NCHRP Project 20-113F

Preparing for Automated Vehicles and Shared Mobility: State-of-the-Research Topical Paper #6

POTENTIAL FOR IMPACTS OF HIGHLY AUTOMATED VEHICLES AND SHARED MOBILITY ON MOVEMENT OF GOODS AND PEOPLE

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Transportation Research Board
500 5th Street NW
Washington, DC 20001
www.trb.org

Prepared by:

Stantec

ARA

For:

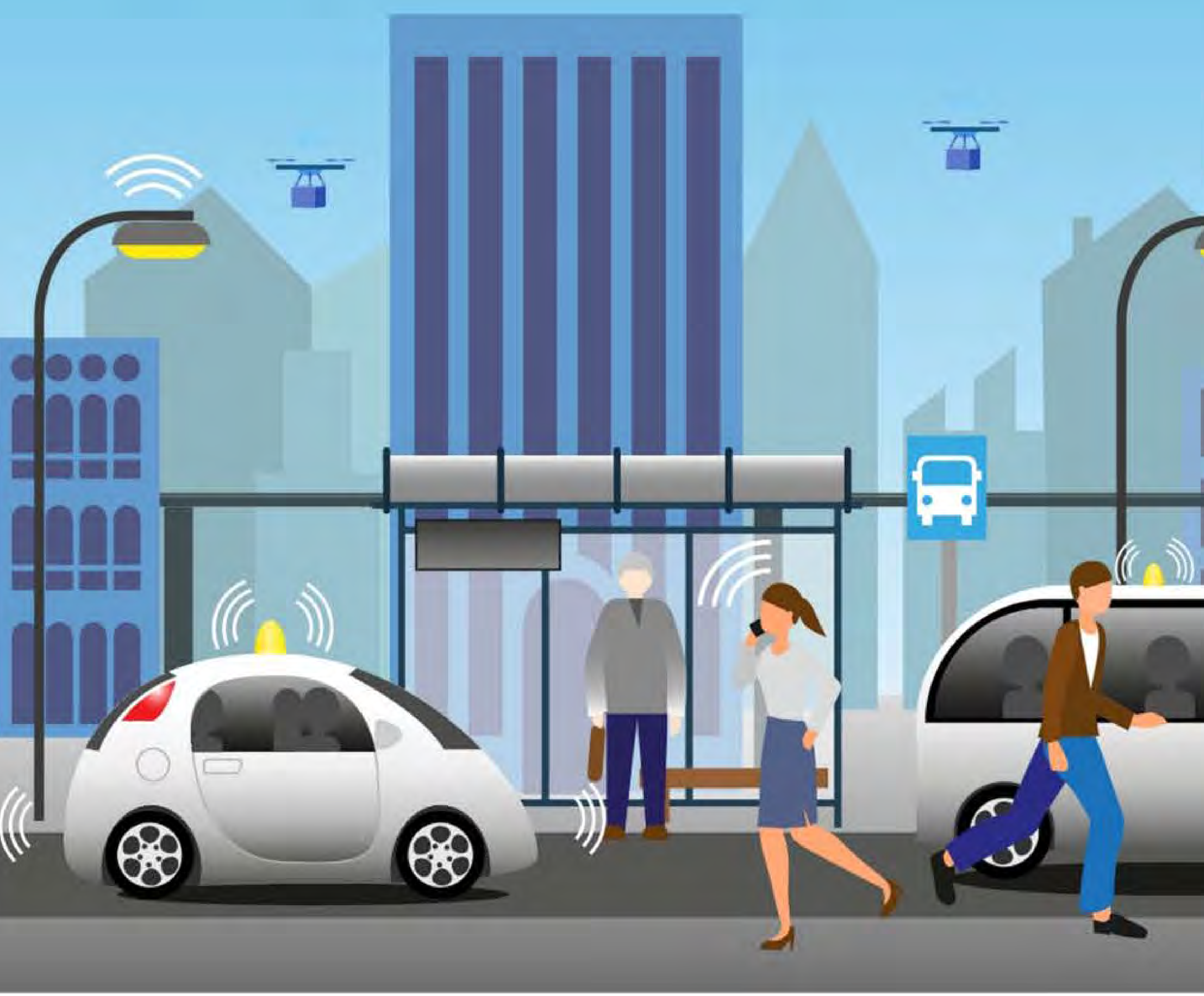
TRB AV/SM FORUM
AUTOMATED VEHICLES + SHARED MOBILITY

1 Introduction

1.1. Background

In coordination with the National Cooperative Highway Research Program (NCHRP), the TRB Forum on Preparing for Automated Vehicles and Shared Mobility (Forum) has developed nine (9) Topical Papers to support the work of the Forum (Project).

The mission of the Forum is to bring together public, private, and research organizations to share perspectives on critical issues for deploying AVs and shared mobility. This includes discussing, identifying, and facilitating fact-based research needed to deploy these mobility focused innovations and inform policy to meet long-term goals, including increasing safety, reducing congestion, enhancing accessibility, increasing environmental and energy sustainability, and supporting economic development and equity.



The Topical Areas covered as part of the Project include the following:

- *Models for Data Sharing and Governance*
- *Safety Scenarios and Engagement during Transition to HAV*
- *Infrastructure Enablers for Automated Vehicles and Shared Mobility*
- *Maximizing Positive Social Impacts of Automated Vehicle Deployment and Shared Mobility*
- *Prioritizing Equity, Accessibility and Inclusion Around the Deployment of Automated Vehicles*
- *Potential Impacts of HAV and Shared Mobility on the Movement of Goods and People*
- *Impacts of Automated Vehicles and Shared Mobility on Transit and Partnership Opportunities*
- *Implications for Transportation Planning and Modeling*
- *Impacts and Opportunities Around Land Use and Automated Vehicles and Shared Mobility*

For this Project, the important goals of the papers are to provide a snapshot of all research completed to date for a Topical Area and within the proposed focus areas identified below. The papers are intended to provide a high-level overview of the existing research and to make recommendations for further research within a Topical Area. The Project establishes a foundation to guide the use of resources for further development and support of more comprehensive research that tracks the identified research gaps noted in each Topical Paper and to support the Forum.

The research reviewed varies by paper, but generally, only published research was included as part of the Project. For clarity, the scope of the project is to report on research that has been done without judging or peer reviewing the research conducted to date and referenced herein. While considered for background purposes, articles, blog posts, or press releases were not a focus for the work cited in the Topical Papers. Also, in consideration of the focus of the Forum and the parameters of the Project, the research was narrowed to publications focused on the intersection between automated vehicles and shared mobility. Materials reviewed and cited also include federal policy guidance and applicable statutes and regulations.

Each of the papers are written to stand on its own while recognizing there are cross over issues between the Topical Areas. If desired, readers are encouraged to review all 9 Topical Papers for a more comprehensive view of the Project and the points where topics merge.

The goals of the Topical Papers are the following:

Snapshot of research completed under a particular topic area

Summary of research completed to date

Identification of gaps in research

Recommendations for additional research

1.2. Approach to Topical Paper Development

The approach to development of the Topical Papers and their focus included the following:

- Meetings with the Chairs of the Forum
- Engagement with the Members of the Forum, including during the Forum meetings in February and August of 2020
- Feedback from Chairs and Forum Members during the development of focus areas for the Topical Papers and receiving comments to the draft versions of the papers

During the meetings with the Forum in February 2020, the research team discussed the Project with the Forum over two days in two separate sessions. On Day 1, the research team presented the proposed scope for each Topical Paper and broke out into break-out groups to further refine the focus of each paper to match the interest and goals of the Forum and its Members. During Day 1, the Forum also heard from different organizations highlighting previous and ongoing research. These organizations[1] included the following:

- Brookings Institution
- The Eno Center for Transportation
- National Governors Association
- Future of Privacy Forum
- AARP
- American Public Transportation Association

On Day 2, the research team reconvened with the Forum to summarize the break-out discussions on Day 1 and to receive final comments on the focus for each Topical Paper.

In August 2020, the draft papers were presented to the Forum for review and feedback. Comments were received in writing and verbally during a virtual Forum meeting. The final papers incorporate the comments and feedback received as part of the review process. This paper identifies a large body of research regarding this topic area associated with shared and automated vehicles. As reviewer comments pointed out, there remains considerable uncertainty regarding if and when highly automated vehicles will be deployed on a large scale. This is reflected in much of the research that has been completed to date. Consequently, this paper summarizes common themes from the research available to date as much as possible, while acknowledging that various scenarios may impact the issues, recommendations, and areas for future research. Many of the issues addressed in this research are forward-looking and anticipate an environment where fully automated vehicles (SAE Level 5) are a ubiquitous part of the transportation system.

[1] The research team and the Forum thank these organizations for their time in sharing their work and insights in support of the development of the Topical Papers.

2 Paper Areas of Focus

This Topical Paper reviews research conducted and published as of July 10, 2020, unless specific papers were identified as part of the final review and comments process. In approaching this topic, the paper focuses on the following issue areas:

1. Examine the opportunities that highly automated and shared mobility solutions offer for the movement of people and goods, both over short and long distances, and in connection to economic opportunities and which they offer for new public-private partnerships
2. Apply insights from ongoing work focused on real estate development and planning work examining more efficient movement of goods on highways and within urban environments
3. Consider how to leverage technology and potential pricing, delivery prioritizations and curb management techniques to manage transportation of both goods and people
4. Evaluate ongoing use cases associated with freight deliveries through automation, including considerations around right-of-way, privacy and congestion; also consider post-COVID-19 implications for local deliveries without direct human contact
5. Determine research completed and needed to understand the supply chain focused impacts of new technologies on the workforce

3 Summary of Findings

Automated freight across use cases and vehicles types appears to be the most active area for HAV deployment over the last twelve months. New vehicles are being tested and pilots are being implemented on public roadways in the United States. Ground and aerial drones are being deployed for first and last mile applications in rural and urban areas via air and on local streets, sidewalks, and trails. These activities appear to have accelerated since the outset of the COVID-19 pandemic, with heightened concerns about supply chain resiliency and contactless delivery. Federal, state, and local governments have shown interest in understanding use cases, operational considerations, and workforce implications of freight and logistic applications of this technology.

Automated driving and vehicle platooning are considered to be key issues in supply chain logistics, especially given the continued diminution of brick and mortar retail stores and restaurants. Increased deliveries driven by e-commerce and the pandemic already provide a new set of challenges for managing curbside and parking needs. These considerations have been further emphasized by the pandemic-induced rise in telecommuting.

The review of available literature and ongoing research on highly automated freight within the focus areas of this Topical Paper reveals several emerging themes:

- **Freight applications of HAV technology appear to be among the most active applications.** Commercial piloting of truck platooning and automated long haul trucking builds on pilots at the federal level through the U.S. Department of Defense's Army Tank Automotive Research, Development and Engineering Center, and the award of a government contract for a fleet of heavy vehicles for the U.S. Army. The U.S. Department of Transportation's Automated Driving System grant program includes an assessment of connected and AV trucking deployment. By and large these pilots have not been evaluated in publicly available research, or the research is underway.

- **HAVs for freight encompass a broad range of use cases and operating environments.** Use cases include first and last mile delivery as well as middle distance and long-haul trucking. These use cases take place in a range of operating environments, including limited access highways, arterials, and local streets, as well as off-road on sidewalks, trails, and underground. The vehicle types include retrofitted heavy, medium, and light duty vehicles; small electric vehicles; purpose-built electric vehicles; and unmanned aerial vehicles (UAVs) deployed in the air.

- **Job loss related to highly automated trucking is an important topic in current research.** Research notes existing shortages of long-haul drivers with commercial driver's licenses, However, concerns around job losses due to automated trucking are prevalent in ongoing research. Research also points to a generation of new jobs around automation in transportation, and the likely need for different skill sets associated with logistics and fleet management. Several technical training programs are underway to train safety operators and technicians, including partnerships with community colleges.

- **Automated heavy-duty trucks offer significant fuel savings compared to traditional trucks.** The drafting effect of platooning non-automated trucks shows fuel savings between 10% and 17%. Automated trucks show a similar improvement in fuel efficiency resulting from more efficient operating conditions.

- **Automated transportation for people and goods further heightens challenges in managing competing uses of the curb.** These competing uses include parking, deliveries, passenger pick-up and drop-off, and increasing space for parklets for dining and recreation, walkways, and bike lanes. Approaches to curbside management include zoning via ordinance, geo-fencing, camera enforcement, dedicated loading, shared mobility drop-offs, and congestion pricing. Evaluations around goods deliveries will impacted by size of vehicles, which vary among automated delivery solutions being piloted.

- **Demonstration programs provide meaningful lessons.** However, the transfer is limited by disconnects between defense and commercial efforts, the proprietary nature of some research (even that conducted by public institutions), and the proliferation of new vehicles types (outside of the Federal Motor Vehicle Safety Standards framework).

4 Summary of Research Reviewed

Our research effort included review of papers and reports developed by individual university transportation centers in the United States, USDOT studies, published papers in academic journals, state sponsored initiatives, corporate research and development work, and NCHRP sponsored research. The following is a summary of the research reviewed.

4.1 Examine the opportunities that highly automated and shared mobility solutions offer for the movement of people and goods, both over short and long distances, and in connection to economic opportunities, including tourism, jobs, and which they offer for new public-private partnerships

A large body of research examined the opportunities that highly automated and shared mobility solutions offer for the movement of people and goods, both over short and long distances and in connection with new economic opportunities. Much of the research around the movement of goods has focused on automated trucking with lesser emphasis on drones, last-mile deliveries, and even underground transportation systems. Automated movement of people is often shared, and the current research primarily focuses on the TNC model and carsharing. There is a large body of work around the effect of automated freight on trucking jobs, indicating that, while many jobs are expected to be eliminated, new ones will spring up. However, some of these jobs may be for lower wages.

4.1.1 Automated Movement of Goods

Much of the research around automated movement of goods focuses on automated trucking. Service categories for the automated movement of goods include warehouse to warehouse, warehouse to retailer, and deliveries to homes or office and retail spaces. Automated heavy trucks on highways are most often warehouse-to-warehouse. Slowik and Sharpe (2018) describe some of the main benefits, finding that automated trucking offers improved on-road safety, greater fuel efficiency and reduced emissions, ease of driving, increased operational efficiency, and reduced labor costs.[2] Lewis (2018) indicates that long-haul automated trucks could operate in a terminal to terminal model moving goods over long distances.[3] Early adoption (SAE Levels 1-2) of automated trucks starts with improved fuel economy and safety. At the individual level, Lewis indicated that a SAE Level 4 truck is economically feasible, even when considering the salaries for long-haul truck monitors. They did not specifically address the technological feasibility. The use case discussed by Lewis included a hand-off to human drivers for the first and last mile trips in urban areas.[4]

Viscelli (2018) identifies eight scenarios for how automated trucks may be implemented.[5] He notes that automated trucks will likely soon be driving on highways and smaller delivery vehicles are already in service in a limited capacity in urban settings. However, larger automated trucks in urban environments will take much longer; even perhaps several decades. He describes that the most likely first scenario of adoption would be for long-distance highway trips, while human intervention will likely still be needed to navigate local streets.[6] This view was echoed in a number of other research sources.[7] The other scenarios Viscelli describes include:

- human-human platooning where a series of trucks driven by humans would be electronically linked;
- human-drone platooning where a human-driven truck would lead a platoon of automated driverless drone trucks on highways;
- highway automation and drone operation where human operators would remotely control the truck in urban areas and the trucks would drive autonomously on highways;
- autopilot where a human would handle loading and urban driving and the truck would drive autonomously on the highway;
- highway exit-to-exit automation; and
- facility to facility automation.[8]

The highway exit-to-exit automation and facility-to-facility automation are similar to the concepts Lewis presents.[9]

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[2] Peter Slowik and Ben Sharpe, "Automation in the Long Haul: Challenges and Opportunities of Autonomous Heavy-Duty Trucking in the United States," 2018, https://www.theicct.org/sites/default/files/publications/Automation_long-haul_WorkingPaper-06_20180328.pdf.
[3] Dale Lewis, "OPERATING ECONOMICS LONG-HAUL TRUCKS LONG-HAUL TRUCK," no. July (2018).
[4] Lewis.
[5] Steve Viscelli, "Autonomous Trucks and the Future of the American Trucker," 2018.
[6] Viscelli.
[7] Similar research includes the International Transport Forum's "Managing the Transition to Driverless Road Freight Transport," Texas DOT's Assessment of Innovative and Automated Freight Strategies and Technologies – Phase 1 Final Report" and the Regional Plan Association's "New Mobility: Autonomous Vehicles and the Region."
[8] Viscelli, "Autonomous Trucks and the Future of the American Trucker."
[9] Lewis, "OPERATING ECONOMICS LONG-HAUL TRUCKS LONG-HAUL TRUCK."

On the topic of automated goods movement by UAVs, the International Transport Forum (2018) notes that freight UAVs for urban good deliveries may improve connectivity, help alleviate traffic congestion, and reduce travel times.[10] The Regional Plan Association (2017) finds that using UAVs would allow trucks to avoid the most congested roads and route goods more directly between origin and destination.[11] It finds that several companies, most notably Amazon, have begun testing UAVs as an alternative method for deliveries.[12] The International Transport Forum's list of future UAV use cases includes on-demand passenger UAV services, fleets of automated freight delivery UAVs in urban areas, and automated aerial "conveyor belt" UAVs carrying large payloads and connecting continents.[13]

A third type of automated goods movement includes freight transport systems; this research describes underground freight systems. Shahooei, Najafi, and Ardekani (2019) assert that options to increase the capacity of freight systems are limited and an underground automated freight transportation system under highways would increase that capacity.[14] They develop two models, a long-haul system that transports standard shipping containers and a short-haul system that carries pallet-sized freight. As the logical question on that concept centers around cost, an earlier report conducted a cost-benefit analysis of the underground freight transportation systems.[15] This analysis indicates that the economic feasibility of large and medium-sized underground freight transportation systems is sensitive to construction costs and revenue from shipments. The economic feasibility of underground freight transportation systems with short routes and small sizes is sensitive to shipment pricing and discount rates. They conclude that the price of shipping for underground freight transportation systems is competitive with the price of shipping by trucks, although a price comparison with rail is not provided in the paper.

A fourth type of automated goods movement is small delivery applications. These include options such as delivery AVs and UAVs, automated cargo bikes, and innovations in the final handoff such as delivery robots and automated kiosks. This is discussed in Section 4.4.1 "Last Mile Use Cases" below.

4.1.2 Automated Movement of People

There is also research around opportunities for the movement of people. The automated movement of people shares research with shared mobility. Current forms of shared mobility, such as TNCs, are considered as applicable models for AVs. Schaller (2018) has several suggestions for policy makers on how to accomplish the transition to shared AVs within the TNC

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[10] ITF Corporate Partnership Board, "(Un)Certain Skies? Drones in the World of Tomorrow Corporate Partnership Board Report Corporate Partnership Board CPB," 2018.
[11] Regional Plan Association, "New Mobility Autonomous Vehicles and the Region," 2017.
[12] Regional Plan Association (RPA), "New Mobility: Autonomous Vehicles and the Region," no. October (2017): 1–36, http://library.rpa.org/pdf/RPA-New-Mobility-Autonomous-Vehicles-and-the-Region.pdf.
[13] ITF Corporate Partnership Board, "(Un)Certain Skies? Drones in the World of Tomorrow Corporate Partnership Board Report Corporate Partnership Board CPB."
[14] Sirwan Shahooei, Mohammad Najafi, and Siamak Ardekani, "Design and Operation of Autonomous Underground Freight Transportation Systems," *Journal of Pipeline Systems Engineering and Practice* 10, no. 4 (2019): 1–8, https://doi.org/10.1061/(ASCE)PS.1949-1204.0000403.
[15] Seyed Ehsan Zahed, S. M. Shahandashti, and M. Najafi, "Lifecycle Benefit-Cost Analysis of Underground Freight Transportation Systems," *Journal of Pipeline Systems Engineering and Practice* 9, no. 2 (2018): 1–9, https://doi.org/10.1061/(ASCE)PS.1949-1204.0000313.

model.[16] His premise is that TNCs today compete mainly with public transportation, walking, and biking but are generally not replacing personal cars. Current TNC usage is highest where parking is expensive or difficult to find. He asserts that, without specific public policy intervention, as the use of shared AVs expands, we can expect the autonomous future to mirror the TNC models resulting in the same side effects that are seen today. He advocates that policy makers need to implement regulations to manage TNCs now to ensure the framework is in place for automated TNCs. His suggested changes include limiting single-occupancy vehicles in city centers and requiring that TNCs and other fleets use street space efficiently to reduce double-parking or blocking lanes of traffic for drop-off and pick-up.[17]

Carsharing is another model of shared mobility that AVs may use. Shaheen, Martin and Bansal (2018) provide two models of automated shared carsharing.[18] The first model is individually owned AVs that are made available on-demand by a third-party broker. The second model is peer-to-peer AV carsharing with decentralized reservations where the "guest" would use some form of open source reservation and payment system to share individually-owned AVs. Shaheen, Martin, and Bansal also discuss barriers to AV car sharing.[19] One factor is a lack of standardization in current carsharing models, which deters usage and could continue as AVs are adopted. Another barrier to AV carsharing is a lack of trust in the carsharing model.[20]

The shared and automated movement of people has some effects on traveler behavior. The International Transport Forum found that if AVs are widely adopted and used, shared AVs are likely be a sizeable portion of trips.[21] However, this also depends on whether personal car ownership simply shifts to AVs or if car ownership is materially reduced. Another option is that shared AV fleets could possibly become widely used without shared rides.[22]

4.1.3 Economic Opportunities

One research area around economic opportunity focuses on jobs. Much of the research agrees that freight automation will result in a loss of certain jobs, specifically existing jobs driving trucks. However, new jobs and tasks will be created. Short and Murray (2019) find that the quality of the remaining trucking jobs could be improved as a result of automation.[23] Level 3 automation may relieve some of the stress of driving and Level 4 trucks could see a rise in productivity and may allow monitors to work on other tasks, such as logistics, while the truck is driving. Also, currently there is a shortage of truck drivers and many are above 55 years old.[24] Lewis

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[16] Bruce Schaller, "The New Automobility: Lyft, Uber and the Future of American Cities," 2018, www.schallerconsult.com/rideservices/automobility.pdf%0Ahttp://www.schallerconsult.com/rideservices/automobility.htm.
[17] Bruce Schaller.
[18] Susan Shaheen, Elliot Martin, and Apaar Bansal, "Peer-to-Peer (P2P) Carsharing Understanding Early Markets, Social Dynamics, and Behavioral Impacts," 2018.
[19] Shaheen, Martin, and Bansal.
[20] Shaheen, Martin, and Bansal.
[21] Natasha Merat, Ruth Madigan, and Sina Nordhoff, "Human Factors, User Requirements, and User Acceptance of Ride-Sharing in Automated Vehicles," *International Transport Forum* 10, no. February (2017): 1–30, http://www.itf-oecd.org/sites/default/files/docs/human-factors-user-requirements-acceptance-ride-sharing.pdf.
[22] Adam Stocker and Susan Shaheen, "Shared Automated Vehicles: Review of Business Models," 2017.
[23] Jeffrey Short and Dan Murray, "Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry," 2016, 1–40, https://doi.org/10.1016/j.ijhydene.2008.11.062.
[24] Dan Murray and Seth Glidewell, "An Analysis of the Operational Costs of Trucking: 2019 Update," no. November (2019).

identifies other new jobs that will be needed to supplement automated trucking, including safety monitors, truck drivers for dense urban environments (where it will be hard to operate automated trucks), and linehaul monitors to monitor automated trucks on highways.[25] While these jobs may pay less than current trucking jobs, Yankelevich et al. (2018) find that higher level engineering, data analysis, and cybersecurity jobs will be created as well.[26] These jobs are likely to have better conditions than current long-haul trucking jobs. Other jobs, such as warehousing or additional types of monitoring jobs, may also be created as new forms of e-commerce come with new types of automated shipping.[27] However, these jobs are likely to pay less and have poorer working conditions as compared to current trucking jobs.

4.1.4 Pilots and Projects

There are several pilot efforts and projects around the automated movement of goods and people. In 2019, the U.S. Postal Service partnered with TuSimple for a two-week pilot where TuSimple completed five round trips between U.S. Postal Service distribution centers in Phoenix, Arizona and Dallas, Texas.[28] The U.S. Army accelerated its Automated Ground Resupply program and in 2019, ten palletized loader system trucks were converted to autonomous trucks.[29] The U.S. Army and the UK Defense Science and Technology Laboratory have partnered on three different projects, including a semi-autonomous convoy of cargo and two different last-mile projects.[30] In August 2020, USDOT announced three project awards for a field test of truck platooning for regular freight hauling by a commercial motor carrier.[31] The awardees included California Partners for Advanced Transportation Technology. The U.S. Maritime Administration and the U.S. Federal Motor Carrier Safety Administration are researching SAE Level 4 trucks at intermodal port facilities.[32] The Maritime Administration Truck Staging Program is completing a study on the economic feasibility of Level 4 trucks at port facilities.[33] The Pipeline and Hazardous Materials Safety Administration is researching alternatives to paper documentation of hazardous materials as shippers of hazardous materials are exploring automation.[34]

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[25] Lewis, "OPERATING ECONOMICS LONG-HAUL TRUCKS LONG-HAUL TRUCK."
[26] Aleksandr Yankelevich et al., "Preparing the Workforce for Automated Vehicles Truck Platooning State of the Industry 2018," 2018, 1–149, https://comartsci.msu.edu/sites/default/files/documents/MSU-TTI-Preparing-Workforce-for-AVs-and-Truck-Platooning-Reports .pdf.
[27] John Zumerchik, Jean-Paul Rodrigue, and Jack Lanigan, Sr., "Automated Transfer Management Systems and the Intermodal Performance of North American Freight Distribution," *Journal of the Transportation Research Forum* 48, no. 3 (2012): 59–76, https://doi.org/10.5399/osu/jtrf.48.3.2326.
[28] Neil Abt, "TuSimple Begins Self-Driving Pilot Program with Postal Service," *FleetOwner*, 2019.
[29] Sydney J. Freedberg, "Army Wants 70 Self-Driving Supply Trucks by 2020," *Breaking Defense*, 2018.
[30] Jerome Aliotta, "US, UK Coordinate Autonomous Last-Mile Resupply," US Army, 2019.
[31] Intelligent Tranportation Systems Joint Program Office, "Broad Agency Announcement Awards for Phase 1 Truck Platooning Early Development Assessment," 2020.
[32] NHTSA and US Department of Transportation, "Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0," 2020.
[33] NHTSA and US Department of Transportation.
[34] NHTSA and US Department of Transportation.

4.2 Apply insights from ongoing work focused on planning work examining more efficient movement of goods on highways and within urban environments

Much of the research around the movement of goods on highways centers around fuel efficiency and platooning. Another key issue for the efficient movement of goods on highways is congestion. Much of the research around more efficient movement of goods in urban environments through freight automation focuses on last-mile deliveries and new forms of automated urban goods movement.

Much of the research around more efficient movement of goods in urban environments through freight automation focuses on last-mile deliveries and new forms of automated urban goods movement

4.2.1 Movement of Goods on Highways

Much of the literature around the efficient movement of goods on highways is centered around automated trucking. A key idea mentioned in much of the literature was the fuel efficiency of automated trucks. TuSimple and the University of California San Diego partnered on a study of fuel efficiency. They found that automated heavy-duty trucks have significant fuel savings, especially at lower speeds, because of the complex driving that happens at lower speeds.[35] McAuliffe et al. demonstrate the energy savings potential of truck platooning.[36] They find that energy savings increased as the gap between trucks was reduced.[37] In a three-truck platoon there is a wide range of fuel savings, with the lead vehicle experiencing up to 10% fuel savings, the middle vehicle delivering 17% fuel savings, and with the trailing vehicle showing up to 13% fuel savings. This was echoed by Huang et al., who adopt an energy-centric perspective. They state that automated trucks can improve fuel economy and efficiency by reducing the power loss due to braking and operating the engine in high efficiency regions. Their results show a 5-15% improvement in fuel economy.[38] In addition, the U.S. Department of Energy's National Renewable Energy Laboratory is working on a project analyzing multi-modal energies for inter-city freight movement around Chicago.[39]

Automated truck platooning is another key idea. Tsugawa, Jeschke, and Shladover (2016) defined the objectives of truck platooning as the energy saving and enhanced transportation capacity by platooning.[40] Smith and Bevly (2020) find that in on-road highway tests of automated truck platooning using the cooperative adaptive cruise

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[35] Ryan Gehm, "Self-Driving Trucks Cut Fuel Consumption by 10%," *SAE Mobilis*, 2019.
[36] Brian McAuliffe et al., "Influences on Energy Savings of Heavy Trucks Using Cooperative Adaptive Cruise Control," *SAE Technical Papers*, 2018, https://doi.org/10.4271/2018-01-1181.
[37] McAuliffe et al.
[38] Chunan Huang et al., "An Energy and Emission Conscious Adaptive Cruise Controller for a Connected Automated Diesel Truck," *International Journal of Vehicle Mechanics and Mobility* 58, no. 5 (2019): 805–25.
[39] Alicia Birky, "Multi-Modal Energy Analysis for Inter-City Freight Movement," 2019.
[40] Sadayuki Tsugawa, Sabina Jeschke, and Steven E. Shadlover, "A Review of Truck Platooning Projects for Energy Savings," *IEEE Transactions on Intelligent Vehicles* 1, no. 1 (2016).

control system, the benefits of platooning were realizable.[41] Smith and Murray find that another key issue for the efficient movement of goods is congestion.[42] With automated trucking and potentially a connected vehicle system, trucks will be able to travel in platoons at close distances, mitigating highway congestion due to stop and go traffic in a truck lane.[43]One idea that is less frequently discussed surrounds providing an automated highway system with dedicated truck lane for inter-city trucking.[44]

[41] Patrick Smith and David Bevly, "Analysis of On-Raod Highway Testing for a Two Truck Cooperative Adaptive Cruise Control (CACC) Platoon," 2020.
[42] Short and Murray, "Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry."
[43] Short and Murray.
[44] H Jacob Tsao and Jan L Botha, "An Automated Highway System Dedicated to Inner-City Trucking: Design Options, Operating Concepts, and Deployment," *ITS Journal* 7 (2002): 169–96, https://doi.org/10.1080/10248070290117585.

4.2.2 Movement of goods in urban environments

Much of the literature focuses on more efficient movement of goods in urban environments through freight automation, especially in the last mile. Jaller, Otero-Palencia and Pahwa describe the urban freight system and the effect that automation could have on it.[45] The urban freight system includes deliveries to urban freight terminals and last-mile delivery to customers and businesses. They consider this to be inefficient and argue that much of the work for urban freight systems comes in the form of robot testing for package delivery.[46]

There are several new forms of automated urban goods movement. Knowles and Lightstone (2017) identify innovations in North American freight.[47] New forms of last-mile mobility are being examined for more efficient movement of goods, such as UAVs, off-peak delivery, and sidewalk robots. UAVs are one of the key automation innovations for efficient urban freight movement. Aurambout et al. (2017) find that UAVs could lower labor costs and could make urban parcel delivery more efficient.[48] Their study looks at European Union countries and finds that a significant number of European Union citizens could benefit from UAV parcel delivery.[49] Another innovation for efficient urban freight movement is sidewalk delivery robots. Jennings and Figliozzi (2019) find that automated sidewalk delivery robots can provide substantial cost and time savings and reduce on-road travel per package.[50] Paddeu and Parkhurst (2020) note that on-demand sidewalk delivery robots, such as Starship robots, can dramatically decrease the number of failed deliveries and can lower operational cost.[51] There are some concerns surrounding sidewalk robots, including the limited capacity and range, potential to clog sidewalks, and social acceptance. This is discussed further in Section 4.4.1.

Another key idea around the movement of goods in urban environments focuses on automated trucks on highways and humans driving in urban areas. Viscelli finds that, while automated trucks will be able to move goods on highways, it may be more efficient to have humans drive in urban environments.[52]

The planning field has done some research around the efficient movement of goods in urban environments. This work is often based in land use. The Regional Plan Association makes several suggestions to improve the movement of goods in urban environments.[53] It notes that street space should be regulated in urban areas, and AV impacts on public transportation need to be understood.

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[45] Miguel Jaller, Carlos Otero-Palencia, and Anmol Pahwa, "Automation, Electrification, and Shared Mobility in Urban Freight: Opportunities and Challenges," *Transportation Research Procedia* 46, no. 13–20 (2020).
[46] Jaller, Otero-Palencia, and Pahwa.
[47] Alec Knowles and Adrian Lightstone, "The Impacts of Connected and Automated Vehicle Technologies on Goods Movement and Distribution in North America," in *Proceedings of the 52nd Annual Conference Canadian Transportation Research Forum*, 2017, 1–8.
[48] Jean Philippe Aurambout, Konstantinos Gkoumas, and Biagio Ciuffo, "Last Mile Delivery by Drones: An Estimation of Viable Market Potential and Access to Citizens across European Cities," *European Transport Research Review* 11, no. 1 (2019), https://doi.org/10.1186/s12544-019-0368-2.
[49] Aurambout, Gkoumas, and Ciuffo.
[50] Dylan Jennings and Miguel Figliozzi, "Study of Sidewalk Autonomous Delivery Robots and Their Potential Impacts on Freight Efficiency and Travel," *Transportation Research Record* 2673, no. 6 (2019): 317–26, https://doi.org/10.1177/0361198119849398.
[51] Daniela Paddeu and Graham Parkhurst, "The Potential for Automation to Transform Urban Deliveries: Drivers, Barriers, and Policy Priorities," in *Policy Implications of Autonomous Vehicles, Volume 5*, 2020.
[52] Viscelli, "Autonomous Trucks and the Future of the American Trucker."
[53] Regional Plan Association, "New Mobility Autonomous Vehicles and the Region."

4.2.3. Pilots and Projects

There are several projects around highway and urban automated goods movement. DHL is delivering cargo by electric cargo bike in Germany and the Netherlands.[54] Flirtey, an Australian startup, is using drones to deliver small packages, including mail and medicine and Matternet, a California startup, is partnering with Mercedes-Benz on a combined UAV and van last-mile delivery system.[55] Ocado is using AVs to deliver groceries in London.[56] Kiwi delivers food to UC Berkeley students using delivery robots.[57] There are also AV deliveries to various U.S. campuses including George Mason University, Northern Arizona University, Purdue University, and the University of Pittsburgh.

4.3 Consider how to leverage technology and potential pricing, delivery prioritizations and curb management techniques to manage transportation of both goods and people

There is a body of research around curbside management and urban freight, including delivery prioritizations and curb management techniques related to the transportation of both goods and people. Much of the research around curbside management and AVs focuses on creating loading zones and ensuring freight and passengers have access to the curb, although some research emphasizes freight. An interesting aspect of research on this topic suggests using public transportation for a combined movement of people and goods, with the automation being in the form of freight delivery robots.

4.3.1 Curbside Management

In assessing future management of the curbside for HAVs, it is useful to consider research such as that from Schaller identifying current measures that cities use or are considering to manage congestion generated from TNC trips.[58] These measures include trip fees, congestion pricing, bus lanes, and traffic signal timing. These could be adapted as AVs are used for both the movement of people and goods. Schaller also states that traffic impacts from delivery vehicles most often arise from double parking to make deliveries. This could be alleviated by providing adequate delivery zones and imposing fines or other sanctions for vehicles that do not use designated curb space for deliveries.[59] Sharma et al. (2017) identify land use planning

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[54] Jaller, Otero-Palencia, and Pahwa, "Automation, Electrification, and Shared Mobility in Urban Freight: Opportunities and Challenges."
[55] Knowles and Lightstone, "The Impacts of Connected and Automated Vehicle Technologies on Goods Movement and Distribution in North America."
[56] Jaller, Otero-Palencia, and Pahwa, "Automation, Electrification, and Shared Mobility in Urban Freight: Opportunities and Challenges."
[57] Jaller, Otero-Palencia, and Pahwa.
[58] Bruce Schaller, "The New Automobility: Lyft, Uber and the Future of American Cities."
[59] Bruce Schaller.

strategies to manage the curbside and reduce congestion.[60] Similar to the Schaller suggestion, these include providing established common loading areas in congested business areas to effectively manage curbside truck parking and deliveries.[61]

Clark (2019) found that, while commercial loading zones are a traditional element of the right-of-way, TNCs and AVs create additional needs at the curbside for both freight and people.[62] He suggests that commercial loading zones should be available at the right time of day and at the right place to make it easier for businesses to use them and avoid congestion from trucks and delivery vans blocking the streets. Trucks, taxis, and TNCs can cause delays at the curb, so designating loading spaces in high-traffic areas can help limit delays and manage congestion. Cities could assign curb spaces to specific uses based on distance from a destination and reserve the main-street curb for short term uses.[63]

4.3.2 Transportation of Both Goods and People

Some research around the transportation of both goods and people suggests an integrated system where people and freight are moved together. Mourad, Puchinger, and Van Woensel (2020) present a system where freight deliveries could be done using a fleet of autonomous delivery robots integrated with the public transit system.[64] Passengers and the delivery robots would share capacity on public transportation, with passengers being prioritized. This system would be most effective during off-peak public transit hours. Beirigo, Schulte, and Negenborn (2018) present a similar system.[65] However, in their approach, passenger requests and delivery requests are pooled into mixed purpose compartmentalized shared AVs.[66]

4.3.3 Pilots and Projects

There are several pilots around automated freight and management of curbside activity. There have been some loading zone pilots, including one in Washington DC. Other pilot projects have focused on development of a platform to identify and reserve virtual loading bays as guaranteed time slots at the curb for delivery vehicles. This is intended to prevent circling and double parking, reducing congestion. It is anticipated that research and pilot projects focused on curb management will continue to be a focus, particularly for AVs in a subscription and shared use format and for automated deliveries.

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60 Sushant Sharma et al., "Methodologies and Models for Selection of Optimal Truck Freight Management Strategies," in *Transportation Research Board 96th Annual Meeting*, 2017.
61 Sharma et al.
62 Benjamin Clark, "How Will Autonomous Vehicles Change Local Government Budgeting and Finance? Case Studies of On-Street Parking, Curb Management, and Solid Waste Collection," no. May (2019), https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?article=1003&context=trec_data.
63 Clark.
64 Abood Mourad, Jakob Puchinger, and Tom Van Woensel, "Integrating Autonomous Delivery Service into a Passenger Transportation System," *International Journal of Production Research* 0, no. 0 (2020): 1–24, https://doi.org/10.1080/00207543.2020.1746850.
65 Breno A. Beirigo, Frederik Schulte, and Rudy R. Negenborn, "Integrating People and Freight Transportation Using Shared Autonomous Vehicles with Compartments," *IFAC-PapersOnLine* 51, no. 9 (2018): 392–97, https://doi.org/10.1016/j.ifacol.2018.07.064.
66 Beirigo, Schulte, and Negenborn.

4.4 Evaluate ongoing use cases associated with freight deliveries through automation, including considerations around right-of-way, privacy and congestion; also consider post-COVID-19 implications for local deliveries without direct human contact

A large body of work focuses on freight deliveries through automation. Some of this work focuses on considerations of right-of-way, privacy, and congestion. There is also a recent research focused on deliveries without human contact resulting from concerns associated with COVID-19. In the area of contactless last-mile freight delivery, innovations include automated delivery vehicles, delivery robots, UAVs, and innovations in the final handoff such as automated kiosks. Research around congestion from freight deliveries focused on strategies to lower congestion, including providing loading zones and using technology like sidewalk robots that are intended for small parcels. However, sidewalk robots may cause congestion on the sidewalk.[67]

4.4.1 Last Mile Use Case

As e-commerce becomes more popular, there is a growing demand for fast home delivery that has spurred research on last-mile delivery use cases. Last-mile delivery is the movement of goods from a transportation hub to the final destination.[68] Rothbard (2018) calls last-mile deliveries the biggest problem of the freight system.[69] The innovations identified by Rothbard include delivery AVs, delivery robots, drones, automated cargo bikes, innovations in right-of-way including bike and truck lanes or a cargotram (a rail tram consisting of a few cars for freight delivery, which could be automated), and innovations in the final handoff such as delivery robots and automated kiosks.[70] In the now defunct Sidewalk Labs Quayside project, a last-mile freight system was designed with a focus on reducing truck traffic.[71] The Sidewalk Labs freight system would have been comprised of a consolidation and fulfillment logistics hub, an automated

In the area of contactless last-mile freight delivery, innovations include automated delivery vehicles, delivery robots, UAVs, and innovations in the final handoff such as automated kiosks

[67] Jennings and Figliozzi, "Study of Sidewalk Autonomous Delivery Robots and Their Potential Impacts on Freight Efficiency and Travel."
[68] DHL, "Last Mile Delivery: Solutions for Your Business," Discover DHL, 2019.
[69] Sandra Rothbard, "Innovation in Freight Transportation: Sidewalk Toronto," 2019.
[70] Rothbard.
[71] Rothbard.

dolly, connected basements, and an automated final handoff.[72]
There is a growing body of research around last-mile deliveries by automated robots and drones. Jennings and Figliozzi (2019) describe automated sidewalk delivery robots as pedestrian-sized or smaller robots that deliver items directly to customers.[73] Their research finds that sidewalk automated delivery robots can provide substantial cost and time savings as well as reduce on-road travel.[74] Boysen, Schwerdfeger, and Weidinger (2018) propose using autonomous delivery robots launched from a truck. [75] The truck would be loaded with delivery robots holding freight for a defined set of customers. The freight would then be launched from the truck and ultimately directed back to a central depot.[76] The International Transport Forum found that freight drones for goods delivery will have positive impacts, including improved connectivity in remote and rural regions where the last mile delivery can be costly.[77] Paddeu and Parkhurst (2020) note that UAVs and unmanned autonomous cargo vehicles have been used largely in military contexts, though also in civilian contexts for emergency deliveries in

[72] The University of the West of England's "New Technology and Automation in Freight Transport and Handling System", Anne Goodchild, Barb Ivanov, and Haena Kim's "Common Carrier Locker System Pilot Test in the Seattle Municipal Tower Final Project Report" and Jean-Philippe Aurambout, Konstantinos Gkoumas, and Biagia Ciuffo's "Last Mile Delivery by Drones: An Estimation of Viable Market Potential and Access to Citizens Across European Cities" echoed this research.
[73] Jennings and Figliozzi, "Study of Sidewalk Autonomous Delivery Robots and Their Potential Impacts on Freight Efficiency and Travel."
[74] Jennings and Figliozzi.
[75] Nils Boysen, Stefan Schwerdfeger, and Felix Weidinger, "Scheduling Last-Mile Deliveries with Truck-Based Autonomous Robots," *European Journal of Operational Research* 271, no. 3 (2018): 1085–99, https://doi.org/10.1016/j.ejor.2018.05.058.
[76] Boysen, Schwerdfeger, and Weidinger.
[77] International Transport Forum, "(Un)Certain Skies: Drones in the World of Tomorrow," 2018.

areas with limited accessibility, including rural areas.[78] However, their application to last-mile deliveries may be limited due to their small capacity compared to a regular cargo van and a requirement for larger landing zones for UAVs.[79]

4.4.2 Congestion and Right of Way Considerations

As freight deliveries increase, there are more concerns around congestion and right-of-way in automated freight deliveries. As mentioned above, sidewalk automated delivery robots are one potential method to reduce congestion. However, they may also increase sidewalk congestion. Jennings and Figliozzi (2019) note that these robots can reduce roadway congestion and the number of on-road vehicle miles traveled by delivery vans and trucks.[80] However, these vehicles will travel on the sidewalk, creating new externalities and potential issues of pedestrian safety and sidewalk congestion.[81] The authors also find that, similar to now, delivery drivers occupy metered regular parking spots or loading zones in downtown areas, it is also likely that sidewalk autonomous delivery robots would require a new type of "parking" space and would behave differently than standard delivery vans, creating new right-of-way and congestion concerns.[82]

As freight deliveries increase, there are more concerns around congestion and right-of-way in automated freight deliveries

4.4.3 Implications for Deliveries without Human Contact Post COVID-19

The COVID-19 pandemic has several implications for deliveries without human contact. Knowles and Lightstone identify several firms, including Flirtey, Matternet, and Amazon, that have begun testing UAVs for last mile deliveries.[83] As previously mentioned, sidewalk automated delivery robots are another potential option for deliveries without human contact. Jennings and Figliozzi find that these robots could be used in conjunction with transport vans as a viable alternative to standard delivery vehicles to reduce delivery time, on-road vehicle miles traveled, costs, and human contact.[84] In the wake of the COVID-19 pandemic, some original equipment manufacturers and local governments have started demonstrating their vehicles for contactless use. AVs are being used in Sacramento, CA for contactless delivery of medical supplies and in San Mateo, CA to transport food and water for medical workers. In Florida, AV shuttles are being used at the Mayo Clinic to transport COVID-19 tests while in California they

[78] Paddeu and Parkhurst, "The Potential for Automation to Transform Urban Deliveries: Drivers, Barriers, and Policy Priorities."
[79] Paddeu and Parkhurst.
[80] Jennings and Figliozzi, "Study of Sidewalk Autonomous Delivery Robots and Their Potential Impacts on Freight Efficiency and Travel."
[81] Jennings and Figliozzi.
[82] Jennings and Figliozzi.
[83] Knowles and Lightstone, "The Impacts of Connected and Automated Vehicle Technologies on Goods Movement and Distribution in North America."
[84] Jennings and Figliozzi, "Study of Sidewalk Autonomous Delivery Robots and Their Potential Impacts on Freight Efficiency and Travel."

are being used for meal delivery at an elder community. Other firms are investigating grocery delivery and item delivery to elder-care facilities.

4.4.4 Pilots and Projects

There are a few projects around last mile and contactless automated delivery. A drone delivery firm in Canada is working with Staples and NAPA to deliver small packages. UPS was the first commercial entity in the U.S. to receive full certification for drone deliveries from the Federal Aviation Administration[85]. Sidewalk automated robots are being used for contactless delivery to various U.S. university campuses including George Mason University, Northern Arizona University, Purdue University, and the University of Pittsburgh. There is ongoing research in this area as well. USDOT is working on a forthcoming paper, “Automated Delivery: State of the Practice Scan.” The University of North Carolina Charlotte has sponsored an active research project “Assessment of Parcel Delivery Systems Using Unmanned Aerial Vehicles (Phase III)” to study drone alternatives to traditional delivery.

4.5 Determine research completed and needed to understand the supply chain focused impacts of new technologies on the workforce

Much of the research around the workforce focuses on the potential job losses and workforce training needs resulting from the shift to automated trucking. This is an area that could be explored further. Much of the other research focuses on the job and workforce training that will be needed and the work that policymakers will need to do. There is some on-going research in this area, including a USDOT study.

4.5.1 Workforce Implications of Automated Freight

There is a large body of work centered around workforce implications of automated freight with a primary focus on job losses. As discussed in Section 4.1, Yankelevich et al. (2018) find that the adoption of AVs may lead to the displacement of driving jobs in the trucking sector as well as the passenger transportation sector, namely taxis.[86] Rouse et al. (2018) note that the reduction in jobs will occur over the next decades as automated trucks are adopted, not all at once.[87] Recent predictions on the growth of automated trucking have recognized that job losses are likely to be gradual and may be accommodated as older truck drivers retire.[88] Other research supporting the idea that automated trucks will displace traditional driving jobs come from the U.S. Government Accountability Office and the U.S. Department of Commerce, Economic and Statistics Administration Office of the Chief Economist.[89] The levels of job losses and whether these losses will be permanent is debated, however.

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[85] UPS Flight Forward announcement of first full Part 135 Standard certification to operate a drone airline, 10/19/19.

[86] Yankelevich et al., “Preparing the Workforce for Automated Vehicles Truck Platooning State of the Industry 2018.”

[87] David C. Rouse et al., “Preparing Communities for Autonomous Vehicles,” 2018.

[88] Yankelevich et al., “Preparing the Workforce for Automated Vehicles Truck Platooning State of the Industry 2018.”

[89] US Government Accountability Office, “Automated Trucking: Federal Agencies Should Take Additional Steps to Prepare for Potential Workforce Effects,” 2019, https://www.gao.gov/assets/700/697353.pdf%0Ahttps://trid.trb.org/view/1591085.

Mudge et al. (2018) state that AVs will likely not lead to a long-term loss of jobs, although some workers will experience unemployment and wage losses.[90] Impacts will be tied most closely to the adoption of Level 4 and Level 5 trucks; Simpson et al. (2019) noted that these trucks will likely be available in ten years but it could take up to 25 years for the technology to be widely adopted.[91] Partial automation of trucks is unlikely to have significant negative impacts on the workforce, as repeated in Fitzpatrick (2017).[92] However, this must also be taken in the context that the trucking industry is currently facing a labor shortage and highly automated SAE Level 4 and above trucks may attract new drivers with improving quality of life and decreasing stress.

Some of the research around job losses also mentions that potential new jobs that will be created. Yankelevich et al. (2018) name engineering, data analysis, cybersecurity, and vehicle monitoring as areas that will see new jobs created.[93] Viscelli asserts that new freight-moving jobs will be created, but these jobs will be local driving and last-mile delivery jobs that will likely be classified as independent contractor jobs with low wages and poor working conditions.[94] However, SAE Level 4 trucks are expected to need remote monitoring and support which would provide jobs for licensed drivers.[95]

4.5.2 Job Training Needs

Some of the research focuses on the job training needs of the workforce. Yankelevich et al. (2018) find that AVs will require substantial changes in the way that workers perform their jobs in the trucking and transportation sectors.[96] This will necessitate the acquisition of new skills. Wang (2019) published recommendations focused on increasing training for trucking and transportation professionals to be competitive as automated trucking and transportation arrives.[97] Wang notes that better and more frequent training will ease the adoption of new automated technologies, address skill gaps both now and for the future, and allow workers to make career moves. In line with the recommendations from Wang, Pima Community College and TuSimple created an autonomous driving certificate program for truck drivers to equip drivers with the skills to expand their roles as automated trucks are adopted.[98] The certificate teaches drivers to operate and work with autonomous trucks, allowing these drivers to prepare for future jobs like test drivers, driving the automated trucks in areas where autonomous driving is not suitable, or remotely monitoring trucks.

4.5.3 Role of Stakeholders and Policymakers

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[90] Richard Mudge et al., "America's Workforce and the Self-Driving Future," 2018.
[91] Jesse R. Simpson et al., "An Estimation of the Future Adoption Rate of Autonomous Trucks by Freight Organizations," *Research in Transportation Economics* 76, no. July (2019): 100737, https://doi.org/10.1016/j.retrec.2019.100737.
[92] David Fitzpatrick et al., *Challenges to CV and AV Applications in Truck Freight Operations*, *Challenges to CV and AV Applications in Truck Freight Operations*, 2017, https://doi.org/10.17226/24771.
[93] Yankelevich et al., "Preparing the Workforce for Automated Vehicles Truck Platooning State of the Industry 2018."
[94] Viscelli, "Autonomous Trucks and the Future of the American Trucker."
[95] Yankelevich et al., "Preparing the Workforce for Automated Vehicles Truck Platooning State of the Industry 2018."
[96] Yankelevich et al.
[97] Xinge Wang, "Preparing the Public Transportation Workforce for the New Mobility World," *Empowering the New Mobility Workforce*, 2019, https://doi.org/10.1016/b978-0-12-816088-6.00010-9.
[98] Auvsi News, "Pima Community College, TuSimple Launch Autonomous Driving Certificate Program for Truck Drivers," *AUVSI News*, 2019.

Research also addresses the role of stakeholders and policymakers. Viscelli writes that proactive action will be needed by policymakers to develop an industry-wide approach to worker training and stability. This includes ensuring worker protections, regulating the automated trucking industry, and developing new technology.[99] USDOT (2018) provides many recommendations for stakeholders and policymakers primarily focused on public transit operators, but which could be adopted for automated freight.[100] Veryard (2017) recommends establishing a temporary advisory board for the transition to AVs and considering a temporary permit system to manage the speed of adoption and to support truck drivers in the transition to automated trucking.[101] Wang (2019) suggests a joint labor management partnership to provide assistance to displaced workers, retraining, and other job placement programs.[102]

Proactive action will be needed by policymakers to develop an industry-wide approach to worker training and stability

4.5.4 Pilots and Projects

USDOT is currently doing a study on the impact of AVs technologies on the workforce. The study focuses on four general areas: labor force transformation and displacement, labor force training needs, technology operational safety issues, and quality of life effects due to automation. The first phase of the study is expected to have a report issued in late 2020.

[99] Viscelli, "Autonomous Trucks and the Future of the American Trucker."
[100] US Department of Transportation, "Preparing For the Future of Transportation: Automated Vehicles 3.0," 2018.
[101] Daniel Veryard and International Transport Forum, "Managing the Transition to Driverless Road Freight Transport," 2017.
[102] Wang, "Preparing the Public Transportation Workforce for the New Mobility World."

5 Further Research Opportunities

The suggestions below identify topics for future research to inform and focus the important discussion around *Potential Impacts of Highly Automated Vehicles and Shared Mobility on the Movement of Goods and People*. These topics will be evaluated by the Forum in coordination with the appropriate TRB Committees and staff to determine which topics can be expanded into more detailed research statements and proposals. Where possible, crossover to other Topical Papers has been identified to assist with the development of more robust and cross-issue research statements.

Subtopic	Research Opportunity	Crossover to Other Topics
4.1	Survey pilots/deployments, document use cases at ports, (airports, maritime ports, and inland ports), public roads and mixed-use traffic, and sidewalks and trails for 10,000-pound delivery options. Include applications drayage, gantry movements, and forklifts. Consider ODDs including public right-of-way on roadways, sidewalks, and trails. Create a practitioners' guide to last mile AV applications. Inventory current projects and technology applications including synergistic or precursor technologies, especially e-cargo in the case of last mile.	*Infrastructure, Planning*
4.1	Identify use cases, safety, and land use considerations for rural and urban applications for aerial drones.	*Safety, Land Use, Equity & Accessibility*
4.1	Create lessons learned case studies from surface and air contactless delivery of medical and other provisions. Identify best practices for privacy protection.	*Data Sharing, Social Impacts*
4.1	Develop a practitioner's guide to best practices in automated cleaning and decontamination of vehicles.	*Safety, Social Impacts*
4.2	Inventory demonstrations, pilots, and projects for long haul and middle-distance trucking including synergistic or precursor technologies such as platooning and electrification. Create safety scenario repositories, assess coverage, and examine presence and evaluation of edge cases.	*Planning, Safety*
4.3	Identify best practices (planning, policy, and technological) for curbside management and off-road shared use of sidewalks and trails. Carsharing, ecommerce, and other deliveries should be addressed as well.	*Social Impacts, Equity*
4.4	Document activities around urban package delivery with special purpose vehicles smaller than conventional trucks.	*None*
4.4	Identify applications for AV deliveries after COVID-19, including evaluation of pandemic focused demonstration projects.	*None*

Subtopic	Research Opportunity	Crossover to Other Topics
4.5	Segment workforce impacts by specific market segments, such as long haul versus networked trucking, and regional economies rather than strictly national economies and markets. Analyze which jobs will be lost by whom, when, and where to align training for new job types.	*Social Impacts*

6 Appendix

A. Definition of Terms

ADA	Americans with Disabilities Act
ADS	Automated Driving System
AV	Automated Vehicle
EV	Electric Vehicle
FTA	Federal Transit Administration
HAV	Highly Automated Vehicle
LSAV	Low-Speed Automated Vehicle
MaaS	Mobility as a Service
NHTSA	National Highway Traffic Safety Administration
ODD	Operational Design Domain
OEDR	Object and Event Detection and Response
SAE	Society of Automotive Engineers
TNC	Transportation Network Company
USDOT	US Department of Transportation
VMT	Vehicle Miles Traveled

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Principal Research Manager: Greg Rodriguez, Stantec, Mobility Policy Principal
Principal Research Coordinator: Pamela Bailey-Campbell, Stantec, Senior Transportation Strategic Advisor
ARA Research Lead: Jason Bittner, Principal and Practice Area Lead
Researcher: Jennifer Shriber, Stantec, Transportation Planner
Researcher: Sophia Constantine, Stantec, Researcher
Principal Investigator: Kelley Coyner, Innovation4Mobility

Subject Matter Experts for this Topical Paper: Robert Brown, TuSimple, Head of Government and Public Affairs and Kelley Coyner, Innovation4Mobility