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Expectations of Emergency Communication Systems in Autonomous Bus Shuttles

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ABSTRACT

The application of driverless autonomous vehicles in public transport implies the transformation of communication tasks with passengers to communication systems. Especially, passengers have to deal with communication systems in the variety of event and emergency situations. However, it is still being determined which communication modalities passengers prefer, such as collective or individual devices, personal or impersonal features, audio or video calls. This paper addresses this research gap by presenting the results from a user survey with 114 participants on their usage preferences regarding emergency communication systems in autonomous bus shuttles in public transport in different emergency scenarios. The goal is to evaluate the differences in interaction preferences between emergency scenarios, such as fire, medical emergency, and robbery. The results indicate that the emergency scenario has an influence on the preferred emergency communication system and raise the challenge of integrating different emergency communication systems in public autonomous bus shuttles for higher acceptance.

Keywords: Emergency communication systems, Autonomous bus shuttles, Public transport, User survey

INTRODUCTION

The further development of public transportation integrating autonomous bus shuttles makes a major contribution to more efficient and multi-modal mobility systems (Salonen, 2018). Public autonomous shuttle buses are characterized as vehicles for up to 15 passengers driving with a speed up to 25 km/h for public transport services (Iclodean et al., 2020). Despite the effort and advancements achieved in technological development (Wang et al., 2019), public autonomous bus shuttles will only succeed in becoming part of our transportation system if they are accepted and utilized by society (Nordhoff et al., 2018). In addition to technological factors, the acceptance is also influenced by the quality of service offered and the usability of the systems (Şimşekoğlu et al., 2015). For this paper, the expectations of passengers regarding completely driverless operation without additional service personnel are considered in Germany. In consequence to the absence of personnel, there would also be no personnel available for the direct communication with passengers. Especially in the event of an incident or emergency, communication systems have to be integrated compensating personal direct support (Mayas et al., 2023). Communication with users have to be handled via indirect communication, for example by the operating staff in the control centre or automated assistance.

The goal of this paper is to provide first insights into the passengers' preferences on interaction with emergency communication systems in public autonomous bus shuttles. In particular, the research question explores whether the emergency scenario has an influence on the preferred use of emergency communication systems. An online user survey with 114 participants is conducted to reveal expectations of the provided availability and interaction features of emergency communication systems in emergency scenarios. The results serve as a foundation for developing an emergency communication system prototype to evaluate the user experience of user interfaces and communication processes within a usability test laboratory adapted for autonomous bus shuttles.

RELATED WORK

User studies on the user acceptance for future public transport systems emphasize that trust and perceived safety are essential user needs for automated and autonomous shuttles (Amador et al., 2022), (Salonen, 2018). Especially, non-rail-bound systems, like autonomous bus shuttles on streets, lack acceptance in contrast to rail-bound systems, such as trains or subways (Nordhoff et al., 2019). Next to driving style and passengers' trust in the technology, passengers, in particular women, also emphasize the importance of having contact with a control room to enhance their sense of safety (Salonen, 2018). Grippenkoven et al. (2018) identify three main categories of fears: fear of other passengers, lack of transparency, and technical malfunctions. Proposed measures for improving the perceived safety are for instance mobile security services, video assistance systems, and panic buttons to enhance passenger safety and ensure user acceptance and successful adoption. Due to the required interactions by the high heterogeneity of passengers in public transport, it is important to consider user-oriented design for these communication systems (Kong et al., 2018).

These considerations are particularly evident in emergencies. In the context of public transport, the security guidelines define emergencies as events where the lives and health of company employees, passengers or the general public, traffic safety and material assets are endangered or impaired (VDV, 2018). These events require immediate special measures that go beyond normal incident handling. If necessary, third parties (fire department, police, rescue services) have to be involved as part of emergency management. In case of an emergency, Miring et al. (2020) highlight the importance of clear and concise incident-related instructions that address both auditory and visual sensory channels to overcome diffusion of responsibility among passengers. Additionally, the study underscores the need for remote assistance and effective communication to enhance passenger safety. In addition, Chowdhury and Dewan (2024) suggest the use of apps at personal mobile phones in an emergency while traveling by using a ride sharing platform with an integrated possibility of emergency contact.

The emergency management of driverless bus shuttles is assessed worse than a conventional bus in the case of an emergency (Salonen, 2018). Therefore, this user study focuses on expectations of the interactions with emergency communication systems considering differences between the context of emergency scenarios.

METHOLOGY

The user study is conducted as an online survey presenting different emergency communication systems in three emergency scenarios to the participants.

Emergency Scenarios

To understand specific user expectations during emergencies, the user study includes three hypothetical scenarios. In all scenarios, the passenger is imagined to be traveling in a public autonomous bus shuttle in Germany. Provided emergency information in the shuttle is available in both English and German. The shuttle is operating smoothly without a driver on board through a quiet area, where is no other person outside the autonomous vehicle to provide immediate help. The scenarios also assume that the emergencies are not yet detected by a monitoring system.

The study differentiates between the following three emergency scenarios referring to a varying danger of personal injuries and damage of property:

- Fire detected in autonomous bus shuttle: passenger travelling alone smells smoke and realizes a fire has started in the engine compartment.
- Unconscious foreign passenger within the autonomous vehicle: an elderly passenger becomes unwell and loses consciousness within the vehicle.
- Robbery in the autonomous vehicle: a robber enters the public autonomous bus shuttle, taking out a weapon and demanding valuables.

Emergency Communications Systems

In the event of an emergency, as described in the previous section, passengers should have the possibility to interact with an emergency communication system, both to provide information about the situation and to receive help. Participants should indicate their likelihood of using different emergency communication systems through the provided devices. Participants are asked to choose their preferences of availability among collective and individual devices:

- Collective devices such as public tablets with touch interaction are built-in communication systems accessible to all passengers and designed for handling various emergencies and information.
- Individual devices such as smartphones are personal electronic equipment that passengers carry to access emergency services via apps or QR-codes.

For both types of availability, the following six interaction features with emergency communication systems are considered in the survey and extended by a non-interacting option:

- Contact service centre via audio call: The acoustic system enables synchronous voice communication between passengers and operating personnel for emergency management.
- Contact service centre via video call: The video call feature allows passengers to have real-time visual communication with the service centre, providing a more comprehensive understanding of the emergency.
- Use a chatbot: The chatbot provides automated assistance by guiding passengers through emergency procedures and answering any queries they may have in real-time.
- Press SOS button: The SOS button allows passengers to send an immediate distress signal to the service centre with a single press, requiring no further indicated interaction.
- Use a step-by-step guide: The step-by-step guide offers passengers clear, sequential instructions on how to handle various emergency scenarios, ensuring they take the correct actions promptly.
- Fill in a report: This feature enables passengers to document and submit detailed information about the emergency in a written form, helping the service centre to assess and respond appropriately.
- Do Nothing: This option allows passengers to choose not to take any immediate action. It is important to recognize that in some situations, passengers may feel uncertain or believe that another passenger will respond.

Data Collection

The data is collected in an online questionnaire including three parts: introduction, demographic section and scenario section.

The survey introduces public autonomous bus shuttles by an example video to help participants familiarize themselves with these vehicles. This ensures that all respondents have a baseline understanding of the technology being discussed.

In the demographic section, participants are asked to provide basic demographic information, including their year of birth, gender, level of education, and nationality. Then participants provide information about their experiences with public transport, familiarity with autonomous vehicles and technological devices, and their special needs regarding mobility.

In the scenario section, participants are presented with the three emergency scenarios in public autonomous bus shuttles. Participants assess their likelihood of using an emergency communication system on a Likert scale from 1 (very unlikely) to 5 (very likely).

Participants

The participants for this study are recruited via university mailing lists. The rationale behind this decision is that studies have indicated individuals with a college education and those residing in urban areas generally hold more positive views toward autonomous vehicles with greater willingness to use the technology (Schoettle & Sivak, 2014). In order to reduce the effect of other influencing factors outside the emergency scenario, this group of university members was selected for the user study. A total of 150 individuals took part in this survey. Out of the 150 respondents who began the survey, 114 people completed it. The demographic of the participants completing the survey are shown in Table 1.

Among the participants, 59 identified as female (51.3%), 51 as male (44.4%), and 4 preferred not to disclose their gender (4.3%). The age of the participants is between 18 to 58 years old, and the average age of the respondents is 30.87 years (SD = 8.22 years). According to the recruiting method the majority of participants possess at least a high school diploma. The study is conducted in English for international respondents. Most of the participants originate from Europe with 52 respondents (45.6%), Middle East with 36 respondents (31.6%), and South Asia with 9 respondents (7.9%).

The majority of participants utilise public transport frequently (74.8%) and only 28 respondents rarely (25.2%). Public transport demonstrates to be the primary mode of transportation for 43 participants (37.4%), followed by 30 respondents using personal vehicles (26.1%). Most participants have at least some familiarities with autonomous vehicles, which may be related to the pilot studies with public autonomous bus shuttles in the survey region. However, the results indicate that 25 respondents are not familiar at all (21.7%), respectively. In contrast, 18 respondents state that they are very familiar (11.3%) and completely familiar (4.4%) with autonomous vehicles.

Table 1. Demographic and mobility profile of survey participants (n = 114).

Gender		**Frequency of public transport use**	
Female	51.3%	Daily	29.6%
Male	44.4%	Weekly	25.2%
Prefer not to say	4.3%	Monthly	20.0%
		Rarely	25.2%
Age		**Primary mode of transport**	
18–24 years	22.8%	Public transport	37.4%
25–34 years	49.1%	Personal vehicle	26.1%
35–44 years	22.8%	Bicycle	7.8%
45–54 years	3.5%	Walking	27.8%
55+	1.8%	Other	0.9%
Level of education		**Familiarity with autonomous vehicles**	
Mid school exam	0.9%	Not familiar at all	21.7%
High school diploma or equivalent	18.3%	Slightly familiar	35.7%
Trade/technical/vocational training	0.9%	Somewhat familiar	27.0%
Bachelor's degree	29.6%	Very familiar	11.3%
Master's degree	39.1%	Completely familiar	4.4%
Doctorate/professional degree	10.4%		

Data Analysis

The data is collected online and anonymously via the Unipark platform in June 2024. The analysis of ANOVA (Schrum et al., 2023) are implemented using R.

Table 2 shows the mean values and the associated standard deviations for the user ratings for the respective interaction features of the emergency communication systems and associated devices, depending on the respective scenario. For each combination of interaction feature and device, an ANOVA is performed to determine whether the usage scenario had an influence on the mean values of the user ratings. The corresponding F and P values of the ANOVA are also included in the table. For all cases a Tukey's post hoc test is carried out. The differences at a statistically significant influence of p< 0.001 are also reported in the table.

Table 2. Correlation between the preference of interactions with emergency communication systems on collective and individual devices and the emergency scenario.

Emergency Com-munication System	Scenario (mean ± SD)			F-value	*p*-value	Post hoc Tukey's test[1]
	Fire	Medical	Robbery			
Collective Device						
Audio Call	4.18±0.96	4.09±1.08	2.96±1.53	35.11	<0.001	Fire, Medical > Robbery
Video Call	3.46±1.28	3.54±1.32	2.51±1.49	20.05	<0.001	Fire, Medical > Robbery
Chatbot	2.11±1.20	2.20±1.27	1.86±1.20	2.40	<0.1	-
SOS Button	4.18±1.16	3.70±1.34	4.28±1.19	7.23	<0.001	Fire, Robbery > Medical
Guide	3.18±1.26	2.96±1.32	1.89±1.16	34.92	<0.001	Fire, Medical > Robbery
Report	2.11±1.13	2.02±1.17	2.11±1.38	0.21	0.81	-
Nothing	1.56±0.98	1.46±0.90	1.96±1.29	6.94	<0.01	Robbery > Medical
Individual Device						
Audio Call	4.13±1.02	4.21±0.96	3.28±1.55	20.84	<0.001	Fire, Medical > Robbery
Video Call	3.09±1.42	3.32±1.45	2.61±1.54	7.06	<0.001	Medical > Robbery
Chatbot	2.02±1.22	2.04±1.24	1.94±1.25	0.20	0.82	-
SOS Button	3.64±1.32	3.43±1.47	4.18±1.25	9.46	<0.001	Robbery > Fire, Medical
Guide	2.97±1.40	2.84±1.39	1.98±1.28	17.95	<0.001	Fire, Medical > Robbery
Report	2.18±1.26	1.99±1.17	2.18±1.36	0.81	0.45	-
Nothing	1.56±1.00	1.40±0.84	1.85±1.17	5.72	<0.01	Robbery > Medical

[1]Differences are shown for p < 0.001

RESULTS

According to the results of Table 2, there are significant differences between the preferences on emergency communication systems depending on the emergency scenario.

Regarding the differences between the usage of individual and collective devices, five communication features show an overall preference on collective emergency communication systems. Only the emergency communication via audio call is preferred to be conducted with individual devices in the case of medical emergency or robbery.

Regardless of the device, the communication feature of audio calling to the control centre is the most preferred interaction in the event of fire and medical emergencies. This interaction is significantly more preferred in these scenarios compared to robberies on both collective and individual devices. Following a step-by-step guide shows the same trend on preferences but with a lower mean level than the audio calling. Therefore, step-by-step guide are only suitable as fallback feature for faulty audio call.

Video calling is more preferable on collective devices for fire and medical emergencies than on individual devices. These high preferences on interactions of audio and video callings highlight the need for interactive communication with help instructions adapted to the personal situation of passengers in autonomous bus shuttles to compensate the lack of human interactions with driving personnel in presence.

In contrast, the SOS button is more preferred for robbery on collective and individual devices. This preference underscores the additional need for silent emergency communication in public autonomous bus shuttles for passengers. Silent SOS buttons are currently provided for driving personnel in conventional busses at hidden positions to unobtrusively draw the attention of controls centres to a crime. In contrast, a hidden SOS button would lack of usability for passengers. Therefore, it is useful to enhance collective SOS buttons with mobile application features in individual devices. In addition, the SOS button is the second most preferred communication feature for the fire and medical emergency scenario.

In case of robbery, the preference of doing nothing is significantly higher than in medical emergencies which might require first aid actions to save lives. Using chatbots or filling reports are no preferred interaction features in the events of emergency and do not show significant differences between the scenarios.

The results show that based on the emergency scenario, several emergency communication systems on collective and individual devices are required within autonomous bus shuttles to meet the passengers' expectations.

CONCLUSION

This paper presents a user survey with 114 participants on their preferences to interact with emergency communication systems in autonomous bus shuttles in public transport. The findings of the statistical analysis reveal that passengers' preferences on the communication systems in case of an emergency depend on the emergency scenario. Consequently, there should be more than one emergency communication system installed in autonomous bus shuttles. Audio and video callings with active synchronous communication as well as step-by-step-guides are preferred for fire and medical emergencies. More passive and silent interaction options are preferred for crimes, such as robberies.

The presented pre-study relies primarily on survey data with Likert scales. This paper also analyses individual items which could reduce the quality of the results. Furthermore, the results are related to imaginary scenarios. The lack of practical implementation and testing in real autonomous shuttle environments could limit the applicability of the results.

For this reason, the next step involves prototyping and conducting usability tests in a lab environment tailored to public autonomous bus shuttles, aiming to enhance the participants' sense of realism. Conducting field studies or realistic simulations of emergency scenarios in autonomous shuttles would even provide deeper insights into passenger reactions and the effectiveness of the proposed emergency communication system but are restricted by the legal and technical restrictions of the public road regulations.

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