

CARNEGIE MELLON HEINZ COLLEGE



Future of Work:
TRUCKERS ON THE ROAD TO AUTOMATION

SYSTEMS SYNTHESIS PROJECT

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EXECUTIVE SUMMARY

This research project grew out of a desire to explore the impacts of emerging technologies on work. Specifically, the Carnegie Mellon University H. John Heinz III College (CMU) research team and the Aspen Institute Future of Work Initiative partnered together to explore potential impacts to long-haul truckers and policy responses to automation in the trucking industry.

The project began with a literature review to better understand possible workforce and industry impacts, as well as potential policy responses to the issue of automation in long-haul trucking. Our CMU research team was most interested in exploring likely workforce impacts on truckers' wages, displacement, changes in job duties/skills, and any changes to demographics. Our team was also interested in understanding impacts of automation on the trucking industry.

After completing the introductory literature review, our team concluded that there was a lack of comprehensive publicly available policy analysis regarding the impacts of automation on the trucking workforce and industry. As a result, our team decided to implement the Delphi method, a systematic way to analyze expert opinion and make predictions, to gather primary data from stakeholders in the trucking industry, as well as policy and academic worlds.

As part of the Delphi method, our team administered a non-representative three-round survey to uncover several themes on workforce, industry, and potential policy responses. Our team received 40 responses from the first survey round, 30 from the second, and 26 from the third. Survey participants were allowed to select multiple professional areas of expertise, and the most commonly selected areas across all three surveys were legislative policy and academia.

Survey participants had the most consensus when predicting impacts to the long-haul trucking industry, with over 90% of survey two participants (28 out of 30) being optimistic about the impact of automation on the trucking industry. Expected improvements to the industry were a key driver of this optimism as the majority of participants believed automation would increase efficiency and reduce costs within the industry.

There was much more variation amongst survey participants' answers when asked to predict potential workforce impacts from automation. There was a nearly even split when survey two participants were asked about their overall attitude towards the impact of autonomous technology on the long-haul trucking workforce, with 46.7% (14 out of 30 respondents) optimistic and 36.7% (11) pessimistic. Participants identified existing workforce trends such as the aging workforce, the current driver shortage, the adoption rate of autonomous technology, and increasing demand in the industry, as factors that would likely impact workforce issues.

With regards to potential policy responses, a majority of survey participants identified a limited role of government to handle the disruption of autonomous technology. The majority of participants believed government *will* enact performance and safety standards with respect to autonomous technology. But, when asked what government *should* do, the majority felt that government should not be primarily responsible for supporting displaced long-haul truckers as a result of automation. Many of these participants who did not believe government was responsible

clarified that government intervention was not necessary beyond existing retraining and welfare options.

Results from our survey research suggest that there will be time for regulators and the larger government to prepare for the disruption of automation in the long-haul trucking industry. For the next 15 years, our survey participants largely agreed that the job of a truck driver will remain relatively the same. Autonomous technology, however, does promise to change future truck driving jobs. Given the uncertainty around the timing of potential impacts, we conclude that regulators and policymakers should focus in the near-term on better understanding how autonomous technology will be used in the long-haul trucking industry. Having a better sense of how the technology will be used will allow for more informed policy development on performance and safety standards, as well as workforce issues.

INTRODUCTION

The Future of Work systems team is composed of five students pursuing a Master of Science in Public Policy and Management from Carnegie Mellon University H. John Heinz III College in the Washington, D.C. track. Our graduate program integrates coursework in public policy, management, technology, and analytics with a two-semester Apprenticeship based in Washington, D.C. As part of the Washington, D.C. track, we completed a year of coursework in Pittsburgh, taking classes in Management Science, Economics, and Statistics. During our second year, we moved to Washington, D.C. to work 30 hours per week at an apprenticeship and take classes at night. We apply our data analytic, policy, writing, and other technical and soft skills in the apprenticeship.

This systems research project is a synthesis of our graduate program. Instead of writing a traditional thesis, students in our program complete a systems project during the second semester of the final year. Each project includes a group of five to six graduate students, a faculty advisor, a client, and an advisory board to provide feedback and assist with project development. While each systems project varies based on the client or faculty advisor, most projects analyze a policy issue, include research and analysis, and offer a policy recommendation or key set of findings.

Intent

For our systems project, the team partnered with the Aspen Institute Future of Work Initiative to explore potential impacts to long-haul truckers and policy responses to automation in the trucking industry. This focus grew out of a desire to explore the impacts of emerging technologies on work. In particular, media coverage often highlights trucking as emblematic of this change and has forwarded a narrative of large scale displacement of truckers caused by automation.¹ Furthermore, articles suggest that this outcome would unfold relatively soon.² As a result, our team sought to explore this possibility and other potential workforce impacts of automation in long-haul trucking.

Methodology

This project was initiated by addressing the following research questions:

- How might highly automated commercial vehicles disrupt the trucking workforce and long-haul trucking industry?
- How are states and state trucking advocacy groups responding to this potential disruption?

¹ Natalie Kitroeff, "Robots could replace 1.7 million American truckers in the next decade", *LA Times*, September 25, 2016, <http://www.latimes.com/projects/la-fi-automated-trucks-labor-20160924/>.

Dominic Rushe, "End of the Road, Will Automation Put an End to the American Trucker?", *The Guardian*, October 10, 2017, <https://www.theguardian.com/technology/2017/oct/10/american-trucker-automation-jobs>.

Aarian Marshall, "What Does Tesla's Automated Truck Mean for Truckers?", *Wired*, November 17, 2017, <https://www.wired.com/story/what-does-teslas-truck-mean-for-truckers/>.

² Andrew J. Hawkins, "Uber's self-driving truck company just completed its first shipment: 50,000 cans of Budweiser", *The Verge*, October 25, 2017, <https://www.theverge.com/2016/10/25/13381246/otto-self-driving-truck-budweiser-first-shipment-uber>.

While our interest in workforce and industry impacts was consistent throughout the project, we expanded our focus to policy responses at all levels of government instead of specific state policy. We realized that multiple levels of government would be involved in regulating the long-haul trucking industry, and we also became more interested in exploring whether government should get involved. As the project progressed, we administered a three-round survey to gather primary data from stakeholders on their views and perspectives of future government responses.³

Our team sought guidance from a Carnegie Mellon University librarian to initiate our introductory research. The librarian provided keywords and search terms to conduct a targeted search and review of scholarly research articles, trade publications, industry databases, state legislative records, federal government reports, industry reports, media coverage, and Google Scholar.⁴

The targeted search suggested by the library staff yielded over 100 results relevant to workforce and industry impacts. For state policy, the search yielded a total of 304 results for the 2017 legislative session, including all proposed, passed, or tabled state legislation where automation was mentioned in the context of transportation or drones. The majority of these results mentioned liability, safety, testing and development, and definitions of what counts as autonomous. Most notably, only Virginia had specific language to research automation's potential disruption to the workforce.⁵ This legislation was tabled in the most recent legislative session.

Finally, a web search was conducted to identify state trucking associations' policy positions on automation and the trucking industry.⁶ The main goal of this search was to identify whether trucking advocacy groups, as represented at the state level, were taking an active position on automation in the industry. This search revealed that state trucking associations rarely made public references to automation on their websites; those that did make public references did not specifically mention automation and workforce impacts.

A notable limitation of this search is that many trucking associations have sections of their website or services for members only. It is possible that mentions of automation were featured in the members-only section of their website or included in a newsletter that the general public would not have access to. For this reason, it would be wrong to state that no state trucking association is thinking about the effects of automation on the trucking workforce and industry.

At the end of our introductory literature review, we concluded that there was a lack of comprehensive publicly available policy analysis regarding the impacts of automation on the trucking workforce and industry. The bulk of our search results consisted of news articles, media

³ See Appendix B for further explanation of the survey methodology.

⁴ See Appendix A for a list of our search terms.

⁵ See 2016 VA H.J.R. 615.

⁶ We used the search term “[state name] trucking site:.org” to identify trucking association websites for all fifty states and the District of Columbia.

clips, and blog posts. Therefore, our systems team found it valuable to implement a Delphi method survey to relevant stakeholders to answer our research questions.⁷

The Delphi method is a systematic way to analyze expert opinion and has been used to make forecasts in several highly regarded research studies. The main reason we decided to utilize the Delphi method is because our literature review did little to answer our questions on how autonomous technology will impact the long-haul trucking workforce, industry, and influence potential policy responses. Generating our own data through the Delphi method seemed to be the best way for us to answer our research questions.

As part of the Delphi method, our team administered a three-round survey to uncover themes on workforce, industry, and potential policy responses to automation in the long-haul trucking industry.⁸ It is important to note that our small sample size and non-probability sampling techniques made our survey non-representative. We received 40 responses from the first survey round, 30 from the second, and 26 from the third. The most commonly selected areas of expertise across all three surveys were legislative policy and academia.

The three rounds of our survey helped forecast the potential disruption of autonomous technology on the trucking workforce, industry, and policy. The first round asked open-ended questions centering on the topics outlined in our research questions. In the process of analyzing the results of the first survey, we noted the main ideas, common themes, and outliers. We used our analysis in conjunction with what we learned from our literature review to develop specific close-ended questions for our second survey. In the second survey, we started developing a strong consensus on our research questions by asking specific workforce, industry, and policy questions. Our analysis of responses from the second survey, however, also helped highlight major areas of disagreement mostly centering on workforce topics. In the third survey, we tried to generate more consensus on the areas of disagreement by asking a set of specific questions on a limited set of workforce topics. We then aggregated and analyzed all responses from each survey round.

Background on Trucking Workforce and Industry

According to the Bureau of Labor Statistics, there are 1.7 million heavy and tractor-trailer truck drivers in America.⁹ Truck driving and delivery is the most common occupation in a majority of states; although some of this can be explained by the way the occupation is counted by the government.¹⁰

However, the trucking industry is experiencing a shortage of truck drivers primarily due to an aging workforce with an average age of 55 and a demanding lifestyle that comes with the job.¹¹

⁷ See Appendix B for more information on the Delphi method.

⁸ See Appendices C, D, and E for information on each of our surveys.

⁹ "Occupational Employment Statistics," Bureau of Labor Statistics, *U.S. Department of Labor*, Accessed April 26, 2018, <https://www.bls.gov/oes/current/oes533032.htm>.

¹⁰ Quoctrong Bui, "Map: The Most Common* Job In Every State", NPR, February 5, 2015, <https://www.npr.org/sections/money/2015/02/05/382664837/map-the-most-common-job-in-every-state>

¹¹ Samantha Raphelson, "Trucking Industry Struggles with Growing Driver Shortage," NPR, January 9, 2018, <https://www.npr.org/2018/01/09/576752327/trucking-industry-struggles-with-growing-driver-shortage>.

The American Trucking Association reports a current shortage of approximately 50,000 drivers and “predicts that a total of nearly 900,000 new drivers will be needed over the next eight years.”¹²

Initially, automation was seen as an option to help fill the trucker shortage in addition to other strategies like raising truckers’ wages to attract more workers.¹³ However, automation has recently created workforce uncertainty, and has been portrayed in the media as having the potential to replace the job of 1.7 million American truck drivers.¹⁴ The *Los Angeles Times* refers to truck driving as “one of the last remaining careers that offer middle-class pay to those without a college degree.”¹⁵ In 2017, the median annual wage for truck drivers was \$42,480; truck drivers are able to earn this wage with a high school diploma and commercial driver’s license.¹⁶

SURVEY ANALYSIS

Main Takeaway

Based on the analysis of our three round survey, we found that workforce trends in the trucking industry and uncertainty around technology adoption suggest that widespread automation is unlikely to occur in the short to medium term, which we define as less than 15 years. Given the current trajectory of technology development and its potential impact, dialogue and research should focus on understanding how autonomous technology will be used in the long-haul trucking industry. Once the technology path is better understood, policy will be better positioned to address performance and safety standards and potential workforce impacts.

Industry Impacts

Survey participants had the most consensus when predicting impacts to the long-haul trucking industry across the themes of workforce, industry, and policy. In general, over 90% of survey two participants (28 out of 30) were optimistic about the impact of automation on the trucking industry (see Figure #1). Expected improvements to the industry were a key driver of this optimism as the majority of participants believed automation would increase efficiency and reduce costs within the industry (see Figure #2). However, most of this automation is expected to occur in the long-term. Over 60% of survey two participants (19 out of 30) believed the long-haul trucking industry will not be fully transformed by automation within 15 years (see Figure #3). In contrast to industry impacts, there were significant disagreements on workforce and policy impacts as outlined in the following sections.

¹² David H. Freedman, “Tractor-trailers without a human at the wheel will soon barrel onto highways near you. What will this mean for the nation’s 1.7 million truck drivers?” MIT Technology Review, April 2017, <https://www.technologyreview.com/s/603493/10-breakthrough-technologies-2017-self-driving-trucks/>.

¹³ Oyedele, Akin. "The Trucking Industry Is Handling Its Driver Shortage in a Unique Way - and It Could Crush Others That Depend on It." Business Insider March 29, 2018, Accessed May 04, 2018, <http://www.businessinsider.com/truck-driver-shortage-lifts-prices-but-could-crush-other-industries-2018-3>.

¹⁴ Natalie Kitroeff, “Robots could replace 1.7 million American truckers in the next decade” *LA Times*, September 25, 2016, <http://www.latimes.com/projects/la-fi-automated-trucks-labor-20160924/>.

¹⁵ Ibid.

¹⁶ “Occupational Outlook Handbook,” Bureau of Labor Statistics, U.S. Department of Labor, Accessed April 26, 2018, <https://www.bls.gov/ooh/transportation-and-material-moving/heavy-and-tractor-trailer-truck-drivers.htm>.

Figure # 1:

Many believe automation will benefit the trucking industry

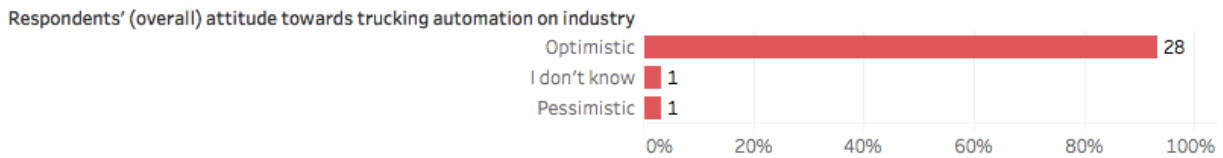
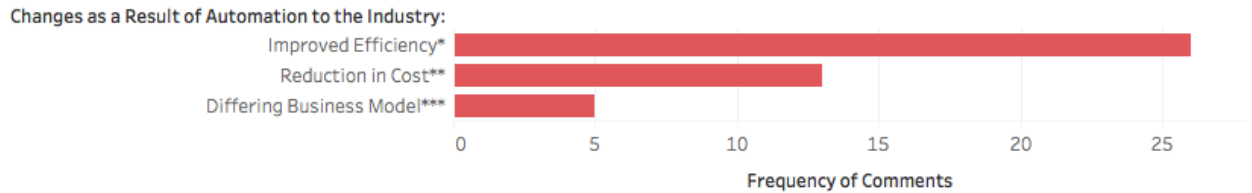


Figure # 2:

Greater efficiency will be one of the main benefits brought by automation



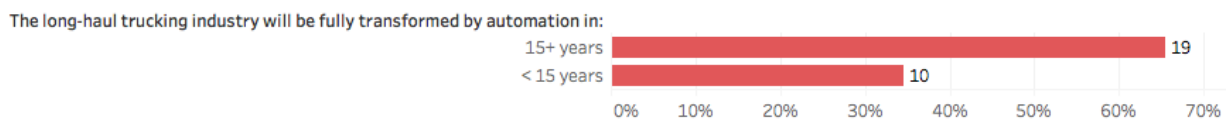
*Fuel economy improvements, safety improvements, reduction in travel time

**Fuel, labor...

***Hub & Spoke

Figure # 3:

The long-haul trucking industry will not be fully transformed by automation within 15 years



Workforce Impacts

General

There was much more variation amongst survey participants' answers when asked to predict potential workforce impacts from automation. For instance, there was a nearly even split when survey two participants were asked about their overall attitude towards the impact of autonomous technology on the long-haul trucking workforce, with 46.7% (14 out of 30 respondents) optimistic and 36.7% (11) pessimistic. A possible explanation for this disagreement is that a multitude of variables could impact workforce issues. As listed by our survey participants, these include policy responses, existing workforce trends such as the aging workforce, the current driver shortage, the adoption rate of autonomous technology, and increasing demand in the industry. One respondent also noted that current truck drivers would remain essential as long as they continue to perform non-driving duties in the vehicle.

Wage Impact

There was a consensus that changes in wages are difficult to predict, especially considering the different level of skills involved with changing job duties. Only three participants mentioned wages unprompted in our first open-ended survey. We sought to gain more insight into this topic in our second survey and determined that participants did not previously mention wages because "potential changes in wages will vary depending on the type of task performed by the driver" and because there was an "insufficient availability of information to support an informed assessment" at this time.

One agreement among respondents was that automation would create higher skilled jobs with higher wages. However, there was uncertainty on whether there would be a greater number of higher skilled jobs. A representative response from one of our surveys described a potential situation: *“There will be fewer workers as drivers, but there will be teams of higher skilled and higher paid pilots.”*

The team concluded that stakeholders were too uncertain to form strong opinions, so we shifted our focus away from wage impact in the third survey.

Displacement of Workforce

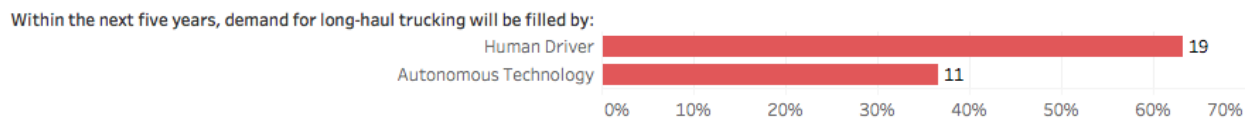
The most common topic identified by survey participants in the first survey was the issue of displacement, but there was disagreement over whether automation would eventually impact the overall workforce size and directly compete with truck drivers for jobs. Several participants believed automation would not cause any displacement of current workers, with some pointing to a reduction in the overall size of the trucking workforce due to workers entering into retirement. However, several other participants mentioned automation would directly reduce the overall workforce size. Two representative quotes follow:

- *“Most of the current workforce will age out before substantial automation of long-haul trucking occurs over 10-15 years...”*
- *“From years 10-20 years out from today, I see autonomous trucks displacing 60-80% of the drivers”*

A majority of survey two participants agreed there would be little displacement of the trucking workforce due to automation in the short to medium term (within the next 15 years). For instance, 63.3% (19 out of 30 participants) of survey participants from survey two believed the increase in demand for trucking services would be filled by human drivers within the next five years (see Figure #4). Furthermore, 69% of participants from survey three (18 out of 26) believed a majority of current truck drivers would retire or exit the workforce before the full adoption of autonomous technology within the industry.

Figure # 4:

Demand for long-haul trucking will be filled by human drivers in the short-term



In addition to the general consensus around short-term impacts of automation, participants agreed having a human presence in the truck was a necessity. When asked if technological advancements would make it possible to have a safe, legal, and fully automated truck with no need for a human driver, 70% (21 out of 30) of survey two participants believed a human driver would be needed for at least some trips. This “driver” might be physically present in the truck but performing tasks outside of driving, or a human driver would be needed depending on the type of load the truck is carrying.

Despite these areas of consensus, survey participants disagreed on the long-term likelihood of displacement. For example, there was more variability on what potential displacement could look like in the long-term or more than 15 years. Some participants believed human drivers would only be present in the lead truck in a situation where trucks would be linked autonomously, while others believed truck drivers would take on a teleoperator role.

The tension between projecting short and long-term impacts of automation on the size of the trucking workforce was evident in one participant's response on the issue of liability. The participant wrote:

As long as there are liability issues associated with the "blue screen" issue of the technology "crashing," every truck will need to have a driver at least on standby to take control of the truck. IF, the liability issue could be overcome, there would be a watershed moment...

The participant's response suggests there are current barriers to the widespread use of autonomous technology. As long as these barriers exist, the trucking workforce will not change dramatically. This supports the overall message we received from participants: in the short-term, while barriers exist and the technology is not yet fully developed, the size of the workforce will not be significantly impacted.

Demographics

Few participants mentioned the demographics of truck drivers in our first survey. However, subsequent survey questions determined that automation could attract younger workers (under 30 years of age) into the trucking workforce. 65.4% (17 out of 26) of survey three participants believed people under 30 would be more attracted to join the trucking workforce due to automation. Of this group, more than half believed automation would increase the desirability of a trucker's work schedule and improve working conditions. One participant explained, *"Millennials would appreciate the new combination of AT [autonomous technology] attributes including high-tech environment, multi-tasking, social media opportunities..."*

Like the topic of displacement, participants were uncertain about long-term changes in truck driver demographics. One participant believed people under 30 would be more attracted to join the trucking workforce but mentioned how his/her prediction would change when thinking about a longer timeline. The participant wrote, *"I am pessimistic about the trucking workforce after full automation, but I check all the above if the question is limited to the near 10 years."* Another participant expressed a similar view: *"As in any factory job, as automation is implemented job longevity begins to be questioned. Without a somewhat secure vision of the job outlook, young people tend to look for alternative careers."*

Change in Job Duties/Skills

Despite uncertainty in other workforce subtopics (wages, size of workforce, demographics), participants were aligned in thinking that automation would make the occupation safer and create demand for specialized skills. The first mention of specialized skills emerged in our first survey with 12 respondents believing automation would create new job duties such as technicians or teleoperators (see Figure #5). One response summarized the teleoperator role by saying, *"I also*

think that some truck drivers will operate trucks from a telepresence location, remotely controlling multiple autonomous trucks at a time.” Responses from the second survey identified the shift to a teleoperator role as a scenario that would cause the largest disruption to the trucking workforce.

Figure # 5:

Automation will introduce specialized skills to future truck driving jobs

Automation's Impact on the Trucking Workforce:



*Supervisory role entails a person in the vehicle to monitor driving and safety duties who can take control when necessary

The second most commonly indicated change in job duty was adaptation of the truck driver to a vehicle supervisor. Several survey one participants mentioned that automation would require truck drivers to assume the role of a supervisor, which we defined as individuals who monitor driving and take manual control of the vehicle when necessary. One participant described this change as “a very gradual conversion of competent drivers to monitors or chaperones of driverless trucks...”

Additionally, the specialized skills and roles described above support the idea that the use of autonomous technology is still difficult to predict. The technology model that is largely adopted by the trucking industry will play a critical role in determining how job duties will change. For example, platooning is a model where trucks are linked autonomously and led by either one human driver in the lead truck or controlled from a remote location. The platooning scenario reveals that the level of demand for truckers with these specialized skills will also not be known until the specific use of automation is determined. While survey participants seem certain that automation will introduce specialized skills, it is not clear which skills will be emphasized in the future of trucking.

Along with specialized skills, participants showed confidence that automation would improve job quality for truck drivers. Most respondents mentioned that quality would improve due to increased safety and efficiency. One participant succinctly wrote, “Truckers’ jobs will likely be made easier, more comfortable, and more appealing.” However, there was an outlier response that stated particular policy responses could lead to lower-quality jobs for truck drivers. The participant explained that if workers were “misclassified” or if they faced “unpaid waiting time,” “automation would lead to significantly worse jobs for truckers...”

Finally, participants agreed that many changes in job duties or skills would not occur in the short to medium term. When asked to predict the first change in a truck driver’s job responsibilities, the majority (17 out of 30 survey two participants) believed the job would remain largely the same but demand for long-haul truck drivers may change. In the first survey, one participant wrote that “In the short-term (next 5-10 years), there will be only a gradual shift in these roles with only pilot programs and trials being allowed.”

Potential Policy Responses

General

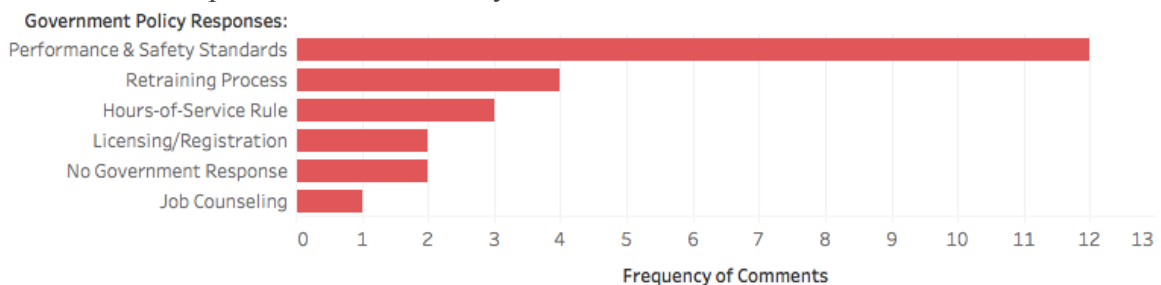
In creating the surveys, the team approached potential policy responses by focusing survey questions on how participants believe government, at any level, will act and how government, at any level, should act. Regarding how government will act, participants identified the importance of establishing performance and safety standards. When asked about what government should do, survey three participants disagreed on the responsibility of government to support displaced truck drivers. There was a slight majority of survey three participants who believe government should not be responsible.

What Government Will Do

The most frequent response to our first survey asking how government will respond to the adoption of automation in the long-haul trucking industry was the creation of new and updated performance and safety standards (see Figure #6). Performance and safety standards were mentioned three times more than responses relating to workforce issues, such as retraining programs or job counseling. This suggests our participants were very confident that government will set these standards. Survey one participants identified the need for performance and safety standards to ensure standardization, as one participant wrote: “some [regulation] is needed to standardize safety of these vehicles, as well as other aspects of the technology...”

Figure # 6:

Government will enact performance and safety standards



In addition to performance and safety standards, participants also agreed that government would make more specific regulations after autonomous technology was better understood. One participant wrote:

The government will need to see real use cases and copious data that shows automated trucking is safe and reliable. This will take time, but with advanced simulation services, rapidly advancing technology and massive amounts of R&D going into building technology, the regulators will slowly create legislation to allow for autonomous trucks.

Furthermore, several participants mentioned that the federal government would move slower than states, as one participant wrote: “The state will be ahead of (but hopefully consistent with) federal standards. Harmonization between state and federal regs/standards will take longer.”

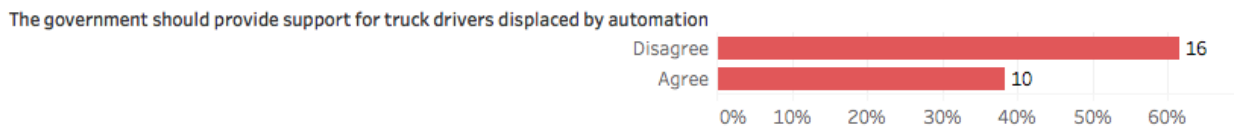
What Government Should Do

The majority of respondents felt that government should not be primarily responsible for supporting displaced long-haul truckers as a result of automation. In our second survey, 56.7% of participants (17 out of 30) believed government is not responsible for supporting long-haul truck

drivers displaced by automation. Specifically, a sizeable portion, 36.7% (11), believed truckers themselves are responsible. We followed up on this question in survey three and received similar results: 61.5% of participants (16 out of 26) did not believe it was the responsibility of government to provide support for truck drivers displaced by autonomous technology (see Figure #7). While most participants did not believe government should be responsible, many participants clarified that government intervention was not necessary beyond existing retraining and welfare options. One thematic response follows: *“Government should assist in retraining as in any other sector, but nothing different than those existing retraining programs.”*

Figure # 7:

Government is not responsible for supporting truckers displaced by automation



Interestingly, 3 of the 16 participants who did not believe it was the government’s responsibility to provide support for displaced truck drivers questioned if a workforce intervention would even be necessary. Participants either *“did not think joblessness is the primary concern (except for rural workers)”* or that *“driver displacement will take care of itself without the need for government to provide exit support for drivers [due to regulatory delay and improvements in technology].”* One participant noted that he/she would want to know *“how many people are displaced and what happens because of it”* before deciding on the type of intervention. While these responses did not represent the majority’s view, they highlighted the larger disagreement over automation’s potential to cause workforce displacement.

Of the 10 out of 26 respondents to the third survey who believed government is responsible for supporting displaced truck drivers, retraining was the top choice. Other potential options that we explored in the survey included monetary compensation, job counseling, and participants’ own policy proposals. Specifically, 6 of these 10 respondents chose retraining as the most viable way government can mediate negative impacts on displaced truck drivers. These participants indicated that the ideal retraining program would be funded either at the state or federal level and retraining would provide applicable skills drivers could use both inside and outside the trucking industry.

LIMITATIONS

The Delphi survey that was administered contained significant limitations relating to our sample. The primary limitation of our survey was the use of non-probability sampling techniques to recruit participants. We used purposive sampling to reach out to leaders in the automotive, technology, policy, and academic worlds, as well as truck drivers with personal driving experience. We also used snowball sampling to recruit more participants, in which we asked potential participants to refer us to other helpful individuals to participate in our survey.

These non-probability sampling techniques were used because the Delphi method centers on using expert opinion to delve deeply into projections, but these techniques also mean that our

final sample is not representative of the larger population. That is, the demographics of our sample (sex, age, and geographic distribution) do not mirror the larger American population. Any conclusions we drew from these survey rounds could not be generalized to represent the larger population. In addition, the snowball sampling technique runs the risk of over-representing a particular viewpoint, as survey participants are likely to refer us to similarly-minded individuals in their professional networks, making it harder to hear from a diverse group within the automation and transportation field.

Finally, another limitation regarding our survey was its small sample size. Survey one had 40 responses, survey two had 30 responses, and survey three had 26 responses. The small sample sizes in surveys two and three made it difficult to conduct statistical tests. Similar to the problems presented with non-probability sampling techniques, our small sample sizes also meant that the survey responses only reflected the feelings and thoughts of our participants. Even though we reached a sizable sample in survey one, we only asked open-ended questions where statistical tests could not be used.

Despite the limitations of our sample, our survey participants did include a wide range of experts from the automotive, technology, policy, and academic worlds.

NEXT STEPS

The next steps for policy makers are to systematically manage the future of work for long-haul truckers through data collection. Even though our survey participants think the biggest disruptions from automation will be beyond 15 years, government can be forward thinking by collecting data on workforce and technology use to model and respond to long-term impacts of automation in the trucking industry. Specific data on workforce can include: the exit and entry of drivers from the workforce, the rate of displacement by automation, and the tracking of new jobs created in the industry due to automation. More data can even be collected on truck drivers themselves, including who leaves the industry and what happens to them afterwards. These types of data can be used to analyze the growth of automation, assess if technology will enhance capabilities or replace them, identify which demographics will be most vulnerable, and inform policy responses such as retraining and alleviating potential future displacement.

A next step for researchers would be to explore the impact of automation on rural communities. Our group would have liked to explore this topic further since it lacked consensus in our surveys. Participants in our second survey, for example, were nearly evenly split when asked if rural areas will be negatively impacted by automation in the long-haul trucking industry. Further, some participants also mentioned that automation will likely come to rural areas first and therefore impact where future truck drivers might live. However, one response from the first survey challenged this idea: “[I] Think there could be some faster displacement of truck drivers on rural, long haul routes vs in cities, but I don't think that rural truckers are actually going to move to cities. Labor mobility in US is not that high.”

CONCLUSION

Results from our survey research suggest that there will be time for regulators and the larger government to prepare for the disruption of automation in the long-haul trucking industry. For the next 15 years, our survey participants largely agreed that the job of a truck driver will remain relatively the same. Autonomous technology, however, does promise to change future truck driving jobs. Given the uncertainty around the timing of potential impacts, we conclude that regulators and policymakers should focus in the near-term on better understanding how autonomous technology will be used in the long-haul trucking industry. Having a better sense of how the technology will be used will allow for more informed policy development on performance and safety standards, as well as workforce issues.

Appendix A: Literature Review Search Term Document

References of our literature review came from the following sources:

- Scholarly research articles
- Trade publications
 - ABI/Inform
 - Business Source Complete
- Industry databases
 - IBIS World
 - Frost and Sullivan
- State legislative documents
 - LexisNexis State Capital
- Federal government reports, documents, and statistics
 - Bureau of Labor Statistics
 - Bureau of Economic Analysis
 - Department of Transportation
- Industry reports
- News articles
- Google Scholar and Google keyword searches

General Topic: How will highly automated commercial vehicles **disrupt the trucking workforce and industry?**

- Highly automated: Level 4 or 5 on SAE scale (SAE scale= Society of Automated Engineers)
- Vehicles: Commercial trucking

Subtopics of this question:

1. Worker Impacts (Trucking Workforce)

- i. Wage impact
- ii. Job displacement
- iii. Change in job duties
 - Will future truck drivers have to be more skilled as a result of an increase in automation?
- iv. Size and demographics of workforce
 - Projected increase/decrease in number of trucking jobs
 - Projected changes in demographics: gender, age, education level

2. Industry Impacts

- i. Change in industry composition
 - Will the number of drivers, trucks, fleet managers change due to automation?
- ii. Associated costs
 - Will AVs increase or decrease costs for trucking industry?

3. Current State Policy Responses & State Advocacy Group Responses

- i. Current laws passed in response to general topics outlined above
- ii. Bills being debated (or introduced but not yet passed)

iii. Responses from state advocacy groups

- Have state trucking associations offered/advocated for any policy responses to handle the potential disruption?

Appendix B: Explanation of Delphi Method

In addition to a literature review¹⁷, our team administered a three-round survey mirroring aspects of the Delphi method. The Delphi method, which is a systematic way to analyze expert opinion, was developed by Rand in the 1950s and has been used to make forecasts in several highly regarded research studies. Knowledge is gained through this method by surveying a group of experts multiple times until a consensus is reached. A key feature of the Delphi method is to keep expert responses anonymous. The anonymity ensures that survey respondents are not swayed by group think or one dominant speaker.

The main reason why we decided to utilize the Delphi method is because our literature review did little to answer our questions on how autonomous technology will impact the long-haul trucking workforce, industry, and influence potential policy responses. Generating our own data through the Delphi method seemed to be the best way for us to answer our research questions.

We reached out to a diverse set of experts for all three survey rounds. These experts included leaders from the academic, industry, policy, and automotive worlds. We felt it was important for our analysis to seek the perspective of a group of experts with diverse backgrounds, so that we could hear from all unique perspectives to answer our research questions. Additionally, we chose professionals based on which sectors we thought would be the main stakeholders driving this debate.

The three rounds of our survey help forecast the potential disruption of autonomous technology on the trucking workforce, industry, and policy. The first round directly asked open-ended questions centering on the topics outlined in our research questions. In the process of analyzing the results of the first survey, we noted the main ideas, common themes, and outliers. We used our analysis in conjunction with what we learned from our literature review to develop specific close-ended questions for our second survey. In the second survey, we started developing a strong consensus on our research questions by asking specific workforce, industry, and policy questions. Our analysis of responses from the second survey, however, also helped us highlight major areas of disagreement mostly centering on workforce topics. In the third survey, we tried to generate more consensus on the areas of disagreement by asking a set of specific questions on a limited set of workforce topics. We then aggregated and analyzed all responses from each survey round.

¹⁷ See Appendix A for Literature Review Search Terms

Appendix C: Survey, First Round

Administration:

We released the first survey on February 9, 2018 and officially closed it on March 2, 2018 to allow time for recruiting participants. During this time frame, the survey was sent to 60 individuals.

Sample Size:

We received 40 responses to our first survey.

Professional Area of Expertise:

Our respondents were able to select more than one professional area of experience from the following categories: legislative policy, regulator, automotive industry, academic, truck driver, technology (engineering, software, design, etc.), economist, advocacy, investor, and other. Respondents were also able to fill in their own professional area of expertise.

The most commonly selected area of expertise was legislative policy (10 respondents), followed by automotive industry (8), academic (8), and technology (engineering, software, design, etc.) (8). The next most commonly identified areas included the following: truck driver (7), regulator (6), advocacy (4), and investor (4). Other areas identified included: consultant (3), research (3), economist (1), journalist (1), and philanthropist (1).

Demographics:

Pittsburgh (7) and Washington, DC (6) had the highest number of respondents who worked in these cities. The Bay Area in California had the next highest concentration (4). 45.2% (19) of respondents were 41-60 years old. 40.5% (17) were between the ages of 20-40 and 14.3% (6) were over 61 years of age.

Survey Questions:

Our first survey round consisted of four open-ended questions in order to understand what respondents' perspectives were on automation's potential impact to workforce, industry, policy, and to draw lessons from analogous industries. The survey can be accessed [here](#).

The full list of survey questions from the first round is listed below:

Describe how you think the US trucking workforce will change due to automation in the long-haul trucking industry. Please also tell us when you think these changes will occur in terms of a rough number of years from 2018. Be as specific as possible.

Aside from workforce issues, do you think automation will impact the long-haul trucking industry? To the extent possible, please elaborate and include a general timeline for these impacts.

How do you believe government will respond to the potential adoption of automation in the long-haul trucking industry? Please distinguish between local, state, and federal government.

Name one other industry or occupation that has undergone a similar transformation due to automation; what lessons (positive or negative) from that transformation might be adapted and applied to long-haul trucking?

Appendix D: Survey, Second Round

Administration:

We released the second survey on March 23, 2018 and officially closed it on March 28, 2018. Given the potential for attrition, we utilized snowball sampling to recruit more participants to the survey.

Sample Size:

We received 30 responses to our second survey, which is a 25% rate of attrition from our first survey. Out of the 30 respondents, 7 were new to our survey and did not participate in the first round.

Professional Area of Expertise:

Our respondents were able to select more than one professional area of experience from the following categories: legislative policy, regulator, automotive industry, academic, truck driver, technology (engineering, software, design, etc.), economist, advocacy, investor, and other. Respondents were also able to fill in their own professional area of expertise.

The most commonly selected areas of expertise were legislative policy (6 respondents) and academics (6), followed by automotive industry (5). The next most commonly identified areas included the following: regulator (4), technology (engineering, software, design, etc.) (3), truck driver (3), advocacy (3), consultant (3), research (3), and investor (1).

Demographics:

Pittsburgh (4), Washington, DC (4), and San Francisco (4) had the highest number of respondents who worked in these cities.

Exactly half of respondents were 41-60 years old. 43.3% (13) were between the ages of 20-40 and 6.7% (2) were over 61 years of age.

Survey Questions:

Our second survey primarily consisted of close-ended questions based on the answers received in the first survey round. The second survey asked 49 questions, spanning topics across workforce, industry, policy and regulation, with introductory questions asking about participants' general attitude towards the impact of automation on the long-haul trucking workforce and industry. The survey can be accessed [here](#).

The full list of survey questions from the second round is listed below:

Overall, what is your attitude towards the impact of trucking automation on the long-haul trucking WORKFORCE?

Optimistic/Pessimistic/I Don't Know

Overall, what is your attitude towards the impact of trucking automation on the long-haul trucking INDUSTRY?

Optimistic/Pessimistic/I Don't Know

What kind of impact do you think public perception will have on the adoption of autonomous technology on the long-haul trucking industry?

It will accelerate the process/It will obstruct the process/It will have no impact on the process

Automation could potentially shift the job of a long-haul truck driver to a more regional/local focus. Long-haul truck drivers will still be needed but only to perform first/last mile deliveries.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

The use of long-haul truck drivers to perform over 50% of first/last mile deliveries will likely occur X years from now (2018).

1-3 Years/4-5 Years/6-10 Years/10+ Years/Won't happen at scale

Several participants mentioned a possible impact of automation will involve platooning where two or more trucks are "linked" through technology and automation. Please provide a short description of what you think the role of the truck driver in the LEAD TRUCK would look like with platooning (i.e. a driver is sitting behind the wheel, a driver is operating the lead truck virtually, etc.).

Platooning, in whatever form you believe it will take shape, will transform the job of a long-haul truck driver to a more skilled teleoperator.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

Current truck drivers will require a limited amount of new training to become teleoperators.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree/Truck drivers will not become teleoperators at scale

Please rank the following potential changes in job responsibilities of a long-haul truck driver based on what you think will cause the BIGGEST DISRUPTION to what will cause the LEAST DISRUPTION to the trucking workforce (with 1 being the biggest disruption):

- The job of a long-haul truck driver will shift to a regional/local focus to perform first/last mile deliveries.
- The job of a long-haul truck driver will shift to a teleoperator, where the “driver” coordinates a platoon of trucks virtually from a location outside of the truck.
- The job of a long-haul truck driver will shift to a technician who is still in the truck serving as back-up in case of failures.
- None of the above.

Please rank the following potential changes in job responsibilities of a long-haul truck driver based on what you think will happen FIRST to what will happen LAST (with 1 being first):

- The job of a long-haul truck driver will shift to a regional/local focus to perform first/last mile deliveries.

- The job of a long-haul truck driver will shift to a teleoperator, where the “driver” coordinates a platoon of trucks virtually from a location outside of the truck.
- The job of a long-haul truck driver will shift to a technician who is still in the truck serving as back-up in case of failures.
- The job of a long-haul truck driver will remain largely the same, but demand for long-haul truck drivers may change.
- None of the above.

If technology advances by 2030 to make it possible to have a safe, legal, and fully automated truck with no need for a human driver, a driver:

- Will not be physically present in the truck for a majority of trips.
- Will still be physically present in the truck for a majority of trips because of the complexity of tasks drivers perform in addition to driving.
- A mixture of both depending on the type of load the truck is carrying.

Please rank the following barriers to widespread adoption of driverless technology for the long-haul trucking industry from STRONGEST to WEAKEST (with 1 being the strongest).

- Policy limitations
- Public perception
- Limitations in current infrastructure (Inadequate signage, Signage that can't be read by sensors...)
- Advocacy groups (Unions, Trucking Groups...)
- Technology (Developing the technology to have fully autonomous trucks)

Autonomous technology will not have any effect on the current overall size of truck driver workforce because of existing workforce trends (many long-haul truck drivers are nearing retirement and/or leaving the trucking workforce).

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

It is likely that the growth in e-commerce businesses and improved efficiency within the trucking industry will increase the demand for long-haul truck drivers. Within the next five years, this demand will likely be filled by:

Autonomous technology/Human drivers/Demand for long-haul truckers will not increase

A long-haul truck driver will be paid less if he/she performs less functions under automation, regardless of the level of skill involved.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

Few participants mentioned potential changes in truckers' wages in the first survey round. Is this because:

- Potential changes in wages will vary depending on the type of task performed by the truck driver.
- Potential changes in wages are not as important as other potential changes (like changes in job responsibilities or potential job displacement).
- Insufficient availability of information available to support an informed assessment.

- Inadvertent omission.
- N/A

Automation may increase the hours-of-service rule (the number of hours worked) for truck drivers.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

The younger generation (people under 30) will become more interested in joining the long-haul trucking industry due to safety and efficiency advancements resulting from automation.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

Platooning, in whatever form you identified in the previous section, will account for over 50% of long-haul miles X years from now (2018):

1-3 Years/5-10 Years/15+ Years/Won't happen at scale

The long-haul trucking industry will be fully transformed by automation (e.g., a majority of tasks within the industry are automated) in:

5-10 Years/10-15 Years/15-20 Years/20-25 Years/25-30 Years/30+ Years/Won't happen at scale

Smaller trucking companies will go out of business due to automation.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

Overall, safety will increase due to automation in the long-haul trucking industry.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

Efficiency made by automation will decrease the costs of operating a long-haul trucking business.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

Rural areas will be negatively impacted by automation in the long-haul trucking industry.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

If public perception and regulation of automated driving technology improve, adoption of automation within the long-haul trucking industry will increase rapidly.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

Automation in the long-haul trucking industry will increase competitiveness for trucking over rail.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

Industry SHOULD work with advocacy groups and policy makers to prepare for the workforce impact of automation.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

Industry WILL work with advocacy groups and policy makers to prepare for the workforce impact of automation.

Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

The _____ government SHOULD set or change _____ in regards to long-haul trucking.

Type of government: local, state, or federal

Set or change: Vehicle safety design standards/Performance and Operation

Standards/Hours-of-service rules (regulating drivers' shifts)/Licensing requirements/None of the Above

Who should be primarily responsible for supporting long-haul truck drivers displaced by automation?

Government/Truck employers/Non-Profit organizations/Truckers themselves

The _____ government SHOULD provide _____ to workers displaced by automation in long-haul trucking.

Type of government: local, state, or federal

Provide: Monetary compensation (beyond standard unemployment insurance)/Retraining (ex: educating truck drivers with new skills)/Job counseling (ex: offering career guidance to truck drivers) /None of the above

The _____ government WILL set or change _____ in regards to long-haul trucking.

Type of government: local, state, or federal

Set or change: Vehicle safety design standards/Performance and Operation

Standards/Hours-of-service rules (regulating drivers' shifts)/Licensing requirements/None of the Above

Overall, how restrictive would you expect safety regulation from a Democratic administration to be?

Scale of 1 to 10, with 1 defined as "Very Light" and 10 defined as "Very Restrictive"

Overall, how restrictive would you expect safety regulation from a Republican administration to be?

Scale of 1 to 10, with 1 defined as "Very Light" and 10 defined as "Very Restrictive"

Overall, how restrictive do you expect safety regulation from a conservative state government to be?

Scale of 1 to 10, with 1 defined as "Very Light" and 10 defined as "Very Restrictive"

Overall, how restrictive do you expect safety regulation from a moderate state government to be?

Scale of 1 to 10, with 1 defined as "Very Light" and 10 defined as "Very Restrictive"

Overall, how restrictive do you expect safety regulation from a liberal local government to be?

Scale of 1 to 10, with 1 defined as "Very Light" and 10 defined as "Very Restrictive"

The _____ government WILL provide _____ to workers displaced by automation in long-haul trucking.

Type of government: local, state, or federal

Provide: Monetary compensation (beyond standard unemployment insurance)/Retraining (ex: educating truck drivers with new skills)/Job counseling (ex: offering career guidance to truck drivers) /None of the above

Overall, how much support for displaced workers do you believe the federal government under a Democratic administration would provide?

Scale of 1 to 10, with 1 defined as “Very Little” and 10 defined as “A lot”

Overall, how much support for displaced workers do you believe the federal government under a Republican administration would provide?

Scale of 1 to 10, with 1 defined as “Very Little” and 10 defined as “A lot”

Overall, how much support for displaced workers do you believe a conservative state government will provide?

Scale of 1 to 10, with 1 defined as “Very Little” and 10 defined as “A lot”

Overall, how much support for displaced workers do you believe a moderate state government will provide?

Scale of 1 to 10, with 1 defined as “Very Little” and 10 defined as “A lot”

Overall, how much support for displaced workers do you believe a liberal state government will provide?

Scale of 1 to 10, with 1 defined as “Very Little” and 10 defined as “A lot”

Overall, how much support for displaced workers do you believe a conservative local government will provide?

Scale of 1 to 10, with 1 defined as “Very Little” and 10 defined as “A lot”

Overall, how much support for displaced workers do you believe a moderate local government will provide?

Scale of 1 to 10, with 1 defined as “Very Little” and 10 defined as “A lot”

Overall, how much support for displaced workers do you believe a liberal local government will provide?

Scale of 1 to 10, with 1 defined as “Very Little” and 10 defined as “A lot”

Appendix E: Survey, Third Round

Administration:

We released the third survey on April 13, 2018 and officially closed it on April 19, 2018. Given the potential for attrition, we utilized snowball sampling to recruit more participants to the survey.

Sample Size:

We received 26 responses to our second survey, which is a 13% rate of attrition from our second survey. Out of the 26 respondents, 5 were new to our survey and did not participate in either of the previous rounds.

Professional Area of Expertise:

Our respondents were able to select more than one professional area of experience from the following categories: legislative policy, regulator, automotive industry, academic, truck driver, technology (engineering, software, design, etc.), economist, advocacy, investor, and other. Respondents were also able to fill in their own professional area of expertise.

The most commonly selected area of expertise was academic (10 respondents), followed by technology (engineering, software, design, etc.) (8), advocacy (8), and legislative policy (7). The next most commonly identified areas included the following: regulator (4), automotive industry (4), and truck driver (4). Other areas identified included: research (2), investor (2), and economist (1).

Demographics:

Pittsburgh (4) and Washington, DC (4) had the highest number of respondents who worked in these cities. San Francisco, CA (2) and Boulder, CO (2) had the next highest concentration. 59.3% (16) respondents were 41-60 years old. 26% (7) were between the ages of 20-40 and 14.8% (4) were over 61 years of age.

Survey Questions:

Our third survey primarily consisted of a mix of open and close-ended questions based on areas of major disagreement in the second round. The third survey used skip logic to ask between 10-15 questions, with a particular set of questions changing based on respondents' answers. These questions focused on workforce issues like displacement and potential policy responses. The survey can be accessed [here](#).

The full list of survey questions from the third round is listed below:

A gradual adoption of autonomous technology would ease displacement of truck drivers.
Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree/Automation will not cause a displacement of truck drivers

Automation will change where truck drivers live.
Agree/Disagree/Unsure

Please state why you agree, disagree, or felt unsure about the previous question.

A majority of current truck drivers will retire or exit the workforce before autonomous technology becomes fully adopted within the industry.
Strongly Agree/Agree/Unsure/Disagree/Strongly Disagree

Previous survey participants disagreed on whether automation will increase the attractiveness of trucking for young people. In ten years, do you think people under 30 would...

- Be more attracted to join the trucking workforce due to automation
- Not be more attracted to join the trucking workforce due to automation

Why do you think people under 30 would be more attracted to join the trucking workforce due to automation? (Check all that apply)
Increase in wages/More desirable work schedule/Improved working conditions/Other

If you checked "Other," please specify:

Why do you think people under 30 would not be more attracted to join the trucking workforce due to automation? (Check all that apply)

- The trucking industry will not become a desirable sector to work in
- Automation will not impact the wages of future truck drivers
- Automation will not drastically change the working conditions of a truck driver
- Other

If you checked "Other," please specify:

It should be the responsibility of government to provide support for truck drivers displaced by autonomous technology.
Agree/Disagree

[If agree] Government should provide support for truckers _____ they are displaced due to automation.
Before/After

[If agree] Which of the following do you think is the MOST viable way government can mediate possible negative impacts on displaced truck drivers?

- Retraining current truck drivers
- Monetary compensation beyond standard unemployment insurance

- Job counseling
- Other (out-of-the-box policy solutions are encouraged)

[If retraining is selected] Who is responsible for funding a retraining program? (Check all that apply)

- Local government
- State government
- Federal government

[If retraining is selected] What type of retraining should be offered? (Check all that apply)

- Retraining current truck drivers for jobs within the trucking industry
- Retraining current truck drivers for jobs outside the trucking industry
- Other
- If you checked "Other," please specify what other type of skills are taught

[If monetary compensation is selected] How much funding should be provided? (Check all that apply)

- A minimum national standard is established
- Each state decides its own amount
- Each locality decides its own amount
- Other
- If you checked "Other," please specify

[If monetary compensation is selected] How long should monetary compensation be provided for? (Check all that apply)

- A minimum national length is established
- Each state decides its own length
- Each locality decides its own length
- Other
- If you checked "Other," please specify

[If job counseling is selected] Who is responsible for funding the job counseling program? (Check all that apply)

- Local government
- State government
- Federal government

[If job counseling is selected] What type of counseling should be offered? (Check all that apply)

- Resume building
- Job search techniques
- Mock interviews
- Soft skill development
- Other
- If you checked "Other," please specify

[If other policy option is selected] What is one other policy solution you would advocate for? Please describe in detail including who is responsible for funding the program.

[If participants did not agree that government should be responsible for providing support to displaced truck drivers] Why do you think it should not be the responsibility of government to provide support for truck drivers displaced by autonomous technology?

Do you have any final comments or thoughts about the premise of the survey, its questions, or answers?