



“The bus is nothing without us”: Making Visible the Labor of Bus Operators amid the Ongoing Push Towards Transit Automation

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ABSTRACT

This paper describes how the circumstances bus operators manage presents unique challenges to the feasibility of high-level automation in public transit. Avoiding an overly rationalized view of bus operators’ labor is critical to ensure the introduction of automation technologies does not compromise public wellbeing, the dignity of transit workers, or the integrity of critical public infrastructure. Our findings from a group interview study show that bus operators take on work — undervalued by those advancing automation technologies — to ensure the well-being of passengers and communities. Notably, bus operators are positioned to function as *shock absorbers* during social crises in their communities and in moments of technological breakdown as new systems come on board. These roles present a critical argument against the rapid push toward driverless automation in public transit. We conclude by identifying opportunities for participatory design and collaborative human-machine teaming for a more just future of transit.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**.

KEYWORDS

bus operators, transit automation, critical HCI, invisible work, political economy, human-machine teaming, autonomous vehicle (AV) technology

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1 INTRODUCTION

The bus makes a stop in front of a drug treatment clinic in Portland, Maine. A man boards and later the driver, Chris Varian, notices him pacing nervously in the back. The next moment, he’s overdosing — collapsed unconscious in the back of the bus. Varian pulls over. He rushes to the back and begins chest compressions (a skill he learned in the military), while a friend of the man begins administering an opioid overdose reversal drug. Before the paramedics arrive, he’s already returning to consciousness [3].

The above story is heroic, but not exceptional. Bus operators not only get riders where they need to go, but do so in a way that ensures public safety. This often means stepping up in the event of a crisis, as Varian did. Yet, across many transit agencies in North America, operators themselves are in crisis, due to a lack of support amid staffing shortages and elevated rates of assault [101]. Alongside these challenges, transit automation is spreading — threatening to deskill and displace transit operators. While automated full-size buses remain largely in the pilot stage, automated shuttles are increasingly being deployed [29]. As investments continue to be made into autonomous vehicle technology, municipalities are looking to further expand deployments. An initiative in Las Vegas, for example, seeks to bring “several thousand” highly automated shuttles to the city’s streets in the coming years [7].

In addition to negatively impacting operators, putting workers in a backseat role or removing them altogether could also have negative impacts on riders and the public at large. HCI literature has generally surfaced skepticism about transit automation from potential riders [19, 21, 24, 84, 90, 92], with particular concern from women on the potential for increased risks of violence [90]. Researchers have also pointed to increased risks to road safety associated with bus automation relative to other contexts, given the large size of public buses and the unpredictable urban environments they operate in. Given these concerns, HCI scholars have called for research on “[t]he role and tasks of the human driver” that exceed route driving [90].

This labor is in some ways highly visible already, but in other ways is hidden by the social structuring of public bus ridership — particularly in the United States. For regular public bus riders, the value of bus operators may be self-evident. Yet, this is not the case for many middle and higher-income people in the U.S. who rarely, if ever, take public bus transit [57]. This latter group includes

many of the designers, technologists, and researchers advancing self-driving technologies — as well as their funders [63]. People who depend on public bus transit often do so because they have no alternative, with personal vehicles and the cost of their maintenance out of reach for many low-income Americans [13]. Bus operators themselves disproportionately come from marginalized communities [13]. We argue that the socioeconomic distance between bus operators and those advancing autonomous vehicles paves the way for a reductionist view of bus operators' work and the introduction of technologies not attuned to the full range of circumstances they contend with [98]. We follow Noopur Raval's challenge to the HCI community to consider how the invisibility of certain kinds of labor is not absolute but unevenly distributed across economic geographies [80]. The omission, with the exception of important contributions from Pritchard et al. [77–79], of bus operators from the HCI literature on public transit has not only led to knowledge gaps about appropriate forms and uses of technology but also reproduces the invisibility of their labor.

In this paper, we seek to reverse these harms by making the labor of bus operators more visible and interrogating how the lived experiences and perspectives of bus operators might inform transit automation. We present findings from a series of group interviews with 16 bus transit operators in the U.S. Through these conversations, operators shared accounts of their work, the technologies they use in their fleets, and their outlooks on automated vehicle technologies currently being developed and piloted. Our findings detail how bus operators' labor exceed the capacity of automation technologies. Even on fixed bus routes (often thought of as the most automatable), bus operators regularly described confronting unexpected circumstances, both in navigating the road and managing the social environment of the bus. These circumstances often required split-second decision-making and nuanced social judgments. In fact, it is sometimes through their driving role that they are able to manage the social environment on the bus and ensure the well-being of passengers. Across each interview, operators emphasized that their role is centered on “expect[ing] the unexpected,” going above and beyond to ensure the safety, comfort, and mobility of a diverse ridership. We then surface accounts of currently deployed technologies in public bus transit. We describe how these technologies, even those that are more rudimentary, often lack worker-voice in design and implementation—to detrimental effect. Operators therefore raise a series of concerns around automation and call for participatory research that involves operators early in the design process of new technologies.

Our research makes four core contributions to the CHI community. First, we share an empirical understanding of bus operators' labor, which includes largely invisible and undervalued work to serve communities in crisis. Second, we offer *shock absorbers* as a concept that explains how U.S. bus operators absorb the impact of suffering and disinvestment induced by long-term disinvestment in public transit and social services, the effects of which have been exacerbated by the COVID-19 pandemic. The framing of “shock absorption” is borrowed from urban studies and political science scholars Hastings and Gannon [44], who examine the UK context where local government workers have borne the brunt of a retreating welfare state over the past decade under austerity politics. Given

these findings, we argue for broadening the range of concerns considered by researchers and designers to include social and political harms. Third, we describe the potential impacts to operators with the near-term integration of autonomous driving systems through their experiences with and perspectives on current transit technologies. In this way, we expand the concept of shock absorption to describe the additional labor bus operators may take on as a result of increased human-machine teaming. We argue that buses may become less safe if operators are positioned as only fail-safes for imperfect automation. Fourth, we identify opportunities for collaborative human-machine teaming that could enhance safety for all, while maintaining dignity for operators. Finally, we conclude by outlining how future work within HCI could help build toward a more just future of transit.

In the paper that follows, we first describe what has led up to the current crisis situation bus operators face, and outline the emerging space of automated bus transit. We then turn to HCI literature that describes efforts to design systems to support public transportation, as well as more recent scholarship on the adoption and acceptance of automated vehicle technology in transit contexts. Next, we turn to work on participatory and worker-centered design that frames our orientation and interview-based methods. We later detail our findings on the changing role of operators under a set of compounding crises, and, finally, relate these insights to wider HCI discussion on automation, labor, and justice.

2 BACKGROUND

2.1 The Current Bus Operator Crisis

To fully understand the realities of public bus transit in the U.S. and the current push toward automation, we first need to retrace the long history of personal automotive transit being prioritized above public transit. This began in the early 20th century when cities were redesigned around automobility. The increasingly powerful automotive industry pushed forward a reconfiguration of our urban spaces to make room for cars, even as the cost to society at large grew — including thousands of lost lives yearly to accidents [63].

Marginalized communities in the U.S. have been underserved by this bias for automobility — making existing public transit infrastructure all the more critical. In many cities, buses provide the only affordable option for transit to and from low-income and lower-density neighborhoods. Bus operators themselves can also be thought of as critical infrastructure. Transit labor unions have fought to make being a bus operator a middle-class profession. Which, particularly after the 1964 Civil Rights Act, provided a means of upward mobility for African Americans and other communities of color [18]. This has led some to argue that automation in public transit may deepen racial inequality [58].

In recent decades, a series of crises have made the work of bus operators more fraught. The 2008 recession intensified pressure in many cities to decrease the labor costs of public employees and reduce transit services. This resulted in bus operators experiencing increased time pressure [32]. The resulting work intensification often meant little time left for meaningful customer service interactions. In subsequent years wage stagnation led to driver shortages across many major cities [101]. Mirroring and exacerbating many of the consequences of the 2008 recession, the COVID-19 pandemic

severely impacted bus operations leading to a significant decrease in ridership and revenue. The pandemic and related lockdown caused heightened safety concerns, led to a sharp decline in ridership, and deepened pre-existing driver shortages [45, 101]. Bus operators were essential frontline workers, offering transit for other frontline workers like healthcare providers. Operators were tasked with enforcing mask mandates which — along with broader public health challenges — contributed to an increase in bus operators experiencing assaults [12]. At the same time, operators risked being exposed to the virus while at work [51]. In New York City alone, more than 100 transit workers died [65].

Ridership has gradually increased from the low experienced in 2020 but has not returned to pre-pandemic levels [101]. Many bus agencies cut services based on this decline and were forced to institute hiring freezes because of budgetary shortfalls [40, 101]. Riders have been burdened by this slow recovery [88], with route times suffering and some routes still not being restored several years on. Driver shortages also remain severe and widespread; transit agencies are struggling to hire and retain enough operators, on top of retirements accelerated by the pandemic [11, 66]. Together, these losses have introduced added pressure on the remaining drivers, who report working longer hours with reduced breaks while being expected to produce heightened levels of efficiency [2, 101].

With the expansion of bus services lagging due to the challenges described above, cities have sought to meet mobility challenges by expanding shuttle and van services that require relatively less capital investments than bus rapid transit or rail services [81]. The expansion of private ride-hail firms, like Uber and Lyft, has also undermined investments in bus transit. Uber has lobbied to deregulate and reduce spending on public transit [48, 104] while positioning themselves as a replacement [93]. Many companies and transit agencies are also looking at autonomous driving systems as a potential solution [9]. This has helped construct an environment where the replacement of bus operators seems not just likely but inevitable.

2.2 Emerging Automation in Public Bus Transit

Autonomous bus pilots and development have been ongoing since the mid-2010s, but have received heightened attention in recent years. This has been reflected in more funding being allocated for transit modernization initiatives by state and federal agencies [27, 28]. It is not that transit agencies now have the funds to raise wages and improve benefits that could alleviate shortages. In fact, researchers warn of impending fiscal crises across many transit authorities [20]. Rather, there are more federal grants available for the development and piloting of automation projects and the purchasing of electric buses [27]. The Federal Transit Administration recently announced more than \$11 million in grants for automation projects with a focus on bus safety [28]. These projects include testing, piloting, and deploying various kinds of advanced driver-assistance systems (ADAS), including precision docking and automatic braking capabilities to avoid pedestrian collisions [28].¹

¹Automation in public buses exists along a continuum as suggested by the Society of Automotive Engineers (SAE) [95], from levels 1 and 2 with some assistive driving features but where someone is always driving (i.e., lane centering and adaptive cruise control) to level 4 on many automated shuttles where an attendant will supervise but not actively drive the vehicle except in specific conditions outside the operational regime of the vehicle (such as during inclement weather) [62]. Level 5 automation is designed to do away with a driver on board entirely.

There have been dozens of autonomous shuttle projects across the country aiming to test fully driverless operations [29], as well as numerous small shuttle deployments in communities across the country. While many shuttles operate without incident, there have also been accidents and injuries that have occurred during pilots. For example, in 2017 an automated passenger shuttle in Las Vegas was hit by a truck backing up [37]. Although there was an attendant on board, they were unable to steer the shuttle out of the way because the controls were locked in a compartment [67]. Rather, the attendant and passengers stood by while they waited for the low-speed collision (no parties were injured). In 2020, a woman was injured after an autonomous shuttle made a hard stop, potentially due to a false positive obstacle detection [61]. There have also been several other incidents that have raised concerns about the safety of autonomous shuttles [30, 55, 82]. Prior research on human-machine teaming in aviation [15] underscores the stakes of such a shift. Novel challenges emerge when operators need to take over quickly during emergency situations [15] such as skill atrophy [23, 75] and mode confusion [87].

Despite these emergent safety issues, pilot projects designed to test automated shuttles and vans continue and firms are working to develop and market full-length buses that do not require a human driver [1, 86]. These buses would directly replace current bus rapid transit and require significantly more advanced automation systems and safeguards than are currently used in autonomous bus shuttles [74]. This is because full-length buses operate at higher speeds and are slower to stop given their size. Whether these highly automated buses in development will receive widespread adoption remains uncertain [62, 74].

3 RELATED WORK

3.1 Technologically Mediated Public Bus Transit

A growing body of HCI literature considers the use of and potential for digital interfaces and automation technologies in bus transit. To date, HCI literature has primarily engaged public bus transit by focusing on passenger-facing technologies in the interest of making bus transit more accessible, convenient, and enjoyable — thus increasing ridership [6, 31, 36, 41, 50, 73, 85, 99, 106–109]. Early papers tended to focus on sustainability impacts and use mobile tools to support taking public transit as a greener alternative to personal vehicles [36, 41], reflecting broader interest in mobility beyond personal vehicles [39]. There are also important studies that explore the unique experiences and needs of people with disabilities [5, 54, 99] and people with HIV [59] using bus transit.

Recent work in HCI has interrogated rider perception of automation and how to address the needs of specific rider groups in a more highly automated future of transit. This research often begins with a different paradigm for the future of mobility than is dominant in the U.S. and in vehicle automation more generally [19, 21, 33, 84, 90, 92]. As opposed to advancing autonomous vehicles (AVs) for personal private mobility, they argue for shared public mobility. A significant challenge to realizing this future is rider perceptions of bus automation and security concerns, which HCI studies have detailed [21, 84, 89, 90, 92].² Unease at bus automation

²Similar to HCI, much of the transit literature on autonomous buses looks at user perceptions [8, 17, 22, 42, 46, 49, 53, 56, 68, 69, 71, 76, 83]. The findings from this work

described in these studies include security concerns from female passengers [90], roadway safety concerns [19, 92], and privacy concerns [92] among others. Given potential riders' skepticism about high levels of automation, workshops and design artifacts have been used to scope methods for increasing automation acceptance [21] and addressing the needs of riders [33, 60], including women [90] and people with disabilities [84]. In currently deployed low-speed autonomous shuttle pilots, HCI researchers have described how the presence of an attendant is critical for rider acceptance and effective service delivery [91]. Observational studies have also found that attendants on automated shuttles fill a necessary role in ensuring safe mobility even though they do not actively drive the vehicle [24, 91]. Considering these insights and the range of ways full-length bus operators currently serve passengers, Schuß et al. has called for future work on “[t]he role and tasks of the human driver” [90].

While the HCI literature on public transit largely does not describe how bus operators impact service delivery or how new technologies impact operators, there are important exceptions. Pritchard et al. [77–79] focus on the experiences of bus operators with new technologies like passenger-facing transit apps, automated fare payment, and performance management software. Through ethnographic research, they found that services allowing passengers to track bus location “reduced driver autonomy, damaged the driver-passenger relationship and led to the most vulnerable of the passengers becoming stigmatized” [77]. Drivers in their study found themselves having less discretion and reported feeling surveilled by their riders. Pritchard et al. also found that the transition towards paying fares with a card tapped on an electronic reader on London buses helped ease the workload of operators and reduced negative interactions with passengers [78]. However, the transition also produced additional work for bus operators, in the form of assuaging riders worried about not being able to pay with cash. Bus operators were also placed in an ambiguous position of determining if riders without a transit card were “vulnerable” enough to be let on the bus without paying the fare. In another study, Pritchard et al. found a new performance management system increased time pressures on operators leading to work intensification and reduction in meaningful customer service interactions [79]. These examples surface invisible work operators perform and point to how the introduction of new technologies on the bus can produce unintended consequences for not only operators but overall service delivery.

One study has empirically examined the impact of emerging automation on operators [47]. Johansson et al. found that a cohort of Swedish drivers appreciated the use of an automated docking system, which pulls the bus to a docking ramp accurately, and found that it could improve ergonomics and safety. Yet, the docking system presented a tradeoff between greater comfort and slower speed — possibly affecting operator timetabling and inducing increased operator stress. Relatedly, there were also concerns expressed about the process of transitioning from manual driving to the automated docking maneuver. This demonstrates how the affordances of new

technologies must be considered within the parameters of the existing demands on operators. Given the insights from operators when exploring even narrow automation, our work seeks to follow Pritchard et al. in arguing that “there needs to be an *increase in the involvement of drivers in the design of role-transforming technologies*” [77].

3.2 Participatory and Worker-Centered Design

Existing HCI literature on the introduction of automation technologies into service contexts affirms the need for a worker-centered approach [34]. Automation technologies tend to solidify rather than disrupt workplace hierarchies where their use is embedded [34]. HCI scholars have surfaced how the introduction of automation technologies tends to produce new burdens, often in the form of invisible work [96, 97]. In contexts where worker voice is limited or nonexistent in technological development, design, and implementation, workers often find themselves “articulating” the distance between the full range of circumstances they face and technologies built with a more limited range of circumstances in mind [96].

In the mid-twentieth century, when an earlier wave of automation was spreading, participatory design emerged as a framework for enacting workplace democracy. In Scandinavia, where trade unions are strong, participatory design became a way to elevate worker voice in the development of new workplace technologies [14]. In the U.S., participatory design has often been adopted to drive engagement with local communities, yet there have also been applications that align more explicitly with its original worker-centered aim. In the mid-1990s, Blomberg, Suchman, and Trigg [10] describe a collaboration with a law office in which they were contracted to explore possibilities to automate or outsource document coding, thought of by the firm’s leadership as “mindless” work. When attending to the work of document coders and consulting them through collaborative prototyping sessions, the researchers found that it actually entailed a great deal of skilled judgment. Their efforts then turned to challenging reductionist representations of the work to company higher-ups [98].

More recently, Tandon et al. describe efforts to partner with the United Taxi Workers San Diego (UTWSD) in order to build a platform that could directly compete with exploitative TNCs [100]. Over two years, the researchers worked with UTWSD to co-develop a strategy for the development of a worker cooperative and platform, beginning with workshops with drivers and later establishing a funding flow that could support community-driven innovation. This case study directs us to the importance of attending to the market and policy context in which participatory design might be enacted. Cities frequently back tech- and business-friendly modernization initiatives, sometimes at the stake of equity- and safety-centered concerns of workers and marginalized communities [100]. This arguably includes many of the bus automation pilots that have spread across North America [64]. Amidst this context, making visible the labor of frontline transit workers becomes all the more important. Thus, our work aims to understand and learn directly from public transit workers’ experiences and perspectives.

also point to challenges in terms of user acceptance. Summarizing, Dong, DiScenna, and Guerra argue that an “abrupt shift to buses without employees on board [...] will likely alienate many transit users” [22]. They also point to perceptions of decreased safety, particularly among female passengers [22].

4 METHODS

Given that there is little worker voice in the discourse around transit automation, our methodological approach explicitly intervenes to elevate operator perspectives. Our work follows a longstanding tradition of participatory research within HCI, with particular emphasis on movement-aligned scholarship that calls for "redistributing power in the making of technology" [103]. Our research was done as a part of a broader collaboration with two international transit labor unions, the Amalgamated Transit Union (ATU) and the Transport Workers Union of America (TWU), as well as the AFL-CIO Technology Institute. Together, we sought to understand the changing landscape of automation in transit, and ensure frontline workers' voices meaningfully contribute to the design and deployment of new technologies. We began our research by seeking to understand the range of roles bus operators take on, and how existing technologies have affected their work. For this project, we specifically focused on the following research questions:

- (1) What are the full range of tasks and roles that bus operators take on?
- (2) What are bus operators' own perspectives on automation?
- (3) What does a deeper understanding of operators' roles tell us about what automation could mean for bus operators and the communities they serve?

4.1 Recruitment and Details on Interviewees

To understand the experiences of bus operators and the potential impacts of automation on their work, we conducted a series of 7 remote group interviews with 16 currently working operators with valid commercial driver's licenses [35]. In order to recruit active bus operators, we prepared a call for participation and shared our contact information with our international union collaborators, the ATU and TWU. They in turn circulated the call to individual local unions. Recruiting from the unions' members limited participation to North American operators, with all eventual participants being located in the U.S. Participants represented every major region in the country — including the Northeast, Midwest, Pacific Northwest, Southwest, to the Southeast — and drove in a variety of climates and settings including urban, suburban, and rural communities, as well as a university campus. Our participants also represent a range of driving experiences, from a couple of years to a couple of decades with a variety of vehicles. This includes 20 ft shuttles, 40 ft regular sized buses, and 60 ft articulated buses. Operators were also evenly split between men and women. We include a detailed table of information regarding participants below in Figure 1.

Due to the sensitive nature of these interviews, at times covering difficult subject matter through their experiences at work, we did not ask participants to disclose extensive demographic information. We saw it as important to maintain a sense of privacy and respect for participants. We also took active measures to prevent the accounts described in our findings from being traceable to individual operators. For further protection, we used pseudonyms and do not share the cities in which our participants work. Doing so might have increased the risk of disclosure and managerial retaliation.

4.2 Data Collection

Through group discussions, we sought to create opportunities for operators to share openly about their experiences with those who would know best — fellow operators — the depth and complexity of their concerns. These groups mostly included two to three operators and at least one researcher, and lasted between 60 - 90 minutes. One research team member facilitated the interview using a set of slides, with each interview question appearing individually so that interviewees could refer to it while sharing their answers. The facilitator ensured that each participant had the opportunity to speak and asked follow-up questions when relevant. These interviews took place remotely via the video conferencing software Zoom, between January of 2022 and April 2022.

Given these interviews were conducted amid the COVID-19 pandemic, operators reflected on being at the frontlines day in and day out transporting those who did not have the kinds of flexible jobs that might allow them to work from home. This also thrust them into positions of being mask enforcers, which opened up new tensions and made them vulnerable to assault. Furthermore, bringing together operators from different parts of the U.S. allowed them to compare and contrast their experiences; for example, interviewees drew out distinctions between operating across urban, suburban, and rural contexts and within particular geographic regions (with different climates). Over the course of the interview sessions, operators were frequently reminded about particular episodes in their own work based on another interviewee's response or story, thus creating opportunities to build and expand on each others' insights and reflections. Though the interview didn't include questions around assault or harassment, mention of traumatic incidents was emergent across our discussions. When appropriate, we anonymously shared these events with our international union collaborators, who are actively advocating for additional safety measures. Over the past decade, national organizations such as the American Public Transportation Association have begun to recommend courses in conflict management and de-escalation, but this type of training is not standardized in the same way as vehicle operations. We did not collect information explicitly on relevant training.

4.3 Data Analysis

We analyzed the interview transcripts using an inductive and iterative approach guided by contextualized grounded theory [16], between the Summer of 2022 and the Spring of 2023. Through multiple rounds of coding and memoing reviewed weekly, we surfaced initial themes focused on operator identity and technological shifts, passenger needs, road safety, AV concerns, and training. Through subsequent refinements of our interpretations, we elevated and focused on the operators as public servants, as it cut across the vast majority of our initial themes. In the sections that follow, we consider the key role operators play in supporting safety onboard and on the road, and the often under-considered ways they support their communities.

4.4 Positionality

Our academic research team includes members with a diverse set of domain expertise that enriched this project. The authors have backgrounds in human-centered engineering, mechanical engineering,

Table 1: Table of participant information, including group number, pseudonym, region according to the U.S. Census Bureau designated regions, driving setting, and years of experience at time of interview.

Group	Pseudonyms	Region	Setting	Years of Experience
1	Manuel	Pacific	College campus / Small City	12
1	Brianna	Middle Atlantic	Rural	12
2	Catherine	East North Central	Suburban	16
2	James	New England	Suburban	24
2	Mark	South Atlantic	Suburban	10
3	Charles	Middle Atlantic	Urban	16
3	Maya	Middle Atlantic	Urban	16
4	Jose	Pacific	Urban	15
4	Caleb	Pacific	Urban	5
5	David	West North Central	Suburban	21
5	Gabrielle	East North Central	Urban	30
5	Destiny	South Atlantic	Urban	21
6	Danielle	Middle Atlantic	Urban	23
6	Ida	East North Central	Suburban	23
6	Ruth	Pacific	Urban	9
7	Anthony	West South Central	Urban	2

the sociology and anthropology of work, communication studies, computer science, and public policy. More specifically, several authors on this paper have experience conducting research in the domains of transportation automation and/or worker-centered design. One team member also formerly worked as a data scientist at a major transit authority in the U.S., and is a board member of a local public transit advocacy group. The entire team’s experience as regular public transit riders also informs our work. The authors had no financial incentive to conduct this research, and thus have no conflicts of interest to declare.

5 FINDINGS

The bus operators we spoke with largely drive fixed routes, navigating the same roads over the course of the day. During interviews, they often commented that they take pride in being able to drive a full-length bus. “[T]he most exciting thing about my job is driving the bus, actually driving the bus handling that 18 ton vehicle,” Ruth stated. Danielle noted a similar feeling: “I take pride in what I do and I actually love driving.” Despite what may seem routine, across our interviews, bus operators described how they also frequently confront circumstances on the road and inside of the bus that require split-second decision making and emotion work that go beyond driving. In what follows, we describe the roles and responsibilities bus operators take on. We then describe operator experiences with currently deployed technologies and highlight their perspectives on bus automation, which includes potential challenges they foresee and ways they imagine technology augmenting their work. Finally, we voice the perspectives of operators calling for more participatory research and worker-centered design in regard to their roles as operators, technologies used on the bus, and bus automation.

5.1 “Expecting the unexpected”

5.1.1 Contending with Adverse Road Conditions. Bus operators drive in highly variable environments that change across geographic locations and local road conditions. Those we spoke with described facing a range of events from hurricanes and blizzards to flooding and black ice, and reported the need to alter their driving behavior to remain safe. They also recounted being called on to provide emergency shuttle services during disasters, which would entail driving alternate vehicles and routes amid difficult circumstances. Danielle, for instance, described operating a shuttle in the wake of Hurricane Sandy, a weather event in late 2012 that caused heavy flooding in the New York regional area. Beyond weather events, operators, particularly in urban areas, described needing to reroute because of road closures, construction, and major public events. These circumstances may exceed what their dispatchers are aware of at the time, and operators like Danielle described using their knowledge of current on-the-ground conditions to collaboratively reroute the bus. They might try “to tell [dispatch] the detour is not safe,” she further explained. Another operator also emphasized that many residential streets are too narrow for a full-length bus, and that rerouting requires more than knowing the quickest way around an area.

In other instances, bus operators exercise discretion independently and reroute based on emerging conditions on the road. Maya described being “caught in the crossfire between rival gangs” and having to “reverse the bus down the street to try to get myself and my passengers out of a dangerous situation.” Rather than a one-off, she recounted this incident as being endemic to the area. Similarly, Caleb reflected that “everyday we have something unexpected happen.”

Operators also spoke about the variability of pedestrian behavior. Manuel, an operator working on a college campus, stated that,

"I got people jumping out of the bushes, jumping in front of me crossing the street, you know. And so that's completely unexpected. So we have to *expect the unexpected* as part of our driving routine."

David also emphasized that people trying to catch the bus will often run out in front of it. A heavy vehicle such as a bus requires increased time to stop, and thus a heightened attentiveness while driving. Describing school traffic, Charles emphasized the importance of this level of awareness, "you never know when kids get out of school — running not paying attention."

Over time, drivers described learning to intuitively predict what people on the road may do. Caleb described how he saw a child well ahead on the sidewalk and decided to preemptively slow down. This action turned out to be critical, because even though the child was not in the roadway when initially noticed from meters away, they ran into the street just as the bus was approaching, forcing the operator to stop completely. Caleb underscored this demand to be ever watchful to ensure safety. "If you zone out just one second and get out of that driving zone, you could miss something that could be really key and important."

Bus operators also described encountering dense traffic. While Bus Rapid Transit³ operations may utilize designated lanes, more common road infrastructures require sharing road space with passenger vehicles. Bus operators described the difficulties of being on the road with aggressive or distracted drivers. Destiny explained:

"You can be driving and [other drivers] come from the left lane to make a right turn in front of you. Now you have to stop all of a sudden with people on the bus. It becomes very scary because you don't... you never want to hit anyone, and you never want anyone to get hurt."

Several others describe the general lack of regard and even hostility they receive from drivers on the road, especially under conditions of heavy traffic. Reflecting on everyday traffic challenges, David recounted how a car on the highway "just pulls right in front of you and slows down to 35 real quick." He also noted that when bus operators arrive at a stop, they may find it blocked by rideshare drivers waiting for a ride request.

In more rural areas, operators described contending with a different set of challenges. While pedestrians, traffic, and road construction were less prominent, wildlife was an issue. When asked if she encountered unexpected events on her route, Brianna replied,

"Always unexpected. Well, you always have to look out for the bears that decide they want to cross the road, the deer that decide they want to have a parade, the ducks and their babies, and just people."

Rural operators also described how monitoring people on the roadway was not only about accident avoidance, but also about being on the lookout for passengers waiting to board, with some routes lacking consistent street lighting (making it difficult to see those wearing dark clothes) or designated stops.

³Bus rapid transit systems incorporate features such as designated lanes, platforms, and signaling to allow buses to operate more efficiently and reliably similar to light rail.

Additionally, operators described the need to pay attention to what is happening on the road more generally. This included keeping an eye on public safety by scanning the scene outside of the bus and beyond their immediate purview. Jose described leaving the bus temporarily to check on a man who had been sitting in his car in the same spot along their route for hours. This man turned out to have had a stroke and the operator was able to call emergency services and get him the help he needed. Another operator, Destiny, described how a colleague at her agency intervened in an emergency:

"[W]e had an operator... He was traveling and he saw a car going into the canal. And he actually stopped the bus. And he jumped in the canal. It was a sister, a brother, and a baby. And they threw the baby because they couldn't swim. And they just told him to save the baby. But he was so tall, he was able to stand up. And people came to help him on the bank. And he went back in to save the sister and brother."

Bus operators' trained attentiveness to the road — being in "the driving zone," as Caleb put it — enables them to notice circumstances that demand intervention. This may include slowing down preemptively when seeing a child at a crosswalk or actually intervening in an emergency situation outside the vehicle — as these two examples demonstrate. Although we separate out our descriptions of unexpected circumstances on the road and those on the bus, we note that these groupings do not simply map onto bus operators' role as drivers. Rather, interviewees consistently identified as public servants, with agency and discretion to support public safety and serve their communities.

5.1.2 Attending to the Needs of Riders. Beyond responding to events on the road, bus operators also described how they attend to riders' distinct needs. For example, operators spoke about instances where they noticed something was "a little off": an elderly passenger looks down or around in seeming confusion, an anxious child who appears to be alone, or a fleeting expression of desperation. Bus operators described choosing to intervene by offering assistance or even assuming responsibility for the rider's well-being. The following examples make clear how bus operators go beyond their role as driver to actively look out for passengers on the bus. These accounts also clarify the relationship between the crises occurring in communities and the sometimes immense social and relational work bus operators take on. While the individual experiences of each bus operator was singular, across interviews they spoke to a set of shared conditions.

Providing Information. Operators described everyday interactions with passengers that include helping people find their destination, which stop to get off at, and when to transfer to another route. While many local transit apps and navigation services provide route and schedule information, access issues persist. Danielle described how many of her elderly passengers "need help reading the signs." This is also true of passengers with limited English proficiency. Bus operators may act as interpreters or, as Brianna described, communicate with riders through a translation app. Filling in the gaps created by accessibility barriers extends beyond providing route and schedule information. Operators described offering directions

to social services, food pantries, and more generally giving advice on where to get other forms of help. They use their knowledge of the city and situational awareness to direct passengers where they need to go. Reflecting on this role, Catherine explained, "we're like the information and referral source for social services and all those things."

At other times attending to passenger needs means recognizing the bus itself can be a destination. For people experiencing homelessness, the bus can be more than a way to get from one place to another. It can be a space for rest and reprieve from an urban environment that criminalizes their presence in public spaces or extreme weather conditions. Operators may exercise discretion by waiving fare or letting them rest undisturbed — extending compassion and preventing potential conflicts around fare enforcement.

Ensuring Safety. In other circumstances, bus operators may take a more active role in ensuring the safety of passengers in need. This might include helping riders in wheelchairs get securely positioned on the bus, which operators described as an everyday experience. Deciding to intervene may also involve more complicated circumstances and engage a skilled capacity for social judgments which often builds off years of experience. David recalled a particular incident where he felt compelled to subtly intervene — even when the constraints of bus operation make intervention complex or potentially dangerous:

"I noticed a young girl sitting next to a man, and she looks absolutely terrified. And tears are coming down her face. And I'm looking at that, and I asked her if everything's all right. And she just kind of, you know eyes got real big, didn't say anything. And the guy next was like, 'Oh, she's my cousin.' He was drunk... it just didn't sit right with me. So I said, 'Why don't you come up and sit next to me?' So the young lady got up, sat down next to me. And she whispered to me, she says, 'Please, please don't let that guy get off the same stop.'"

And not letting the man off at the same stop is exactly what he did. The girl went to the front door and her "cousin" to the back. He opened the front but not the back, letting the girl off without him. "We continued about a good eight blocks, and he's yelling and screaming, 'I'm going to kill you...'" David described feeling deeply moved by this incident, proud of how he was able to protect a child in need, even if it meant putting himself at risk. David and other operators later noted a dynamic where other riders may have recognized that something was wrong, but did not feel empowered or responsible to act.

Gabrielle related another striking incident of taking responsibility for passengers' well-being. She described starting out one morning at 4am in the bitter cold. Snow and ice were on the ground, yet an older woman was waiting for the bus without a coat. Gabrielle found herself worrying about the woman and eventually approached her to find out if there was something wrong. Gabrielle learned she was traveling to a medical center that would not open for hours. So, instead of leaving this passenger "out in the cold", Gabrielle took her to the transit center to wait and stay warm — even though it was not yet open to the general public. She then helped her senior passenger get situated and determine which bus to take to arrive

when the center opened. Gabrielle, like David, took responsibility for the passenger's well-being after noticing something not quite right. Moreover, it was their capacity as drivers, as operators of the vehicle specifically, that enabled them to intervene in the way they did. For David, this meant using discretion to selectively open passenger doors and for Gabrielle this meant deviating from her route to stop by the transit center and provide access to shelter.

Operators described other instances of using their discretion as drivers to intervene for passengers. Several bus operators describe coming to the end of their route and still finding passengers in the back seats. This included people who had sought out refuge on the bus, as well as others who were lost and disoriented. Danielle, for instance, came to the end of her route and found a child in a seat in the far back. He was on his way to school but the stop had long passed. Danielle decided, instead of waiting for the police to show up, to "detour from my route and take him to school." This example is one of many where operators will go above and beyond their required job responsibilities to assist riders. The unexpected circumstances bus operators describe on the bus at times both exceed and confound the understanding of bus operators only as drivers.

Intervention During Medical Emergencies. Our participants gave accounts of assisting riders who are experiencing medical emergencies. As Gabrielle recounted, "we've had people who are just drunk or so drunk that you can't rouse them at the end of the line. And actually, we've had a few people that you stopped the bus and you tried to go to get them off and they were just actually dead." Strokes, heart attacks, seizures, and people collapsing seemingly without reason were remarked on by most operators in our study. When they could, operators described reacting proactively to assist those in need. Jose described taking initiative to call emergency services on his personal phone and waiting with a passenger — even though protocol merely required notifying his transit dispatch. Ruth went a step further and, with the assent of other riders, drove the bus directly to the emergency department of a local hospital.

Medical emergencies may also include drug overdoses, which can create disruptive social effects on the bus. Operators described being watchful for riders who are not quite "with it," both in order to offer emergency assistance and to ensure other passengers feel safe and comfortable. Catherine described how operators in her transit agency "carry Narcan," which is an emergency medical treatment for opioid overdose that often needs to be injected — echoing Varian's experience that opened this paper.

Role During COVID-19. The pandemic brought about new challenges for bus operators. There was the threat of being infected with the virus, but operators also described new challenges arising from a broader public health context where the social fabric of urban areas, in particular, seemed to be fraying. James noted, "there's definitely a change out there. Not only from the passengers but even our own members, you know. This has taken a toll on them. These last couple of years have been really trying."

Bus operators cited rising rates of violent crime, opioid abuse, unsheltered homelessness, a mental health crisis, and a pervasive sense of social atomization. These challenges were worsened by conditions of a pandemic lockdown, diminished access to in-person services, and a generalized sense of anxiety built on long-term

disinvestment from low-income communities. As public servants with years, even decades, of experience out in communities, day in and day out, they felt those changes and absorbed their impact. Bus operators describe de-escalating tension, soothing and calming upset passengers, and maintaining safety in the bus.

Bus operators experienced these public health challenges by being on the receiving end of fear, anger, and vitriol. Many operators describe having been victims of assault, verbal abuse, and even theft from riders, who are often clearly unwell. This is, in part, because bus operators often must take on an enforcement role for fare collection. This can lead to volatile situations and escalate tensions. Even more mundane interactions with passengers, such as offering a morning's greeting, can lead to escalating conflict. Caleb reported one such situation:

"Just recently, I had an unexpected assault. There was nothing I could do. This person got on, he was having a bad day. He had just recently gotten out of jail. He was held overnight. He was still inebriated. And I said good morning to this guy. And I guess that might have made him mad, and he began to attack me."

From his own telling of the incident, Caleb suggested that incarceration had destabilized this man. This example elucidates the visceral way bus operators are on the front lines of social and public health crises. Brianna stated that experiencing assault is a product of her hypervisibility at the front of the bus and the social dynamic that shapes how she is perceived. Gender played a role here in shaping her vulnerability. Maya described experiencing sexual harassment and assault on the job. She remarked, "As a young woman... there's literally no protection for you." She suggested her experiences were so common they were almost unremarkable.

In response to increased incidents of violence and the threat of contagion from COVID-19, transit agencies have put up plastic curtains and plexiglass barriers. This physical separation from passengers has been met with a mixed response with some welcoming additional protections and others ambivalent about the effect they have had on reducing interactions with passengers. While operators express concern and care for riders, they are also made vulnerable by them. Navigating being a "public servant" is troubled by the conditions of need and violence described above. At the same time, it is a core locus of many bus operators' sense of meaning and dignity. "We are the unsung heroes," Danielle explained. The crises described in this section have made this role more fraught while also attenuating its urgency.

5.2 Views on Increased Technological Adoption

In thinking about future automation technologies, we looked to understand how operators experienced other technologies implemented on the bus. The accounts bus operators gave of current technological adoption include many examples of technologies working well to service them and their riders. However, other instances point to pervasive problems due to not accounting for the nuances and particularities of their work, their vulnerability vis-à-vis passengers, and all too frequent occurrences of mechanical failure and breakdown. Along with the experiences described above, these accounts inform operator perspectives on autonomous driving systems in bus transit.

5.2.1 Current Passenger Facing Technologies. Many passenger-facing technologies are core features of bus operations that directly impact the workload of bus operators. For example, transit or navigation apps provide passengers with information about routes, schedules, and bus location, and reduce the need for operators to provide route assistance to passengers while driving. Automated announcement systems also reduce the need for operators to balance making passengers aware of stops while driving. As we previously detailed, accessibility is a significant barrier to users who may be elderly, disabled, lack access to mobile devices, and/or have limited English proficiency. Even with these assistive apps, operators still find themselves providing directions and information on routes. In many cities, transit apps do more than provide information by controlling fare payment. Accessibility issues extend here too and also directly affect operators. These apps may be launched without first consulting, training, or even informing bus operators. David described what happened when his transit agency transitioned away from having transfer cards and towards using a QR code on the transit app. He recounted the "fiasco" that ensued when bus operators had no way of reading the QR codes:

"It all could have been avoided if they had talked to the operators and asked us our opinion on the technology and what problems that could arise from this new technology. That way, we could work all the bugs out and launch it with no issues and be all on the same page"

Even when these applications work as intended, there can be other challenges. Apps designed for passengers often track the precise GPS location of bus operators and include concurrent information about ridership levels. Brianna expressed feeling vulnerable because passengers know when she is alone on the bus.

"For riders to know and have the app and know that I'm coming. Maybe they don't like me. And for whatever reason. The man that always tries to rap to me, but I'm not interested. You know, they're sitting there waiting. 'Oh, she's alone on the bus?' I don't like that part of the app. I really don't."

For bus operators at risk of assault, these privacy concerns are direct and immediate. Yet, the app Brianna describes and others like it are clearly not designed with these concerns in mind.

Many of these technologies are part of baseline operations. This includes display screens that indicate what route the bus is running. On some buses, there are sensors that automatically open doors or register fare cards. The more these technologies are essential for day-to-day operations the greater the impact is when something goes wrong. Gabrielle reflected on what happens when the display screens malfunction, "all day long all you get is, 'What bus is this?' 'Is this so and so?' Or God forbid, it says out of service... Everybody has to tell you. That's where technology, when it's bad, it's horrible."

The introduction of new technologies creates new opportunities for malfunction with direct impacts on operators. They spend more time troubleshooting and managing instances of breakdown. Gabrielle described how handling these situations involves taking on additional customer service roles in clarifying information and de-escalating tense situations. Issues around fare are frequent epicenters of friction. David describes bracing himself that "it doesn't

cause any assaults to occur because some people get wild over a \$1.25 fare.” When other technologies malfunction the bus itself may stop functioning. Brianna relayed an experience where a computer malfunction led to a wheelchair lift getting stuck “and it wouldn’t let the bus move.”

Onboard surveillance cameras are often installed to enhance safety and monitor bus operators. David reflected “sometimes it’s irritating to have big brother watching you all the time” and described specific instances where surveillance was used to reprimand colleagues for snagging a bite to eat. But, ultimately, he and other operators were glad to have visibility on the bus given the range of challenges they confront around passenger safety. Similarly, panic buttons in the driver cabin that alert dispatch and emergency services and can be used to discreetly call for help.

5.2.2 Emergent ADAS Features. Advanced driver-assistance systems (ADAS) are becoming increasingly common in transit buses and the operators we spoke with had mixed feelings about such technologies. Catherine expressed a belief in the strong potential of ADAS features to enhance safety. Several operators who had used ADAS had positive experiences with features such as blind spot monitoring and pedestrian warning systems. Some spoke about how they had similar technologies in their personal vehicles, and would appreciate them on the bus as well. Yet, bus operators also expressed wariness about how ADAS features tend to work in practice. For example, lane departure warning (LDWs) and other vehicle alert systems fail to function as intended if not calibrated correctly. Gabrielle contrasted the pedestrian alert system on her bus with an ADAS lane assist feature that impaired rather than enhanced her driving.

“[T]hey’re making our lanes more narrow... then they put these bike lanes to the right on both sides... And so lane assist in those situations... It’s very annoying unless you ride the line more and more so then you don’t have to constantly hear the beeping.”

As Gabrielle highlights, applying ADAS features that are likely designed with the assumption of personal vehicles may fail when applied without extensive testing to full sized buses. Driving lanes in dense urban areas are often narrow and buses may be oversized. It is also notable that in this instance a lane assist feature actually encouraged less safe driving practices. David described worrying that auditory alerts may “be a safety issue because the moment you’re hearing that beep you’re drawing your attention to where that noise is coming from and maybe that split second that you lost your attention to what you were doing, something happens.”

Operators also noted that ADAS may include features that actively track and surveil them. As mentioned previously, there are often cameras and GPS tracking. Cameras may face both the interior and exterior of the vehicle to simultaneously monitor driving and operator performance. Jose described how the camera turns on and sends a video to their manager whenever sensors notice indicators of unsafe driving. He noted consequential errors when his behavior was falsely reported: “if it senses that you’re on the phone but actually just scratching your head, it will activate.”

When GPS tracking is utilized for ADAS, it is also likely to be used for performance management. Destiny described how her agency implemented a tracking system displaying green, yellow,

and red indicators compelling operators to keep to the route schedule. For her, it was “a plus” and helped her stay on top of the route. This was largely, but not wholly echoed by other operators. David related that “it can be kind of a nuisance. Especially, you know, there are times where you’re like, ‘Man, I don’t get a break. I’m out here for eight hours.’” In that context, a performance management system can intensify work and decrease recovery time. The issues with currently deployed technologies described here reflect a context where operators face mounting pressures and often have little say over the conditions of their work.

5.2.3 Operator Perspectives on Highly Automated Futures. Not surprisingly, given this reflection on the shortfalls of current systems, operators in our study were skeptical about a more highly automated future of transit. In asking operators to reflect on the potential for driverless buses they challenged both technical feasibility and the impact on passengers. Imagining an automated system handling the full range of circumstances they experience while operating a bus seemed all but impossible.

Based on their experiences of contending with unexpected circumstances, bus operators pointed to specific scenarios that would present challenges for an AV system. For example, James wondered if “someone blows through the intersection, is it gonna be able to react quick enough to something like that? Is it going to be able to see far enough ahead?” Operators expressed disbelief that an automated system could contend with the range of road conditions they experience, and also concern about public safety issues that could result from their deployment. This included reflecting on their own ability to exercise discretion to avoid or intervene in dangerous situations. Operators emphasized that even those who normally run a fixed route will occasionally need to deviate on the spot or collaboratively work with their dispatch to reroute. Participants in our study wondered how AV systems could possibly exercise discretion under these circumstances.

Other concerns raised include liability and risks of mechanical failure. Catherine suggested that there are “increased liabilities for the agencies because who’s responsible if these technologies fail? Am I responsible? Is the operator or is the agency responsible? Is the company who made the product responsible if it’s a faulty sensor?” Recalling her own experience watching an autonomous shuttle bus accident, Ida stated plainly, “I would never get in a driverless vehicle.”

With regard to the potential impact of bus automation on passengers, operators here too found the idea of high levels of automation both amusing and disturbing. There was also anger and frustration. Gabrielle described how with automation, “you lose the human factor,” which ranges from the lack of a morning greeting to the reduction of nuance around fare payment to the lack of a safety monitor. Operators suggested that the experience of riding the bus, in general, would become less humane.

The impact of reduced human engagement would be most severe for those in need of care. Reflecting on her critical role in providing customer service, Brianna pointed to the example of a regular rider with Tourette Syndrome “who just starts cursing and carrying on. Who’s gonna tell him to calm down? Take a deep breath. Did you take your medicine? And direct him into a different train of thinking

so he could stop cursing, for no apparent reason? Who's gonna do that?"

Operators suggested the bus may become less accessible for people with disabilities and other riders whose needs they service. "We have a lot of wheelchair people that get on the bus or [people with] walkers... Who's going to hook these people in," Brianna questioned. Operators also expressed doubts about AV systems' capability to discern subtle social cues essential for timely intervention in critical moments of need. As in the incident where David helped a girl get away from a seemingly dangerous man, "an autonomous vehicle wouldn't be able to pick up on the body language of that child." Gabrielle emphasized, "there are always things that we as human drivers see that an autonomous bus could not."

Others suggested that removing the bus operator could lead to a general deterioration of conditions, worsening safety on the bus. The work bus operators do to maintain safety might be as ordinary as ensuring packages do not cause a tripping hazard. Maya reflected:

"I don't know that an autonomous vehicle would be able to say to a person 'Hey, can you put the brakes on the stroller so the baby doesn't fall out?' 'Miss, can you take your grocery cart and put it to your side? So that people can walk past?' Canes, crutches, walkers, wheelchairs, you name it, all of those things, like I said, can clutter the aiseways where people have to be able to walk freely without causing harm to themselves or other people."

Operators also spoke about how their presence can be a deterrent to more severe safety issues. Brianna argued that the presence of bus operators may deter theft, vandalism, and assault. Similarly, Ida posed the question, "with a driverless bus how are you going to help the passengers if a fight breaks out?"

At the conclusion of one of our group interviews Danielle, Ida, and Ruth concurred that what is really needed is for the people designing new technologies to take the expertise and professionalism of bus operators seriously. This conversation echoed other operators in our study, like David, who called for "talking to operators first when introducing new technologies." Danielle invited technologists to "come take a walk in our shoes" and Ida reminded us that bus operators have many roles, truly "wear[ing] many hats" on the job. They argued that knowledge about their day-to-day experience can be the foundation of mutual understanding and respect. From the vantage point of bus operators, this is the necessary starting point. Danielle made clear that with the introduction of new automation technologies, bus operators need to be trained and consulted from the very beginning. As Ida put it, "The bus is nothing without us."

6 DISCUSSION

Our interviews with operators reveal the many roles and responsibilities operators take beyond typical operations. Through these accounts operators spoke to potential impacts of automation. We now turn to a discussion these findings through the framing of shock absorption to elucidate the socio-technical impacts of transit automation. We then outline the path towards a more just future of transit, following calls from operators for more worker participation.

6.1 Bus Operators as *Shock Absorbers*

6.1.1 Absorbing Crisis on the Bus and in Communities. Our findings detail some of the everyday and extraordinary ways operators look out for riders. In communities where social care and support are artificially scarce, we argue that bus operators have taken on the structural function of shock absorbers. Urban studies and political science scholars in the U.K. have described how frontline government workers absorb the impact of a retreating welfare state and austerity politics [44]. They describe how librarians and social workers not only resist and adapt but take on additional support and service roles. Our findings suggest that bus operators may serve a similar role in their communities. Examples from our interviews include Gabrielle's intervention to make sure a passenger was not "out in the cold," Brianna's attention and care for a passenger with Tourette Syndrome having an episode, and David proactively looking out for passenger well-being and the potential vulnerability of a child. Hastings and Gannon also indicate that absorption implies bearing the brunt of unmet need and suffering. These experiences have become all too common for bus operators as well [101]. Our interviewees, including Caleb, Brianna, and Maya, spoke about personal experiences of being attacked by disturbed passengers and experiencing harassment.

In the U.S., bus operators are on the frontline of crises that are inherently social and political. While intensified by the pandemic, challenges around homelessness, mental illness, and poverty have been decades in the making. During what has come to be known as the neoliberal era, we have seen the expansion of policies that encourage cutting back on social services, disempowering workers, and privatization of public goods [26, 43, 102]. This includes increased pressure on transit unions and their members—as cities demand greater efficiency and, in the wake of crises like the 2008 financial crash and the COVID-19 pandemic, cut funding [32, 101]. At the same, we have seen the rise of over-policing, mass incarceration, and the criminalization of homelessness in the midst of rising housing costs and stagnating wages for those not at the top of the income distribution [38, 70].

In this context, moving towards a driverless future can be seen as a step further towards disempowering workers and constricting public services. Operators themselves underscore how a driverless bus would not only be less human but less humane—expressing concern about what would happen to riders experiencing emergencies and those with complex accessibility needs. They also fear a more general deterioration of conditions on the bus, which resonates with concerns from riders [22]. We'll note here again that in many of the examples we describe where operators assist passengers in need they do so through their driving role and that their ability to help passengers is tied to their control of the vehicle. Think of Ruth choosing to go off route or David controlling when doors open and close. Realizing a driverless future would be a shock that would leave others, including those in crisis, picking up the burden of absorption.

6.1.2 Absorbing the Impact of Partial Automation. Our findings suggest that problems presented by unexpected circumstances operators contend with on the road are intractable for even more advanced autonomous driving systems [62]. This is something that operators readily describe through their own experiences, such as

a child stumbling onto the road or bullets flying. This also includes more everyday situations that sometimes require driver discretion, such as deciding when to stop and open the doors. We also highlight examples of when bus operators need to be able to deviate from fixed routes, in order to go around an accident or, in extraordinary circumstances, take a passenger to a nearby ER. These are clear examples of where the driving role that bus operators take on is critical to safety and ensuring the well-being of passengers. Given these realities of bus transit, we argue that the paradigm for automation dominant in contexts like passenger vehicles — to remove the driver entirely — is not adequate. Instead, a model of continuous driver engagement would lead to safer and less burdensome outcomes than an intermittent approach [23, 62, 75, 87].

Yet, there are potential harms from more limited automation systems too, even those intended to enhance safety. While operators in our study were excited about new tools that can improve safety, they also described technologies that were ill-suited for the realities of their work. Distance from the experiences of operators encourages an overly rationalized understanding of the circumstances they contend with [98]. This makes it all the more likely that automation systems produce hidden, potentially severe, impacts on operators. We argue that frontline workers absorb the impact of not only the social consequences of austerity and neoliberalism [44] but also automation designed in that context.

Work Intensification and Roadway Safety Harms. In a model of intermittent driver engagement, operators would intervene when systems fail or reach their limits given road conditions. Prior literature suggests having an intense “hand-off” may actually be harder than driving the bus continuously [72, 87], which resonates with concerns raised by Johansson et al. in their study of operator experiences with an automated docking system [47]. These burdens are a form of work intensification and shock absorption — worsening job quality for operators. If a system suddenly fails, it is the driver who becomes responsible for averting disaster. This was what happened when Uber’s self-driving car killed a pedestrian [94]. In our findings, we describe how operators are aware that if they “zone out for just one second,” they could easily have an accident. Relatedly, operators raised concerns about “increased liability.” Workers may end up taking the fall for imperfect automation when something goes wrong [25].

In the near term, integrating warning and detection systems could produce distraction, and increase the cognitive burden of driving. For example, we describe Gabrielle’s experience with a hypersensitive lane departure warning system that encouraged unsafe driving in our findings. This experience and others like it suggest a need to ensure safety systems are designed alongside operators. These concerns resonate with existing HCI literature on the impact of new transit technologies on bus operators. Recall Pritchard et al.’s work [77–79] on how seemingly more basic technologies such as automated fare collection, passenger facing transit apps, and performance management systems produce wide ranging and unexpected impacts on both bus operators and service delivery. For example, increasing time pressure, even in small ways, affects how operators interact with passengers. These findings, as well as those from Johansson et al. [47], indicate that the organizational

context in which the use of new technologies are embedded deeply matters.

Workplace Surveillance and Managerial Control. In a context where technologies are introduced onto the bus without meaningful participation from operators, it is no surprise that some of these tools are used to surveil and discipline them. In our findings, we detail how bus operators are already monitored regularly. Brianna described concerns about surveillance from passenger facing transit apps. Others detailed surveillance by management using GPS tracking and cameras. We describe how this can create the sense, as David described, that “big brother [is] watching.” Operators also described the upsides to visibility in being able to make sure an incident will not be misconstrued or have someone watching in the event of a safety concern. The salience of the framing of harmful surveillance as opposed to helpful monitoring though is largely due to organizational context, where operators may already lack adequate support and respect.

It is therefore concerning that with the introduction of more ADAS we might see an increase in the surveillance of operators. The technical infrastructure of many ADAS systems require additional sensors and visual data capture. Alongside novel ADAS systems we could see more intense surveillance of operators directly. Karen Levy has described how this dynamic has unfolded in long-haul trucking, producing tactics of resistance and subversion among drivers [52]. Without worker voice, automation technologies could end up not only inducing new burdens but heightening workplace power imbalances.

6.2 Toward a More Just Future of Transit

Given these potential harms from both high and lower levels of automation, it is important that HCI researchers and practitioners do not simply encourage adoption, without the voices of workers. Rather, our work suggests opportunities to help advance a more just future of transit. This includes treating operators and their communities not as bystanders to technological adoption but as core users who should have agency in the design and implementation process.

Bus transit is a workplace context where participatory design is needed. We suggest that bus automation should be collaboratively designed with operators and premised on integrated human-machine teaming. There are lessons to be learned from aviation where automation has not only improved safety but improved job quality for pilots [15]. Over time, commercial pilots have become more highly trained and their expertise has been taken seriously in the design of human-machine teams. We argue that bus operators should also be treated like the skilled professionals they are and involved early in the development of emerging technology for transit. This paper lays some of the groundwork for this future work by scoping operator experiences with technologies on the bus and gauging perceptions of automation. But there is more work needed to facilitate operator participation [78]. This includes more detailed empirical work on the roles and task structure of bus operators as well as the current conditions they face, alongside design-focused engagements such as workshops.

Centering workers will also mean expanding beyond technical interventions, toward operational and policy changes as well. For

example, implementing designated lanes helps ensure safe and efficient bus transit and automated fare collection is known to help reduce potential confrontation and assault [77]. Route design and scheduling should also support bus operators to access breaks, avoid strain, and drive under safe conditions. Given our findings about how bus operators absorb the impact of crisis, meaningful support for these service roles is necessary. This might include more trained professionals available to address immediate needs, while also pushing for municipalities to address the root causes of the crises bus operators confront on a daily basis. All of these interventions stand to improve service delivery and aid riders.

We follow Whitney et al. in advocating for design and research “from below” with communities [103]. Through this process we might expand whose voices are heard and matter in the design of public transit. Rider advocacy groups already work collaboratively with union partners to protect public transit. Our findings demonstrate what these community groups already know, that dignity for operators is entangled with that for riders [105]. It is no surprise then that operators and their unions have long joined riders in demanding equitable fares, fighting service cuts, and arguing for the expansion of critical transit infrastructure [2, 4]. We therefore call for HCI researchers and practitioners to act in solidarity with both operators and riders as public transit faces new challenges. In doing so we can help build a more just future of transit.

7 LIMITATIONS

Our study was designed to survey the range of roles and unexpected circumstances bus operators contend with. We therefore sought to speak with operators from diverse backgrounds and geographic contexts. This approach has some limitations in terms of the representativeness and depth of our research findings. Future work might address these shortcomings by including more operators and using more ethnographically oriented methods, in order to more fully speak to the context of bus operator experiences.

The accounts and experiences we present are also inherently one-sided, from a frontline worker perspective. As we describe throughout the paper, operators have an interest in avoiding autonomous systems that might harm them (either through labor displacement or intensification). Though they offer a particularly critical point of view, operators’ perspectives are largely absent from the HCI literature and the broader discourse, which has so far focused on the attitudes of prospective passengers and highlighted positive aspects of transit automation. Our paper is an attempt to rebalance the dialogue around transit automation, such that those who are poised to be most impacted have a say in this proposed future.

8 CONCLUSION

Our work expands the range of concerns for automation in public transit by elevating the voices of transit workers and making visible their labor. We describe the range and breadth of circumstances bus operators contend with on the road, which presents serious challenges to a driverless future. On the bus, we find that bus operators take on the relatively invisible and undervalued work to care for communities in crisis. We use the concept of shock absorption to explain how bus operators are responding to layered

crises of homelessness, substance abuse, mental illness, and poverty in the U.S. We pose the question through the accounts of operations: who would take on the burden of absorption if bus operators are displaced? Given these findings, we argue for broadening the range of concerns considered by researchers and designers to include social and political harms. We then describe potential harms to operators with the near-term integration of autonomous driving systems. We expand the concept of shock absorption to describe these harms that may result from positioning operators as fail-safes for imperfect automation. We then identify opportunities for collaborative human-machine teaming that could enhance safety and dignity. We call for HCI researchers and practitioners to involve bus operators through participatory design to advance a more just future of transit for all.

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