WHAT DO PEOPLE THINK ABOUT AUTONOMOUS MINIBUSES IN GERMANY?

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ABSTRACT

Autonomous minibuses gain increasing importance as a mobility option for public transport. In order to realize advantages like increased safety and productivity as well as reduced emissions and congestion (1) user's needs have to be considered when further developing this technology. So far, there is only a little knowledge about use intentions for autonomous minibuses in public transport and the general perception. This paper presents the results of a Germany-wide online survey and answers the questions: What do people think about autonomous minibuses? When and how would people use them? What are the perceived advantages and disadvantages? Firstly, we analyzed the data descriptively. Secondly, we performed a principal component analysis to reduce data complexity and to identify attitude-based influences on people's perception. Over 60% liked the minibuses and could imagine to use them in the future. We found one component representing a general attitude towards the minibuses that correlates strongly with the intention to use.

INTRODUCTION

Autonomous vehicles are expected to change the mobility sector and people's travel behavior fundamentally. Autonomous minibuses are a promising application that can run in different operation types (e.g., fully integrated into public transport or as an additional on-demand service). Studies dealing with the acceptance of autonomous vehicles in general are diverse (see 2 for a summary). Those examining the acceptance of minibuses in public transport are rarer in literature and often connected to a test operation (e.g., 3–5). Thus, they cover the acceptance of a small and sometimes biased user group (e.g., when testing the bus in a closed area), as test operations might attract interested people more than skeptics (3, 6). Investigations of the acceptance and intended use of a more diverse sample are missing. To close parts of this gap, we conducted an online survey in Germany to answer the following research questions: What do people think about autonomous minibuses? When and how would people use them? What are perceived advantages and disadvantages?

LITERATURE REVIEW

Becker & Axhausen (2) give an overview of existing literature regarding the acceptance of autonomous vehicles (AV) in general. As user acceptance is crucial for AV success, many studies analyzed intended use of different levels of automation and the willingness to pay (e.g., 7–9). In literature, autonomous minibuses are also called autonomous/driverless/self-driving shuttles, pods, robocabs or automated road transport systems (ARTS). Since 2014, the number of test operations increased significantly due to technical progress. Unfortunately, only a few of them investigated or reported information on user acceptance.

Studies in Lausanne (10), Sion (11, 12) (both Switzerland) and Berlin (3, 6) (Germany) examined that users had a favorable opinion about the minibuses. Participants rated the vehicle useful, easy to use and as an important part of the future public transport. They also liked the innovative aspect of the new technology. However, the vehicle was often not perceived to be better than the current mode of transport. Some criticized the speed and comfort. Some passengers and pedestrians had difficulties to interact with it, as actions seemed unpredictable. Nordhoff et al. (3) found a positive correlation between age and use intention and a negative between age and perceived ease of use. Further, "shuttle characteristics" and "shuttle effectiveness" correlated positively with the intended use (6).

Based on Venkatesh et al.'s (13) "Unified Theory of Acceptance and Use of Technology" (UTAUT) Madigan et al. (4, 5) examined the influence of performance expectancy, effort expectancy and social influence on use intention. Significance was shown but only 22% of the variance could be explained. Therefore, they adopted the questionnaire following Venkatesh et al. (14). During a second study in Trikala (Greece) (4) they found hedonic motivation, performance expectancy,

social influence and facilitating conditions to be better predictors for use intention. The “4P Acceptance Model” (15) contains various factors affecting acceptance for autonomous minibuses. Besides the predictors from models like UTAUT and the Pleasure-Arousal-Dominance-Framework (PAD), it combines psychological variables (e.g., trust, sensation seeking), sociodemographics, mobility, vehicle and contextual characteristics.

By now, the majority of studies regarding autonomous minibuses focused on Europe and was connected to test operations. People who were attracted by these demonstrations might have a favorable opinion whereas skeptics would not participate (3, 6). Nordhoff et al. (16) conducted an online survey to investigate cultural or geographical influences on the acceptance of minibuses as last-mile-transport. A principal component analysis resulted in only one “general acceptance component” for minibuses that showed high or medium loadings from perceived usefulness, intention to use, ease of use, pleasure and trust.

So far, factors influencing acceptance are still insufficiently investigated. Studies examining the opinion about autonomous minibuses that use a broader and more general sample are rare. Accordingly, there is a need for a more representative study to enhance knowledge.

ONLINE SURVEY

In May 2018, we conducted an online survey about autonomous minibuses with people aged 18 years and older. Participants decided by themselves whether to participate or not. They were free to leave the survey right at the beginning, reading the first information about the studies’ topic. To avoid self-selection effects and bias regarding respondents, the first survey information did not contain information about AV but only about a travel behavior study in general. Nevertheless, a certain self-selection effect in the sample could not be avoided. Sampling quotas were aligned to age, gender and urban-rural distributions in the German population. The realized percentage for age and gender deviated with a maximum of 1.5% and for regional distribution with a maximum of 5%. In total 1,078 people completed the survey, after data cleaning 900 remained to be evaluated. Respondents needed an average of 14 minutes to fill out the questionnaire having the following structure:

1. Questions about personal and household situation
2. Questions about personal travel behavior
   2.1. Frequency of mode use, mode use for specific purposes
   2.2. Attitudes towards different modes of transport in general
   2.3. Current mobility situation
3. Introduction of autonomous minibuses
4. Questions about autonomous minibuses
   4.1. Prior knowledge of this technology
   4.2. Attitudes towards autonomous minibuses
   4.3. Possible advantages and disadvantages
   4.4. Use intentions in specific situations
5. Questions about technology
   5.1. Ownership of technical devices
   5.2. Use frequency of different functions
   5.3. Attitudes towards technology
   5.4. Use of driver support systems

Attitudinal questions based on literature review (4, 9, 17) and own developed items for our use case. In order to guarantee a common understanding, we introduced autonomous minibuses by showing the respondents an explanation with pictures and the following system characteristics:

- The minibus is powered by electricity.
- The minibus has a capacity of approximately ten people.
- The utilization of buses can vary, e.g. to replace traditional busses or to create a new system that drives you to your doorstep.
- The minibus operates driverless; a central control station monitors the actions.

USE INTENTION ANALYSIS

Descriptive Analysis

Attitudes influence people's use intention especially in the case of new and partly unknown technologies. In our study, we included questions about habits and attitudes related to mobility and technology. Table 1 shows different attitudinal statements and illustrates average opinions. People were asked to evaluate the statements on a Likert scale from 1 = "I strongly agree" to 5 = "I strongly disagree". Since the response option "I do not know" was given, N varies for every item. The general opinion about autonomous minibuses was positive. Over 60% stated that introducing them is a good idea (item *Minibus1*, 1 or 2 on the scale). More than 50% believed that the buses will become an important part of future public transport (item *Minibus3*) and that

public transport will become more appealing (item *Minibus2*). Over 40% could even imagine forgoing their own car if autonomous minibuses would operate on demand (item *Car5*). The respondents' environment seemed to have only little impact on mode choice (items *Social1*, *Social2*, *Social3*).

To get a deeper understanding of people's perception, we asked the participants to evaluate the probability of occurrence of various advantages and disadvantages. The increase in mobility of elderly and mobility-impaired people and an improvement in accessibility (68% or 65%, 1 or 2 on the scale) were rated most likely. The most unlikely rating was a decreasing accident rate with only 37% agreement (1 or 2 on the scale). The most likely problems were job loss of bus drivers and interaction problems with other road users (50% or 52%, 1 or 2 on the scale).

Subsequently, respondents evaluated the use of the bus for various purposes (shopping, work, etc.) and as an alternative to their current modes of transport. This was done on an individual basis, i.e. exclusively taking into account modes of transport used in everyday life. The use of minibuses on leisure trips was most popular (56%, 1 or 2 on the scale), the least on business trips (41%). A minibus would mainly be used on trips that are currently taken by taxi (62%) or public transport (63%). Less respondents could imagine using them to cover previous foot or cycle paths (34%, 33%, 1 or 2 on the scale). Overall, the use of minibuses was rated conceivable in both urban and rural areas.

Moreover, we investigated the intended use of different operation types. We distinguished between a traditional bus having a fixed route and fixed operating hours, a transit feeder that operates as last mile transport to other public transport stations, and several on-demand services (with/without route, private/shared use). Shared use was more appealing than private use. By comparing the mean, we also found that men were slightly more willing to use the buses in every operation type. Furthermore, we determined travel behavior types by analyzing all modes used at least once a week by a person. Bicycle users, transit users, and highly multimodal people (i.e., three or more modes used per week) had the highest intention to use autonomous minibuses for most operation types, car drivers the lowest. Additionally, people having prior knowledge about autonomous minibuses were slightly more willing to use them. Differences between age groups, areas (i.e., rural vs. urban) and income were negligible. Correlation analysis showed no significant results between use intention and these sociodemographic characteristics.

Table 1 Descriptive Information about Attitude Items

A. Attitudes related to current travel behavior

Item		Mean	SD	N
Public transport / Transit				
Transit1	It is difficult for me to do everyday trips by public transport.	2.92	1.50	890
Transit2	I like to travel by bus and train, as this means that I do not have to focus on traffic.	2.94	1.38	884
Transit3	I can use the travel time on the bus and train conveniently to do other things.	2.76	1.27	870
Transit4	In public transport, I sometimes feel my personal space invaded by other travelers.	2.73	1.23	871
Transit5	I would use public transport more often if connections were better.	2.67	1.26	870
Transit6	Changes and waiting prevent me from using public transport.	2.76	1.29	874
Transit7	I am satisfied with the connection to public transport where I live.	2.38	1.32	900
Social influence				
Social1	People who are important to me think that I should use public transport.	3.50	1.20	800
Ridesharing				
Sharing1	I find it interesting to talk to (unknown) passengers while sharing a ride.	3.69	1.21	861
Car				
Car1	When sitting in a car, I feel safe and protected.	2.18	0.97	892
Car2	To me driving a car implies fun and passion.	2.63	1.23	889
Car3	Driving a car means freedom to me.	2.29	1.18	882
Car4	I can manage my everyday life very well without a car.	3.08	1.42	891
Climate protection				
Climate1	I feel obligated to contribute to climate protection through my choice of transport.	2.95	1.20	875

B. Attitudes related to autonomous minibuses

Item		Mean	SD	N
Climate protection				
Climate2	I would use an autonomous minibus in the future to protect the environment.	2.62	1.14	846
Social influence				
Social2	I would be more likely to use autonomous minibuses if people who are close to me recommended it.	3.96	1.18	834
Social3	People who are important to me would think that I should use autonomous minibuses.	3.07	1.10	764

Social4	I would be proud to tell people who are close to me about using autonomous minibuses.	2.96	1.21	838
Safety				
Safety1	Passengers could behave inappropriately when there is no driver on the bus.	2.80	1.12	822
Effort				
Effort1	It would not take me a long time to learn how to use an autonomous minibus.	1.94	0.94	850
Effort2	It would be difficult to understand for me how to use an autonomous minibus.	3.95	1.09	834
General attitudes towards autonomous minibuses				
Minibus1	The introduction of autonomous minibuses is a good idea.	2.26	1.06	843
Minibus2	Public transport would get better/more appealing due to autonomous minibuses.	2.42	1.09	835
Minibus3	Autonomous minibuses will be an important part of future public transport.	2.35	1.03	816
Minibus4	Autonomous minibuses would make my everyday life easier.	2.88	1.18	819
Hedonic motivation				
Hedonic1	I would most likely enjoy using an autonomous minibus.	2.58	1.20	824
Car replacement				
Car5	I could imagine forgoing my own car if the autonomous minibus would pick me up at any time and place and drive me directly to my destination.	2.88	1.39	849
Speed				
Speed1	It is important to me that autonomous minibuses are faster than other modes of transport.	2.54	1.10	849
Costs				
Costs1	It is important to me that autonomous minibuses are less expensive than other modes of transport.	2.31	1.08	861
Test run				
Test1	I would like to get further information about autonomous minibuses and take part in a test run near my home.	2.47	1.16	853

C. Attitudes related to technical affinity

Item		**Mean**	**SD**	**N**
Technical1	I know most of the features of my technical devices.	1.88	0.91	896
Technical2	I am interested in technical innovations and digitalization for households (e.g., Smart Home).	2.69	1.29	896
Technical3	It bothers me that many technical devices are hard to handle.	2.93	1.24	892

Principal Component Analysis

We conducted a principal component analysis (PCA) using varimax rotation to condense data and to identify attitude-based influencing factors. We took all attitude items into account (see Table 1). If necessary, we recoded items to match the scale. Moreover, we standardized the items to guarantee suitability for PCA. The Kaiser-Meyer-Olkin criterion (value >0.9) confirmed the data adequacy. Only respondents who answered all items without "I do not know" were considered as we equated this answer with a missing (N=575). Table 2 summarizes loadings and scale reliabilities (i.e., Cronbach's alpha coefficient) for the seven components extracted by Kaiser-criterion (i.e., eigenvalue >1). Altogether, these components explained 63% of the variance in attitudes. To interpret the components, we considered all items with a loading > |0.5| and classified the components as follows:

- Component 1 = positive attitudes towards autonomous minibuses
- Component 2 = positive attitudes towards public transport in general
- Component 3 = feeling comfortable in a car
- Component 4 = easiness to use public transport in everyday life
- Component 5 = expected high effort to use an autonomous minibuses
- Component 6 = interest for technical innovations
- Component 7 = being afraid of other people in public transport

The internal scale reliability was confirmed for component 1, 2, 3 and 5 by Cronbach's alpha coefficients >0.7. The reliability for component 6 was questionable ($\alpha = 0.61$). The short item list loading on this component could be an explanation. Component 4 and component 7 were dropped because of poor Cronbach's alpha coefficients <0.5. Next, we analyzed the correlation between these components and use intention. We found a high correlation ($r>0.5$ and $p<0.0001$) between component 1 and use intention for all operation types.

Table 2 Loadings and Reliability (Cronbach's Alpha)

	Item	Loading	Item	Loading	Item	Loading
Component 1 (α = 0.91)	Climate2	0.79	Minibus2	0.80	Car5	0.65
Eigenvalue = 7.63	Social2	0.67	Minibus3	0.74	Speed1	0.70
	Social3	0.63	Minibus4	0.79	Costs1	0.62
	Social4	0.76	Hedonic1	0.81	Test1	0.77
	General1	0.76				
Component 2 (α = 0.77)	Transit2	0.72	Social1	0.69	Car4	0.73
Eigenvalue = 3.39	Transit3	0.69	Sharing1	0.63		
Component 3 (α = 0.78)	Car1	0.76	Car3	0.83	Car2	0.83
Eigenvalue = 2.47						
Component 4 (α = 0.21)	Transit1	0.77	Transit6	0.51	Transit7	0.72
Eigenvalue = 2.01	(Recoded)		(Recoded)			
	Transit5	-0.53				
Component 5 (α = 0.71)	Effort1	0.63	Effort2	0.84		
Eigenvalue = 1.81	(Recoded)					
Component 6 (α = 0.61)	Technical1	0.80	Technical2	0.68	Technical3	0.70
Eigenvalue = 1.79					(Recoded)	
Component 7 (α = 0.49)	Transit4	0.71	Safety1	0.69		
Eigenvalue = 1.68						

DISCUSSION AND CONCLUSION

This was the first approach to investigate perceptions of autonomous minibuses in Germany based on a more representative sample. With our study, we broaden current knowledge regarding the acceptance and intended use for autonomous minibuses. We used an online survey to reach people all over Germany and to prevent that people were attracted because of a specific interest in autonomous driving. As the buses are not yet operating in regular service, we could only examine hypothetic use intentions. Further, respondents answering the questionnaire have not experienced a minibus. The majority has already heard of it and we provided a description, however, we cannot guarantee a correct, common understanding. Shared operation forms obtained higher use intention. It is unclear if this is because the wording "bus" is nowadays connected to a shared form of traveling. Besides, we did not distinguish between different costs or travel times but asked about the general intention of using the bus in different ways. So far,

prices and travel times are not available due to missing regular services and assumptions could be wrong and affect the results.
In general, people in Germany seemed to be open for a new system like autonomous minibuses; a certain group could even imagine replacing private cars. Most respondents expected that using the system will be easy. As people had different use intentions for different operation types, the concrete implementation will certainly affect use. People would use it mostly for leisure trips and would most probably replace current taxi or public transport trips. A principal component analysis with all attitude related items resulted in five components:

- positive attitudes towards autonomous minibuses
- positive attitudes towards public transport in general
- feeling comfortable in a car
- expected high effort to use an autonomous minibuses
- interest for technical innovations

In comparison to Madigan et al. (5), we could not distinguish between various influencing factors like hedonic motivation or performance expectancy. We found one component summarizing all bus-related items except for expected effort which is more in line with Nordhoff et al.'s (16) findings. The positive attitude towards the minibuses correlated highly with use intention.
As the technology is continuously developing, more research is needed when further system characteristics are known and people can, therefore, better evaluate the system.

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