Empirical investigation of the acceptance of the automated shuttle bus in Stolberg

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Abstract:

Automated shuttle buses are one of the future mobility concepts. As part of the AS-NaSA project, an automated shuttle bus was tested in Stolberg (Germany, Saxony-Anhalt) in 2021. Besides the use, the acceptance of such systems is very important. In addition to the users, however, the residents who live along a pilot route of an automated shuttle bus are also affected. For this reason, a household survey on the acceptance of automated shuttle buses in Stolberg is being conducted in 2022. A questionnaire based on the "Unified Theory of Acceptance and Use of Technology" model was created and every household in Stolberg received two questionnaires. The results show that the current mobility situation and public transport connections in Stolberg needs improvement. Automated shuttle buses are a possibility for the future, but the use of rail has the most support.

1. Introduction

Due to demographic change, increasing urbanization, scarcity of resources and climate change, mobility needs to change in the future [1, 2]. One of the future mobility services is the automated shuttle bus, which is electric, connected and safe [3, 4]. Since the vehicles can be shared, they combine the flexibility of individual transport with the cost efficiency of public transport [5]. Therefore, automated shuttle buses are part of the future and sustainable mobility concepts in urban and rural areas (Figure 1) [3]. Right now, the automated shuttle buses are classified in the SAE levels between "Partially Automated" to "Fully Automated" [6, 7]. This development will proceed continuously so that autonomous driving will be possible in the future [8, 9].

Figure 1: Automated shuttle bus from EasyMile

However, without the acceptance of the users and the population, technological development will not be able to prevail in the future [10, 11]. One of the reasons for this is that the role of the driver changes completely. With autonomous driving, the driver only has to monitor and no longer steer [12]. There a lot of acceptance studies of automated shuttle buses, but most have focused on user acceptance. For example, in Mainz, where the shuttle bus operated in public space, but without motorized traffic [13]. This survey had a detailed look on performance parameters of the shuttle bus, such as speed, space, and braking. Schäfer & Altinsoy asked passengers about their feeling of safety, future use and driving experience of the shuttle bus operating in Frankfurt am Main [14]. In the pilot operation in Bern, the user experience during the ride, the acceptance of an on-demand operation as well as the preference of the pricing model were investigated [15]. One last example is

a pilot operation in Michigan, where Kolodge et al. asked about safety, performance parameters and reasons why passengers used the automated shuttle bus [16].

In addition to the users, however, the residents who live along a pilot route of an automated shuttle bus are also affected. As road users, they are also confronted with the new technology on a daily basis. Therefore, the acceptance of this population group is of great importance. Currently only three household surveys regarding automated shuttle busses were found. During the pilot operation in Bad Birnbach, residents were asked about the active use and evaluation of the automated bus in Bad Birnbach [17]. Regarding the general evaluation of the vehicles, passengers rated the shuttle buses safer, more reliable and more trustworthy than non-testers [17]. Finally, the question was asked about the willingness to use and openness for autonomous minibus systems in the future [17]. Mantel analysed the acceptance of passengers and residents during the pilot operation in Lauenburg and compared them with each other [18]. A third household survey was conducted in Neuhausen am Rheinfall [19]. The focus of this study was on the ride experience [19]. Since the user survey during the pilot operation in Stolberg was filled out almost exclusively by tourists and hardly by residents, the aim of this publication is to determine the acceptance of the residents of Stolberg [20]. Therefore, as a first step, it is important to understand what acceptance is. This is followed by an analysis how acceptance can be measured. Next, it is important to select the right survey methodology for resident acceptance. Finally, the questions needed for the acceptance survey are selected. In summary, the following research questions are examined (see Table 1).

Table 1: Overview research question

Research Question	Method
What is acceptance?	Literature research
How can you measure acceptance?	Literature research, best-practice-analysis
How can you determine the acceptance of residents?	Literature research, empirical research
What questions need to be considered when surveying acceptance?	Literature research, expert interviews, Own research work

In the following, the methodological approach is first explained and the appropriate method selected. Then the results are presented and discussed. Finally, there is a summary with future research needs.

2. Methodical approach

This chapter is divided into place of survey, definition of acceptance measurement, selection of the research method and implementation of the survey.

2.1. Place of the survey

Stolberg is with 732 households a small city in the rural area of Saxony-Anhalt (Germany). Nevertheless, a lot of tourists are visiting Stolberg especially at the weekends. As an element of the AS-NaSA project, an automated shuttle bus ran there between 27th June to 30th November 2021. Operating hours were from 10 am and 4 pm between Wednesday and Sunday. The automated shuttle bus EZ10 from EasyMile was used, which is electrically driven and can be used at a speed of 15km/h. The pilot route of 3.2 km lies entirely in public space, where the bus had to interact with a wide variety of road users, such as cars, buses, trucks, cyclists and pedestrians. More than 2,000 people travelled with the automated shuttle bus. During the pilot operation, the acceptance of the passengers was surveyed. In general, the automated shuttle bus was rated very positively and a clear majority was in favour of continuing the pilot operation. However, only 5% of the respondents were residents in Stolberg. The rest were Tourists. [20]

2.2. Acceptance measurement

The term acceptance is understood to mean the positive acceptance decision of an innovation by the users [21]. Acceptance research in the field of technical innovations is based on the "Theory of Reasoned Action" by Ajzen and Fishbein and the "Theory of Planned Behaviour" by Ajzen [22]. Two proven models for technology acceptance research are the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) [23–25]. As UTAUT has already been successfully used in previous studies on the acceptance of automated shuttle buses and also in the user acceptance in Stolberg, this model is selected for this questionnaire [20, 26]. The moderating variables and main categories auf UTAUT are:

- Gender,
- Age,
- Experience,
- Voluntariness of Use,
- Expected Performance,
- Effort Expectancy,
- Social Influence and
- Facilitating Conditions [23, 24].

These categories form the basis for the creation of the individual questions.

Table 2: Selection of the methodological approach

Criteria	Type of expression			
Scientific approach	Empirical research		Non empirical research	
Type of measurement and evaluation	Qualitative		Quantitative	
Investigation facility	experimental		Non experimental	
Selection procedure	Full survey		Partial survey	
Investigation	Longitudinal section		Cross-section	
Data collection methods	Questioning	Content analysis	Observation	Physiological measurement
Types of survey	Standardised questionnaire	Unstructured Interview	Guided interview	Group interview
Medium	Written survey		Online survey	
Survey period	1 week	2 weeks		4 weeks
Feedback	In person	Report		Publication

2.3.   Selection of the research method

In order to determine the acceptance of the residents near the use of an automated shuttle bus and to answer the research questions, the appropriate methodology must be selected. According to Brosius et al. there are different criteria that have to be considered with the different types of expressions (see Table 2) [27]. As this study is related to a pilot operation of an automated shuttle bus, we are in the field of empirical research, where experiences about reality are collected [27, p. 2]. In order to avoid subjective opinions as much as possible, a quantitative rather than a qualitative measurement is preferred [27, p. 4]. The pilot operation has already been completed, which is why the study cannot be conducted as part of experimental research [27, p. 218]. Since the pilot route led through the entire city, which only has a total of 732 households, a full survey was chosen [27, p. 60]. The study takes place at the time after the pilot operation and thus represents a snapshot, which is why a cross-sectional study is chosen. The questioning methodology is used to collect attitudes or opinions and is therefore best suited to answer the research questions [27, p. 5]. For the types of survey, a standardised questionnaire, a report, an interview as well as a conference are available as choices [27, p. 104-107]. For time and capacity reasons, it is not possible to interview all residents of the city individually, which is why a standardised questionnaire is selected. The questionnaire can be divided into a written questionnaire and an online questionnaire [27, p. 108]. To ensure that all residents have the opportunity to complete the questionnaire and are not dependent on the internet, a written survey was chosen. Four weeks was set as the survey period. The results are published as a report and a publication.

In summary, a household survey of all households will be conducted to determine the acceptance of the residents near the use of an automated shuttle bus. A standardised questionnaire is used as a written survey.

2.4.   Implementation of the survey in Stolberg

After the study has been designed, the indicators are formed, the data collection carried out and the data analysed [27, p. 28].

2.4.1. Creation of the survey

After the methodological approach for surveying acceptance has been selected, the next step is to create the questionnaire by forming indicators and formulating questions (fourth research question). This research question is divided into five sub-questions:

1. Are the traffic situation and public transport services in Stolberg satisfactory?
2. Is the current performance of an automated shuttle bus satisfactory?
3. Should an automated shuttle bus drive through Stolberg in the future?
4. Should automated shuttle buses in general be used as a mobility system in the future?
5. What are the differences in the acceptance of automated shuttle buses between passengers and residents?

On this basis indices are formed in the next step [27, p. 28].

For the sub-question "Are the traffic situation and public transport services in Stolberg satisfactory?" the index "Is the public transport system well developed?" is being created for example. Subsequently, for each index, various questions are then formulated. The content of the questions is based on the user acceptance survey, a literature review and stakeholder (district, city, tourism promotion, transport company) interests. Formally, the appropriate question type is selected for each question. Since this is a quantitative evaluation, almost exclusively closed questions are use [27, p. 86]. With regard to the response

options, a dichotomous nominal scale and a six-point Likert scale are predominantly used [27, p. 87]. At this point, a scale without a centre point was deliberately chosen so that the respondents could decide on a tendency [27, p. 90]. Afterwards, the questions are combined into categories in the questionnaire. In total, five chapters are created in the questionnaire (see Table 2). In the chapter on demographic data, introductory questions are asked. The following four chapters are each related to a research question. Chapters 3, 4 and 5 have already been asked in user acceptance, so these three chapters serve to identify the difference between passenger and resident acceptance. How exactly the questions were formulated is illustrated by the example "How often have you ridden the automated shuttle bus in Stolberg?". The response alternatives are "Never", "1x", "2x - 5x" and ">5". This question serves to divide the sample into testers and non-testers. Furthermore, this question is intended to determine how well the automated shuttle bus was used in Stolberg, that is why the quantity is important. After all questions were created, a pre-test was conducted to check the wording of the questions and the answer specifications [27, p. 131]. All questionnaires were printed and sent to all households in Stolberg by post.

2.4.2. Data collection
The questionnaire was sent out on 8th of February 2022. Each of the 732 households received two questionnaires and a stamped envelope so that the questionnaires could be returned free of charge. The residents had until 13th of March 2022 to return the questionnaire. A contact person was always available in case of any uncertainties during the completion of the survey. It took 10 to 15 minutes to answer the questionnaire.

2.4.3. Data analysis
A total of 133 out of a total of 1464 questionnaires were handed in. This corresponds to a share of nine percent. The first step is to digitalize the records [27, p. 30]. Then the data are cleaned and checked for plausibility [27, p. 132]. Only now are

the data analysed, mean values and level deviations calculated and the correlations between different variables revealed.
Finally, the quality of the survey is checked. The fact that a full survey was conducted ensures the representativeness of the survey [27, p. 62]. UTAUT was used as an acceptance model and has been successfully applied in previous studies, which ensures the validity of the survey [27, p. 51]. For the reliability check, a test evaluation was conducted to confirm that the method measures what it is supposed to measure. The objectivity of the questionnaire is achieved through the closed questions and the full survey. In addition, the evaluation is done by researchers and the interpretation by trained personnel.

3. Results and Discussion
The results are divided into five categories "Demographic Data", General Mobility in Stolberg", "Pilot Operation of the Automated Shuttle Bus in Stolberg", "Future Use of Automated Shuttle Buses in Stolberg" and "General Future of Automated Shuttle Buses".

3.1. Demographic Data
All age categories from 15 to over 80 years are represented in the entire sample. Analogous to the local population in Stolberg, 80 % of the respondents are over 50 years old. With 52% male participants and 48% female participants, the gender distribution of the respondents is equal. 83% of respondents own a car and 80% use their car more than twice a week. In contrast, only 16% use public transport at least once a month. Overall, the sample has a high affinity with cars and 70% are satisfied with their personal mobility. When choosing a means of transport, availability (19.8%), punctuality (17.3%), flexibility (15.9%) and safety (14.4%) are the most important criteria.

Table 3: Structure of the questionnaire

Sub-questions	Chapter in the questionnaire	Number of questions
	1. Demographic data	7 questions
Are the traffic situation and public transport services in Stolberg satisfactory?	2. General Mobility in Stolberg	8 questions
Is the current performance of an automated shuttle bus satisfactory?	3. Pilot operation of the automated shuttle bus in Stolberg	4 questions
Should an automated shuttle bus drive through Stolberg in the future?	4. Future use of automated shuttle buses in Stolberg	7 questions
Should automated shuttle buses in general be used as a mobility system in the future?	5. General future of automated shuttle buses	2 questions
What are the differences in the acceptance of automated shuttle buses between passengers and residents?	Chapter 3, 4 and 5	Σ = 28 questions

3.2. General Mobility in Stolberg

More than 70% of the respondents are dissatisfied with the public transport connections within and to Stolberg. In order for more people to use public transport in the future, according to the respondents, the frequency of the buses should be increased, the nearest towns should be directly connected and the railway station in Stolberg should be made accessible again.

Although Stolberg is a small town with few inhabitants, it is visited by many tourists, especially at weekends and during holiday periods. 75% of the respondents think that too many cars drive through Stolberg. Due to the fact that it is possible to park on the street in a no-parking zone, there are often traffic jams in Stolberg. Likewise, 75% of the sample believe that too many vehicles are parked in the no-parking zone for longer than permitted. Suggestions for improvement ranged from parking bans, more parking facilities on the outskirts of the city, the use of a shuttle bus to observing the speed limit.

With regard to the first sub-question, it becomes clear that too many cars drive through Stolberg and that the parking ban is often not respected. This leads to traffic jams in the city at weekends and at peak times. Furthermore, the current public transport offer is not satisfactory and should be improved in the future.

3.3. Pilot operation of the automated shuttle bus in Stolberg

In this chapter, the respondents were asked about their general attitude towards the project and their experiences during the pilot operation with the automated shuttle bus. While 50% consider the project useful, 50% also consider it not useful. It is striking that the two extreme values ("very useful" = 25.6% and "not useful" = 27.9%) were selected most frequently. This attitude is also evident in the case of riding on the shuttle bus. 30% of respondents have ridden the bus once. The remaining 70% have never ridden the automated shuttle bus.

In the next question, participants rated the satisfaction of riding the automated shuttle bus on a six-point scale from "Very satisfied" to "Very dissatisfied" (Figure 2). More than 50% of the respondents were satisfied with the entire journey and the braking behaviour.

Although this is the majority, both criteria were rated significantly worse than in the user survey. There, for example, 85% of the respondents were satisfied with the entire journey. Speed was also rated better in the user survey than in the household survey. Similarly, however, speed was rated the weakest overall. This was also the case in the user survey. [20]

As a note on these results, more votes were cast on this question than respondents had ridden the bus. Thus, the performance parameters of the bus were also evaluated by people with no driving experience. Nevertheless, it is clear that the technological development of the bus, especially in terms of speed, needs to be improved in the future.

Within the last question in this section, participants had to give their agreement to statements about the automated shuttle bus (six-point scale from "Totally agree" to "Do not agree at all"). Figure 3 shows that 69% agree, that the automated shuttle bus is a tourist magnet in Stolberg. This is only slightly lower than in the user survey (80%). Furthermore, the majority (54%) believe that the bus is a useful addition to the public transport services in Stolberg. However, only 34% agree with the statement that the automated shuttle bus will improve the traffic situation in Stolberg. This value is quite similar to the assessment in the user survey (39%). The
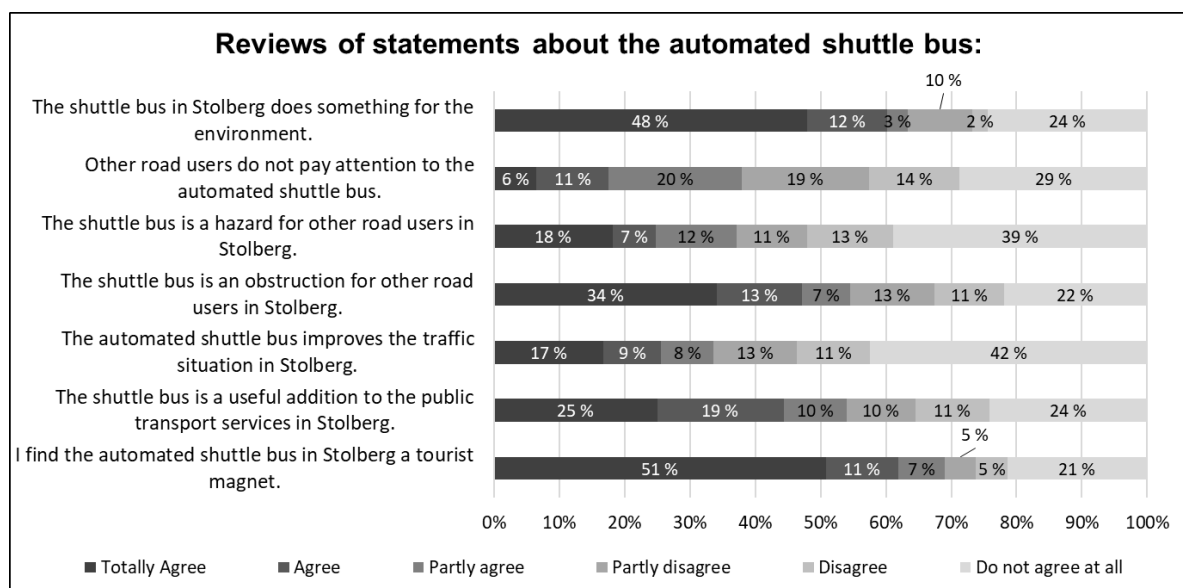

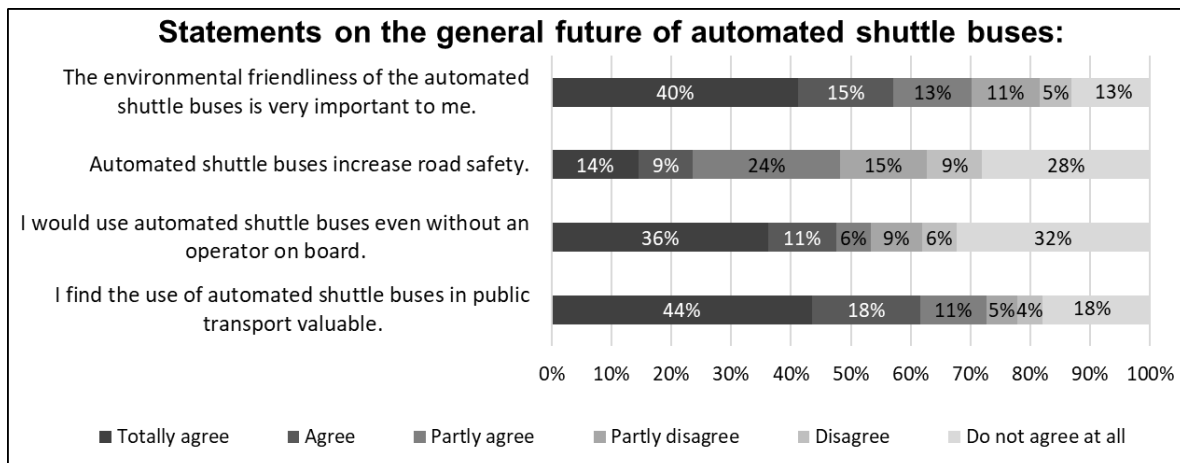*Figure 3: Reviews of statements about the automated shuttle bus*

Figure 4: Statements on the general future of automated shuttle buses

automated shuttle bus is perceived as an obstruction by 63% of the respondents and as a danger for other road users by 46% of the respondents. On the other hand, other road users seem to pay attention to the automated shuttle bus, as 63% of the respondents stated. Finally, 63% of the respondents voted, that this shuttle bus does something for the environment. [20]

With regard to the fifth sub-question (the difference in acceptance between passengers and residents) it is clear here that the automated shuttle bus and the interaction with other road users were rated worse by the residents. One reason for this question is also that most respondents have not ridden the bus. Regarding the questions about the tourist magnet and the improvement of the traffic situation, the answers are very similar to the results from the user survey. Although the ride of the automated shuttle bus is rated as in need of improvement, the bus is seen as a tourist magnet that can also contribute to environmental friendliness and to improving the traffic situation in Stolberg (second sub-question). [20]

3.4. Future use of automated shuttle buses in Stolberg

First, the participants were asked which mobility services should be used in Stolberg in the future. The vote was as follows:

- Diesel-powered minibus: Yes = 69%; No = 31%
- Electrically powered minibus: Yes = 60%; No = 40%
- Rail-based automated vehicle: Yes = 75%; No = 25%
- Automated shuttle bus (current state of development): Yes = 41%; No = 59%

Furthermore, the sample was asked about the requirements that must be met in order for them to also travel with the automated shuttle bus in the future. "Higher speed" (45%), "Different route" (31%) and "Improvement of vehicle technology" (17%) were most frequently mentioned. The

improvements to the vehicle correspond to the results from the user survey. However, the adaptation of the infrastructure was also mentioned there, which does not appear in these results. [20]

Nevertheless, 62% of the respondents would be willing to pay money for a ride in an automated shuttle bus in the future. The amounts range from 1.00 to 7.00 euros. The mean value is 1.87 euros. These results are in line with the responses of the user survey, where the mean value was 1.99 euros. This clearly shows that the residents of Stolberg would like to see an expansion of the mobility offer. Analogous to the previous categories, the use of rail is the favoured solution, while the automated shuttle bus scores slightly lower, which is an answer on the third sub-question. However, this also confirms the evaluation of the driving experience (chapter 3.3). [20]

3.5. General Future of Automated Shuttle Buses

The participants had to give their agreement to statements about the general future of automated shuttle buses (six-point scale from "Totally agree" to "Do not agree at all"). 68% of the respondents find the environmental friendliness of the shuttle bus as very important (Figure 4). This is the majority, but a lower value than in the user survey (87%). Only 47% believe that the use of these vehicles increases road safety. This is similar to the user acceptance (52%). Overall, 53% of respondents would use the bus even without an operator on board. This is slightly lower than the results of the user survey (66%). This could be due to the fact that only a small part of the sample has ridden the automated shuttle bus. Finally, 73% find the use of automated shuttle buses in public transport valuable. In the user survey, this was 87%, which again confirms this result. This shows that the respondents generally find the automated shuttle buses useful and welcome the future use of such mobility systems (4th sub-question). [20]

4. Conclusion

A large number of pilot operations with automated shuttle buses have already been carried out worldwide. Following on from this, the acceptance of the users of these shuttle buses has very often been surveyed. In addition, there have also been some acceptance surveys of residents along the routes of automated shuttle buses. They interact with these vehicles on a daily basis, which is why the acceptance of this group of people is very important. Since in Stolberg mainly tourists have used the automatic shuttle bus and the acceptance of the population is important, a written household survey was chosen as methodology. Besides other household surveys, this study focusses on the permanent continuation of an operation with an automated shuttle bus.

In retrospect, the methodology worked well, as all households could be involved and the time required was not too high. Another possibility would be to use an online questionnaire. This would save costs for sending the letters and the data would be directly available digitally. However, the results show that a large part of the population is over 50 years old and internet access is questionable. Therefore, in order not to exclude anyone from the survey, only a written household survey is suitable.

Overall, the results show that the public transport offer in Stolberg needs improvement. Most residents have their own car and use it regularly. Furthermore, the flow of traffic in the city stagnates at peak times because too many vehicles drive through the city and too many vehicles are parked for longer than permitted in no-parking zones. For this reason, many residents would like to see the public transport services in Stolberg expanded in the future. The use of rail transport is preferred.

The results also show that residents are generally positive about the use of automated shuttle buses and find these vehicles useful. However, the use in Stolberg with the current state of technology is viewed critically. This is reflected, among other things, in the fact that the performance parameters of the shuttle bus were rated somewhat weaker and the use on a different route was often selected.

In conclusion, the results refer to Stolberg and depend on the local conditions and the fact that many residents have not used the shuttle bus. Nevertheless, it can be deduced from these results that in the future use of automated shuttle buses, the residents as well as the users must be involved and a real benefit for these target groups must be apparent. This applies not only to Stolberg but also to other deployment scenarios.

Future research needs should address the acceptance of users and residents in a long-term operation of an automated shuttle bus.

5. Funding Information

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