Will Automated Vehicles Solve the Truck Driver Shortages? Perspectives from the Trucking Industry

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Abstract

The United States (U.S.) has experienced persistent truck driver shortages for the past several decades, as demand for truckers has increased while individuals willing to fill driving jobs have decreased. Studies in the transportation literature have not examined industry views on driver shortages, which are expected to become more severe, in combination with trucking industry perspectives on the impact of automated vehicles (AVs) on driving jobs. This study addresses these knowledge gaps through focus groups with trucking industry participants (N = 67) working in three organizational levels (25 upper-level management or owners, 20 supervisors or dispatchers, and 22 drivers) and a supplemental online survey. Using an inductive thematic analysis approach, findings indicate that companies struggle to address driver shortages because of difficulties recruiting younger workers related to quality-of-life issues, job requirements, and low rates of pay. AVs were thought to be a potential solution to the driver shortage, although there will be a continued need for drivers to perform certain tasks. The potential changes in industry positions could attract new workers but would require older workers to adapt to using new technology. From a workforce development perspective, training programs targeting technicians and drivers can help prepare the trucking workforce for an autonomous future.

Keywords: Truck drivers; Trucking industry; Driver shortages; Automated vehicles; Focus groups

1. Introduction

Trucking is one of the most important industries in the United States (U.S.). In 2020, the U.S. trucking industry transported about 10.2 billion tons of freight across the country, representing 72.5% of the total domestic tonnage with an estimated value of over $732 billion (*1*). Much of this is due to a truck's ability to complete the "last mile" delivery of products, as other modes of shipping such as rail and water lack the infrastructure needed to reach necessary distribution centers and end product locations (*2*). The importance of the trucking industry is further highlighted by its position as a major employer in the U.S. In 2020, the trucking industry employed 7.65 million Americans, or about 5.8% of the entire country's workforce (*3*); 3.36 million employed in the industry are truck drivers (*1*).

Unfortunately, persistent truck driver shortages continue to plague the trucking industry, making it a critical issue in the industry (*4*). In 2021 the number of unfilled truck driving positions in the U.S. industry was estimated to be around 80,000 and is expected to reach 160,000 by 2030 (*5*). Truck-based freight demand is expected to increase rapidly due to the growth of e-commerce (*2*), which may further exacerbate driver shortages in coming years. Several attempts have been made to reduce the driver shortage and mitigate its negative effects on the economy. For example, the federal government recently released a plan to address the shortage by creating advisory boards and task forces commissioned to develop apprenticeship programs to train and produce qualified drivers (*6*). This plan includes speeding up the process of issuing commercial driver's licenses, expanding apprenticeship programs with industry partners, and connecting veterans to truck driving career pathways (*7*). Trucking companies have also attempted to make the driving occupation more appealing through increased benefits and pay (*8*); however, the average heavy and tractor-trailer truck driver's pay ($53,090) still falls short of the national average for all occupations ($61,900) (*9*). There have also been calls for amending the minimum age requirement standards which would lower the minimum age requirement of 21 years to 18 years for interstate driving (*10*). This has been met with some success, as apprenticeship pilot programs have begun to be implemented with younger drivers (18-20 years) in preparation for such regulatory changes (*11*). Ironically, some efforts to improve drivers' working conditions may have exacerbated the shortage. For example, the Hours-of-Service regulation, which limits the amount of time that drivers may spend behind the wheel, has been criticized for limiting driver productivity and worsening the driver shortage (*2*).

Given recent advances in automated vehicle (AV) technologies, several public and industry stakeholders seek to leverage them in the trucking industry to alleviate driver shortages, reduce operating costs, and increase safety (*12–15*). However, most existing research related to AVs and the U.S. trucking industry has focused on their expected adoption timeline, workforce impacts, or economic benefits based on industry expert interviews or scenario analysis (*16–18*). Some studies have investigated the trucking industry workers' perceptions of AVs and their impacts on the trucking industry in a non-U.S. context (*14*, *19*). However, the introduction of AVs in the U.S. may be more tumultuous for trucking companies and drivers, compared to other countries, due to the size of the country (*19*) and weaker social safety net (*20*). In this context, we examine the perceptions of U.S. trucking industry workers at three organizational levels (i.e., upper-level management, supervisors or dispatchers, and drivers) to understand the potential impacts of AVs on the driver shortage.

2. Background

2.1.Truck Driver Shortages

Truck driver shortages have been cited as one of the major problems in freight and logistics (*21*, *22*). Research about the trucking industry highlights several factors behind the driver shortage problem including job demands, challenging working conditions, and health-related concerns (*23*, *24*). One of these factors is the inability to attract younger workers, which means the trucking workforce is aging. The median truck driver is 46 years old (*25*), and the proportion of drivers who are 65 years-old or older is growing (*26*). Younger workers may be less interested in becoming drivers because of the more intensive physical and psychological job demands of truck driving (*27*) and greater prevalence of alternative career options (e.g., construction) (*28*). At the same time, trucking companies often prefer to hire drivers with more than two years of driving experience to meet safety concerns and insurance requirements (*28*), which could dissuade younger workers from pursuing truck driving as a career. Additionally, truck driving is male-dominated, with women representing only 6.6% of the driver population (*28*). Entrenched masculinity within the trucking industry may serve as a deterrent for women to enter driving jobs (*29*). Women seem to view the profession as a short-term opportunity and fear sexism, as well as potential harassment and assault in the workplace (*30*). Although recruitment strategies focused on female and minority populations have been discussed (*31*), thus far, there is a lack of progress in broadening participation to combat the driver shortage.

Lifestyle issues are often referenced as a reason why drivers may wish to transition into a different occupation (*5*, *28*). Truck driving is a physically and mentally demanding occupation (*32*). Drivers' work hours are often irregular, making it more difficult for them to engage in healthy behaviors such as exercising and eating nutritional meals (*33*). Many new drivers are often assigned atypical work schedules that may require that they spend long amounts of time away from their home and social network (*28*). This social isolation may lead to negative health effects, including feelings of loneliness, depression, and anxiety (*34*). Lack of respect for the occupation and poor treatment by shipping and receiving staff can compound work stress (*35*, *36*). There are several safety risks involved in truck driving (*37*), such as inclement weather, poor road conditions, driving hazards, and the potential of experiencing violence that may further impair driver well-being (*36*). Drivers who are fatigued or suffering from poor mental health are at a higher risk of being involved in a traffic accident (*38*). Yet despite these stresses, 80% of truck-car accidents are caused by car drivers (*39*) and compared to passenger vehicles drivers, truck drivers have a lower rate per mile traveled of crashes (*40*).

Adequate compensation has also been a long-standing issue within the trucking industry, especially considering the lack of pay for non-driving hours (*41*). While the average hourly wage for heavy-duty truck and trailer drivers appears high $25.52 (*9*), it does not account for uncompensated work, delays or detention times, or overtime compensation, since the Fair Labor Standards Act exempts employers from having to pay drivers overtime (*42*). However, pay is not the only factor behind the persistent driver shortage (*43*), as "driver churning" (i.e., drivers moving from one company to another without a pay increase) accounted for almost 80% of the driver shortage problem in the U.S. (*44*). Instead, drivers may turnover to gain better working conditions

(*45*) or when it becomes clear that management purposefully misled them about their role requirements (*46*).

In addition to the day-to-day work-related stresses that truck drivers contend with, they also have had to adapt to several changes that have affected the trucking industry. One of these notable changes is a shift in manufacturing away from practices that involved holding large inventories to practices related to "just-in-time inventory," which helps manufacturers reduce inventory costs by getting supplies transported on demand (*47, 48*). This shift places more demand on truck drivers to deliver inputs to meet fluctuating consumer demand.

The recent growth in the e-commerce sector further changed the paradigm for supply chain management with the creation of more, near-to-destination distribution centers as opposed to spread out, giant inventory management areas (*49*). These supply chain transitions not only increased the demand for truck drivers, but also changed their responsibilities in terms of how far and how frequently goods are delivered. Another technological change that negatively impacted drivers is the implementation of mandated electronic logging for drivers to accurately track hours of service and shipments (*50*). This change led to a decrease in driver salaries and more reckless driving behavior to complete deliveries on time, especially for perishable goods (*51*). Further, several large motor carriers are partnering with retailers to offer value-added services for customers on their deliveries (e.g., installation of home appliances). These partnerships require more training for drivers to navigate residential neighborhoods and provide service to customers (*52*).

Federal regulations also played an important role in exacerbating the truck driver shortage. Over the last two decades, regulations enacted that were intended to provide safeguards for overworked truck drivers yielded unintended consequences for drivers. For example, the federal Hours-of-Service (HOS) regulation limits the maximum number of driving hours (60 hours/7 days or 70 hours/8 days) with a 34-hour rest period. This law means truck drivers are off-duty for 10 hours each day (*53*). Although, drivers have the option to split the 10-hour off duty, either as an 8/2 or 7/3, with neither counting against the 14-hour driving window (*53*). Importantly, these off-duty time splits can result in inconsistent driving hours that do not account for drivers' circadian rhythms and can lead to increased levels of emotional and physical exhaustion (*54*). In 2020, the HOS regulations were amended to require a 30-minute break after eight total hours of driving time (including time on-duty, but not driving) (*55*). While the HOS regulation could reduce the number of fatigue-related crashes (*56*), an unintended consequence of the regulation is the intense time pressure drivers feel to complete their job in a shorter amount of time, leading to stress and emotional exhaustion (*57*).

The COVID-19 pandemic greatly impacted the trucking industry and in many ways, exacerbated truck driver shortages (*58, 59*). In the early days of the pandemic, trucking companies changed their business models to transport different types of goods, based on consumer demand, or to avoid additional costs (*60*). Many drivers also left the workforce at this time. From May 2020 through December 2020, nearly 13% of workers in the U.S. trucking industry were unable to work due to COVID-19 (*61*). Those workers that remained in the trucking industry reported unprecedented hardships throughout 2020 and into 2021 (*60*). On top of the risk of contracting the virus, drivers had issues accessing receiving facilities and struggled to fulfill basic needs (e.g., showers and meals) while on the road (*60*). Team driving, where two drivers cooperatively operate

a vehicle, significantly declined as a result of the COVID-19 pandemic (*62*). Team driving has been thought to help reduce worker fatigue and loneliness while adhering to productivity and hours-of-service requirements (*63*), and its reduction may be a potential antecedent for increased voluntary turnover. The impacts of COVID-19 on the global supply chain also resulted in intense scrutiny on the truck driver shortage whose impacts on consumers were highly visible at this point in time (*64*).

2.2.Automated Vehicles and the Trucking Industry

Above and beyond removing the need to recruit, retain, and compensate drivers, which will impact the ongoing driver shortages, there are several other reasons the trucking industry is a very likely candidate to be the first adopter of AV technology in the U.S. AVs are categorized based on six levels of automation. At level 0 there is no automation, and a human is performing all the driving tasks. In level 3, a human is not driving, although a human is still needed to be in the driver's seat in case there is a need to take over driving when automated conditions are not met, such as maneuvering through a traffic jam. AV level 5 operates without human assistance everywhere and in all conditions (*65*). Unlike passenger cars, a majority of truck miles are traveled on highways (*66*), which are less complicated and more predictable than other types of roads (e.g., city streets) (*67, 68*). Second, the integration of AV technologies in trucking could reduce the number and severity of road accidents (*12, 69*). Third, research shows AVs can increase profit margins of trucking companies by reducing fuel costs by 5-10% (*12, 70*). AVs could also reduce costs associated with driver wages and benefits, which accounted for about 44% of the total marginal cost per mile in 2020 (*71*).

When AVs will be rolled out in the trucking industry is uncertain and subject to a variety of factors including the level of automation, type of trucking industry, technology availability, and public opinion. Accordingly, studies offer varied predictions about AV deployment timelines (*16, 18, 72, 73*). A European industry report provides some indication about what the rollout of AVs may look like for the trucking industry by 2030 (*74*). The first phase will involve platooning of trucks on highways with a driver in the leading truck only. In the second phase, trucks will have full autonomy on highways, but will require a driver to pick-up and drop-off trucks at designated truck stops. In the third phase, trucks will be able to operate on all highways without driver involvement at any point in the trip. Recently, AV technology developers, such as Waymo and TuSimple, started publicly testing automated trucks in the U.S. sometimes in partnership with freight-hauling companies (e.g., C.H. Robinson) to demonstrate their effectiveness in improving supply chains (*75, 76*).

The impacts of AVs on the driving workforce vary. Some studies suggest that AVs are a threat to driving jobs (*77*). Mohan & Vaishnav (2022) estimate that a transfer-hub operation model for trucks, with full-automation driving on less complex highways, and humans driving on more complex regional routes, could impact 30,000 to 500,000 truck driving jobs, depending on the region and weather conditions (*78*). Some studies are less pessimistic about the impact on jobs and suggest that level 4 AVs will not completely eliminate the need for drivers, because people will still be needed for non-driving tasks (*79*) or to guide a platoon of AVs in dense areas (*80*). Other

studies suggest AVs may be the solution to the chronic driver shortage problem in the industry (*75*, *76*).

Some studies have investigated the perceptions of trucking industry workers towards AVs, but in a non-U.S. context and not specifically about driver shortages (*14*, *19*). Other studies have analyzed trucking manager's perceptions of AVs within the U.S. (*81*). However, the nexus of perceptions regarding driver shortages and the utility of AVs in resolving this issue in the U.S. has yet to be examined. The present study addresses this knowledge gap by analyzing survey data and focus group interviews of trucking industry workers to investigate: (i) their attitudes about the driver shortage, (ii) the strategies they use to deal with the driver shortage, and (iii) their perceptions of automated trucks and their adoption to alleviate the persistent driver shortage in the industry.

3. Methods

3.1.Participant Recruitment

We recruited U.S. trucking industry workers at three organizational levels: upper-level management or owners ("managers" group), supervisors or dispatchers ("supervisors" group), and drivers ("drivers" group), to participate in the study through convenience sampling. Managers were recruited by telephone calls made to trucking companies located in one Midwest and one Southern U.S. state, advertisements placed in trucking association newsletters, and professional contacts of members of the research team. Supervisors and drivers were recruited by advertising posts placed on social media (Facebook, Instagram, Reddit, and Twitter) and participant recruitment service (Respondent.io) platforms. Advertisements contained a weblink that directed interested parties to complete a pre-screening survey to help determine eligibility. A member of the research team followed up with potential participants to verify that inclusion criteria for the study had been met: (i) they worked in the trucking industry (manager, supervisor, or driver) and (ii) they worked in the U.S. Snowball sampling was also used in participant recruitment. All participants were asked to provide contact information of colleagues in the trucking industry that might be interested in our study and were encouraged to share information with them. Those who met the inclusion criteria were scheduled for a focus group and received an email with the consent form, virtual focus group information, and a link to the online survey.

3.2.Data Collection

Data were collected between June 2020 and January 2022 through focus groups and a supplementary online survey and with trucking industry workers (N = 67). The focus group protocol and questions for the online survey were developed from knowledge gaps in the transportation literature. We pilot tested the focus group protocol and online survey with ten industry experts and revised based on the experts' feedback. Participants completed the online survey prior to the focus group. The online survey asked questions to collect the following information: organizational tenure, perceptions about the impacts of AVs on an organization's workforce, and projections about the impact of AVs on the size of the U.S. workforce, and demographics (age, gender, race/ethnicity). Organizational tenure was assessed by an open-ended question, *how long have you worked for your current organization?* Perceptions about the impacts

of AVs on an organization's workforce was measured by, *how do you think that automated vehicles will affect the size of the U.S. workforce?* Response options included the workforce will decrease in size, will stay the same in size, or increase in size. Projections about the impact of AVs on the size of the U.S. workforce was assessed by, *do you expect the size of your organization's workforce to increase, stay the same, or decrease in the next 2, 5, and 10 years as a result of automated vehicles?* Response options for each year (i.e., 2, 5, 10) included decrease in size, stay the same, or increase in size. One manager and one driver did not complete the online survey.

Thirty-seven focus groups were conducted virtually on Zoom with trucking managers (n = 25), supervisors (n = 20), and truck drivers (n = 22). Focus groups consisted of a moderator, two note takers, and one to four participants. All participants provided informed consent prior to the start of the focus group. A semi-structured protocol was used to guide each focus group. At the onset of each focus group, the moderator briefly described the six SAE levels of vehicle automation (*65*) and informed the participants that the interview would focus on the higher levels, including levels 2-5. Participants were asked open-ended questions about driver's experience in the trucking industry. *What are the biggest challenges you encounter in your job currently? Do you foresee any challenges moving forward?* Participants were also asked open-ended questions about the future of AVs in the trucking industry. *What do you think will be the impact of AVs on the job of truck driving? How do you think AVs will impact your job, as well as the job of truck driving, in 2, 5, 10 years?* See Appendix A for the focus group protocol. The average duration of focus groups was 72.8 minutes (SD: 25.0; range: 21-118). Due to the pandemic and no-show participants, some of the focus groups only had one participant, which meant these focus groups were shorter compared to those with multiple participants. Focus groups were audio recorded and transcribed verbatim by a third-party transcription service.

The majority of participants were male (78%), White (69%), and, on average, 44.68 years old (SD=12.46) and reflects the demographics of workers in the trucking industry. The composition of the truck driver sample in this study is consistent with the U.S. truck driver demographics, mainly male, White, and, on average aged, 46.6 years (*82*). Managers worked at their company the longest, on average 20.79 years (SD =14.12). TABLE 1 presents participant characteristics.

[TABLE 1 About Here]

3.3.Data Analysis

Online survey data were analyzed descriptively. Focus group data were analyzed using an inductive thematic approach because it is data driven and not reliant on a preexisting framework (*83*). The inductive thematic analysis process consisted of six steps: (i) an initial review by research team members; (ii) the creation of codes based on similar content; (iii) the organization of codes based on themes; (iv) the analysis of themes based on coded quotes; (v) definition of themes; (vi) formation of final analysis by the selection of relevant examples and connecting these examples to research questions and relevant literature (*84*). Inter-coder reliability was established among the two coders (graduate research assistants) with a Cohen's kappa value greater than or equal to 0.80. NVivo software was used to assist with coding and to measure Cohen's kappa.

4. Results

4.1. Online Survey Results: Workforce Impacts of AVs

The majority of supervisors (50%) and drivers (62%) thought that AVs would reduce the size of the U.S. workforce. Most participants thought the size of their organization's workforce would stay the same in the next two (71%) to five years (58%). The responses about organization size in ten years are more varied. Twenty-seven percent of respondents thought the size of their organization would increase while 32% thought the size of their organization would decrease. A large proportion of managers (52%) reported their organization would stay the same in the next ten years. See

TABLE 2 for workforce impacts of AVs.

[

TABLE 2 About Here]

4.2.Focus Group Themes

Focus group data contained three main themes. Theme one discussed participants' explanations for persistent truck driver shortages. Theme two is focused on solutions to the driver shortage. Theme three discusses viewpoints about AVs as a solution to the driver shortage.

4.2.1. Theme 1: Driver Shortages.

Participants described a constant struggle between the number of available truck driving jobs, but rarely enough drivers to fill those jobs. A 57-year-old manager explained, "Today, drivers are in very high demand and very short supply." As a result, participants were pessimistic about the driver shortage ending. A 58-year-old manager shared, "I do think that there's going to be continued shortage in our industry for truck drivers, whether you have automated vehicles or not. It's going to be a challenge."

One of the factors discussed by participants influencing the gap in the driver shortage was the aging workforce. As a 72-year-old manager noted, "At my company, my median age is 58 for my fleet." Participants explained that their current workforce was older and closer to retirement, which is a problem since there is not an influx of younger people training to become professional truck drivers. Younger drivers were portrayed as uninterested in professional truck driving because of low wages, the difficulty of the position, and the lack of respect for truck drivers. A 59-year-old manager elaborated:

> The old breed is moving out and retiring. Driving a truck is not a glamorous job. These young people don't go to school to get a degree in truck driving. They want to be an engineer or a chemist or a doctor or have a different profession than driving trucks. There could be a big void there.

Aspects of quality of life such as physical and mental health, wealth, and leisure time were factors considered to influence the driver shortage. Participants acknowledged that truck driving is a stressful job physically and mentally. They elaborated that it is a hard job due to the long hours, short breaks, and inconsistent work. A 27-year-old supervisor explained, "Sometimes these guys can be out there for 14 hours a day behind the wheel and are just taking 30-minute breaks here and there." Participants also noted other stresses that drivers encounter including a lack of respect by dock workers, poor treatment by customers, and safety uncertainty related to the COVID-19 pandemic. A 27-year-old manager said, "There's a lot of stressful things that can happen. Traffic can be bad. They can be treated really poorly, some of these customers, the people on the docks are sort of rude, and other things." Since the role of a truck driver is difficult, drivers placed importance on their compensation (wages and benefits) for their level of work. Drivers have expectations about their wages and will not work unless they receive their desired level of income. A 58-year-old manager stated, "People don't want to put in 12 hours only to make $50,000 a year. It's just not enough." Another quality-of-life aspect for truck drivers is that they want to be home at night, not long-haul driving. A 33-year-old manager said, "Nobody wants to drive over the road. It's a struggle. Everybody wants to be home daily."

Managers and supervisors also discussed experience as an element playing into the driver shortage. A 57-year-old supervisor stated, "That's the big challenge right there, is the drivers, and that's a very big challenge in trucking is not just getting any driver, getting a good driver." Manager and supervisor participants emphasized how difficult it was to hire a "good driver," one who had at least two years of experience, was capable in driving in extreme weather and in different regions, had a commercial driver's license (class A & B), and a safe driving record. A 58-year-old manager shared, "For me, it's a horrible thing to try to find a qualified driver. I think as the driver pool keeps getting smaller..."

4.2.2. Theme 2: Current Strategies Used to Address Driver Shortages.

Participants described several strategies companies are implementing to address the persistent driver shortage. One solution is to fill open positions with less experienced drivers. However, these drivers require more oversight because they are undertrained and do not have the preferred skills and experience. A 36-year-old manager explained:

> ... with the insurance requirements we have, the youngest driver we can take is 21, and that person has to have already 2 years of verified CDL-A experience, so that person doesn't really exist in the way that the system is set up right now. We have to move towards a model via apprenticeship programs....

Trucking companies focus on trying to meet the drivers' expectations about their wages by providing better pay and company benefits. A 31-year-old supervisor described:

> We are very competitive with our pay scales. We look at everyone and see what they're paying, and we try our best to be better if not, equivalent. We have new equipment, we have newer trucks, and we have good managers that work with us.

However, if companies are unable to meet drivers' compensation expectations, drivers will find alternative employment at other trucking companies. As a 33-year-old supervisor explained, "Retirement and health and job stability is always an issue for drivers. They're always moving around- they're always looking for a company that'll pay 'em just a little bit more." Some trucking companies worked hard to try to accommodate their drivers' desire to be home more frequently. A 25-year-old supervisor explained:

> A lot of companies, they'll keep a driver out for two weeks at a time [70 hours] and send him home for his 34-hour reset [federal regulation]… if you think about 34 hours, if you get home at eight o'clock at night on a Saturday, then you leave out at 6 AM on Monday, that's really not a lot of time at home. Especially after being gone for so long. Especially for people who have kids and whatnot. We strive to not treat our drivers like that. We want them to have a life outside of work.

Two managers shared that companies were branching outside of the U.S. to find truck drivers as they struggle with the driver shortage. A 45-year-old manager explained:

> Not only from the Southwest, but you have a lot of Eastern Europeans that are over here. Again, you can't attract the driving force out of the American high schools, but these guys can come over here with their family, drive a truck, and they make a living 10 times better than what they had in their home country.

4.2.3. Theme 3: AVs as a Solution to Driver Shortages.

Participants had mixed opinions on whether AVs could be a plausible solution to easing the driver shortage. Some participants thought that AVs would be beneficial. A 55-year-old manager stated, "I look at the total jobs and the lack of filled positions right now, I think automation will help fill that gap." But other participants were skeptical that AVs would be a solution to fixing the driver shortage. A 52-year-old manager noted, "I certainly don't think it's going to solve the driver shortage or have a large impact right out of the gate." Participants described three motivating factors for how AV adoption could affect the driver shortage, including AVs as a solution, the continued need for drivers, and the changing trends of industry positions.

A clear advantage shared by many participants was that automation, both partial and full, would provide an incentive to be a truck driver for those currently in the field or those considering employment within the industry. Participants stated a primary reason was the benefit to drivers on the road, particularly in the circumstances of dropping off and picking up freight and safety due to less accidents A 55-year-old manager claimed, "If you could solve the backing in autonomously right now, we could hire drivers way faster, couldn't we?" Participants also noted the appeal of AVs to tech-savvy younger drivers. As explained by a 53-year-old manager, "I can see the younger kids being more interested doing the computer stuff or running the vehicles like that, the trucks like that." For those currently in the profession, participants were hopeful that the automation would help solve their driver retention issues. A 40-year-old manager noted, "The reason why we cannot get bigger because the drivers not coming to us and not staying with us. Once we have automated truck, they're not going to be leaving us hopefully." Although, there were participants who disagreed that AVs would be an incentive for truck drivers or future truck drivers due to the potential for variability in job roles. A 27-year-old supervisor expressed:

> …most people are going to say like, "I don't want to go to driving school and learn how to drive if... Yeah, I mean, there might be a job now, but in five years, I'm just going to have to learn a new skill."

Participants' ideas about how the adoption of AVs may solve the shortage differed in complexity. Some pointed out that AVs would allow companies to recruit less skilled drivers, with a 57-year-old manager stating:

> It's going to make, I guess, less skilled people available. Today, drivers are in very high demand and very short supply. So, we think that automation is going to help us get some people into driving that maybe we couldn't get in before.

Others did not know how exactly AVs could solve the truck driver shortage, but still pointed out the correlation. A 59-year-old manager shared, "I think for the most part, the driver shortage has

been going on for the last few years. it would help alleviate that, as far as getting that from the warehouse to the distribution center."

Although participants held varying views on the feasibility and benefits of AVs, there was a consensus that AVs would shift roles and industry positions. The shift in the age of drivers was one of the changes related to AVs discussed by participants. Participants explained that with AVs, newer, younger drivers, who already have technology experience, would begin to outnumber the older, experienced drivers, who may not have the same technological knowledge or may not want to learn how to use technology in their driving role. A 57-year-old driver explained:

> It's going to [weave] out the old people, the experienced and put lesser experienced people, less cheaper people in the seats. And be able to take them like right out of college or which you can't do at this point, right out of high school and put them in a truck.

Participants also thought that AVs would cause a shift in industry positions to a more technical skillset, which could ultimately create more jobs. A 60-year-old manager noted, "I think there'll be a new skillset. If you're a level five, you're not going to need a driver, but you'll still need technicians to repair the trucks, you'll need computer folks to program the trucks." This change was viewed optimistically by some participants. A manager (age unknown) explained, "I have faith that the ones that are in the industry now can adapt to new technology." However, others were concerned for individuals within the industry who may get lost as roles change. A 53-year-old manager shared, "I think you're going to lose a lot of people that won't know where to transition, that won't know where to go." See TABLE 3 for additional quotes.

[TABLE 3 About Here]

5. Discussion

AVs are projected to have wide-reaching impacts on society and the workforce. The trucking industry is projected to be one of the first adopters of AVs, which will impact millions of driving jobs. Decades long shortages of truck drivers, which were made visible by the COVID-19 pandemic, may hasten the industry's adoption of AVs. This study advances our knowledge about AV impacts by using online survey and focus group data to examine trucking industry workers' views at three organizational levels (i.e., managers, supervisors, and drivers) about AVs as a solution to persistent truck driver shortages. The present paper provides new perspectives about AVs from trucking industry professionals, which is a different group of people than has been considered given the large body of prior work focusing on AV perceptions of potential consumers (*85–89*) or car industry professionals (*90*, *91*)**.** Given recent work indicating a lack of alignment between experts and public perceptions of AVs (*92*) and the influence of the portrayal of events related to AVs in the news media on public sentiment (*93*), it is important to examine perspectives from other parts of society. Our analysis of these data provided several explanations for the persistent driver shortage including an aging workforce, quality of life issues, and a lack of qualified drivers with the necessary experience. Although companies have implemented several solutions to these issues, driver shortages persist.

Additionally, our analysis produced new information about the industry perceptions of AVs to solve the present driver shortage. Several participants believed that AVs could pose a potential

solution to the truck driver shortage if properly implemented. Specifically, they recognized the potential for AVs to provide an incentive for more truckers to enter the industry through a combination of improvements to road safety and appeal to the younger workforce. This aligns with past literature that has reported technology utilization in trucking as a major attraction for younger drivers (*11*). Other benefits reported by the participants included a general decrease in accidents, and lower insurance costs, which have been widely noted in the literature (*73*). They also noted that AVs may enable more people to participate in the profession that are not currently able to because of lack of experience or a fear of particular aspects of driving (e.g., backing up trucks). Some participants thought AVs may actually increase the number of jobs in the trucking industry, particularly for people with technical skills that can repair and interact with automated trucks. Previous studies have echoed similar findings, suggesting that automated truck operators may need to acquire new technical skills (*72*).

However, some participants had a more pessimistic view of AVs and noted the hurdles to AV adoption, citing issues with present infrastructure and liability. While not necessarily a positive or negative, participants also noted the likelihood of continuing need for drivers in the vehicles, and the changing role of industry positions that would emerge following any level of AV adoption. Many also contended that, even with an increase in certain positions with AV adoption, some sectors and job positions may be rendered obsolete, causing job loss for those who fail to adapt. This is in line with the potential automation-induced job losses reported by previous studies (*78*, *79*). From a practical perspective, these results provide an indication to industry leaders and policymakers about the trucking industry's current views and preparedness for AV adoption. For example, proactive training programs for technicians and drivers are needed to prepare them for a future where automated vehicles are on the road. Interestingly, any changes to the workforce are not anticipated to occur in the short term (2-5 years). Instead, these impacts are expected to occur farther into the future. These viewpoints align with prior work indicating longer timelines for full adoption of level 4 and 5 AVs (*73*).

That said, there are some limitations to this study that are important to mention. The first of these limitations is that our findings may be specific to U.S. based companies and may differ from the trucking workforce in other parts of the world. A second related limitation of this study is that the sample, which is comprised of respondents from one Midwest and one Southern state, may not be representative of trucking industry members in other U.S. states or other countries, who may have political and cultural differences from the participants analyzed in this study. These differences could impact their views about causes of the trucking shortage and associated impacts of AVs. A third limitation is that this study does not make a distinction among the different types of trucking (e.g., road trucking, parcel, or owner-operated) or different company sizes. Another limitation of this study is that the data were collected over a period in time that coincided with the COVID-19 pandemic, which was a tumultuous time for the trucking industry. The events of this period, such as fluctuations in shipping demand and worker problems, may have influenced participants' views. However, this tumult may also have prompted participants to think more carefully about new solutions, including AVs, to trucking industry challenges. Lastly, the data were collected from a fairly small number of participants (N=67) which may not represent all workers in the industry. That said, the demographics of the study participants in this paper, as well

as many of the issues identified by participants, align with prior research (*14*, *19*, *27*, *31–33*). Thus, the number of participants does not appear to have impacted our analytical results.

These limitations provide opportunities for future research. One line of future work could conduct repeated focus groups with the same participants over time to understand how temporal distance from the pandemic changes or does not change their views on the utility of AVs as a solution to the issue of truck driver shortages. This time series of data would also help us understand how views about AVs change or do not change as mass deployment becomes a more likely reality. A second line of future work could conduct ethnographic research about the trucking industry to get a better sense of the knowledge, skills, and abilities (KSAs) the future trucking workforce will need to stay competitive in an age of automation. This research approach would permit time with workers on a daily basis for an extended period of time to make inquiries about daily tasks drivers perform that may or may not be automated. These tasks may be so routine to workers that they forget to mention them in a one-time focus group but are core tasks to driving work.

6. Conclusion

The study findings indicate that the truck driving industry views the driver shortage as a constant issue, which has implications for every aspect of industry operation. This shortage is caused by problems within the trucking profession, as well as external forces that pull potential workers to other workforce sectors. Given the necessity of a reliable and efficient supply chain, of which trucking holds an invaluable and irreplaceable position, the potential of AVs as a solution is one that can and must be contemplated. From our study, it is clear that AVs can be a valuable asset for the industry moving forward, so long as particular concerns are addressed.

CRediT Author Statement

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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TABLE 1 Participant Characteristics

	Total[a] (N=65)	Manager[b] (n=25)	Supervisor (n=20)	Driver[c] (n=22)
	N (%)			
Age (years), M(SD)	44.68 (12.46)	51.36 (11.45)	38.65 (9.48)	42.58 (12.12)
20 to 24 years	2 (3%)	0	1 (5%)	1 (5%)
25 to 34 years	16 (25%)	3 (13%)	7 (35%)	6 (32%)
35 to 44 years	11 (17%)	3 (13%)	6 (30%)	2 (11%)
45 to 54 years	15 (24%)	4 (17%)	5 (25%)	6 (32%)
55 to 64 years	17 (27%)	13 (54%)	1 (5%)	3 (16%)
65 years and over	2 (3%)	1 (4%)	0	1 (5%)
Gender				
Male	51 (78%)	22 (88%)	13 (65%)	17 (77%)
Female	14 (22%)	3 (12%)	7 (35%)	4 (18%)
Race/Ethnicity				
White	45 (69%)	21 (88%)	12 (60%)	14 (64%)
African American	11 (17%)	1 (4%)	5 (25%)	6 (27%)
Asian	3 (5%)	0	2 (10%)	0
Hispanic/Latino	2 (3%)	1 (4%)	1 (5%)	1 (5%)
American Indian/Alaska Native	1 (2%)	0	0	1 (5%)
More than one race	2 (3%)	0	0	2 (9%)
Other	1 (2%)	1 (4%)	0	0
Tenure at company (years), M(SD)	12.07 (12.79)	20.79 (14.12)	5.10 (4.29)	8.59 (10.68)

Notes. [a]Missing 4 age, 1 race/ethnicity, and 3 tenure at company responses. [b]Missing 1 age, 1 race/ethnicity, and 1 tenure at company responses. [c]Missing 3 age and 2 tenure at company responses.

TABLE 2 Workforce Impacts of Automated Vehicles

	Total[a] (N=65)	Manager[b] (n=25)	Supervisor (n=20)	Driver[c] (n=22)
	N (%)			
The size of the U.S. workforce				
Decrease	29 (45%)	6 (25%)	10 (50%)	13 (62%)
Stay the Same	28 (43%)	16 (67%)	5 (25%)	7 (33%)
Increase	8 (12%)	2 (8%)	5 (25%)	1 (5%)
The size of your organization's workforce in the next:				
2 years				
Decrease	3 (5%)	0	1 (5%)	2 (10%)
Stay the Same	46 (71%)	17 (71%)	11 (55%)	18 (86%)
Increase	16 (25%)	7 (29%)	8 (40%)	1 (5%)
5 years				
Decrease	9 (14%)	0	4 (20%)	5 (25%)
Stay the Same	37 (58%)	16 (67%)	6 (30%)	15 (75%)
Increase	18 (28%)	8 (33%)	10 (50%)	0
10 years				
Decrease	20 (32%)	7 (30%)	7 (35%)	9 (45%)
Stay the Same	26 (41%)	12 (52%)	6 (30%)	8 (40%)
Increase	17 (27%)	4 (17%)	7 (35%)	3 (15%)

Notes. [a]Missing 2 responses for size of U.S. workforce, 2 responses for change in next 2 years, 3 responses for change in next 5 years, and 4 responses for change in next 10 years. [b]Missing 1 response for size of U.S. workforce, change in next 2 years, and change in next 5 years. Missing 2 responses for change in next 10 years. [c]Missing 1 response for size of U.S. workforce and change in next 2 years. Missing 2 responses for change in next 5 years and change in next 10 years.

TABLE 3 Additional Quotes

Themes	Quotes
Theme 1: Driver shortage	
Aging Workforce	Our average age of driver that we have currently is right around the 50 mark. *50-year-old driver* ...most of the drivers I have, have been driving for a long time, and in the next 10 years will probably be retired. I don't have any younger drivers at this point in time. *59-year-old manager* But it's a growing age. I mean, the average age of a long-haul truck driver is 55+ and it's not getting younger. it's a dwindling industry of that age-type. *42-year-old supervisor*
Quality of Life	it's [truck driving] not a glamor job and it's very underrated and I just don't see... And very underpaid. You definitely are underpaid. *50-year-old driver* ...they (drivers) all want to get home. They don't want to go over the road. *60-year-old manager* I mean, retirement and health and job stability is always an issue for drivers. They're always moving around- they're always looking for a company that'll pay 'em just a little bit more. *33-year-old supervisor*
Experience	...truck driving is not the profession that it used to be. We don't get as many people. When I was young I wanted to be a truck driver, and I've been doing it since I was 19, and I'm 65. So, if the kids don't see it as a profession anymore. They see it as just an easy way to make money. And I really think that people need to... we need to figure out how to get better trained drivers. So, I see that as a challenge for us. *65-year-old driver* Today, a driver has to have a fairly high skill level, a CDL and of course experience. And probably, depending on what level you're at and how much assistance really needs to happen, we are of the opinion that there'll be some opportunity for either a younger driver possibly. Today, it's 21. Maybe an 18 year old or a person who doesn't have all the skills of today's CDL driver.

Themes	Quotes
	But that's the big challenge right there, is the drivers, and that's a very big challenge in trucking is not just getting any driver, getting a good driver. *57-year-old supervisor*
Theme 2: Current strategies used to address driver shortages	
Hire less experienced drivers	... bringing in less experienced people, because right now, that's a big part of what they require of us. So I do think, in theory, we'll have more opportunities to bring in people if the barriers were lowered appropriately. *27-year-old manager* It's an aging workforce... I think also the flip side of that is the standards for incoming drivers has gone down in order to get more. *25-year-old supervisor*
Provide better pay and company benefits	We also have longevity bonuses, sign-on bonuses, safety bonuses. I feel like I'm forgetting a couple of the bonuses. We have so many bonuses. That's all geared at retaining the talent as well as attracting new talent. We find that if we really take care of our employees and our contractors, that that good will spreads much further than any algorithm is going to find good drivers, but I do try to employ both of them just because we've had success both on avenues. *52-year-old manager* You really have to open the pocket book and we pay guarantees to our drivers daily. *27-year-old supervisor*
Drivers home more frequently	I continuously work at the lifestyle to get to the point where people can if they choose to be home every night, and I've got to build that... I've got to meet the driver's needs, there's no way around it. *55-year-old manager* I do have drivers that get to be home every day. And then I have drivers that go out for a week. And drivers beyond that, if they want to go out for longer than a week, I leave that up to them. I have some drivers that love to be out for a month, two months at a time, that's up to them, my company, we say a week out and then the rest is up to you, if you want to stay out, then stay out, you know. So we like that we're flexible like that with our drivers. *34-year-old supervisor*

Themes	Quotes
Go outside of the U.S. to find truck drivers*	Now, the drivers that we hire out of Mexico, they do it, and I have a quite a few young guys in that part of the fleet, they do it because the money's good. They're going to drive, whether they drive it in Mexico, but if they get a B-1 visa and drive in the US, they're all over that. *72-year-old manager*
Theme 3: AVs as a solution to driver shortages	
Advantages of AVs	Maybe we'd be in less accidents...less accidents means less ambulance chasers, less insurance. I think insurance would go down, which would mean the costs overall would go down. Maybe that means more money in our pocket. Not necessarily, but maybe. *31-year-old driver* Essentially, it [AV] could potentially, you know, fill in some of those gaps. If it's a short, if it's a manageable space [route]. Easy, simple and smooth. I wouldn't expect it to go across the country. Something in one area. *39-year-old supervisor* The level four thing, where you've got a guy in the truck to deal with the stuff that we think we need to, but it's largely driving that truck, taking the human element out, being safer, is that going to make the roads safer to the extent that trucks are at fault in accidents? Yes, although even AAA says that 80% of the accidents out there are the car's fault, not the truck's. So driving down our insurance costs, making the road safer, again, level four makes a lot of sense. *59-year old manager*
Continued need for drivers	I could definitely see that, hey, at the most we would be um level four autonomous wise because the DOT would highly prefer that, hey, we have a driver there just in case if something were to happen, or yeah, just safety reasons wise and insurance purposes. *24-year-old driver* I don't know or feel that there will be technology to solve all the problems that are out there as far as rescheduling and over short damage issues, breakdowns, you're gonna need that human touch to solve those problems and fixing equipment is a big, big part of that. *38-year-old supervisor* if you got to move something as power-only, where it's already loaded on a trailer, there's a mechanical breakdown. You're still going to have that, and that's something where you kind of need that human interaction. *37-year-old manager*

Themes	Quotes
Changing trends of industry positions	So I think with drivers, a company per se, trying to protect our job as drivers, I don't know that that would happen...: I think they would look at us and say, "You need to change your skills a little bit and learn different skills and new skills." *50-year-old driver*
	I think once the automated trucks going to come out, the shippers and receivers going to be trained to secure, and unsecure the freight, and maybe there's going to be some stations in between if the automated truck pulls in and somebody checks the freight. *40-year-old manager*
	Securement. That's going to be a big one. Having people stationed at these facilities just to secure material on to trailers. You're going to have damage out there like crazy. These trucks are going to be ran without a human aspect that's going to be mindful of filters, to get them changed. So you're going to have different truck stop locations with people dedicated to just serving these automated units that's pulling in. So the maintenance area is going to boom because you no longer have that truck driver that know how to fix the light, or that truck driver that know how to switch out a mud flap or whatever it might be. You're taking that away, so they're going to be stationed at these ports. *31-year-old supervisor*

Note. * Discussed by two participants

Appendix A: Focus Group Protocol

Introduction to AVs

Before we begin the interview, we want to elaborate on what we mean by automated vehicles.

When people refer to automated vehicles, they talk about different levels: Automated vehicles are defined in 5 levels, from 0 (with no automation) through 5 (highest level of automation). For the purposes of this study, we are mainly interested in the higher levels – Levels 2, 3, and 4. And, ultimately 5 – full automation.

- In Level 2 (L2) vehicles, the vehicle performs the control functions, but the human driver is responsible for monitoring the driving environment and taking control when necessary.
- In Level 3 (L3) vehicles, the vehicle does most of the driving, but requires and requests transition to human driver control and monitoring when needed.
- And in Level 4 (L4), no human driver assistance is needed, but the vehicle only operates in a defined ODD (operational design domain), such as a defined urban area, or on limited access highways.
- Level 5 (L5) – vehicle does all the driving functions under all conditions.

Focus Group Questions

1. Overall, what is your life like as a [manager, supervisor, driver]?
    a. What is the job like?
    b. What does a typical day look like?
2. What are the biggest challenges you encounter in your job currently?
3. Do you foresee any challenges moving forward for the job of truck driving?
4. Where do you see the truck driver job being in 2, 5, and 10 years?
    a. Do you see this job as continuing, and [for drivers] do you still want to continue in this job?
5. What knowledge, skills, and abilities (KSAs) are needed to do the job of truck driving?
    a. Which of these KSAs could be automated or replaced by a computer or other types of machines?
6. How do you think AVs will impact the job of truck driving in 2, 5, and 10 years?
    a. Will drivers need to learn new skills?
    b. What are your thoughts about whether the job of truck driving will change or go away?
7. What do you know about AVs? What do you think will be the impact of AVs on the job of truck driving?
8. Is there anything else related to your job, AVs, or your quality of life that we haven't asked you today that you would like to share with us?
9. What impact has COVID had on your company and driving jobs?
10. What do you think is the most important question that we asked you today? Why?