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A Mixed-Method Approach for Assessing User Perspectives in Autonomous Urban Ferries

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ABSTRACT

Autonomous urban ferries may become a new solution for future urban public transport. The perception of users and their attitudes plays a vital role in the acceptance and use of autonomous technologies. In this method article, we present a mixed-method approach to assess users' perspectives on autonomous urban ferries. The method is based on citizen engagement and consists of four sessions with a broad range of representative public transport users. The sessions are (1) information and table discussions, (2) an immersive virtual mixed-reality simulation of a ferry trip in a full-scale ferry mock-up, (3) a ferry trip onboard a working autonomous prototype ferry, and (4) reflective table discussions. The method collects rich and multidimensional data which can be used to inform researchers and practitioners on how to study passengers' perspectives on public autonomous transport solutions.

Keywords: Autonomous urban ferries, Mixed-method approach, User perspectives, Full-scale mock-up, VR tangible simulation, Focus group, Survey

INTRODUCTION

Autonomous technologies are increasingly present in the maritime sector due to their promising benefits such as cost efficiency, environmental sustainability, and operational safety (Reddy *et al.*, 2019). Battery powered zero-emission autonomous urban passenger ferries can serve as an efficient solution in future public transport in urban areas. Given that around 90% of urban areas are coastal (*Climate Change | UN-Habitat*, no date), together with the urban population expected to increase, there is a need for more efficient modes of transport to ensure the quality of life in urban spaces (Goerlandt, 2020) – a task autonomous ferries potentially can fulfil.

An autonomous ferry differs from a conventional ferry in that it can – with the help of different sensors such as lidar, radar, and cameras – navigate and maintain a safe course at a certain Level of Autonomy (LoA) (Smogeli, 2023). Prototypes such as the milliAmpere2 (Alsos *et al.*, 2022) are currently operated at Level 2 – onboard supervised autonomy implying a human safety

host aboard who intervenes if necessary (Smogeli, 2023). Within the field of autonomous transportation, a critical point with respect to the LoA is abandoning the human safety host aboard which has been outlined in several studies (Goerlandt, 2020; Goldbach *et al*., 2022).

Besides the technological development required to reach the implementation of higher LoAs, investigating the user perspectives is important to understand if and how the general public would accept autonomous ferries. Safety is a prominent aspect to be researched in the field of autonomous transportation. Even if an autonomous ferry would be objectively considered safe, it might not be perceived as such. Some studies have investigated safety perceptions of autonomous ferries already such as (Goerlandt, 2020; Munim *et al*., 2022), but restricted to survey-based and interview methods only. This approach is valuable for gaining insights into the perceptions of participants towards autonomous ferries but limits the possibility of obtaining first-hand experiences of passengers interacting with the technology.

Simulation of different kinds is another method commonly used to study passenger perceptions of trust and safety towards autonomous transportation (Pan *et al*., 2017; Hock *et al*., 2018). Simulations can enhance the experience based on their type and their level of realism. They can help people immerse in an experience, that otherwise would remain abstract and theoretical at best. Nevertheless, simulations often have hard-coded scenarios and lack the characteristics of an open system with unexpected scenarios and unplanned social encounters and influences.

Real-world testing allows for piloting the autonomous ferry within the intended context and specifically investigates how environmental, socio-technical, and human factors influence user perceptions of autonomous transportation. On a general level, the need for public trials of autonomous transportation is also evident in policy documents both in the US (U.S. Department of Transportation, 2018) and the EU (*EU Comission*, 2018). In research, examples of real-world testing of AVs can be found (Mouratidis and Cobeña Serrano, 2021; Stålhane, Myklebust and Haug, 2021; Goldbach *et al*., 2022).

All these methods have advantages and limitations in capturing the safety perception of AVs. Besides safety perceptions, societal and sustainability perspectives would also influence the acceptance of autonomous ferries. However, these are difficult to capture with only some of the methods described. Therefore, it is necessary to take a holistic approach and combine these methods and triangulate data in an exploratory approach in order to provide rich insights.

The mixed-method approach outlined in this paper is a product of the TRUSST project—Assuring Trustworthy, Safe, and Sustainable Transport for All. TRUSST aims to develop an integrated assurance framework, grounded in interdisciplinary and socio-technical perspectives. The collaborative project involves DNV as a risk management and assurance provider, the Norwegian University of Science and Technology (NTNU), and Zeabuz, a spin-off company from NTNU specializing in autonomy infrastructure for autonomous ferries.

As the context of autonomous ferries is still novel in society, this work proposes a method based on citizen engagement with several sessions in order to gain a deeper understanding of the public perception of autonomous ferries. A discussion on opportunities and limitations of applying the method concludes the paper.

DETAILS ABOUT THE METHOD

The approach was framed using a set of methodologies to engage with citizens. This qualitative approach is inspired by citizen engagement, where citizens engage with governmental and/or industrial actors in policy-making and technology development (Olphert and Damodaran, 2007). Engaging with citizens enables end users to contribute with experiences, and (local) knowledge and provides an opportunity for learning and skill sharing. Positive outcomes can be improved quality and effectiveness of solutions as well as increased social inclusion, ownership and faster technology uptake (Olphert and Damodaran, 2007). In this approach, the citizen engagement approach was used to explore user perspectives in autonomous ferries and to define a set of recommendations for further development of technology and assurance. The structure of the engagement activities was based on thematic analysis method (Braun and Clarke, 2006).

Recruiting Participants and Complying With Research Ethics

Due to practical considerations of conducting several sessions, the recommended participant limit was found to be 20. As the study is set in a specific context, emphasis on recruiting from the specific context was prioritized, focusing on residents already using public transport. A recruitment profile, including residency postal codes, transport usage, gender, age, disabilities, education, and ethnicity, guided the process. A third-party company handled recruitment, and participants received vouchers as incentives.

To adhere to ethical standards, participants were fully informed about the study's purpose, data collection, processing, storage, and voluntary nature. Anonymization was ensured through code-only identification. The informed consent form and data management plan were approved by the Norwegian Centre for Research Data (SIKT) under project number 37623.

Establishing Four Sessions of Immersive and Collaborative Nature

The method is based on a citizen engagement consisting of four sessions as depicted in Figure 1. The sessions consisted of (1) information and table discussions, (2) an immersive virtual mixed-reality simulation of the ferry trial between destinations in the area of operation (Figure 3), (3) real ferry trials with the autonomous prototype milliAmpere2 within the real context (Figure 2), and (4) reflective table discussions.

The sessions focused on the topics of safety, sustainability, and societal impact. The study emphasized capturing the participants' initial perceptions but also understanding how these would change after gaining more knowledge and immersion in the overall concept. The sessions were arranged with

some time in between to obtain immediate feedback as well as reflected answers.

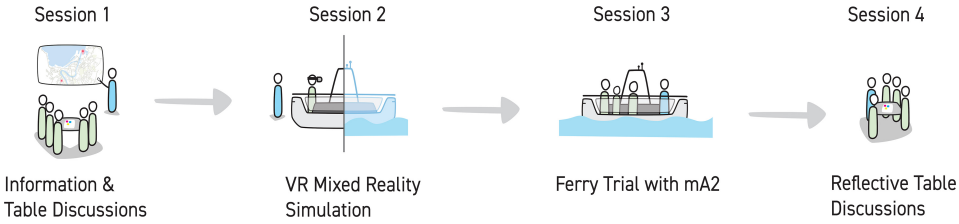

Figure 1: The four sessions of the mixed-method approach (Pantelatos *et al.,* 2023).

Session 1: Information and Table Discussions

Before the first session, participants were briefed on basic information and shown pictures of the autonomous urban ferry concept by Zeabuz. The first questionnaire (WS1-A) was handed out at the beginning of the first session to gauge the initial perceptions of the participants. Informative presentations on future possibilities for urban spaces, technology, and a visualized user journey followed. It was emphasized that the material presented was not a representation of how a potential implementation would look but rather concepts and ideas for discussion. After the presentations, participants were divided into four groups for table discussions. The discussion was guided by large worksheets containing a set of questions listed in Appendix 1. Participants wrote their individual reflections on post-its for each question and shared them on a large sheet, from where a discussion arose in the group. A facilitator accompanied each group taking notes and keeping time. Each question ended with a presentation of the discussion in plenary, during which participants had the chance to ask questions to the different stakeholders present. Concluding the session, participants filled out a second questionnaire (WS1-B) to measure how their perceptions had changed after the session having gained more knowledge and further perspectives.

Session 2: VR Mixed-Reality Simulation

During the second session, participants were offered a mixed-reality simulation of milliAmpere2 in the canal. The simulation was conducted using a full-size mock-up of milliAmpere2, making it a tangible virtual reality lab further described in Alsos *et al.* (2022). Three different scenarios were simulated (Appendix 1). A facilitator followed each participant during the simulation and took notes on their behaviour, actions, and comments using the think-aloud protocol (Nielsen, 1994). After the simulations, participants filled out a questionnaire (VR) to capture their immediate thoughts and perceptions. The session concluded with a focus group interview moderated by a facilitator. The interview was semi-structured, and the facilitator had an interview guide at hand. The session was conducted in smaller groups (5–7 participants) spread over three different dates, where the participants could choose a preferred date.

Figure 2: Ferry trial with the milliAmpere2 in the canal in Trondheim.

Session 3: Ferry Trial

During the third session, participants experienced a real ferry trial with the prototype milliAmpere2 (Figure 2). The trials were spread across three dates in smaller groups and consisted of two parts. In the first part, a "normal" ferry crossing without any obstacles was conducted. In the second part, a leisure boat demonstrated crossing traffic and caused milliAmpere2 to stop. Two safety operators onboard monitored the autonomous system during all the trials and answered questions the participants had. Two facilitators noted the participants' behaviour, actions, and comments. As in the VR session, a questionnaire (FERRY) was handed out, and a semi-structured focus group interview concluded the session.

Session 4: Reflective Table Discussions

In the final session, participants were divided into smaller groups and asked a set of open-ended questions to reflect on and give recommendations for the further development of the autonomous ferry concept. The table discussions were conducted in the same manner as in session 1 (Appendix 1) and were followed by the plenary presentation of the recommendations discussed in the groups. At the end of the session, participants filled out a final questionnaire (WS2).

COLLECTING QUESTIONNAIRE, INTERVIEW AND VIDEO DATA

Throughout the sessions, several different data samples were collected, as summarized in Table 1.

Table 1. An overview of the data collected in the different sessions.

Session 1	Session 2	Session 3	Session 4
Questionnaires (WS1-A), (WS1-B) Work Sheets Facilitator notes	Questionnaire (VR) Video Facilitator notes Interview notes	Questionnaire (FERRY) Video Facilitator notes Interview notes	Questionnaire (WS2) Work Sheets Facilitator Notes

Questionnaires

Five different questionnaires were handed out over the four sessions, each consisting of a quantitative and qualitative part. Some questions were

repeated through several or all the questionnaires to investigate if and how the different sessions would influence the participants. The questions were developed by the research team building on similar studies within autonomous transportation such as Goerlandt (2020), Stålhane, Myklebust and Haug (2021), and revolved around the use of public transport, interest in and experience with autonomous transportation, perceived safety, and usage. In the quantitative part, a 5-point Likert scale or "Yes" or "No" was used. In the qualitative part, open-ended questions on thoughts, needs, expectations, and concerns related to the autonomous ferry were asked. A detailed overview of the questions can be seen in Appendix 1.

Worksheets

During the table discussions, participants used large-format worksheets (DIN A1) with open-ended questions for discussion. The questions allowed for individual reflection and freedom of thought before starting a group discussion, where different perspectives were built on and expanded. A detailed list of the questions can be found in Appendix 1.

Interview Guides

Semi-structured group interviews were conducted as part of the method's explorative nature. An interview guide was created for the debriefing interviews in sessions 2 and 3, with group sizes varying between 4–7 participants. The interview guide started with an easy question to make the participants comfortable before asking more in-depth questions of interest to the matter of investigation. A detailed list of the questions can be found in Appendix 1.

Video

During the immersive sessions (2 and 3), cameras were installed in front of the rig and on the side to capture the movement of the participant in two dimensions. The VR view of the participant was also recorded as depicted in Figure 3. During the ferry trial in session 3, cameras were installed under the mast and in the front and back of the ferry.

Figure 3: Video footage from the VR mixed-reality simulation.

ANALYSIS

The collected material underwent semantic thematic analysis (Braun and Clarke, 2006), incorporating written content from questionnaires, worksheets, facilitator and interview notes, and video analysis for triangulation. The sessions, spanning immersion, collaboration, and discussion over time, yielded immediate feedback and perceptions, together with retrospection. Thematic analysis of combined data samples generated hypotheses on factors affecting acceptance and the impact of perceived safety, including information, the presence and role of a safety host, and ferry design features. Consolidating diverse data through thematic analysis allowed for an in-depth exploration of first-hand interactions with technology and reflections over time. The combination of individual thoughts and group discussions enriched the analysis, providing insights into perceptions of implementing autonomous urban ferries in a specific context.

DISCUSSION

The proposed and novel mixed-method approach builds upon citizen engagement with a set of immersive and reflective sessions. The approach collects rich and mixed data that allows for triangulation during the analysis. Nevertheless, there are several points we would like to discuss further.

Opportunities With the Approach

Research on user perspectives of autonomous public transportation has been conducted using a variety of methods. Methods in studies on the closely related field of autonomous buses range from surveys, and telephone interviews (Goldbach *et al.*, 2022) to field studies with physical prototypes in specific contexts (Salonen and Haavisto, 2019; Mouratidis and Cobeña Serrano, 2021). The use of physical prototypes often involves surveys or interviews to gather immediate participant responses, as demonstrated by Stålhane, Myklebust and Haug (2021), who combined focus groups and questionnaires before and after bus trials for more detailed insights.

In contrast, research on user perspectives on autonomous ferries is still limited. Existing studies rely on online/telephone surveys and interviews (Goerlandt, 2020; Munim *et al.*, 2022), potentially lacking immersion in the ferry concept. The unique aspects of being on board an autonomous ferry, exposed to wind, waves, and currents, necessitate immersive trials to obtain deeper insights into user perceptions. The introduction of autonomous ferries has broader implications for a city, requiring a holistic approach that considers various perspectives besides safety and security.

The proposed mixed method approach emphasizes three key dimensions. Firstly, the chronological order of sessions progresses from theoretical to increasingly realistic scenarios, allowing participants to reflect on the overall concept and track changes in their thoughts and perceptions. This enhances the validity of the data. For instance, a study following this approach (Pantelatos *et al.*, 2023) found that the participants' views on the importance of a human host onboard changed between the immersive sessions with a virtual milliAmpere2 and the real milliAmpere2, leading to recommendations

for a transparent ferry superstructure and a human host at quay areas in the reflective session. Familiarity with the context and prototype provided trustworthiness, yielding valid recommendations to ensure safety and security for further exploration.

Secondly, conducting sessions with spaced intervals gives participants time for individual reflection, potentially minimizing group influence on opinions. The mixed methods research design and session sequence provide valuable insights into the impact of time on forming perceptions of a novel concept.

Thirdly, the approach captures both individual and group perspectives through questionnaires, individual note-taking, and table discussions. While individual methods ensure independent expression, group discussions facilitate in-depth exploration of diverse topics, including safety, trust, job security, and broader societal and environmental implications on the specific context.

The proposed mixed method approach produces multidimensional data for triangulation, including surveys, interview notes, personal notes, observations, video observations, individual interviews, and group interviews. This broad exploratory method, while specific to a context, serves as a foundation for more targeted studies and explores the feasibility of implementing a ferry system. The analyzed data can be highly relevant for academia, the local municipality, and providers of autonomous infrastructure.

Limitations of the Approach

Besides the mentioned opportunities, there are limitations to consider. Conducting the approach as in Pantelatos *et al.* (2023), indicated that the discussions in later sessions became somewhat repetitive. Furthermore, the group dynamics could potentially introduce positive bias as participants would meet over several sessions, especially if the hosts are directly involved in the development of the ferry. The approach can thereby be seen to be optimized further. The resource-intensive nature of the approach necessitates close collaboration among various stakeholders, such as researchers, technicians, facilitators, maritime authorities, harbour authorities, and the municipality etc. Furthermore, it limits the number of participants.

In the current setup 15 participants required 5 facilitators and technical crew in the immersive sessions. A more streamlined setup allowing for a higher number of participants would be more likely to reach theoretical saturation within the individual context. In turn this could give more generalizable conclusions of overarching themes such as environmental impact and societal aspects.

Despite these limitations, the explorative nature of the research, both in terms of subject as well as the method, makes us believe that there is ground to build on this method. The rich data the method provides can be used for informed decision-making within the specific context and can guide further in-depth research.

Acknowledging limitations to the approach, the authors believe that the complexity of introducing autonomous ferries requires rich and multidimensional data of user perceptions in order to research and develop solutions benefiting society.

APPENDIX 1

Session 1 Information and Table Discussions	**Session 2** Mixed Reality VR Session	**Session 3** Ferry Trial with mA2	**Session 4** Reflection and Discussion
Preread with information and visualization of the Urban Autonomous Ferry system before the session.	**Informative film** on the the use of simulations.	**Ferry trial** between Ravnkloa and Vestre Kanalkai. Tour of the mA2.	**Informative presentation** Representative from DNV: Building an assurance case
Questionnaire (WS1 A) at the very beginning of the session: ***QB1:*** Age, Sex, Number of kids, Have you read the preread? ***QB2:*** How much time do you use to work/school? What mode of transportation do you use to work/school? What mode of transport do you use outside of work/school? How often do you use public transport? Have you tried an autonomous vehicle or vessel before? ***QB3:*** How important is the following aspect to you (likert scale 1 (not important) - 5 Very important)): Human host aboard Safety Fare rate Comfort Travel time ***QB4:*** How important is the following aspect to you when implementing an autonomous ferry (likert scale 1 (not important) - 5 Very important), idk): Environment Frequency of departures Employment ***QB5:*** How safe would you feel on a ferry of the following LoA (likert scale 1 (not important) - 5 Very important), idk): Level 0-Level 4 (Smogeli, 2023). Can you specify your answer?_____	**VR experience** with the use of mockups and three different scenarios: (1) Sunny day without traffic (2) Snow, wind and thunder without traffic (3) Rain and Traffic. **Questionnaire after the VR experience (VR)** with the following questions: *QB3 Repeated* *QB6 Repeated* *QB7 Repeated* *QB8 Repeated* *QB9 Repeated*	**Questionnaire after the ferry trial (FERRY),** with the following questions: ***QB10:*** I would like to try a UAF again (Idk, not agree at all, not agree, neutral, agree, very agree) *QB6 Repeated* *QB3 Repeated* *QB7 Repeated* *QB8 Repeated* *QB9 Repeated*	**Table discussions** on reflections and recommendations for further development: What is positive? What should be reconsidered? What should be dropped or changed? Universal Design – How can the urban autonomous ferry become a mean of transport for all?
Informative presentations: Representative from Zeabuz: *Possibilities for Urban spaces through UAFs* Representative from Zeabuz: *The Zeabuz history* Representative from DNV: *Information about the TRUSST project* Representative from NTNU: *A user journey with the UAF.*	**Debrief session after the VR experience.** The following questions were used as a guide to the facilitator: ***QVR1:*** How did you experience the virtual reality simulation? ***QVR2:*** As how real did you experience the virtual realty simulation? ***QVR3:*** Was there anything you experienced as uncomfortable? In the simulation, you were alone on the UAF. What thoughts do you have about this, versus being more people onboard, concerning safety? ***QVR4:*** Did the experience affect your confidence in the UAF perceiving what is happening around it, in any way? ***QVR5:*** Do you have any thoughts on the design of the ferry?	**Debrief session after the ferry trial.** The following questions were used as a guide to the facilitator ***QFR1:*** How did you experience the ferry trial? ***QFR2:*** Has your view on UAFs changed? – If so in what way? ***QFR3:*** Was there anything that was uncomfortable? ***QFR4:*** What are your thoughts on safety aboard the UAF? ***QFR5:*** Did the experience influence your trust in the ability of the UAF to detect other traffic on the river? ***QFR6:*** Do you have any thoughts on the design of the ferry?	**Questionnaire after the session (WS2):** ***QB11:*** To what extent would you agree to the following statements? (likert scale 1 (do not agree at all) - 5 (Very agree)): Having a human host onboard an UAF is important to me. It is important that there is a human host onboard during the evening/night. It is sufficient that the host is available on Quay areas (but not onboard an UAF). There should be camera surveillance on board an UAF. Passengers must be able to access an emergency button to "stop" the UAF. Passengers must have access to a screen to be able to communicate with an operator at a shore control center who monitors the ferry. I am afraid that someone might hack/take control of the ferry if there is no human host onboard. It is important that passengers can easily both small and large deviations. QB3 Repeated QB4 Repeated QB5 Repeated QB6 Repeated QB7 Repeated QB8 Repeated QB9 Repeated
Table discussions on the topics of Safety, sustainability, and societal impact: ***Sheet 1:*** *Your use of public transport today* How do you plan your travel with public transport? What are the positive aspects to public transport? What are the negative aspects to public transport? ***Sheet 2:*** *Safety* What are your concerns regarding you as a passenger? How do you consider the importance of a human host aboard the UAF? What are your concerns regarding kayaks and other traffic on the canal? ***Sheet 3:*** *Sustainability* How important is Sustainability to you? Is sustainability something you think about when choosing mode of transportation? ***Sheet 4:*** *Societal Perspectives* What do you think will be societal consequences of a potential implementation of UAFs?			
Questionnaire (WS1 A) at the very beginning of the session: ***QB6:*** What are your most important thoughts after the seession? ***QB7:*** What are your most important expectations towards UAFs? ***QB8:*** What are your most important concerns towards UAFs? ***QB9:*** What are your most important needs towards UAFs? *QB3 Repeated*			

**UAF - Urban Autonomous Ferry*

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