Responsible Innovation in the Development of Autonomous Trucks

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Gilchrist Johnson

Spring 2023

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

MC Forelle, Department of Engineering and Society

Introduction

Current trends suggest the future of driving is driverless, as odd as that sounds (VTPI, 2022). The global market for autonomous vehicles is expected to reach $2 trillion dollars by 2030, with no signs of stopping (Wire, 2022). While many would believe the automotive industry is leading this market, the biggest players are within the transportation industry (PriceWaterhouseCooper, 2022). Defined by the U.S. Bureau Of Labor Statistics (BLS) as "providing [the] transportation of passengers and cargo, warehousing, and storage for goods" (BLS, 2022), the transportation industry is essential to the successful operation of many industries today. Given this importance, the industry looks to automation as a way to optimize its processes, increase safety, and increase profits (Lynch, 2021).

To discuss this transition to automation, there must be a clear definition of what autonomy is. The Society of Automotive Engineers (SAE) categorizes automotive autonomy into 6 distinct levels (Figure 1), ranging from No Automation (Level 0) to Full Automation (Level 5) (SAE, 2021). While most commercial self-driving vehicles are currently between Level 1 and

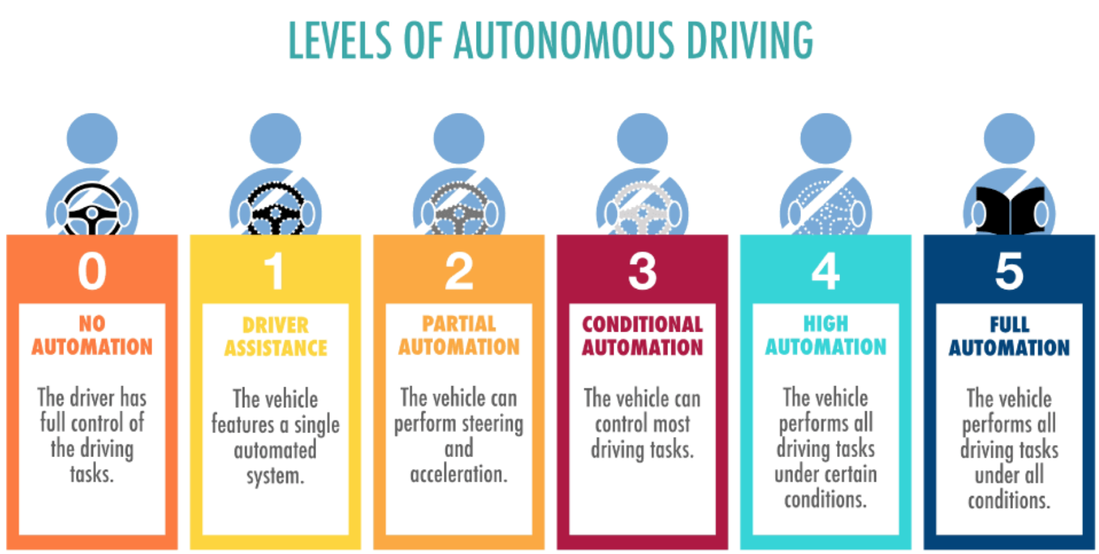

Figure 1: Levels Of Driving Automation, as defined by The Society of Automotive Engineers. (Credit: Semiconductor Engineering, 2019)

Level 2 autonomy, vehicles with higher levels are imminent (Morris, 2021). For the transportation industry, these higher levels of autonomy are necessary to reap the potential benefits outlined previously. However, these higher levels of autonomy do not come without repercussions, as many social side effects are attributed to such a large change in the transportation industry's infrastructure. To analyze these effects, I will use the framework of responsible innovation as outlined in the article "Developing a Framework for Responsible Innovation" (Stilgoe's interpretation of responsible innovation) (Stilgoe et al., 2013). By conducting this analysis, I hope to address the potential social and ethical ramifications that automating the transportation industry will bring.

As such, the purpose of this paper is to determine if the trajectory of automation in the transportation industry adheres to the guidelines of responsible innovation. To properly understand this framework and its implementation, a review of Stilgoe's interpretation of responsible innovation is included in this paper (Stilgoe et al., 2013). Additionally, a review of previously published literature is used to establish context into the trajectory of the transportation industry, including references to the current implementation strategy, timeline, and anticipated outcomes of this strategy (from both the industrial and public perspectives). To align with the methodology outlined in the framework, news articles and journalistic accounts are used as supporting evidence for claims made in the analysis section of the paper (Stilgoe et al., 2013). Through this analysis, I conclude that the automation of the transportation industry does not adhere to the cornerstones of responsible innovation (Anticipation, Inclusivity, Reflexivity, and Responsiveness), and will make suggestions to the transportation industry to improve this adherence.

Literature Review

Background

According to the U.S. Department of Transportation, the transportation industry employs 14.9 million people, 10.2% of the labor force in the United States (BTS, 2022). Many of these people are commercial truck drivers. As the industry transitions into an autonomous future, many of these drivers are concerned with the prospect of losing their jobs (Grosne, et al., 2019). While it's easy to ignore their concerns in the face of innovation, it's important for engineers to understand the context and ethical ramifications of their work (Johnson, 2020). To accomplish this, I review how automation has become so prevalent. While concepts of autonomous vehicles (AVs) can be traced back to as early as the mid-20th century, the development of the modern autonomous vehicle started in the early 2000s, with the U.S. Defense Advanced Research Projects Agency (DARPA) (Anderson et al., 2014). During this time, DARPA held three "Grand Challenges" to increase research interest in autonomous vehicles (Figure 2).

Figure 2: A Caterpillar-sponsored car participating in the DARPA Grand Challenge. (Credit: Anderson S, 2019)

The agency found much success in these challenges, with prototype vehicles going from barely driving eight miles to completing complex 60 miles courses by the end of the series of challenges (Anderson et al., 2014). The popularity of these challenges lead to many partnerships between automotive and research groups, creating a continuous push for research into autonomous vehicles (Anderson et al., 2014). As the research and development of autonomous vehicles continued to progress, the transportation industry began to take notice and explore the potential uses of autonomous vehicles in their industry. In 2015, the first commercially available level 3 autonomous truck was introduced by Freightliner, known as Inspiration (Freightliner, 2023). While many other companies would start developing autonomous trucks during this time (including Google, Uber, and TESLA), autonomous trucks wouldn't see a true boost in popularity until early 2020 (Insider, 2021). While there are many factors contributing to this, the most notable may be COVID-19.

The coronavirus (COVID-19) pushed unemployment to an all-time high (BLS, 2021). In the first two months of the pandemic (March-April, 2020), employers cut 22 million jobs, and the unemployment rate dropped to 14.8 percent (Casselman, 2021). Many Americans felt as if working during the pandemic wasn't worth the risk of infecting themselves (or others) (Depillis, 2022). During this phase, some industries were able to regain workers by offering virtual working options, while others – such as the transportation industry – were unable to make such adaptations due to the nature of the jobs (Depillis, 2022). More than two years later, many industries are still struggling to find workers (Casselman, 2021). While many industries have attempted to incentivize workers back, others look to automation as a solution (Petropoulos, 2021). When asked about employers' difficulties retaining employees, Stephen Steinour, chief executive of Huntington Bancshares, states "Universally, they [employers] talk about [the] inability to get adequate labor, very high turnover, and clear wage inflation at the low end. A consequence of that will be more investment by many of them into automation" (Steinour, 2021, as cited by Lynch, 2021). While full automation is still a few years away for the transportation industry, many workers are worried about losing their jobs (Mitz, 2022). To address this, we must consider the ethical responsibilities of our work as engineers (Johnson, 2021).

Responsible Innovation

Responsibility is a concept that has always been intertwined with scientific research and innovation in one form or another. From the realities of leaded gasoline to the fantasies of Jurassic Park, there has always been a heated discussion among the public if (and when) researchers should be held accountable for the products of their work. In an attempt to define what constitutes innovation in a responsible and ethical manner, Jack Stilgoe, Richard Owen, and Phil Macnagheten attempted to define this concept in the article "Developing a framework for Responsible Innovation", stating, "Responsible innovation means taking care of the future through collective stewardship of science and innovation in the present." (Stilgoe et al., 2013). This is accomplished by the analysis of the public debate around innovation. By taking questions that present themselves in public debate as a societal concern (who is in control, what are the alternatives, etc.), responsible innovation attempts to embed them within the innovation process (Stilgoe et al., 2013, p. 3). This results in four dimensions of responsible innovation. Each dimension (Anticipation, Reflexivity, Inclusion, and Responsiveness) represents an aspect of "responsibility", as defined by the authors (Figure 3) (Stilgoe et al., 2013).

With regard to the transportation industry, these cornerstones are an important consideration when trying to implement automation in a responsible and ethical manner. Anticipation can be used to thoroughly consider the effects of automation. Reflexivity demands

Figure 3: Diagram of the Responsible Innovation Framework (Stilgoe et al., 2013). (Credit: Gilchrist Johnson)

"holding a mirror up to one's Anticipation can be used to thoroughly consider the effects of automation. Reflexivity demands "holding a mirror up to one's

own activities, commitments and assumptions, being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held" (Stilgoe et al., 2013). For the transportation industry, this means considering the purposes of innovation and the motivations of the innovators. Inclusivity refers to the inclusion of unheard voices and ideas in the conversation of automation, not only as a way of representation but as a means of evolution. Finally, responsiveness combines the previous three dimensions of responsible innovation and assesses the capacity of the industry to change in response to them**.**

Research Question & Methods

The purpose of this study is to answer the following research question: Does the trajectory of automation in the transportation industry adheres to the guidelines of responsible innovation? To analyze this question, I will reference the guidelines provided in Stilgoe's interpretation of responsible innovation (Stilgoe et al., 2013). Utilizing the framework, I will find how well the industry aligns with the four cornerstones of responsible innovation: Anticipation, Inclusivity, Reflexivity, and Responsiveness (Stilgoe et al., 2013). To align with the methodology outlined in the framework, previous research from various academic journals is used as supporting evidence for claims made in the analysis section of the paper. These academic journals were selected for their relevancy to each pillar of responsible innovation, with a focus on university studies focused on polling workers, executives, and other patrons associated with the transportation industry (Stilgoe et al., 2013). Additionally, various news articles and journalistic accounts from the last 10 years were chosen to provide societal and situational context to references in the studies. This limited range in time was chosen to maintain relevancy to the current conversation around automation.

Analysis

To address workers' concerns about an unethical future, I must find a framework to analyze the ethical effects of innovation. For this project, I will use Stilgoe's interpretation of responsible innovation (Stilgoe et al., 2013). Utilizing a multi-dimensional analytical approach (Anticipation, Reflexivity, Inclusion, and Responsiveness), responsible innovation aims to address the social and ethical concerns of technological evolution. By comparing autonomous innovation in the transportation industry to these dimensions, I will determine if the trajectory of automation in the transportation industry adheres to the guidelines of responsible innovation. The following sections contain an analysis of each one of these dimensions with respect to automation in the transportation industry.

Anticipation

Responsible innovation requires innovators to not only assess current challenges with the implementation of systems but to also anticipate future challenges that could rise from said systems (Stilgoe et al., 2013). In the context of the transportation industry, this means asking what ramifications automating the industry could have. This includes the effects on workers, companies, engineers, consumers, and the public at large. For the context of this paper, I will primarily focus on comparing the effects anticipated by the working class of the transportation industry and the industries executive class.

For the working class of the transportation industry, there is a growing concern that the there will be no place for them within the future of the industry as automative technologies continue to progress (Sindi, et al., 2021). As the transportation workers are closely intimate with the procedures associated with the work in their industry, their concerns seem to be well placed. Research shows the introduction of autonomous cars and trucks could directly eliminate 1.3 to 2.3 million workers' jobs over the next 30 years, depending on the adoption scenario followed (Groshen, 2019). When anticipating effects from the most aggressive forms of implementation, laid-off workers could lose up to $80,000 in lifetime income due to the disruption, for a total loss of about $180 billion for U.S. workers alone (Groshen, 2019). This loss in both employment and gross income could devastate the transportation economy and put both the workers and their families at risk if they are unable to find alternative employment.

The executives of the transportation industry seem to disagree with this analysis, believing workers will still have a place in the industry (ATBS Staff, 2022). In an interview with Transportation Topics, Chris Spear, the president of the American Trucking Association -the largest and most comprehensive national trade association for the trucking industry- said he "doesn't view the ongoing advancement of autonomous trucking as a threat to drivers, since economic factors will ensure demand for drivers for years to come". (Spear 2022, as cited in Transportation Topics, 2022) Spear later laments on the topic, stating "Right now, one in 16 jobs in the United States is trucking related. The top job in 29 states is being a truck driver…I don't look at this as a threat" (Spear 2022). Spear is just one of many transportation executives whose current anticipations don't align with current research (Groshen, 2019).

While one could argue that the disconnect in the anticipations of resarchers and executive classes of the transportation industry is simpily a lack of communication, I believe there is a deliberate attempt by industry executives to ignore the concerns of the working class in lieu of potential profits. According to a study conducted by the University of Warwick, many workers associated with the transportation industry believe potential cost-savings are the primary reason for the increasing push for automation (Sindi, et al., 2021). While there is room for criticism in this statement due to the lack of evidence supporting this concern, the working class having this concern at all shows a clear conflict in the anticipations of each party. Regardless of where you stand on such a statemtement one thing is for certain: for responsible innovation of autonomous transportation vehicles, better anticipation from industry executives is required.

Reflexivity

Responsible innovation requires innovation to have reflexivity upon the motivations of innovation promoting scientists to “blur the boundary between their role responsibilities and wider, moral responsibilities” (Stilgoe et al., 2013, p. 4). With regard to the transportation industry, there must be more incentive than profit. To find this incentive, I will utilize the previously referenced study conducted by the University of Warwick. In that study, another primary concern of transportation workers in the implementation of autonomous vehicles is safety (Sindi, et al., 2021). Instead of focusing on the topic of safety in autonomous vehicles as a whole, for the purposes of this paper, I will focus on aspects of safety that primarily affect the workers of the transportation industry.

With regard to safety in autonomous vehicles, the research is clear: workers in the transportation industry feel safer when implementing autonomous driving capabilities on vehicles without humans (Sindi, et al., 2021). This is due to the general consensus that if a vehicle did not have an occupant, it would remove the risk of anyone within the vehicle being hurt (Sindi, et al., 2021). To respond to this, the transportation industry has modified its implementation strategy. Instead of automating the entire transportation industry simultaneously, an industry focus on freight trucks is prioritized (Figure 4) (Porter, et al., 2018). Since freight

Figure 4: Render of Autonomous Amazon Freight Truck. (Credit: Fleetowner, 2020)

trucks usually have a single driver and consist of mostly interstate driving, the implementation of this sector of transportation would be generally safer than a more civilian focus mode of transportation, such as a charter bus. While this implementation strategy allows a potentially minimal loss of life as the result of a crash, there is an inadvertent side effect to this strategy, the improvement of driver health.

Truck driving is a hard job, requiring drivers to work roughly seventy hours in an 8-day period, time almost entirely spent sitting at a steering wheel (AAC, 2022). As a result of this inactive and unstimulating nature, truck drivers are twice as likely to be obese and smoke as compared to the population; with many drivers smoking only under the assumption it keeps them awake longer. (CDC, 2021). These activities are cited as the cause of a myriad of additional health issues, such as cancer, high blood pressure, and diabetes. (CDC, 2021) The detrimental nature that truck driving has on worker health makes it a prime target for automation. Research shows that proper implementation of autonomous trucks could have the effect of improving driver health and fatigue from working conditions (Talebian, et al., 2022). For example, if automation is implemented in a way where the workers supervise driving instead of constantly controlling it, this could relieve the constant stress the drivers are under while operating the vehicles. This combined with the safer and staggered implementation of autonomy in freight trucks draws me to the conclusion that the industry has been relatively well in being reflexive to the concerns of the workers. As with all concerns, however, there is always more that can be done to address the concerns of workers and address their health and safety.

Inclusion

Inclusion refers to the questioning of who is making – and benefiting – from innovations. Inclusivity is a key component of any form of responsible innovation due to the insights and perspectives underrepresented communities give innovators (Stilgoe et al., 2013). One such example is the Transport Workers Union of America’s (TWU) protest campaign “People Over Robots” (Figure 5). During a campaign rallying Ohio lawmakers to address the changing transportation industry, the union argued the role of transportation workers extends far past what is being addressed by automation (Figure 5). Instead, the workers argue transportation is a job focused on serving the community, something automation cannot emulate. The impact the drivers argue they have on their community is vast, ranging from knowing which regular passengers have health issues to protecting passengers from Immigration and Customs Enforcement (TWU, 2018). Despite the compelling arguments made by the TWU, the members of the organization feel as if their insights into the industry are not being considered in the conversation around the implementation of transportation; Michele Lepore Hagan – a TWU

Figure 5: Transportation Workers Union (TWU) Protest. (Credit: TWU, 2018)

representative – states, "It's a lot more than driving people from A to B. You deserve a seat at the table," (TWU, 2018). Transportation worker's unions play a critical role in ensuring that the needs of the public are protected within the transportation industry. While there is room for critique in their claim of these social aspects being impossible to autonomize, I believe the larger point the TWU wants to convey is that there will always be human factors that autonomy can't account for. As we move towards greater adoption of autonomous vehicles, it is important to include these unions and other underrepresented groups in the conversation to ensure that we are addressing all aspects of the transportation industry.

Responsiveness

The final cornerstone of responsible innovation, responsiveness, is arguably the most important. It assesses if the system undergoing innovation allows for a response from the other three criteria (Anticipation, Reflexivity, and Inclusion) (Stilgoe et al., 2013). For the transportation industry, this means implementing strategies to further the industry's responsibilities to the public. The transportation industry has only halfheartedly addressed the anticipated concerns of automation. Better communication of anticipation from researchers is essential to industry responsiveness. The transportation industry has done well addressing some concerns of public health and safety but should strive to address lesser-discussed issues, such as the concerns posed by the TWU. The transportation industry has done a poor job of inclusivity in the voices it follows. Many workers feel as if they are being ignored. Fostering better relationships between workers, executives, and lawmakers is key to industry responsiveness. While the transportation industry has come a long way in responding to the questions of responsible innovation, it still has a long way to go.

Conclusion

In conclusion, we are in an age of autonomous innovation. As such, it is vital that we address any potential risks and responsibilities that come with it. As with all innovation, there are ethical issues that cannot be analyzed from one perspective alone. By using the four cornerstones of responsible innovation, we can assess the transportation industry's adherence to its responsibility to the public. While the transportation industry does do some things well, many more steps should be taken to adhere to the guidelines of responsible innovation. The inclusion of excluded voices, along with better communication with regard to industry anticipations and reflexivity, will help improve both the implementation and efficacy of autonomy in the industry.

As stated by Deborah Johnson in her book *Engineering Ethics* (2020), it's important for engineers to not only understand the technical aspects but the context and ethical ramifications of their work. As such, the findings of this paper are meant to demonstrate the shortcomings of the transportation industry with respect to responsible innovation. To my fellow engineers, I present this paper as a document demonstrating an acknowledgement of some of the concerns shared by the working class of the industry with the hopes of us acknowledging their considerations in our future pursuits of innovation. To the executives and other patrons within the industry, I present this paper to highlight the shortcomings within your current implimenation strategies and propose measures to be acted upon in order to responsible move forward. By addressing the potential risks and responsibilities head-on, we can ensure that the benefits of autonomous vehicles are enjoyed by everyone, without sacrificing the wellbeing of the working class. In doing so, we present a better and more responcible future for everyone.

References

American Legislative Exchange Council. (2018, January 20). Vehicle Platooning for Safety and Efficiency Act. Retrieved October 27, 2022, from https://alec.org/model-policy/vehicle-platooning-for-safety-and-efficiency-act/

Anderson, J. M., Kalra, N., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2014). Brief History and Current State of Autonomous Vehicles. In *Autonomous Vehicle Technology: A Guide for Policymakers* (pp. 55–74). RAND Corporation. http://www.jstor.org/stable/10.7249/j.ctt5hhwgz.11

Anderson, S. (2019, April 30). DARPA challenges drive dual-use Innovation. Retrieved April 5, 2023, from https://spie.org/news/spie-professional-magazine-archive/2019-april/darpa-grand-challenges?SSO=1

Bureau of Labour Statistics. (2021). Transportation Economic Trends: Transportation Employment. Retrieved October 27, 2022, from https://data.bts.gov/stories/s/Transportation-Economic-Trends-Transportation-Empl/caxh-t8jd/

Businesswire. (2022, May 9). The Global Autonomous Vehicle Market Will Grow to $2,161.79 billion by 2030, at a CAGR of 40.1%. Retrieved April, 2023, from https://www.businesswire.com/news/home/20220509005442/en/The-Global-Autonomous-Vehicle-Market-Will-Grow-to-2161.79-billion-by-2030-at-a-CAGR-of-40.1---ResearchAndMarkets.com

Casselman, B. (2021, July 19). Officially, the pandemic recession lasted only two months. *The New York Times*. Retrieved April 30, 2023, from https://www.nytimes.com/2021/07/19/business/economy/pandemic-recession-over-coronavirus.html

Depillis, L. (2022, September 12). Who Are America's Missing Workers? *The New York Times*. Retrieved April 30, 2023, from https://www.nytimes.com/2022/09/12/business/economy/labor-participation-covid.html

Freightliner (2023). Introducing the Freightliner Inspiration Truck. Retrieved April 5, 2023, from https://freightliner.com/why-freightliner/industry-leading-results/introducing-the-freightliner-inspiration-truck/

Groshen, E., Helper, S., MacDuffie, J., & Carson, C. (2019). Preparing U.S. Workers and Employers for an Autonomous Vehicle Future. *Upjohn Institute Technical Reports*. https://doi.org/10.17848/tr19-036

Hiring troubles prompt some employers to eye automation and machines. (2021, May 19). *Washington Post*. Retrieved October 27, 2022, from https://www.washingtonpost.com/business/2021/05/19/automation-labor-economy/

Johnson, D. (2020). How Should Engineers Think About Ethics? In Engineering Ethics (pp. 46–70). *Yale University Press* ; JSTOR. https://doi.org/10.2307/j.ctv10sm953.7

Kirschner, M. (2019, May 2). Dude, Where’s My Autonomous Car? Semiconductor Engineering. Retrieved October 27, 2022, from https://semiengineering.com/dude-wheres-my-autonomous-car/

Litman, T. (2022, November 6). Autonomous Vehicle Implementation Predictions: Implications for Transport Planning. *Victoria Transport Policy Institute* Retrieved April 30, 2023, from https://www.vtpi.org/avip.pdf

Matousek, M. (2021, June 23). Self-driving trucks are heating up as startups go public and Amazon jumps in. these are the top 6 players to watch in the booming industry. Retrieved April 5, 2023, from https://www.businessinsider.com/top-6-players-self-driving-semi-truck-embark-waymo-2021-6

Metz, C. (2022, September 28). The Long Road to Driverless Trucks. *The New York Times*. Retrieved October 27, 2022, from https://www.nytimes.com/2022/09/28/business/driverless-trucks-highways.html

Morris, J. (2021, March 13). Why Is Tesla's Full Self-Driving Only Level 2 Autonomous? *Forbes*. Retrieved October 27, 2022, from https://www.forbes.com/sites/jamesmorris/2021/03/13/why-is-teslas-full-self-driving-only-level-2-autonomous/

Petropoulos, G. (2021). Automation, COVID-19, and Labor Markets. *Asian Development Bank Institute*. 26. Retrieved April 30th, 2022, from https://www.adb.org/sites/default/files/publication/688896/adbi-wp1229.pdf

PricewaterhouseCoopers. (2022). Industrial mobility: How autonomous vehicles can change manufacturing. Retrieved October 27, 2022, from https://www.pwc.com/us/en/industries/industrial-products/library/industrial-mobility.html

SAE International. (2021, May 3). SAE Levels of Driving Automation™ Refined for Clarity and International Audience. Retrieved October 27, 2022, from https://www.sae.org/site/blog/sae-j3016-update

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. Research Policy, 42(9), 1568–1580. Retrieved April 30, 2023, from https://doi.org/10.1016/j.respol.2013.05.008

Transport Workers Union. (2018, September 20). The TWU Launches Statewide Coalition Against Driverless Buses in Ohio: People Before Robots! Retrieved October 27, 2022, from https://www.twu.org/the-twu-launches-statewide-coalition-against-driverless-buses-in-ohio-people-before-robots/

U.S. Bureau of Labor Statistics. (2022). Industries at a Glance: Transportation and Warehousing: NAICS 48-49. Retrieved October 27, 2022, from https://www.bls.gov/iag/tgs/iag48-49.htm

U.S. Bureau of Labor Statistics. (2022, June). U.S. labor market shows improvement in 2021, but the COVID-19 pandemic continues to weigh on the economy. Retrieved October 27, 2022, from https://www.bls.gov/opub/mlr/2022/article/us-labor-market-shows-improvement-in-2021-but-the-covid-19-pandemic-continues-to-weigh-on-the-economy.htm