Co-Designing Safety-Enhancing ADAS with Transit Operators

Sarah Fox, ORCID 0000-0002-7888-2598
Nikolas Martelaro, ORCID 0000-0002-1824-0243
Carnegie Mellon University

FINAL REPORT

September 13, 2024

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated in the interest of information exchange. The report is funded, partially or entirely, under [grant number 69A3552344811] from the U.S. Department of Transportation's University Transportation Centers Program. The U.S. Government assumes no liability for the contents or use thereof.

Problem and Approach

Over the past several years, there has been increased investment in automated vehicle (AV) technology for full-size public transit buses, with deployments planned across the country [41]. Yet, operating transit is more complex than the light-duty passenger vehicles for which AV technologies are commonly designed. Buses are significantly larger and operate in highly variable environments with many stops and starts near vulnerable road users (VRUs) such as pedestrians and cyclists. Even in the case of smaller vehicles such as vans, there are still many technical challenges to overcome to navigate these complex environments safely. Furthermore, transit operations require supporting passengers and maintaining safety inside the vehicle. Due to both technical and operational challenges, transit vehicles including buses and vans will continue to require skilled human drivers, even as automated vehicle capabilities are incorporated [72,84].

While recent accidents and controversies surrounding AVs highlight the risks involved in deploying driverless vehicles on public roads, the responsible development of lower levels of automation specifically designed for transit applications has the potential to augment operations. Yet, to help maintain transit's already high level of safety for passengers, it is essential to understand how automation stands to affect the roles and day-to-day tasks of trained drivers. For example, driver assistance automation such as pedestrian warnings and lane-centering has the potential to improve the safety and workload of drivers. At the same time, automation can create new kinds of safety issues caused by the interactions in human-autonomy teams [105] and can intensify work as people primarily take over from automation in the most challenging situations. Therefore, it is crucial to carefully consider how to go about incorporating automation technologies into fleets and to develop new interfaces for transit drivers to work effectively in maintaining safety on the road, and alongside vulnerable road users. Changes in a driver's job and vehicle automation can also impact the rider experience, including shifts in providing information or assistance. Issues that exist for riders today, such as having limited knowledge of bus schedules and location [107], riders with disabilities being passed [58,131], and maintaining social order and safety for passengers [114] could also be impacted by changes to a driver's role.

In this research, we draw on our ongoing partnerships with the Amalgamated Transit Union, the Transport Workers Union, and the AFL-CIO Technology Institute to understand the role of bus operators within the context of increased transit automation. Our early work together involved a group interview study of working bus operators across the United States. Through this work, we gained insight into the kinds of unexpected circumstances they encounter, their current technological tools, and perspectives on automation [1]. During the 2023-24 grant period, we extended this research through a long-term diary study, designed to gain a deeper understanding of day-to-day experiences operators face and identify opportunities for the design of ADAS technologies to support transit operations. Through this study we have gained a rigorous empirical understanding of the current task structure, technological tools, and challenges of bus operators. Bus operators report facing severe challenges around harassment and assault and persistent mechanical issues that impede safe day-to-day operations. We find that with these concerns, and many more, bus operators lack effective and non-punitive reporting mechanisms. Their accounts also point to difficulties in loading and securing passengers with disabilities and the importance of attending to riders' dignity and independence. Operators describe the persistence of digital display screens that are distracting and require them to divert their attention while driving. Collectively, these findings point to a need for a multi-stakeholder process of designing, assessing, and implementing transit technologies.

In the following sections, we describe our methodology, present the findings in more detail, and offer a set of recommendations for future scholarship and technical development within the space of transit.

Methodology

Our preliminary research found that many transit workers already regularly keep diaries or work logs to

document incidents on the job and hours worked to prevent wage theft. Informed by these existing practices of documentation, we developed a diary study (Reiman 1993) and semi-structured interview approach to study the daily work experiences of bus operators. Over the course of a year, from the spring of 2023 to the spring of 2024, we collected over 2,000 diary entries and over 100 hours of in-depth interviews with 47 transit operators from across North America. Our participants were all unionized bus operators. To respect the privacy of drivers we did not require the disclosure of demographic information and refer to participants with pseudonyms in our findings. We can confirm that our pool of drivers is representative of bus operators at large, in terms of racial/ethnic, gender, and age composition. The study included operators from each major region of the U.S. and Canada.

For the diary study, participants received text or email reminders that led them to a short survey (administered via Qualtrics) for a daily entry. This log contained four questions that were workshopped with union representatives: (1) Did you help someone on your most recent day of work? How did this affect your day? (2) What other situations did you encounter on your day that were noteworthy? What stood out to you today? (3) How did tools, technology, or equipment impact your work? (4) Is there anything else you would like to tell our team about your day? Participants were paid via gift card in their local currency, $7.50 USD per diary entry submitted.

Not all participants completed the diary study process, defined as submitting 30 entries or participating over the course of sixty days. The diary study process can be a big commitment, especially given the hours and conditions bus operators face. We had one participant explain that she worked weeks without having a day off and was regularly required to put in overtime. Another was so severely assaulted that she needed time off from work to recover and never came back to the diary study.

Despite challenges we conducted in-depth interviews with 47 participants. Prior to an exit interview at least one researcher analyzed and coded the participant's diary entries to generate a list of follow-up questions. These interviews were semi-structured and gave workers space to reflect on different aspects of their work process (Woodcock 2021). We also had a standard set of background questions. We began by asking participants to describe their daily work routine in detail, how many years they had been driving, the kind of vehicles they drive, and overall perspective on their work. The responses to these background questions often opened up new themes, especially on scheduling and safety. After asking our background questions, the interviewer would transition to asking questions based on the participant's diary entries. These discussions lasted 90 minutes on average with some lasting several hours over the course of a few days. As these interviews were conducted with operators across North America and had to work around operators' busy schedules, all but one interview were collected remotely over video conference (Zoom); one interview was conducted over email. One researcher led the interview and in many there was at least one other researcher taking notes and asking follow-up questions. Interviewees were paid $30 an hour.

Data Analysis

Because of the scale of the data collection, analysis began early in the research process. As mentioned above, diary entries were analyzed throughout the interview process. After each interview, the interviewer took notes on relevant themes and findings. These contributed to summarized findings presented to the research team and union partners in bi-weekly meetings.

After data collection ended, all of the transcripts were reviewed again, uploaded to a collaborative qualitative coding environment (Atlas.ti), and analyzed using a grounded theory approach along with diary entries as relevant (Charmez 2014).

Due to the vast amount of data collected, our analysis is ongoing and we only present partial findings below.

These focus on experiences of assault, inhumane schedules, and unsafe operational conditions because these were the issues most prevalent among the participants we interviewed and the concerns that most profoundly impacted all other aspects of bus operations. As we iteratively continue this process, we will develop additional findings on topics such as the various service roles drivers take on, fare collection, transit apps, and much more. We expect to produce several academic papers and public outputs from the research, targeted at both transportation and computing research venues.

Findings

In what follows we briefly describe major challenges bus operators confront on the job, why these challenges persist, and how they might be overcome. Operators described accounts of workplace violence, inhumane schedules, and unsafe operational conditions, leading to significant harm to their well-being. We describe why they believe this has become the case through a description of ineffective and sometimes punitive reporting mechanisms. Despite this, some bus operators share stories of positive change within their agencies, offering potential models to be replicated elsewhere.

Challenges Faced by Bus Operators

Bus operators described facing significant safety risks on the job, including frequent incidents of assault, harassment, and threats. These experiences, often minimized by supervisors and dispatchers, contributed to a pervasive sense of fear and vulnerability among drivers. A lack of adequate support, training, and resources also exacerbated these challenges, leaving operators feeling unprotected and unsupported. The physical and psychological toll of workplace violence was substantial, with many drivers we spoke to experiencing trauma, anxiety, and even considering leaving the profession. While the need for increased security measures was often voiced by operators, it is clear that addressing the root causes of violence, such as homelessness and mental health issues, is also crucial.

In addition to safety concerns, bus operators described enduring demanding and often unsafe working conditions. Inhumane schedules with minimal break times, coupled with the pressure to maintain on-time performance, contributed to physical and mental health problems. Poorly maintained buses, inadequate air quality, and long hours were also referenced as creating a hazardous work environment. The lack of reliable reporting mechanisms for safety concerns further compounded the issue, as drivers described feeling discouraged from reporting problems due to fear of retaliation or lack of response. These challenges, combined with the psychological toll of workplace violence, created a toxic work environment that was detrimental to the well-being of many bus operators we spoke with.

Ineffective reporting mechanisms and possible paths forward

A central issue contributing to the ongoing challenges faced by bus operators was a systemic breakdown in reporting mechanisms. Across various concerns – from assaults and harassment to unsafe working conditions – drivers consistently encountered barriers to reporting incidents. These barriers included cultures of fear and retaliation, where operators were met with hostility, apathy, or even disciplinary action for reporting safety issues. Additionally, the reporting process itself was often described as cumbersome and time-consuming, deterring drivers from reporting incidents. These factors created a cycle of silence, allowing problems to persist and worsen over time.

Interviews highlighted specific organizational and technological factors that contributed to the ineffectiveness of reporting systems. A lack of support from supervisors, coupled with a culture that prioritizes productivity over safety, created a hostile environment for reporting. Furthermore, the burden placed on drivers to initiate and complete reports, further discouraged reporting. These issues, combined with inefficient reporting systems, created significant obstacles for bus operators seeking to address safety concerns.

The study also found that increased transparency in reporting processes, as well as the establishment of worker-centric training programs like the one at VTA, have empowered employees to feel heard and valued. This, in turn, has led to improved morale and a more engaged workforce. Additionally, participants emphasized the critical role of supportive management in creating a safe and respectful work environment. By prioritizing worker feedback and implementing safety measures, transit agencies can effectively address challenges such as violence and improve the overall well-being of employees.

Recommendations and Conclusions

This research highlights the critical role of bus operators as essential yet undervalued workers facing significant challenges. Beyond physical dangers like assaults and unsafe working conditions, the study reveals the psychological toll of systemic disregard for operator well-being. To address these issues, a fundamental shift is necessary to prioritize the human experience of transit work. This includes empowering operators through increased agency in decision-making, improving reporting mechanisms, and fostering a culture of respect and support. Ultimately, reimagining public transit as a worker-centered system is crucial for creating a safer and more equitable environment for all.

Addressing the Root Causes and Redesigning the System

The challenges faced by bus operators stem from complex societal issues and systemic failures within the transit industry. To effectively address these problems, a multifaceted approach is necessary. This includes addressing the root causes of violence and inequality through transformative justice approaches, as well as implementing design-focused solutions to improve working conditions. Redesigning bus interiors to prioritize operator safety, enhancing transit stops and stations, and optimizing scheduling software through human-centered approaches are essential steps towards creating a more just and equitable transit system. Ultimately, prioritizing the well-being and dignity of bus operators is crucial for building a sustainable and resilient public transportation network.

By centering the design process on the needs and experiences of bus operators, it is possible to create more effective and humane systems. This involves not only technological innovations but also a fundamental shift in organizational culture and practices. By investing in worker well-being, transit agencies can improve safety, enhance service quality, and foster a more positive work environment. This requires collaboration between designers, policymakers, transit agencies, and bus operators to develop solutions that address the complex challenges facing the industry.

Reimagining Reporting Mechanisms

Effective reporting mechanisms are essential for addressing the systemic challenges faced by bus operators and creating a more resilient transit system. While policymakers have recognized the need for better data on workplace violence, there is a significant gap in understanding the broader range of issues faced by transit workers. To bridge this gap, the development of user-friendly reporting tools is crucial. These tools should prioritize accessibility, data privacy, and worker empowerment, while also being integrated into existing organizational structures.

Addressing the root causes of these issues requires a collaborative approach involving technology, policy, and labor. Partnerships between academic researchers, labor unions, and policymakers can lead to the development of effective reporting systems and supportive workplace environments. By prioritizing worker voice and implementing accountability measures, transit agencies can create a culture where operators feel safe, respected, and empowered to report safety concerns without fear of retaliation. This transformation will require a significant shift in organizational culture and practices, but the potential benefits for both workers and the

overall transit system are substantial.

Final Report URL(s) or PDFs for any resulting publications:

Project site: https://codesigningtransit.com/

Hunter Akridge, Bonnie Fan, Alice Xiaodi Tang, Chinar Mehta, Nikolas Martelaro, and Sarah E Fox. 2024. “The bus is nothing without us”: Making Visible the Labor of Bus Operators amid the Ongoing Push Towards Transit Automation. In Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24). Association for Computing Machinery, New York, NY, USA, Article 479, 1–16. https://doi.org/10.1145/3613904.3642714

URL(s) to, and associated descriptive metadata for, any final datasets from the research project

N/A.

Any documented project outputs or outcomes resulting from the research project.

- Presentation at the Work and the Data Economy conference
- Presentation at International Workshop on Worker-Robot Relations, HRI
- Invited Panel, Amalgamated Transit Union Legislative Conference
- Presentation at Advanced Infrastructure Systems Seminar Series, Department of Civil and Environmental Engineering, Carnegie Mellon University.
- Presentation at Southwestern Pennsylvania Commission Operations and Safety Forum.
- Paper under review at ACM SIGCHI Conference on Computer-Supported Cooperative Work & Social Computing (CSCW)
- Paper accepted and published at the premier human-computer interaction publication venue, ACM Conference on Human Factors in Computing Systems (CHI)
- NSF Smart & Connected Communities Proposal submitted. Partners on the grant include ATU, TWU, AFL-CIO Tech Institute, as well as rider advocacy organizations in Pittsburgh and Philadelphia. The grant would fund our continued work on the co-design of ADAS technologies with operators and transit riders, with a focus on enhancing safety and accessibility.

<table>
<tr><td>1. Report No.
476</td><td>2. Government Accession No.</td><td>3. Recipient’s Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Co-Designing Safety-Enhancing ADAS with Transit Operators</td><td>5. Report Date
September 13, 2024</td></tr>
<tr><td>6. Performing Organization Code
N/A</td></tr>
<tr><td colspan="2">7. Author(s)
Sarah Fox, Ph.D. https://orcid.org/0000-0002-7888-2598
Nikolas Martelaro, Ph.D. https://orcid.org/0000-0002-1824-0243</td><td>8. Performing Organization Report No.
N/A</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213</td><td>10. Work Unit No.
N/A</td></tr>
<tr><td>11. Contract or Grant No.
Federal Grant No. 69A3552344811</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Safety21 University Transportation Center
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213</td><td>13. Type of Report and Period Covered
Final Report (July 1, 2023-June 30, 2024)</td></tr>
<tr><td>14. Sponsoring Agency Code
USDOT</td></tr>
<tr><td colspan="3">15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation</td></tr>
</table>

16. Abstract
Public transportation is critical infrastructure serving millions of people across the United States. With roughly 4 billion individual trips occurring annually, it is the primary mode of transportation for many commuting to and from work, school, and leisure activities. Over the past several years, there has been an increase in investment in automated vehicle (AV) technology for buses. The use of AV technology has the potential to fundamentally impact public transit operations. While there are ambitious plans for automated bus deployments across the country, operating transit is more complex than light-duty passenger vehicles. Buses, for example, are significantly larger and operate in highly variable environments near vulnerable road users. Even in the case of smaller vehicles such as vans, there are still many technical challenges to overcome to navigate these complex environments safely. Furthermore, transit operations require supporting passengers and maintaining safety inside the vehicle. Due to both technical and operational challenges, transit vehicles, including buses and vans, will continue to require skilled human operators, even as automated vehicle capabilities are incorporated. Introducing new technology will impact operator's duties and actions, as well as passenger safety and experience.

To help maintain transit's high level of safety for passengers, it is essential to understand how automation stands to affect the roles and day-to-day tasks of trained operators. Driver assistance automation, such as pedestrian warnings and lane-centering, can potentially improve the safety and workload of trained operators. At the same time, automation can create new kinds of safety issues caused by the interactions in human-autonomy teams and can intensify work as people primarily take over from automation in the most challenging situations. It is crucial to consider the safety of incorporating automation technologies into fleets and to develop training for operators to work effectively with such technologies. Our research first examines how autonomous vehicle technologies could impact transit operations, and specifically the jobs of transit workers. We will then collaborate with transit drivers to understand the kinds of advanced driver-assistance systems (ADAS) and interfaces that would help them in their work and improve transit operations.

Through a participatory design approach, this project examined past and ongoing transformations of transit infrastructure in order to envision the future of transit with operators. Centering safety and equity of the socio-technical infrastructure of transit, this project yielded (1) empirical findings on the forms of autonomy (current and proposed) drivers perceive as being helpful to their work, as well as necessary components of implementation (e.g., training, human-machine interfaces), (2) methodological insights on co-design strategies for generating novel directions for ADAS within transit, as well as accounting for the potential, unintended harms of autonomy, and (3) theoretical findings that contribute core understandings on autonomous systems impacts to safely and workload.

17. Key Words	**18. Distribution Statement**
Public Transit; Advanced Driver Assistance Systems; Buses; Workforce; Labor Relations	No restrictions.

19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages**	**22. Price**
N/A.	N/A	1-6	N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized