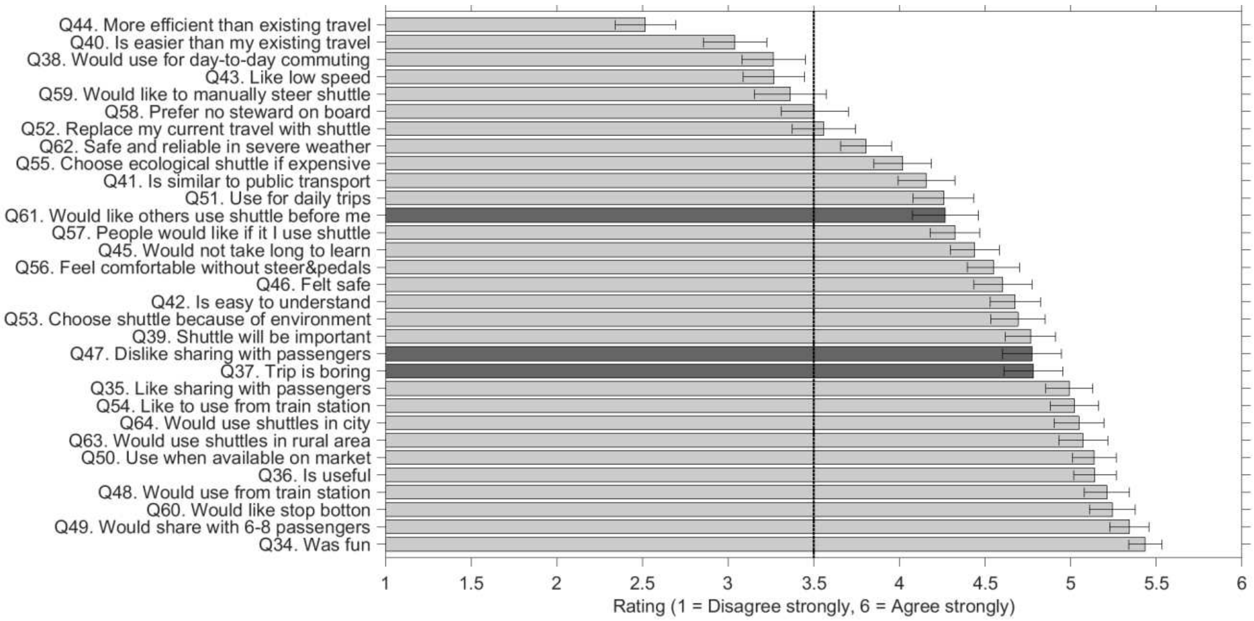

Figure 4. Attitudes towards the shuttle, mean and 95% confidence intervals. The items are sorted by mean rating. The scores for Q37, Q47, and Q61 (as indicated in darker bars) were reversed because these questions were phrased in a negative way. The vertical line at 3.5 indicates a score in the middle of the range from 1 to 6.

An analysis of the standard deviations per item showed substantial differences between items. To illustrate, the lowest standard deviation (0.80) was obtained for Q24 ('Brightness'), with the majority of the respondents giving positive ratings. The highest standard deviation (1.90) was found for Q59 ('I would like to manually steer the driverless shuttle when I want this'), yielding a seemingly bimodal distribution. The distributions of Q24 and Q59 are shown in Figure 5.

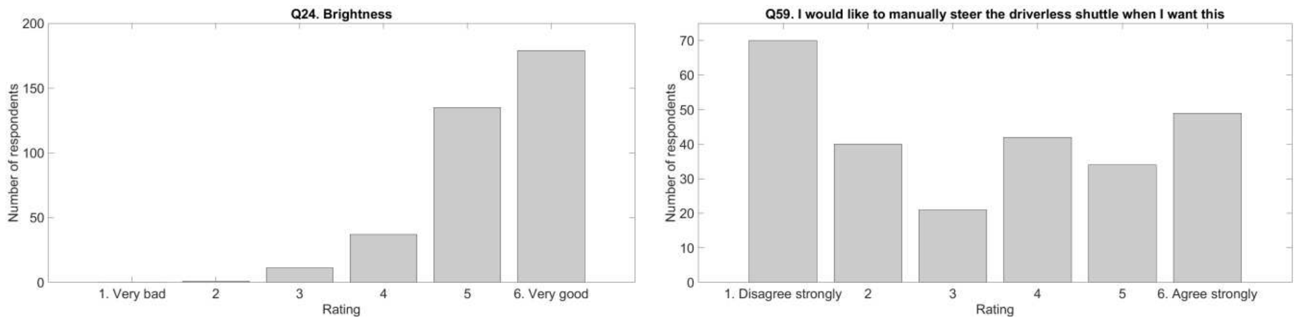

Figure 5. Distribution of the responses for the item with the lowest standard deviation (Q24, left), and the item with the highest standard deviation (Q59, right).

3.4. Results from the Van der Laan Acceptance Questionnaire

Acceptance ratings of the automated shuttle were obtained using a 9-item acceptance questionnaire (Q66-1–Q66-9) (Van der Laan et al., 1997), measuring aspects of usefulness (Q66-1, Q66-3, Q66-5, Q66-7, Q66-9), and satisfaction (Q66-2, Q66-4, Q66-6, Q66-8). Figure 6 shows that the respondents were generally accepting the shuttle, as they gave positive ratings for usefulness and satisfaction. However, they gave higher scores on the satisfaction scale than on the usefulness scale (see the relatively low ratings for Q66-5 and Q66-9).

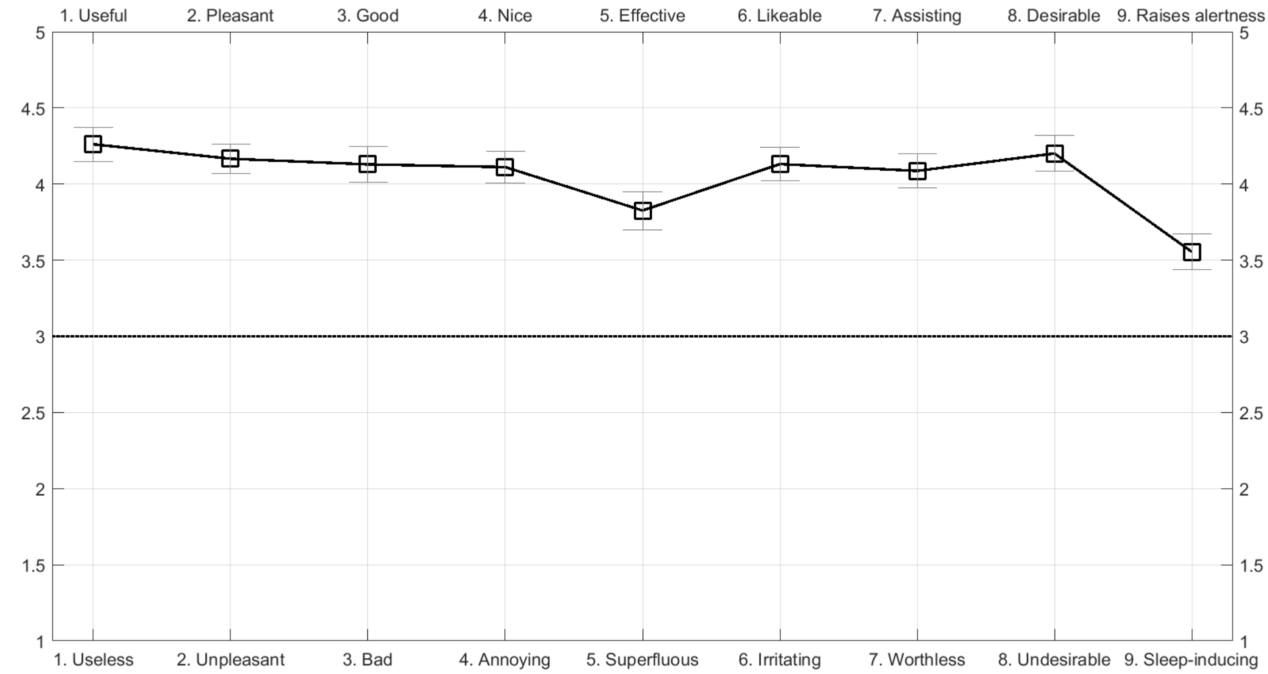

Figure 6. Van der Laan acceptance questionnaire, mean and 95% confidence intervals. The horizontal line at 3 indicates a score in the middle of the range from 1 to 5.

3.5. Willingness to Pay and Intended Frequency of Use

When the respondents were asked how often they would use automated shuttles on their daily trips (Q65), 33% of the respondents reported the intention to use it daily, 33% on 1 to 3 days a week, 18% on 1 to 3 days a month, 8% less than monthly, and 8% never or almost never.

29% of the respondents indicated that they would be willing to pay for a 10-minute ride (Q67) up to €0.50, 27% reported €0.51–1.00, 17% reported €1.01–1.50, 15% reported €1.51–2.00, 3% reported €2.01–2.50, 2% reported €2.51–3.00, and 7% picked the response option 'nothing'.

3.6. Principal Component and Correlational Analysis

A PCA was performed on the responses from 274 respondents on 67 items (i.e., Q9–Q65, Q68, and the Van der Laan scale Q66-1–Q66-9). The Kaiser-Meyer-Olkin (KMO) index of sampling adequacy was 0.907, which is indicative for the suitability of the data for factor-analytic purposes. As suggested by the scree plot (Fig. 7), three interpretable components were retained, explaining 39.4% of the variance (see the Supplementary Material for all component loadings). The three retained components had eigenvalues of 17.8, 5.32, and 3.31, corresponding to 26.6%, 7.9%, and 4.9% of the explained variance. The Cronbach alpha for the three components was 0.942, 0.906, and 0.743 if selecting the 24, 21, and 6 variables that loaded higher than 0.4 on the components, which represents a common cut-off value (Peterson, 2000).

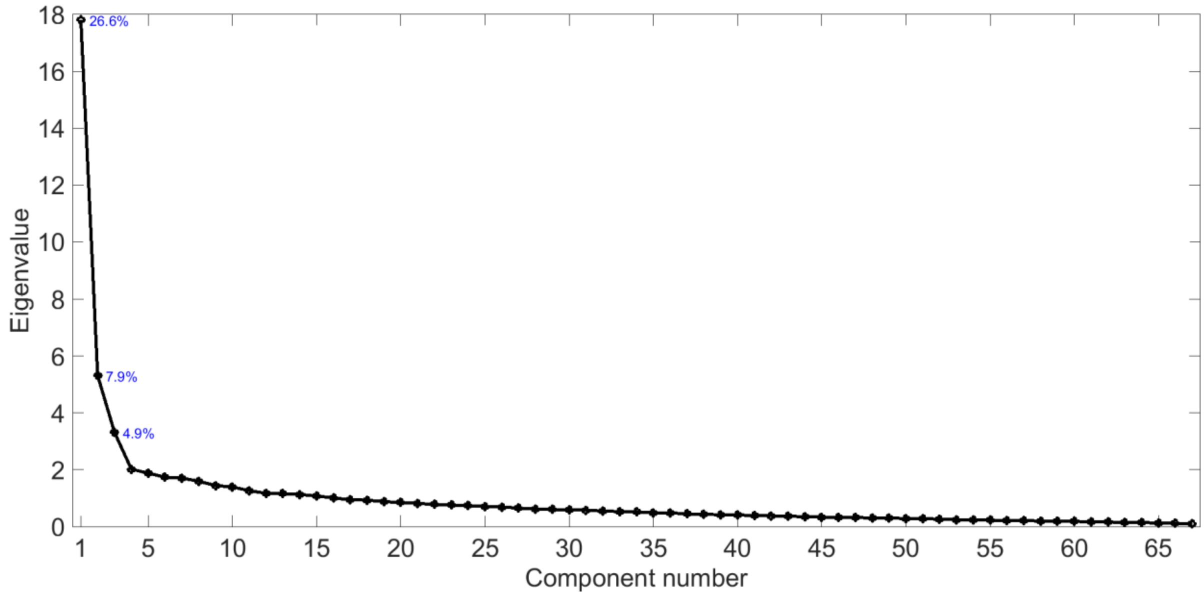

Figure. 7. Scree plot showing the eigenvalues of the correlation matrix, and the corresponding percentages of variance explained.

The first principal component (PCA1), ‘intention to use’, reflects whether the respondents would use automated shuttles (Q30–33, Q36, Q39, Q41, Q42, Q48–Q52, Q54, Q56–Q57, Q63–Q64, Q66-1, Q66-3, Q66-5–Q66-8). The highest loading (0.85) was obtained for Q48 (‘I would use an electric driverless vehicle from the train station or some other public transport stop to my final destination or vice versa’). The second-highest loading (0.84) was obtained for Q31 (‘To what extent can you envision the use of automated busses as mobility service in the city?’).

The second principal component (PCA2), ‘shuttle and service characteristics’, relates to the attitudes towards the physical shuttle itself, represented by Q9–Q10, Q12–Q29 and Q43. The highest PCA2 loading (0.80) occurred for Q26 (‘Design of the bus from the interior’), the second-highest (0.78) for Q18 (‘Spaciousness’).

The third principal component (PCA3), ‘shuttle effectiveness’, pertains to the performance of the automated shuttle in comparison with existing travel modes, represented by Q38, Q40, Q44, Q52, Q59, and Q61. The highest loading (0.75) occurred for Q40 (‘Using the driverless shuttle is easier for me than using my existing form of travel’), the second-highest (0.71) was obtained for Q38 (‘I would use a driverless shuttle in my day-to-day commuting as it is better and more convenient than using my existing form of travel’).

Table 1 shows the correlations between principal components and selected personal characteristics (age, gender, employment on the EUREF) as well as between the components themselves. There were no substantial gender differences between the three PCA scores. There was a positive correlation between age and PCA1 ($r = 0.21$), with older respondents expressing a higher intention to use automated shuttles (PCA1). However, the negative correlation between PCA3 and age ($r = -0.17$) indicates that older respondents rated automated shuttles as less effective compared to their existing form of travel. The negative correlation between employment on the EUREF campus and PCA3 ($r = -0.19$) indicates that people working on the EUREF campus consider the automated shuttle to be less effective compared to their existing form of travel. There were no substantial differences between employees and nonemployees of the EUREF campus concerning their ratings of PCA1 and PCA2.

Furthermore, we found a significant positive correlation between PCA1 and PCA2 (r = 0.53) and PCA3 (r = 0.24), as well as between PCA2 and PCA3 (r = 0.28). These positive correlations indicate that there is some degree of redundancy among the three component scores, as each of the three components expresses a positive valence towards the shuttle.

Table 1.
Pearson correlation matrix

		M	SD	1	2	3	4	5
1	Gender (1 = male, 2 = female) (Q2)	1.38	0.49					
2	Age (years) (Q3)	34.90	14.20	-0.06				
3	Working on campus (1 = no, 2 = yes) (Q4)	1.22	0.41	0.04	0.01			
4	PCA1: Intention to use	0.00	1.00	0.01	0.21	-0.06		
5	PCA2: Shuttle and service characteristics	0.00	1.00	0.04	0.08	-0.05	0.53	
6	PCA3: Shuttle effectiveness	0.00	1.00	-0.04	-0.17	-0.19	0.24	0.28

Note. $p < 0.05$ for $|r| \geq 0.12$, $p < 0.01$ for $|r| \geq 0.16$.

4. Discussion

4.1. Main Findings at the Item Level

This study showed that the respondents accepted automated shuttles and appreciated their potential use in future public transport systems. The respondents reported positive attitudes towards using the system as a form of transport and were willing to share it with fellow travelers. They agreed most strongly with the item that taking a ride in the shuttle was fun and enjoyable (M = 5.40 on a scale from 1 to 6), and so were even more positive than the respondents who experienced an automated shuttle in Trikala as part of the CityMobil2 project (M = 3.80 on a scale from 1 to 5; Nordhoff et al., 2017). More than half of our respondents (59.4%) were willing to pay up to EUR1 per 10-minute use.

The respondents were not inclined to replace their current transport mode for the shuttle, which may not be surprising as the shuttle operated under very limited conditions. In Madigan et al. (2016), respondents’ ratings of performance expectancy (e.g., ‘I think an ARTS would be more efficient/faster than existing forms of public transport’) were relatively low (M = 3.08 on a scale from 1 to 5), consistent with our findings (M = 2.50 on a scale from 1 to 5; Q44). Among the shuttle and service characteristics (Q9–Q28), the speed of the shuttle (Q16) received the lowest ratings (M = 3.38 on a scale from 1 to 6). Previous studies showed that a low shuttle speed was positively perceived because of safety (Bekhor et al., 2003; Rodríguez, 2017), but negatively perceived because of travel time concerns (Bekhor et al., 2003). These low ratings may have important implications, as travel time and waiting time are critical determinants of the use and acceptance of shared autonomous vehicles (Krueger et al., 2016). The operation of shuttles at higher speeds, however, necessitates the equipment of shuttles with better sensors and software as well as an adjustment of legal frameworks and an adaptation of infrastructure (Schreurs & Steuwer, 2016). The space for luggage is another shuttle characteristic that received low ratings.

The supervision of the shuttle from an external control room was preferred to the supervision by a steward and no supervision. These findings correspond with findings in the domain of driverless trains where only few people were comfortable without any type of supervision (Fraszczyk & Mulley, 2017). Why the respondents preferred supervision from an external control room to a steward on board is a question that warrants further investigation. It is possible that the respondents prefer not to encounter a steward, or it is possible that the respondents envisioned a reliable shuttle system where intervention is rarely needed and remote supervision suffices.

4.2. Principal Components

The PCA resulted in the retention of three components (1. intention to use, 2. shuttle and service characteristics, 3. shuttle effectiveness compared to existing transport), which together accounted for a variance of 39.4%. The first and third components resemble the UTAUT constructs 'behavioral intention' and 'performance/effort expectancy', respectively (e.g., Venkatesh et al., 2003), whereas the second component resembles the construct 'service quality' (e.g., Sánchez Pérez et al., 2007).

We observed positive correlations between the three components. The strong positive relationship between shuttle and service characteristics (PCA2) and intention to use (PCA1) is consistent with studies showing that quality of service is linked to intentions to use public transport systems (e.g., Lai & Chen, 2011; Sánchez-Pérez et al., 2007). The moderate positive relationship between shuttle effectiveness (PCA3) and intention to use (PCA1) also corresponds to previous research. For example, Buckley et al. (2018) found that the intention to use conditionally automated vehicles (SAE Level 3 automation) is associated with perceived usefulness. Similarly, Kaur and Rampersad (2018) identified performance expectancy as a significant predictor of the adoption of driverless cars.

Note, however, that the occurrence of positive correlations can also plausibly be explained by a common cause (e.g., positively minded people giving higher ratings), or method effects such as item wording (i.e., items with the same response options correlate strongly, and therefore cluster on the same component). Further experiments with a control group and objective measures (e.g., actual use rather than intended use) are needed to unravel the causal determinants of the acceptance of automated shuttles.

4.3. Individual Differences

The standard deviations of the responses were relatively low regarding physical shuttle characteristics (e.g., luggage space, brightness), indicating that the respondents were generally in agreement with each other. However, our study showed higher variability for items pertaining to hypothetical situations. For example, there was a wide distribution regarding whether the respondents want to have the option to steer the vehicle manually (Fig. 6). This finding is consistent with Kyriakidis et al. (2015) who found that some people prefer automated driving, whereas others were against it.

We did not find substantial gender differences regarding the principal component scores. This corresponds with Madigan et al. (2016) who did not find any gender effects on individuals' behavioral intentions to use automated shuttles. However, our study did find age effects: Older people expressed a higher intention to use the shuttle, but rated the effectiveness of shuttles compared to their existing travel as more negative. Madigan et al. (2017) also found more negative ratings among older shuttle users in Greece, but Madigan et al. (2016) reported more positive ratings among older persons in France and Switzerland. Madigan et al. (2016) further found that age effects in the acceptance of shuttles depend on whether zero-order correlations are assessed, as in the present study, or whether age effects are assessed as part of a multiple regression analysis. The observed inconsistencies in age effects may be due to differences in subcultures (e.g., employees, tourists, visitors), which makes the generalizability of the observed age effects difficult at the moment.

4.4. Study Strengths & Limitations

A limitation of our study is that it may be prone to selection bias, as our study could have attracted people who have a favorable opinion about automated shuttles and were curious about testing them for the first time. This notion is consistent with the fact that employees on the campus rated the shuttle as more negative than outside visitors (Table 1). Campus employees may not have had the same level of excitement about the technology anymore, because they may have seen the shuttle many times before. Similarly, it is possible that the respondents gave high acceptance ratings as a form of cognitive dissonance reduction (i.e., to justify to themselves taking the effort to participate). Although the respondents may have been more positive compared to representative samples, the differences between item responses (e.g., the fact that shuttle speed received relatively low ratings) should be immune to selection bias. Furthermore, current shuttles world-wide operate in similar settings (e.g., office or university campus), which makes our results representative for early-adopter scenarios. Therefore, future research should be conducted using larger samples that are representative of the entire population.

Previous research has used large national or cross-national samples via interviews or online questionnaires and asked them questions about imagined automated vehicles (see Eurobarometer method; European Commission, 2015, 2017; Nordhoff et al., 2018). Although these studies target broad and potentially representative audiences, their results may be of limited validity, as respondents had to respond based on their general beliefs (e.g., as obtained via the media or Internet sources). A strength of our survey is that respondents physically experienced an automated shuttle. For example, the fact that respondents gave relatively low ratings to the shuttle speed would probably not have been obtained when the respondents were merely asked to imagine a fully automated vehicle. However, social desirability biases still cannot be ruled out, as individuals in our study may have responded in line with their general beliefs despite having experienced the shuttle. To illustrate, respondents showed agreement ($M = 4.02$) with the idea of choosing the automated shuttle as a more ecological form of travel if it were more expensive, while the majority (204/274) indicated to be walking (which is arguably the most ecological form of transport possible) on the campus. In other words, it is likely that respondents were overall positive ('yea-saying') without critically reflecting on the meaning of each question. On the other hand, it could be argued that this particular mismatch is sensible as respondents who regularly walk on the campus may be traveling to that campus using the bus or car. To circumvent these limitations, future research should be performed in naturalistic rather than trial-based settings. Furthermore, it is recommended to measure participants' actual usage of the shuttle (e.g., frequency of use), rather than self-reported attitudes towards using the shuttle.

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