Need for Interaction and Behavioral Intention to Use Autonomous Bus Shuttles

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Abstract: Previous research in the context of autonomous bus shuttles has focused mainly on technical and safety-related acceptance determinants while the role of human interaction in the use of autonomous public transport systems has received comparatively little attention. The research project *IMoGer* (Innovative modular Mobility Made in Germany) aims to investigate conditions for the implementation of autonomous mobility services based on modular electric vehicles. In this context, societal readiness lays an important role. A quantitative user study (N = 283) is presented that focused on the relationship between individuals' need for interaction with driving personnel and their intention to use autonomous bus shuttles. The results will be used for further development of the autonomous vehicle technology and service concept in the project and to derive recommendations for researchers and practitioners.

Keywords: need for interaction, societal readiness, trust, acceptability, behavioral intention

1 Introduction

Acceptance of new technologies is a key prerequisite for their successful implementation in everyday life. Acceptability, which is defined as positive mental representation of technology before using it, is thus seen a precursor of acceptance [1]. Giving regard to the fact that most people have not had first-hand experiences with autonomous shuttles, the determinants of acceptability need to be studied to align the technological development with the societal needs. In this context, autonomous shuttle buses as mobility concept of cooperative, connected, and automated mobility (CCAM) are conceptualized as highly automated vehicles operating at SAE Level 4 automation [2], are mostly accompanied by a steward and designed to complement existing public transport systems by offering an on-demand first and last mile service [3].

While technological development of autonomous shuttles is advancing rapidly, many unanswered questions are unanswered regarding user and societal acceptability, among them questions addressing accessibility and inclusivity [4], information needs [5], and effects of personality traits [6]. In the context of acceptability of autonomous shuttles, the absence of a human driver might play a significant role [7, 8]. Whereas current pilot operations of autonomous shuttles still have an attendant or steward on board to monitor or

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intervene, in the future, the service will be operated without on-board personnel in the future [9]. Paving the way to SAE Level 5, teleoperation of vehicles offers a promising solution, assured by a human operator who remotely takes over control in cases of disturbances [10]. The absence of driving personnel in such vehicles might contribute to lower levels of individual and societal acceptability due to concerns about the technical system, the behavior of other passengers and system intransparency [11]. From a passenger perspective, driving personnel in public transport fulfil a crucial role for socio-emotional safety and monitoring function [12, 13]. Thus, their absence is a potentially critical factor affecting the adoption of autonomous shuttle services.

The study was conducted in the context of *IMoGer* (Innovative modular Mobility Made in Germany[1]), a research project currently conducted in Braunschweig, Germany under the lead of the German Aerospace Center. The project's goal is to build and test an innovative mobility service, combining public transport and courier, express and parcel logistics (CEP logistics) in an automated, holistic mobility approach for the last mile, reaching SAE Level 4 for operations without a safety driver. Centerpiece of the research project is a novel, modular, autonomous vehicle - the U-Shift [14]. IMoGer complements to other CCAM projects by focusing on the development of business and operating models. Within the project, we use societal readiness as a framework to gauge and steer the alignment of technological innovations with societal needs, including the acceptability of autonomous vehicles for public transportation [15].

Figure 1: U-Shift vehicle, source: DLR (CC BY-NC-ND 3.0)

[1] https://www.dlr.de/de/ts/forschung-und-transfer/projekte/imoger, funded by Federal Ministry of Transport (BMV)

2 Literature review

2.1 Societal readiness

To ensure that the technical development and service concept of autonomous shuttles effectively address societal challenges and align with societal needs, the perceptions and requirements of stakeholders, such as, most important, prospective users, policy-makers or local authorities, must be systematically incorporated in the development process. In this context, societal readiness (SR) is an emerging concept, stemming from the field of Responsible Research and Innovation that has gained attention throughout the political realm, academia, and industry in recent years [15] and has been shown to have a high potential for use in transportation related projects [16]. It starts with the observations that innovations fail when they are not aligned with societal needs. Within the context of IMoGer, SR is employed to systematically integrate stakeholder needs into the innovation process, thereby ensuring that technical solutions are closely aligned with societal demands. This integration occurs across multiple levels - from strategic business and operational planning to the design and development of tangible technological artefacts, such as the U-Shift capsules, where users directly engage with the technology. By incorporating stakeholder perspectives throughout the development lifecycle, SR enhances the relevance, usability, and acceptability of the resulting solutions, thereby increasing their potential for successful societal uptake and long-term adoption. As for most autonomous vehicles, acceptability, including subjective feelings of safety and security, and usability and ease-of-use are important indicators for assessing how willing individuals might be to use autonomous vehicles.

2.2 The absence of public driving personnel

In autonomous public transport, acceptability is associated with trust and perceived safety, as passengers may experience diminished perceived control in the absence of driving personnel [17]. Empirical evidence from autonomous bus shuttle trials substantiates this perspective: while user evaluations are generally positive, passengers report a preference for onboarding supervision during the deployment phase [18]. Corroborating these findings, Bernhard et al. [19] demonstrated the continued relevance of operator presence in autonomous bus shuttles through their investigation. With regard to operator presence, basically, autonomous shuttle concepts in public road traffic can be divided into two categories – those with a driver's workplace and those concepts without a direct driving task but with an attendant, also called steward with the task to monitoring an if necessary, intervening [19].

From a passenger perspective, driving personnel do not just drive [20]. They fulfil socio-emotional safety and monitoring functions besides their driving tasks [12, 13]. The presence of driving personnel might be calming for vulnerable passengers such as older people [12, 21], people with disabilities [22, 23] or women traveling alone [24]. Thus, their absence is a potentially critical factor affecting the acceptability of autonomous shuttle services.

Dabholkar et al. (2002) demonstrated that individuals exhibiting a high need for interaction with service employees (NFI) prefer personal contact with a service employee in the context of technology-based self-service and tend to utilize technology-based services less frequently [25]. NFI is defined as the importance of human interaction to the customer in service encounters [25]. In contrast, users who prefer technology-based interaction over the interaction with service personnel are characterized by a need for independence [26] and avoiding personnel [27].

While the literature review outlined above suggests that the need for interaction represents a crucial determinant in unstaffed service environments, empirical research within the specific context of autonomous bus shuttles remains limited. In the present study, we examined whether the absence of driving personnel affects behavioral intention to use driverless shuttles moderated by NFI. An online survey was conducted to answer to the research question: How does the need for interaction influence the intention to use autonomous bus shuttles, both with and without a driving personnel? Within the scope of the paper, we address the following hypotheses: 1) Behavioral intention to use an autonomous bus shuttle is significantly higher in the scenario with on-board personnel than in the scenario without. 2) The effect of an on-board operator presence on behavioral intention is significantly stronger for users with higher levels of NFI. Contrary to what is planned in the IMoGer project, the paper addresses only the use case of public transport and excludes the aspects of logistic services.

3 Methods

3.1 Study sample

Data were collected from December 2025 to March 2026. Participants were recruited using a multi-channel strategy targeting individuals aged 16 years or older. Recruitment used the DLR SONA system, institutional panels, university networks, and social media platforms. A total number of 288 people finished the survey. After data cleaning due to speeding, 283 data sets remained for further analysis. The mean age of the sample was 42.1 years (*SD* = 17.0 years), ranging from 16 to 86 years. Slightly more than half of respondents were male (n = 149, 54.0%) whereas 43.5% (n = 120) were female and 7 respondents defined themselves as diverse (2.5%). A total of 14.1% (n = 40) indicated at least one mobility impairment. Regarding public transport frequency, 32.2% (n = 91) reported daily use of public transport, 29.7% (n = 84) one to three times per week, 18.7% (n =53) one to three times per months, 17.3% (n = 49) less than monthly and 1.1% (n = 3) never.

3.2 Study design

The study was conducted as an online survey. Study participants evaluated written vignette descriptions of two hypothetical autonomous shuttle scenarios and indicated their behavioral responses. The independent variable, scenario, was manipulated across two levels: A) an autonomous shuttle operating without driving personnel and B) an autonomous

shuttle operating with driving personnel. In the present study, the term driving personnel referred to individuals who operate the vehicle and transport passengers.

3.3 Measures

Behavioral Intention (BI) as dependent variable was assessed based on three items from the *Unified Theories of Acceptance and Use of Technology (UTAUT)* [28] and adapted to the context of autonomous shuttles based on [29]. To measure need for interaction (NFI) three items from Dabholkar (1996) were used and adapted to the context of autonomous public transport: 1) It is important to me that driving personnel is able to offer personal assistance, 2) The personal interaction with the bus drivers makes the ride enjoyable for me, 3) I enjoy talking to the bus drivers [25]. Additional variables included the frequency of interaction with driving personnel, public transport use, demographic data and mobility impairments. All items were rated on a 5-point rating scale ranging from 1 ("strongly disagree") to 5 ("strongly agree").

Internal consistency of BI was excellent (α = .91 for the condition without driving personnel; α = .88 for the condition with driving personnel) and acceptable for NFI (α = .77).

3.4 Procedure

The survey was structured as followed. First, respondents received a brief introduction outlining the study's purpose. Informed consent was obtained prior to participation. Then, participants completed the NFI scale. Respondents were then introduced to the concept of autonomous shuttle operation through an informational text and an explanatory YouTube video. Subsequently, respondents evaluated the two vignette scenarios. BI was assessed immediately after each scenario. Demographic and mobility-related information was collected at the end of the survey. As an incentive, participants could voluntarily enter a prize draw after finishing the survey.

4 Results

Regarding frequency of interaction with driving personnel, it was shown that the majority of respondents stated to interact less than monthly (n = 116, 41.0%) or never (n = 83, 29.3%) with driving personnel (Figure 2). Almost every seventh respondent stated to interact with driving personnel on a daily basis (n = 12, 4.2%) or on one to three days per week (n = 26, 9.2%).

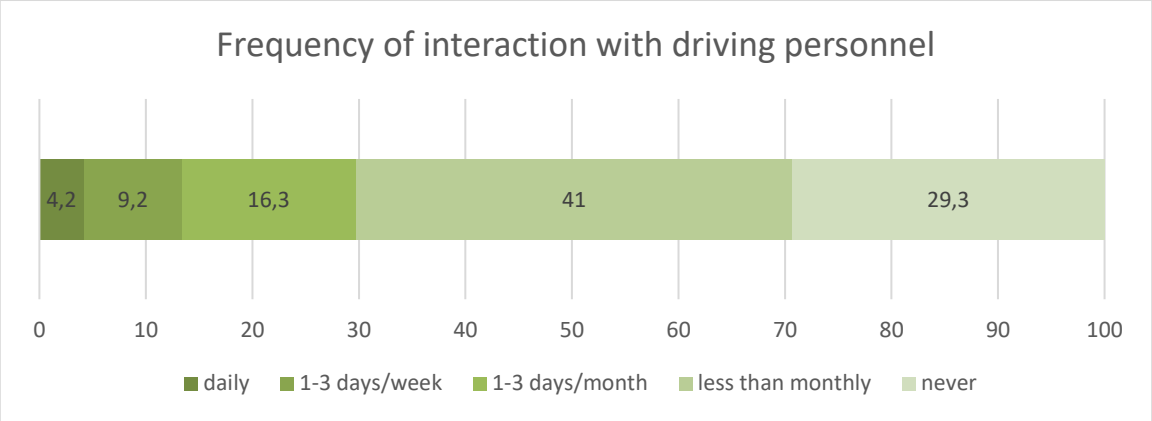

Figure 2: Frequency of interaction with driving personnel in percent

BI was on significantly higher in the scenario with driving personnel (M = 4.06, SD = 0.86) compared to the scenario without driving personnel (M = 3.90, SD = 1.03, asymptotic Wilcoxon-Mann-Whitney-test: z = -3.285, p < .001, Figure 3). The resulting effect size was r = .0195, indicating a weak effect.

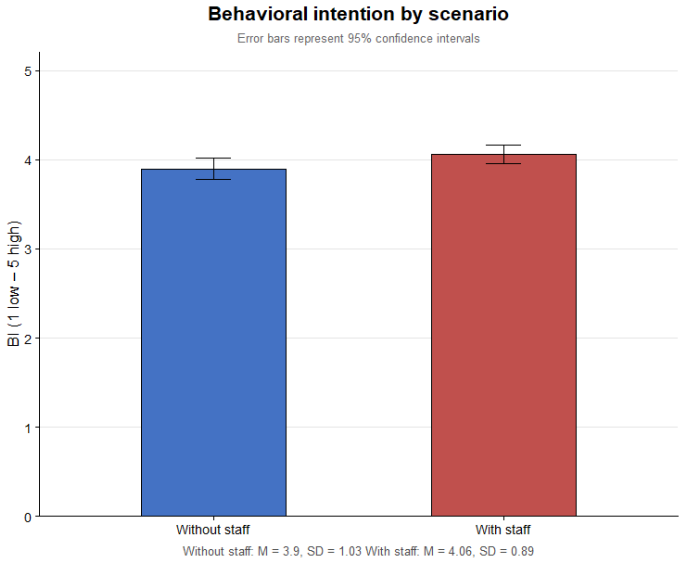

Figure 3: Mean behavioral intention with staff and without staff on board, means and standard errors are displayed

No gender effect was shown for BI with driving personnel (M_{men} = 4.06, SD_{men} = 0.86, M_{women} = 4.08, SD_{women} = 0.87) but for BI without driving personnel (M_{men} = 4.14, SD_{men} = 0.85, M_{women} = 3.69, SD_{women} = 1.07, Figure 4). The difference between men and women for BI without driving personnel was supported in statistical analysis (t(218.27) = - 3.661, p <

.001).

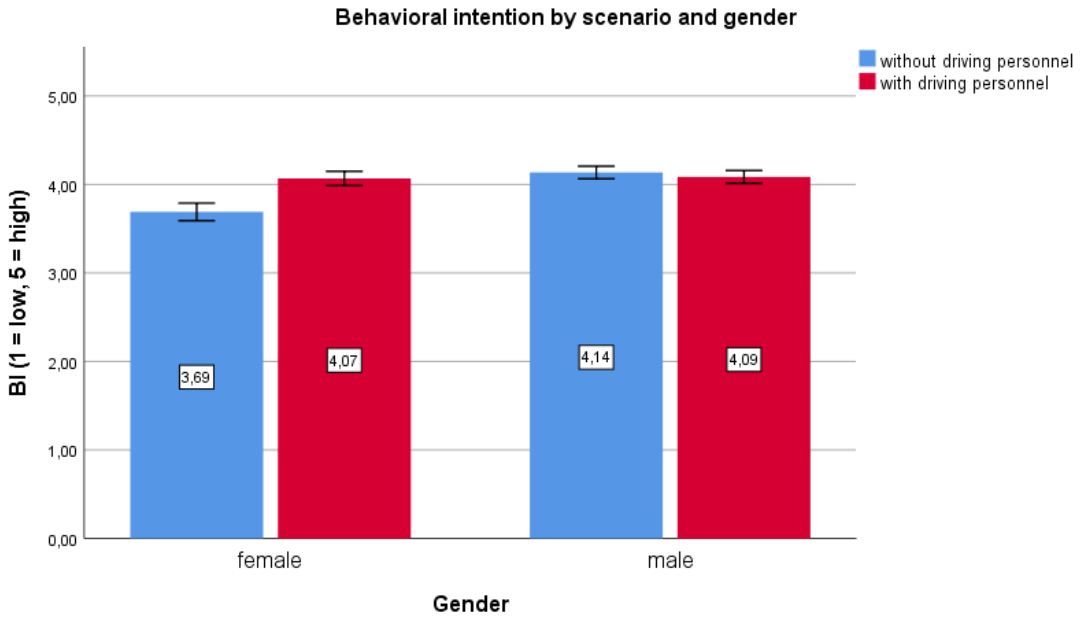

Figure 4: Behavioral intention by scenario and gender, means and standard errors are displayed

A descriptive age effect for BI was shown with the oldest age cohort of 76 to 86 years having the lowest BI for the scenario without (M = 3.71, SD = 1.19) and with driving personnel (M = 3.75, SD = 1.19). No significant age effect for BI was found.
The mean of NFI across the four items was 2.97 (SD = 0.93). With regard to gender, a difference was shown with men reporting a lower NFI (M = 2.87, SD = 0.95) than women (M = 3.12, SD = 0.90) This difference was statistically significant (t(253.33) = 2.184, p = .030). An age effect for NFI was shown with the youngest age cohort of 16 to 25 years having the lowest NFI (M = 2.63, SD = 0.85) and the respondents aged 76 to 86 years having the highest NFI (M = 3.42, SD = 0.73, Figure 5). Differences in NFI between age groups were supported in statistical analysis. NFI was significantly lower in the youngest age cohort of 16 to 25 years compared to the age group from 46 to 55 (t(53.38) = - 3.556, p = .001) and oldest age group (t(10.08) = - 2.785, p = .019).

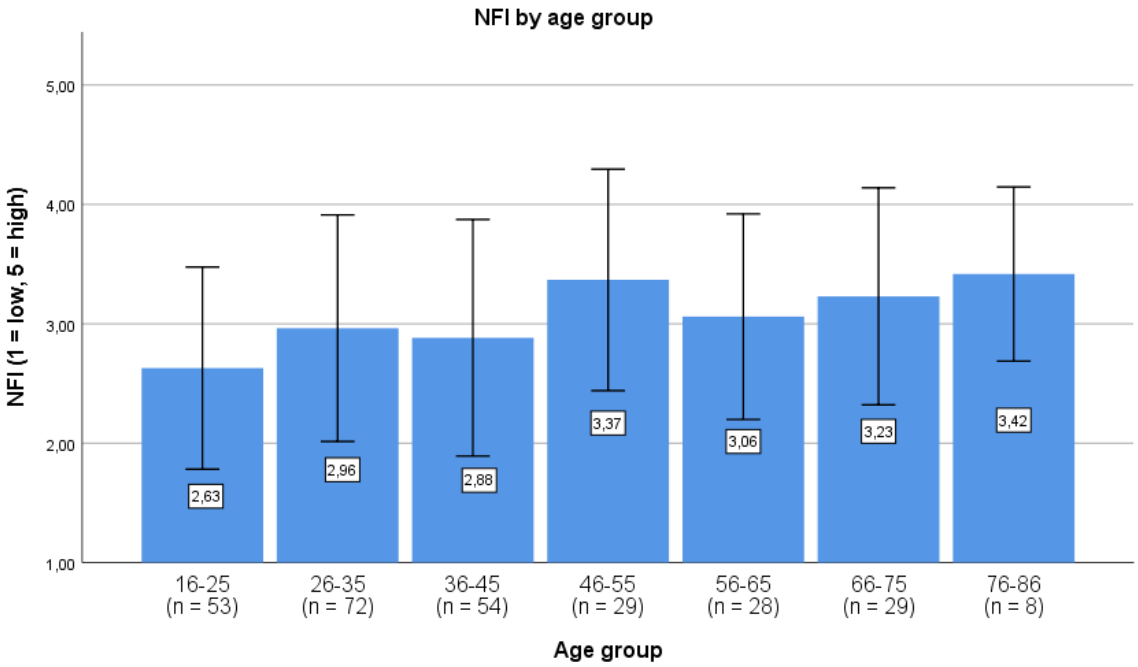

Figure 5: NFI by age, means and standard deviations are displayed

With regard to the moderation effect, a repeated-measures ANOVA revealed a significant interaction between scenario and NFI ($F(1, 282) = 9.718$, $p = .002$). The moderation effect of NFI for BI under the two conditions was shown for participants with high NFI but not among participants with low NFI, as shown in Figure 6 ($t(272.497) = 3.578$, $p < .001$). Participants with above-average NFI scores of 2.98 showed a lower BI ($M = 3.74$, $SD = 1.09$) in the scenario without driving personnel than individuals with NFI scores below the mean of 2.98 ($M = 4.16$, $SD = 0.83$).

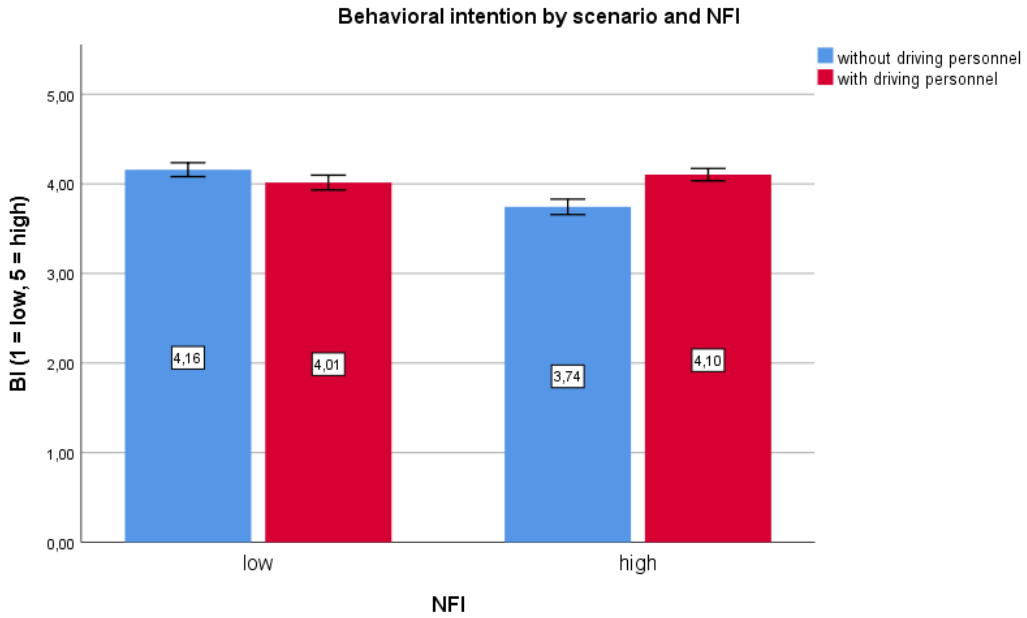

Figure 3: Behavioral intention to use autonomous shuttle depending on need for interaction and scenario, means and standard errors are displayed

5 Discussion

The study investigated the acceptance of autonomous bus shuttles, with a particular focus on the role of the driving personnel. It was shown, that BI was higher for the scenario with than without driving personnel, supporting hypothesis 1. The empirical findings indicate that the absence of on-board personnel significantly reduces passengers' behavioral intention to use autonomous shuttles. However, this effect is not uniform, but is particularly pronounced among specific subgroups, namely women and individuals with a high need for interaction. This indicates that the absence of driving personnel plays an even more important role for the BI of women as shown before for autonomous bus shuttles [24]. The results further indicate, that NFI moderates the effect between scenario and behavioral intention.

To answer the research question, the results indicate that the need for interaction influences the intention to use autonomous bus shuttles but only under the condition without driving personnel. Whereas the difference in BI between people with low and high NFI was not significant for the scenario with driving personnel, the difference was significant under the condition without driving personnel. The findings thus support hypothesis 2 that the effect of an on-board operator presence on BI is significantly stronger for users with higher levels of NFI.

This indicates that NFI played an important role for BI only when no driver was imagined to be on board of the vehicle. This finding aligns with previous research in the field of

technology-based self-services [25]. However, it is questionable whether the expressed need for interaction represents the actual interaction behavior. Our findings show that the actual frequency of interaction with bus drivers is rather low for most of respondents. The need for interaction thus possibly displays other needs such as information needs.
The results of this study will be used to further develop the autonomous vehicle and the mobility service of the IMoGer project. Based on the findings, technical, social, and informational measures will be proposed to compensate for the functions of the traditional driver role, particularly for individuals with a high need for interaction. In addition to informing further technical development in the IMoGer project, results from our study promise important insights useful for maturing autonomous vehicle for public transportation use.

5.1 Implications for practice

The study offers important practical implications for the phased deployment of autonomous bus shuttles. While the long-term vision of full automation aims to eliminate the need for human operators, our findings suggest that a gradual transition is essential, particularly for vulnerable user groups such as women, as well as individuals with a high need for human interaction.
Giving regard to the findings that autonomous shuttles are accompanied by safety concerns [11, 20], the presence of human personnel plays a crucial role in reducing uncertainty and thereby facilitating the adoption process. The familiarization of users with the technology could be facilitated in real-world demonstrations and pilots. In this way, initial usage barriers can be overcome. Targeted information campaigns could help to increase intention to use.
As the technology matures and public trust increases, the role of human personnel may be gradually reduced. However, this shift raises a critical question: How can the psychological functions fulfilled by driving personnel, such as reassurance, immediate support, and social presence, be effectively replaced? One promising approach is the integration of accessible remote assistance systems, enabling passengers to connect with a human support center in real time during unexpected situations [30]. Furthermore, system transparency and ultimately trust should be improved by well-designed human-machine interfaces in vehicles [31]. An innovative alternative might be the development of a mobility companion based on artificial intelligence (AI) to preserve the perception of safety, trust, and social connection, especially for those persons with a high need for interaction.
Another approach to facilitate the adoption phase of driverless autonomous shuttles lies in the empowerment of users. In parallel to empowering customers to use self-service technology [32], it is important to empower users of autonomous shuttles with role clarity and ability, giving them the confidence that anyone can easily use them.
Giving regard to the fact that the IMoGer project aims to design and pilot combined passenger and CEP services using a modular autonomous vehicle, the results could be also used to develop business and operating models. Overall, the development of operational concepts should be based on a phased transition from driver-operated to remote-driven and

ultimately to fully automated models, accompanied by ongoing evaluation of user acceptance and adaptation to user needs. Approaching societal readiness by exploring analyzing the requirements of various user groups helps to design business and operating models that are in line with the needs of the prospective users. For increasing societal readiness, further stakeholder should be included as well, but were not part of this study.
In conclusion, the transition to fully autonomous mobility should not be driven solely by technical feasibility, but by a deep understanding of user psychology and social needs. A phased, user-centered approach, starting with human-in-the-loop systems, progressing to hybrid models with remote support, and eventually integrating intelligent digital companions, offers a realistic and ethically sound pathway toward sustainable, inclusive, and widely accepted autonomous mobility.

5.2 Further Research

The study leaves some open questions for future research. With regard to the finding, that persons with a high NFI have a lower BI for driverless shuttles, the underlying causes remain unclear. It is still an open question why people with a high NFI express a lower acceptability for autonomous shuttles without driving personnel. It might be due to reasons of safety, uncertainty, fears related to using technology or because of the fact that they enjoy interacting with humans.
Future research should explore the effect of further demographic variables such as mobility impairments. This requires a more comprehensive data collection including people that are reached by different measures than an online study. Adding to this, further research should validate the results in a more naturalistic context using a pilot study with first-hand experiences in using autonomous shuttles. It further remains to be answered which trust-building measures could compensate for the absence of on-board personnel. Such measures could be remote assistance services, human-machine interfaces to provide information or AI-powered mobility assistance services. With regard to the modular concept of the autonomous vehicle combining the transport of people and goods, further research is needed to approach the role of service personnel for the use case of CEP. In this context, it might be interesting to study whether personnel can take on various tasks, such as monitoring of driving and delivery of packages in this multi-use functional service concept**.**

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