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STATE AND LOCAL IMPACTS OF AUTOMATED FREIGHT TRANSPORTATION SYSTEMS

Appendix E: Annotated Bibliography

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The Tioga Group
Fehr & Peers
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DISCLAIMER

ANNOTATED BIBLIOGRAPHY

AAA Foundation for Traffic Safety. 2017. Leveraging Large-Truck Technology and Engineering to Realize Safety Gains: Automatic Emergency Braking Systems.

This report discusses research and consequent recommendations by the AAA Foundation for Traffic Safety for preventing large truck collisions and accidents. According to the executive summary, "The objective of this research was to provide scientifically based estimates of the societal benefits and costs of advanced safety technologies in large trucks," to better inform regulators and increase cost-effectiveness. The report discusses the cost effectiveness of automatic braking in trucks, looking into costs involved to install these systems on all trucks as well as only on new trucks. It finds that "the current pricing/efficacy rate used in this study did not suggest that automatic emergency braking systems were always cost effective. Only at the lowest cost considered ($500) were the systems consistently found to be cost-effective regardless of which trucks were equipped with the system." It does not conclude that these systems are cost effective in most instances, but states that "if the cost and efficacy of automatic emergency braking systems can be maintained at (or improved from) $2,500 and 28%, respectively, the estimated economic benefits of equipping all new large trucks with automatic emergency braking systems would be greater than the costs of doing so."

AAA Foundation for Traffic Safety. 2017. Leveraging Large-Truck Technology and Engineering to Realize Safety Gains: Air Disc Brakes.

A continuation of the same AAA series described above; this report discusses air disc brake technology. Air disc brakes, which have been shown to be more effective than drum brakes, have been around for decades but have not yet been widely used in the United States due to costs. They are now widely used in Europe and are gaining popularity in America. The report found air disc brakes to be both highly effective and widely cost effective, though possibly not in cases of retrofitting older vehicles. It concludes that "installing air disc brakes on all new combination unit trucks would likely be cost-effective if it could be accomplished at or lower than the average cost used in the analyses reported here."

AAA Foundation for Traffic Safety. 2017. Leveraging Large-Truck Technology and Engineering to Realize Safety Gains: Lane Departure Warning Systems.

This continuation of the series finds installing lane departure warning systems to be highly cost effective across all trucks, though it does acknowledge that installing them in older vehicles is more costly (but still cost-effective).

AAA Foundation for Traffic Safety. 2017. Leveraging Large-Truck Technology and Engineering to Realize Safety Gains: Video-Based Onboard Safety Monitoring Systems.

This series report concerns video technology that records both the driver and the surrounding environment around the truck. The report concludes that "Despite the significant costs associated with driver coaching, the results of this study suggest that the societal benefit of equipping large trucks with video-based onboard safety monitoring systems, expressed in economic terms, substantially outweigh the associated costs."

Abdel-Aty, M., Saad, M., Wu, Y., & Rahman, S. (2019). Evaluation of Managed Lane Facilities in a Connected Vehicle Environment. Orlando: University of Central Florida.

Abdel-Aty, Saad, and Rahman discuss the safety and usefulness of managed lanes (already in use with good results) in which connected vehicles could be platooned away from other traffic. The study used vehicle behavior models. The report argues that both managed-lane CV platooning and all-lane CV platooning improved safety and performance over current standards, but that managed-lanes outperformed all-lanes. However, the report also states that these findings have limitations, as there is currently no empirical data or examples for these CV practices; it is all based on modeling. As such, this report serves mostly as a platform for further analysis.

Aeronautics and Space Engineering Board. 2018. Assessing the Risks of Integrating Unmanned Aircraft Systems (UAS) into the National Airspace System. Report, Washington: The National Academies Press.

This 2018 Transportation Research Board report begins by highlighting the life-saving potential of drones, citing lifeguards using them to save someone from drowning in Australia. The report makes several recommendations for safely integrating drones. These include considering the level of risk the public is willing to accept regarding drones, considering safety benefits of drones, delegating responsibility (where appropriate) to UAS industries, ensuring that the level of scrutiny matches the potential risk, collecting and analyzing empirical data, and using quantitative risk assessment.

AJOT. 2020. ATA Releases Results of Latest Driver Compensation Study. Article, AJOT.

A 2020 news release covering the American Trucking Association's latest report states that average driver pay rose by almost $6,000 between 2017 and 2019. This increase reflects a shortage in drivers (so more pay and benefits being offered to attract workers to the industry), though the report speculates that this could become a more popular line of work following the COVID pandemic (as many unemployed workers will be seeking something reasonably well-paying).

AJOT. 2021. A (Virtual) Test Ride in a Waymo Long-Haul Truck.

A demonstration of a Waymo self-driving long-haul truck is covered in this 2021 news article, which also discusses Waymo's developments and timeline going forward. The truck was demoed with a driver behind the wheel paying close attention and ready to take control. According to the article, Waymo does not have a specific timeline for deployment of these trucks, but they will be rolled out first in the Southwestern United States, and could use a "depot-to-depot system," where a driver gets in to complete non-freeway, surface street driving. Though interstate highways may be easier to navigate in some ways than city streets, making deployment easier than Waymo's ride-sharing program, the article mentions other problems associated with trucks, stating for example "Stopping 80,000 pounds of freight when something goes wrong at 65 miles per hour, for instance, is not a problem that ride-hail vehicles have to handle."

American Association of Motor Vehicle Administrators. 2018. *Jurisdictional Guidelines For Safe Testing and Deployment of HAVs.* American Association of Motor Vehicle Administrators.

The executive summary states, "The purpose of this report is to address how automated vehicle technology will directly impact vehicle registration and titling programs; driver training, testing, and licensing programs; enforcement of traffic laws; and first response to traffic related incidents." It breaks these into four sections: administrative considerations, vehicle credentialing considerations, driver licensing considerations, and law enforcement considerations. It argues that testing will require government oversight combined with stakeholder engagement in order to address all the many aspects of the technology.

American Journal of Transportation. 2021. ANA Holdings and Wingcopter Partner to Accelerate the Development of Drone Delivery Infrastructure.

ANA Holdings in Japan is partnering with German drone manufacturer Wingcopter to deliver pharmaceuticals and other products using unmanned drones. ANA chose Wingcopter due to their "unique tilt-rotor eVTOL drone and extensive experience in flying under difficult conditions all over the world."

American Journal of Transportation. 2021. Driverless Tech Startup Aurora Adds Volvo to Trucking Partners.

Aurora and Volvo will now be working together to deploy Level 4 autonomous trucks. Aurora, a startup that competes with Waymo, now has deals with Volvo, Paccar, and Toyota (Toyota has also made a deal with Nuro, an Aurora competitor).

American Journal of Transportation. 2021. The (Robot) Pizza Guy is Here.

This brief AJOT article concerns the fast-paced development and implementation of sidewalk robots for delivery purposes. It highlights new robots which are providing fleets for companies such as Domino's, Kroger's, and CVS. It also mentions that technology now allows robots to go inside, which could make deliveries in offices, malls, and airports possible. This technology is developing and being implemented much faster than self-driving trucks are, according to the article, and the developers hope these robots will allow for quicker delivery times at lower costs to answer an increased demand for this from the public.

American Journal of Transportation. 2021. TuSimple Sees Rapid Path to Profits Once Driverless Trucks Roll.

According to this report, prior to its IPO, TuSimple had been losing money in developing self-driving trucks despite large operations in China and significant testing. However, with a plan to get these trucks on the road by 2024, the company expects to begin turning a profit with only several thousand trucks deployed.

American Transportation Research Institute. 2016. Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry.

As of 2015, the ATRI considered AV technology a top priority for further trucking industry research. According to the report, "The technology to demonstrate L3-L5 operations exists today, though motor carriers do not currently have access to AT systems." It states that return on investment is a large issue for carriers, especially because current cost estimates are based on what early-stage demonstration systems cost. Productivity and safety are stated as the main potential benefits for carriers. Other potential benefits include increased driver retention, improvements in health and wellness for drivers, less need for truck parking, and other benefits related to reducing the need for drivers to stop and rest.

American Transportation Research Institute. 2013. Large Truck Safety Trends.

According to this safety report from ATRI, heavy duty trucks (which require a class C driver's license to operate) saw a decline in crashes between 2000 and 2010, whereas slightly smaller medium duty trucks saw an increase during the same time period. Much of this increase was in urban core counties, and hazardous weather equalized the frequency of medium-duty and heavy-duty incidents. The report states that "More data, such as driver citations and vehicle speed, is needed to determine the underlying crash causal factors."

American Transportation Research Institute. 2018. Predicting Truck Crash Involvement: 2018 Update.

The ATRI published this update to a report first published in 2004, which attempts to use historical data to predict future crashes. Its findings show concerns over driver recklessness; the report finds that "driver behaviors again had a statistically significant impact on future crash probability. As in 2005, 'reckless driving' violations again had the largest impact on future crash involvement, increasing the probability of a future crash by 114 percent." The report also considers driver age and gender; it states that "Driver age had a statistically significant relationship with all but eight driver behaviors, while driver gender had a statistically significant relationship with all but 18 driver behaviors. Female drivers were less likely to engage in risky driving behaviors than male drivers for all statistically significant behaviors."

American Transportation Research Institute. 2020. Redefining the Role of Government Activities in Automated Trucking.

The ATRI published this report concerning government regulations around automated trucks. The study seeks to address the regulations necessary for AV deployment in trucking and to compare these with current regulations. It makes many recommendations, including stronger federal leadership on the issue and developing a hierarchy for regulatory agencies. It mostly concludes that clearer leadership is needed on the issue, and it encourages removing barriers to the testing and deployment of the technology. It also mentions the need to establish clear limits for data

usage and to address cybersecurity issues.

American Transportation Research Institute. 2020. Understanding the Impact of Nuclear Verdicts on the Trucking Industry.

This ATRI report concerns large legal verdicts (referred to as "nuclear verdicts") regarding trucks, which are generally over $10 million and usually result from injury or death in a crash. It finds that cases have increased, and juries tend to award significantly more in these cases, compared to a decade ago. It states that crash prevention and strictly following all safety rules and regulations is critical, as any failure to follow these is highlighted in the case. It also states the importance of preparation for dealing with legal issues, stating "litigation preparation is – and should be – both complex and costly." The report also mentions that insurance fraud has been shown to be increasing (and those committing it are going to greater lengths to plan it), and that litigation financing "has become one of the fastest growing trends in trucking litigation."

Auburn University. 2017. Heavy Truck Cooperative Adaptive Cruise Control: Evaluation, Testing, and Stakeholder Engagement for Near Term Deployment: Phase Two Final Report.

Published by the Department of Mechanical Engineering at Auburn University for the Federal Highway Administration in 2017, this report "provides a summary of Phase Two results for evaluating the commercial feasibility of Driver Assistive Truck Platooning (DATP)." These systems are a step up from adaptive cruise control and allow for trucks to operate with 50-75 feet of spacing. The report concludes that this technology has great potential to improve truck efficiency and fuel economy. It also states that this technology will probably be feasible for many truck operators, though OTR and LTL (less-than-truckload) operators will probably be the first to adopt "due to their financial resources and operational aspects including freight lane density and trip length."

Basantis, Alexis, Leslie Harwood, Zachary Doerzaph, and Luke Neurauter. 2020. Standardized Performance Evaluation of Vehicles with Automated Capabilities. Report, Washington: US DOT.

The Virginia Tech Transportation Institute created this report for the US DOT, which lays out a set of standardized criteria for testing and evaluating vehicles with autonomous technology. The abstract for the report states that "Such information is useful to private or public organizations interested in a standardized approach to classifying vehicle capabilities, whether for informing the expectation of operators, or for cataloging and learning from the variety of implementation alternatives. Although not the primary purpose, this project may also help inform efforts to develop certification or other standardized vehicle performance efforts. The results of this project showed that specific roadway factors affected automated feature performance and that there was significant performance variability across test vehicles."

Booz Allen Hamilton. 2020. Airports and Unmanned Aircraft Systems Volume 2: Incorporating UAS into Airport Infrastructure Planning Guidebook. Report, Washington: The National Academies Press.

Volume 2 of the 2020 Booz Allen Hamilton report for the Airport Cooperative Research Program concerns the effect UAS will have on airports, and how to incorporate this into planning concerns. The report's conclusion states that "Some of the biggest barriers to UAS integration include the "status quo mindset" of regulatory agencies toward UAS and infrastructure needs, inflexible rulemaking and/or guidance that does not consider potential technological innovations, and export definitions that currently designate UAS as a cruise missile, hampering commercial development." It states that the US DOT recommends ensuring sufficient revenue to support airspace systems, balancing needs for "modernization, maintenance, access, efficiency, capacity, environmental sustainability, and services," focusing on safe integration of new technologies, improving and modernizing the approach to safety management, and improving surface access to airports.

Booz Allen Hamilton, WSP, New Jersey Institute of Technology. (2018). *Dedicating Lanes for Priority or Exclusive Use by Connected and Automated Vehicles.* Washington: National Academies of Science, Engineering, and Medicine.

This study concerns lane use for AVs, including benefits and disbenefits of dedicated AV lanes, and who benefits from each. The research used modeling based on current AV technologies to determine the effects on efficiency and safety of dedicated lanes. The report states that it makes sense to have combined HOV/AV lanes at lower AV market penetration, then move on to exclusive AV lanes for medium AV traffic, and no exclusive lanes for high AV traffic. It mentions that traffic friction will increase in non-AV lanes, especially with low levels of AV traffic, and that safety measures will be needed due to the large difference in speed between the two vehicle types.

Boudway, Ira. 2020. Zipline Medical Drones Begin Flying in the US. Article, AJOT.

Zipline, a drone company, has begun flying medical supplies with its drones after accelerating development during COVID-19 according to this 2020 AJOT article. The pandemic has presented opportunities for increased drone development, with contact-free delivery methods in demand and general traffic greatly reduced. This also marks the first time the FAA has approved these drone flights.

Bradley, Becky. n.d. At the Intersection of Freight, Freight, Freight, and Freight. Presentation, Allentown: Lehigh Valley Planning Commission.

Becky Bradley, Executive Director of the Lehigh Valley Planning Commission, developed this presentation specifically for the Lehigh Valley region of Pennsylvania. Much of the presentation consists of computerized depictions of planned concepts for various developments. Bradley predicts increased freight activity in the area due to more people ordering items online to be delivered. It argues that policy goals should encourage quality of life for residents (less traffic and pollution, for example), and argues the need to expand public transit for the region and to work with planning agencies and ports in the region to develop plans going forward.

Brown Jr., A., Azevedo, I., Baranescu, R., Cackette, T., Clark, N., Graves, R., . . . Vujovich, C. (2019). *Reducing Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two.* Transportation Research Board.

Phase II of this study into environmental impacts of medium- and heavy-duty trucks discusses in great detail issues such as current regulations and their enforcement; new technologies for reducing power demand and fuel consumption (including hybrid and electric technologies and battery technology); freight operation efficiency (including plans to reduce deadheading), automation (including truck platooning), and concerns over manufacturing and costs and benefits of these technologies. The report also discusses safety-improving technologies including automation, and their effects on efficiency, as well as implementation costs and benefits. The study discusses principles for environmental regulations, and how these differ from current approaches.

Bulusu, Vishwanath, and Raja Sengupta. 2020. Urban Air Mobility: Viability of Hub-Door and Door-to-Door Movement by Air. Report, Berkeley: UC Berkeley.

Bulusu and Sengupta conclude that "for the first time in history, air transport presents a potential competitive alternative to road, for hub-to-door and door-to-door urban services." It takes into account travel time, fuel cost, and emissions compared to those of road vehicles (both freight and passenger air and road transport, over both short and long distances). Though it finds air is always faster, it fares better for fuel costs and emissions only on longer distances. For both consolidated and unconsolidated goods, though, air is on par or ahead of road on all three measurements. It notes that this is based on current designs which favor roads, so argues that changing to more air-friendly design could improve all of these metrics.

Caltrux. 2021. Sophisticated Trucker Technology: Improving Safety, Visibility, and Efficiency.

This article was published by the California Trucking Association, and concerns the rapid progress of technology in trucks, with a more concerted, standardized effort to install new technology and many more developments on the horizon. It points out that technology has also allowed for much more data to reach shippers, increasing visibility for customers. It highlights similar points to other articles about increased efficiency and safety, and states points of view from those in the industry that AV technology will likely be limited to controlled areas

(such as ports) for a long time after it is initially deployed.

Carnegie Mellon University, 2021. Integration of Autonomous Vehicles with Adaptive Signal Control to Enhance Mobility.

As stated in the overview, "This report summarizes the results of a one-year project aimed at exploiting vehicle-to-infrastructure (V2I) communication to enhance the effectiveness of real-time adaptive traffic signal control systems." The series of studies for the project found that vehicles sharing V2I information led to decreased congestion for those vehicles (benefiting travel times), and that these vehicles sharing their information had no negative effect (and perhaps even some positive effect) for those vehicles that did not share their information as well The decrease in congestion from a subset of vehicles sharing information led to an overall decrease in congestion for all vehicles, or at least no adverse effects. The report states, "These results are important in that they show that directly benefiting a subset of vehicles does not have to be a zero-sum game, and enable a new, more sustainable model for upgrading urban infrastructure and improving urban mobility through voluntary tolling at the intersection."

CAVita, LLC. (2017). *Connected & Autonomous Vehicles and Transportation Infrastructure Readiness.* Montreal: National Cooperative Highway Research Program.

This 2017 NCHRP study covers the relationship between AVs and infrastructure, and the need to work with state DOTs to improve infrastructure and mobility. The study suggests ways for DOTs and those promoting automated vehicles to work together, including recognizing state DOTs as "mobility providers" rather than just infrastructure providers, promoting this to legislatures and constituents, and participating more in safety assessments. The study also argues that state DOTs can be more involved with pointing out benefits and increasing awareness of autonomous vehicles, working on what AVs will mean for the workforce; and creating infrastructure models; and working closer with the federal government and local communities. The executive summary describes "taking more initiative," "developing stronger capabilities and resources," and "being a more effective partner."

CDM Smith. 2019. CAV Traffic Simulation Literature Review.

Engineering and construction firm CDM Smith prepared this report, which discusses literature surrounding CAV deployment. It states that expectations for deployment of Level 4 and 5 vehicles have been "unrealistically elevated" by the media, and that high-profile accidents with the technology have not helped with public skepticism. The report concludes that AV deployment will be slow due to political and regulatory issues, exacerbated by potential accidents and the public reaction, and that VMTs will increase (it concludes that interest in shared AVs will likely decline). CAVs are expected to reduce congestion, however, and the value of travel time may increase (as passengers can do other things while in the vehicles). It states that, although there is a potential for increased safety with CAVs, most of the research papers have made dubious safety claims as there has not been enough real-world testing. Since the report concludes that AVs, if deployed, will likely significantly change traffic flow and land use, it concludes that it is important that "stakeholders are continually involved and invested in the vision and the planning process."

Chapin, T., Stevens, L., Crute, J., Crandall J., Rokyta, A., and Washington. A. 2016. *Envisioning Florida's Future: Transportation and Land Use in an Automated Vehicle World.* Tallahassee: Florida Department of Transportation.

This report discusses the impact of AVs on communities and the environment in Florida in coming decades. It mentions several discussions with experts, and states that "Key themes from these discussions included that AVs will require narrower rights-of-way and travel lanes; influence the location, form, and amount of parking; impact the mobility of bicyclists and pedestrians; declutter urban environments through reduced signalization and signage; and provide opportunities for redevelopment on now unnecessary parking lots and excess rights-of-way. In this way, this study affirms that AVs are expected to drastically affect the design and functioning of the built environment and provides a starting point for public and private stakeholders to prepare for these impacts." The report states that these guidelines are preliminary, and further research will be needed.

Cherrett, Tom, Andy Oakey, and Amy Moore. 2020. Drone Deliveries to Reduce Suburban Freight Costs. Report, Southampton: University of Southampton.

The University of Southampton research concerns using drones to deliver medical supplies. The report takes into account the costs and benefits as well as the barriers for doing this, and it covers methodology for transporting these supplies in the UK (including to rural areas). It mentions the impacts of local fly-over restrictions, maximum loads for the drones, and the need for an alternate plan if weather conditions restrict drone takeoff.

CNBC. 2021. Rise in "Nuclear Verdicts" in Lawsuits Threatens Trucking Industry.

CNBC reports that monetary amounts rewarded by juries in large accident settlements regarding trucks have exploded over the past decade. The average verdict size for a multi-million dollar lawsuit has risen from $2.3 million to $22.3 million. As such, only one of these awards by a jury could bankrupt a trucking operator. Therefore, these operators are looking for any way they can to improve safety and reduce accidents. According to the article, "Liberty Mutual Insurance blames corporate mistrust, litigation financing, and social pessimism, a sense that the system is broken, for excessive jury awards." Truckers and insurers are trying to get caps placed on these settlements, especially as they are driving up the price for liability insurance.

Congressional Research Service. (2019). *Issues in Autonomous Vehicle Testing and Deployment.* Washington: Congressional Research Service.

The CRS addressed regulatory issues for autonomous vehicles, and offers some insight into the difficulties involved. CRS acknowledges that AV supporters are hesitant over regulations that will impede development, but notes that legislation did not pass Congress due to issues regarding the division of regulation for automated versus traditional vehicles, how many AVs should be allowed to be tested, how much cybersecurity threats should be addressed in legislation, and how much access to information generated by AVs other parties (manufacturers, insurers, governments, etc.) should have.

CRC Group. 2019. Truck Accident Frequency and Claims Severity on the Rise.

Accidents-per-mile and resulting claims regarding trucks have risen by 59% since 2010, according to this report by the CRC Group, an insurance company. Reasons for this include increased driver fatigue and driver age (the rise due in part to an overall driver shortage), as well as, on a basic level, weight differences between trucks and cars. The AAA and Trucking Alliance are encouraging adoption of safety recommendations, "including various warning, monitoring, and braking systems," to combat this, and studies show drivers support having this equipment installed in trucks as well.

Crute, Jeremy, William Riggs, Timothy Chapin, and Lindsay Stevens. 2018. *Planning for Autonomous Mobility.* American Planning Association.

This report concerns preparing communities for autonomous vehicles, and makes policy recommendations for promoting them in a way that is positive and maximizes potential benefits, not potential downsides. While AVs may improve efficiency, transportation access, safety, and air quality, there is also the potential for them to increase sprawl and emissions, and have a negative effect on transportation systems currently in place. To quote the summary, "A world with AVs will require retrofitting, reimagining, and repurposing transportation infrastructure and the built environment. This PAS report previews these coming changes, and advises planners on how to prepare for and manage these transitions to ensure their communities reap the benefits — and avoid the pitfalls — of AV technology."

CVSA. 2020. CVSA Releases 2020 International Roadcheck Results.

The Commercial Vehicle Safety Alliance (CVSA) completes annual road checks of commercial vehicles throughout North America. If too many violations are found the vehicle is declared "out of service." In addition to

inspecting braking systems, tires, lights, and other physical factors, the alliance also considers driver violations. A top violation was hours of service, likely due in part to the driver shortage. Hazardous material violations are also considered.

Eilbert, Eilbert, A., Berg, I., & Smith, S. B. (2019). *Meta-Analysis of Adaptive Cruise Control Applications: Operational and Environmental Benefits.* Cambridge: Volpe National Transportation Systems Center.

Adaptive cruise control, an early form of automation, and its effects are the subject of this 2019 Volpe study. The abstract states, "With the increasing adoption of adaptive cruise control (ACC) and development of cooperative adaptive cruise control (CACC), their effect on traffic, energy, and emissions is an ever more urgent question. Using the rapidly growing body of research on these impacts, this report presents a systematic review and meta-analysis of 67 recent studies. The majority were simulation studies with a few field tests. While the assumptions and methodology between studies in our review differ widely, a meta-analysis of maximum reported capacity improvements and fuel savings confirmed that CACC applications tend to increase capacity and fuel savings over manual driving due to shortened following time gaps and greater string stability from connectivity. In contrast, ACC applications do not always show capacity improvements, and if so, these improvements are more modest on average than for CACC systems. We found that ACC systems do, however, appear to smooth driving through less braking and reduced hard acceleration events such that fuel consumption is reduced, but not on average as much as CACC systems."

Elizabeth. 2018. Volvo Trucks N.A. partners with FedEx to test platooning vehicles in live conditions. Article, Raleigh: Truck News.

This article from 2018 discusses these companies' long-lasting (but not publicized) efforts to develop & test truck platooning. It discusses the modifications needed to facilitate this on the trucks, and states the tests suggested as high as 10% fuel savings from the platooning. It states that lagging regulations (testing was only allowed in 10 states as of the writing of this article) are a significant barrier to future testing and development.

Federal Highway Administration. 2020. Driving FoRRRwD to Reduce Rural Roadway Departures. Report, Washington: Federal Highway Administration.

FoRRwD is *Focus on Reducing Rural Roadway Departures*, which cause about 12,000 deaths a year. This Federal Highway Administration report on this issue from 2020 highlights the importance of systemic analysis to identify where the greatest risks are, developing a safety action plan, and putting countermeasures (increased road markings and barriers, etc.) in order to achieve this. The report states that officials in 30 states are using these recommended measures to attempt to reduce these accidents.

Fehr & Peers. n.d. How Will Autonomous Vehicles Influence the Future of Travel? Fehr & Peers.

This study concerns passenger vehicles, and states that studies must consider how consumer preferences regarding transportation in the future. The summary states, "Agencies dedicate a great deal of time and effort developing and using models to forecast future travel behavior. A key challenge is that current models often do not account for modes or travel choices that don't yet exist. This makes predicting the effects of autonomous vehicles (AVs) or mobility as a service (MAAS) uncertain, and raises questions about how to best predict their influence. At a minimum, our existing models need to evolve. So our FP Think Initiative tested how current practice regional models in the U.S. responded to commonly accepted AV input effects such as lowering parking costs and increasing freeway capacity. The results are shown for scenarios where AVs are privately owned and where half of trips are made as shared rides similar to potential MAAS offerings. The models confirm that making vehicle travel more convenient has the potential to significantly increase vehicle use and reduce transit ridership."

FHWA. n.d. FHWA Course on Bicycle and Pedestrian Transportation – Walkways, Sidewalks, and Public Spaces. Educational, FHWA.

Essentially an educational handout from the Federal Highway Administration, this covers the basics of planning sidewalk spaces. It includes information on regulation for sidewalk width, and how public spaces (including plazas, restaurants, stores, etc.) are usually planned and developed. It ends with what appears to be a class exercise on planning a public space following these general guidelines.

Fisher, Josh. 2020. Patchwork of Self-Driving Laws Limiting Autonomous Trucking Innovations. Opinion, FleetOwner.

This article covers a 2020 release by the American Transportation Research Institute (ATRI), stating that current regulations and a lack of coordination between different regulators is hampering development of autonomous trucks. The report states that America and China both have a great opportunity for AV testing (due to large rural and undeveloped areas), but that a lack of coordination between different states is making long-distance testing in America difficult if not impossible. The report concludes that "it is incumbent upon federal and state policy makers to avoid implementing policies that needlessly delay testing or deployment of technologies that improve roadway safety."

Fitzpatrick, D., O'Rourke, L., Ross, C., & Bevly, D. (2017). *Challenges to CV and AV Applications in Truck Freight Operations.* Washington: National Academies of Science, Engineering, and Medicine.

The authors discuss challenges to autonomous freight vehicles deployment. It states that truck platooning is considered closest to being rolled out on a large scale, but that even this has many issues. Most notably, no national-scale regulations are in place, so much testing may not actually cross state lines. However, the testing and developments currently in place are enough to attract stakeholders; in the summary, the report states that "Expected small-scale deployments provide opportunities for a range of stakeholders to gain valuable hard and soft data with which to refine concepts, align laws, inform stakeholders, and test new business models for delivery of services." The report also argues that "Further research is needed, as well as integration of research findings with the federal regulatory process. And for all stakeholders, the need to communicate to share experiences across jurisdictions, industry and government segments, and public stakeholders is crucial to enable successful deployments."

FleetOwner. 2020. A For Effort: ADAS and Aerodynamics Lead 2020 Equipment Trends.

This 2020 news article covers developments with Level 1 and 2 automation in trucks during the COVID-19 pandemic, which has left many fleet operators with less cash on hand to pay for equipment upgrades. Many of these features, including automating braking systems, assisted steering, and aerodynamic kits, are still making financial sense for operators. Safety features, such as braking, camera, and radar technologies, especially make financial sense, due to the massive costs associated with "nuclear verdicts," especially in accidents involving fatalities or injuries.

FleetOwner. 2021. Autonomous Endgame: the 10-Year Plan.

This 2021 FleetOwner article covers an interview with trucking journalist Jack Roberts and CEO/President of PrePass Mark Doughty on the future of self-driving trucks. They highlight issues regarding lagging legislation, especially around networks and technology. Roberts points out that some vehicles, including those involving hazardous materials and construction, will always need a driver, and human involvement will still be necessary throughout AV deployment in some form. They also bring up other safety issues, including knowing if an AV is being used for illegal activity, and state that early deployments for AVs will probably involve airport shuttles, refuse collection, and road painting.

FleetOwner. 2021. Embark Standardizes Self-Driving Tech for Major Truck OEMs.

According to this FleetOwner article, AV developer Embark has announced the Embark Universal Interface (EUI), a self-driving technology that can be used with Freightliner, International, Peterbilt, and Volvo trucks. This is designed to allow easier implementation of Level 4 AV technology for truck operators.

FleetOwner. 2020. Experienced Drivers are Benefiting from More Widespread ADAS Adoption.

Drivers and major trucking companies are seeing benefits from Level 1 and 2 automation in their fleets and are looking to continue further automating these trucks going forward, according to this 2020 FleetOwner news article. The article specifically mentions JB Hunt, which has seen a significant reduction in collisions and liability-related costs as a result of systems such as collision warnings and dash cameras (these have been popular with truckers themselves), enough to justify the costs of adding the equipment. However, these technologies still require alert drivers and are not perfect on their own, according to industry experts.

FleetOwner. 2021. FMCSA Driverless Truck Message Stokes Workforce Fear.

This FleetOwner news report from 2021 covers a recent forum held by the Federal Motor Carrier Safety Administration (FMCSA), in which forum participants emphasized the inevitability of self-driving trucks and the fact that this will lead to major workforce changes. According to the article, FMCSA Acting Administrator Meera Joshi highlighted the significant changes in jobs, especially for long-haul truckers, and "advocated for more education and conversations with stakeholders" surrounding the issue. However, Finch Fulton, the former deputy assistant secretary for transportation policy, has argued that these effects will not be as profound due to a rapidly aging and retiring workforce in trucking and slow transition to self-driving trucks. The article also references the above Macroeconomic Impacts of Automated Driving Systems in Long-Haul Trucking report, which makes similar points to Fulton's.

FleetOwner. 2021. Gatik, Isuzu Partner on MD Autonomous Trucks.

Gatik, which "focuses on automating on-road transportation networks for B2B middle-mile logistics," and Isuzu, which manufactures medium-duty trucks, are teaming to accelerate development of autonomous trucks in this size, to address an explosion in e-commerce and the truck driver shortage.

FleetOwner. 2021. Globalization Accelerates Automated Truck Technology Development.

Something of a follow-up to the preceding article, this item discusses the effects of globalization on the development of automated technology for trucks. It specifically discusses how mergers and cooperation between various international companies are leading to increased innovation and an ability to expand across different markets, with the North American market leading the way in adding automated safety technology.

FleetOwner. 2021. Preparing for the Next Generation of Safety Technology and Advanced Driver Systems.

This FleetOwner news report mostly concerns Bendix and its parent company Knorr-Bremse, and how top executives at these companies see the influence of the COVID-19 pandemic on the industry and current trends. They state that truck orders slowed down due to the pandemic initially, but have since rebounded past pre-pandemic levels (despite originally expecting a slowdown in 2020). They also discuss an increase in automated safety features on trucks, and how additional variables for trucks lead to increasing complexity in these systems compared to normal passenger vehicles.

FleetOwner. 2021. The Sunset of 3G Telematics is Nearly Complete.

FleetOwner reports that major cellular service companies (AT&T, T-Mobile, Verizon, etc.) will stop offering telematics services for fleets on the "old generation" of 3G networks this year. They will be transitioning to faster 4G LTE services, and eventually to 5G services as they are rolled out. They expect 4G to be common until at least 2030. Reasons for doing this include making more room for rolling out 5G networks, which could allow for massive increases in vehicle connectivity, and more reliable data with less risk of congestion from 4G networks.

FleetOwner. 2021. Trucking's Safer, Self-Driving Future Is Around the Corner.

FleetOwner published this in-depth news article, stating that Level 4 truck automation will likely be adopted and used within a decade. According to the article, developers have already been testing these trucks in the southwest US and expanding into the Midwest and east coasts (where the climate is more severe, requiring additional features to be added to the technology). As of now, these trucks still have human drivers, partly because the technology is not as good at adapting to sudden, unexpected actions by other drivers or pedestrians (for example, a child running into the street) as human drivers are. Much of the article covers Kodiak, a developer which is looking, along with other developers, to have these trucks on the road by 2030.

FleetOwner. 2021. TuSimple Among Autonomous Truck Companies to Join Self-Driving Coalition.

According to this early 2021 FleetOwner news article, Embark, Kodiak, and TuSimple are the first three autonomous truck companies to join the self-driving coalition started by Ford, Uber, Lyft, Volvo, and Waymo, which is dedicated to promoting self-driving vehicles, mostly for their safety benefits. Many of the reasons given for promoting self-driving trucks also surround safety and increasing scrutiny of truck-related accidents, and the ongoing and increasing truck driver shortage (which is also tied to safety issues through problems related to driver fatigue).

FleetOwner. 2021. TuSimple's Mullen Maps Out Trucking's Self-Driving Future.

TuSimple raised over $1 billion through an initial public offering in April 2021. TuSimple chief administrative officer Jim Mullen discusses the company's plans to test Level 4 trucks in Arizona, and to have them on the road by 2024. He states that money from the IPO will achieve this, and that the company is still working on algorithms to deal with unpredictable motorists, as well as snow. Rain is not a problem for sensors, but snow remains one. He also states that current infrastructure is sufficient for operating these Level 4 trucks, and that highlighting increased safety will be key to winning over the public to the idea of driverless trucks.

Forrester Consulting. 2019. Autonomous Vehicles: From Prototype to Production. Report, Cambridge: Forrester Consulting.

ARM commissioned this 2019 Forrester Consulting report, which examines various technological obstacles to AV deployment. The report states that firms face three main challenges – "Developing higher precision sensors and compute, producing automotive quality systems, and compliance with safety certification standards and regulations that are not yet decided" – but finds that organizations are eagerly exploring AV systems and that hardware & software partners will be key for development.

Fraade-Blanar, Laura, Marjory S Blumenthal, James M Anderson, and Nidhi Kalra. 2018. Measuring Automated Vehicle Safety. Report, Santa Monica: RAND Corporation.

The RAND Corporation, a global public policy think tank, published this report in 2018 concerning developing a framework for AV safety and testing across locations and different companies. The report discusses the need for clearer communication with the public concerning safety, and makes several recommendations, including focusing more on public safety than simply development, more demonstrations, and more consistency in safety and testing as AV systems are continuously updated.

Gaudet, B. (2014). *Review of Cooperative Truck Platooning Systems.* Ottawa: National Research Council Canada.

This report covers truck platooning systems, their potential benefits, and what is needed to make them work effectively. The main benefit mentioned is greater fuel efficiency, as platoons are more aerodynamic. It also mentions that automation may reduce collisions due to slow driver reaction time. The report discusses the technologies and sensors used to make platooning work, though it acknowledges that platooning success is based on many outside factors, including weather conditions, reliability of technology, and other traffic. It also mentions

that joining and leaving platoons creates opportunities for accidents, and that the possibility of alert drivers being more responsive than the technology should be considered. The report states that "In order for CTPS to become popular, drivers must demonstrate an interest in it. Enhanced driving comfort, safety, and efficiency, as well as reduced fuel consumption, would likely influence driver acceptance."

Gettinger, Dan. 2019. The Drone Databook. Report, Annandale-On-Hudson: Bard College.

The Center for the Study of the Drone report covers the current state of military drones around the world, pointing to their growth from 2010 to 2019 (the number of countries with military drones has increased from 60 to 95). It estimates that there are around 30,000 drones currently in service (only 21,000 are confirmed); most of these were imported from the USA or Israel (China also exports a significant number). It analyzes the different uses for these drones, including surveillance, peacekeeping, counterterrorism, border security, anti-crime operations, and also peaceful uses (such as firefighting & environmental protection). It goes into very detailed, country-by-country statistics on infrastructure, development, and use of these drones.

Gettman, Douglas. 2020. DSRC and C-V2X: Similarities, Differences, and the Future of Connected Vehicles. Report, Raleigh: Kimley Horn.

This 2020 news release from planning and design consulting firm Kimley-Horn concerns dedicated short range communication (DSRC) and cellular vehicle-to-everything (C-V2X) technologies. The article states that these systems cannot communicate with each other, and that while C-V2X may have more capabilities, those of DSRC and more than sufficient for most applications regarding connected vehicles. It states that DSRC has already been fully designed & is being tested, but that the advantages of each technology will not be fully known until side-by-side testing has occurred.

Glancy, D. J., Peterson, R. W., & Graham, K. F. (2016). *A Look at the Legal Environment for Driverless Vehicles.* Washington: National Academies of Sciences, Engineering, and Medicine.

The current legal environment for autonomous vehicles, and how it will adapt and change as these vehicles are introduced and become common, are the subjects of this 2016 study. It argues that laws currently in place have already established how autonomous vehicles would need to be made and sold, and establishes liability in the case of accidents and injuries and criminal action for those responsible. The study also states that legal framework currently in place regarding land use for infrastructure will still apply to additional infrastructure needed for autonomous vehicles. However, the paper does note that new laws will need to be put in place, and that legal framework tends to move at a slower pace than technology. As the conclusion states, "Initially, the legal rules devised for driverless vehicles likely will be shaped by analogies to conventional vehicles. Over time, however, policymakers will come to better appreciate, and begin to focus on, the unique capacities of, and challenges presented by, driverless vehicles and the system that supports them." The report also acknowledges that "Overall, however, forecasts regarding the 'likely' or optimal legal policy responses to driverless vehicles should be made only tentatively, and with deep appreciation of their inherent limits.'"

Goetz, A. R., & Alexander, S. (2019). Urban Goods Movement and Local Climate Action Plans: Assessing Strategies to Reduce Greenhouse Gas Emissions From Urban Freight Transportation. San Jose: San Jose State University.

To quote the abstract, "This report examines how freight transport/goods movement has been addressed in U.S. city climate action planning." The report points out that very few Climate Action Plans (CAPs) include any plan for freight emissions despite the fact that they are a major contributor (only six out of 27 studied mentioned freight). It also discusses measures being implemented to reduce greenhouse gas emissions (such as reducing idling and promoting transitioning to electric or fuel cell power), and also points to efforts to improve reliability and efficiency, but argues that "Based on our findings, we recommend that cities specifically target freight transport goals and strategies in their CAPs and better coordinate with planners developing freight transport plans to identify GHG emission reduction approaches."

Governor's Highway Safety Association, State Farm. (2019). *Automated Vehicle Safety Expert Panel: Engaging Drivers and Law Enforcement.* Governor's Highway Safety Association, State Farm.

Summarizing a panel meeting organized by the Governors Highway Safety Association (GHSA) and State Farm insurance, the report suggests four major themes regarding interactions between AVs and law enforcement: complexity (that many different groups are involved and group decisions must be agreed upon); communications; cooperation; and consistency. It argues that cooperation is needed now, as hesitation could delay AV development and cause unnecessary confusion down the road (which could lead to crashes and safety issues). It also recommends that law enforcement and first responders play an active role in AV safety testing and development, and that law enforcement groups dedicated to AVs be created.

HDT Staff. 2020. ATRI Research Redefines Role of Government in Autonomous Truck Testing. Article, HDT Trucking Info.

A 2020 HDT news article states "The American Transportation Research Institute has published a new report that looks at how government regulations are affecting the evolution of autonomous vehicle technology, as well as the role government plays in the testing and overseeing of these technologies in the real world." According to the article, the report states that many local government activities ultimately impede development of an autonomous truck network. The report states that federal bills attempting to create more standardization of local rules around federal ones failed to even get a vote. It emphasizes the need for keeping regulations in line with conducting & supporting research, modernizing regulations and creating a consistent environment, and educating the public.

HDT Staff. 2020. Plus.ai: Autonomous Trucks Possible in Lower 48 by Year's End. Article, HDT Trucking Info.

This HDT article from early 2020 discusses AV developer Plus.ai's new standards for safety testing self-driving trucks, which the company claims will allow them on roads by the end of the year. As of the article, the company had testing in 17 states, and was seeking to expand this to all 50 states (and open significant new testing sites just within the first quarter of the year).

Henaghan, J., Rouse, D. C., Coyner, K., Nisenson, L., & Jordan, J. (2018). *Preparing Communities for Autonomous Vehicles.* American Planning Association.

According to the abstract, "This paper summarizes the findings of a symposium and research on the implications of autonomous vehicles for cities and regions. It is intended for planners and local government officials involved in land-use planning, urban design, and transportation. Readers will learn about the need to plan for the potential benefits and negative impacts of autonomous vehicles and what steps they can take now to prepare their communities." It covers many different aspects of autonomous vehicles, including workforce displacement, environmental impacts, and the estimated cost of rolling out Level 4 automation nationwide. It also includes a section on further research needs, including arguing that more research is needed into how autonomous vehicles and non-autonomous ones will interact.

Hietpas, Jay, and Kristin White. 2019. Connected and Automated Vehicle Strategic Plan. Report, St Paul: Minnesota Department of Transportation.

This is a 2019 Minnesota Department of Transportation plan for preparing for CAV technology, and it will serve as the agency's guidelines. The plan revolves around strategic investment, innovation, and knowledge sharing. The nine focus areas for the plan are capital investment, research and development, partnerships, regulation and policy, operations and maintenance, strategic staffing, multimodal (engaging cyclists, pedestrians, rail, transit, etc.), communications, and long-range planning. Much of this involves funding new infrastructure designs to accommodate truck platooning and other automation (as well as electric vehicles), encouraging safe testing, forming partnerships, conducting public demonstrations, and providing resources to local governments.

Hitch, John. 2020. 'Current' Trends in Heavy-Duty Electric Trucking. Article, FleetOwner.

Though electric truck development is still lagging, it is being discussed more and given higher priority according to this 2020 article (it sites a recent Tesla unveiling). The article states that regional deliveries (where the truck returns to charge at the end of the day) would be a logical first step for electrification. Truck companies are beginning to roll out EVs, and many are looking to use them for as many routes as possible (partly to test their limitations). The article discusses various issues with rolling out these electric trucks, most notably infrastructure (lack of charging facilities and slow charging), but states that environmental regulations will lead to a dramatic increase in the demand for electric trucks in coming years.

Hunter, Michael, Gordon Kingsley, Guin Angshuman, Nathaniel Horadam, Andrew Hanus, Claire Bleckley, and Sorawit Siangjaeo. 2018. *GDOT Roadmap for Driverless Vehicles.* Atlanta: Georgia Department of Transportation.

The summary for this report states, "This study develops a technology roadmap of the development of driverless vehicles, exploring the likely impacts for the transportation systems of the state of Georgia and the operations of the Georgia Department of Transportation (GDOT). The roadmap consists of two elements. First, a range of contingencies shaping the development pathways for autonomous vehicle (AV) technology is examined through: (a) a review of literature in the research and professional communities regarding AV, and (b) semi-structured interviews with 31 industry and public-sector experts representing a range of development strategies and commercial applications. Second, a range of impacts from AV technology on the transportation systems of Georgia is identified through focus groups with GDOT leadership, managers, and consultants representing the full scope of GDOT operations. By comparing findings between the two elements of the roadmap, implementation strategies to prepare for and manage the deployment of driverless vehicles are developed. Drawing from knowledge gained through these resources, five classes of recommendations were developed that address the following areas of implementation: (1) Developing an Internal AV Organizational Structure; (2) Increasing GDOT Familiarity with AV Technology; (3) Managing External Engagements Related to AV Technology; (4) Data, Analysis, and Performance Indicators for AV Technology; and (5) Managing Outside Activities."

Institute of Transport Research, Commercial Transport, German Aerospace Center, 2020. Assessing Long-Term Impacts of Automation on Freight Transport and Logistics Networks by a Large-Scale LRP Integrated in Microscopic Transport Simulation for Strategic Transport and Logistics Network Planning.

This German report discusses the impact AVs may have on bulk transport, which it states have traditionally used a hub-and-spoke system but may end up with much more delivery flexibility due to AVs. This could benefit shippers economically, though there may be some ecological downsides. The study concerns "location routing problems," or LRPs, and how AVs will adjust these going forward, developing a system in order to "find new facilities and adjust the network." It specifically focuses on the case of distribution in Germany. The report states in the abstract "We carry out a case study-based qualitative evaluation of the new optimized network and investigate the logistics effects for the food retail distribution in Germany. In fact, this research reveals that the utilization of autonomous vehicles significantly enhances transportation ranges and the number of tours, while reducing the number of operating facilities."

Institute of Transportation Engineers. 2018. *ITE Statement on Connected and Automated Vehicles.* Washington: Institute of Transportation Engineers.

This is a statement from the Institute of Transportation Engineers (ITE) supporting connected and autonomous vehicles and their development, arguing that they will significantly reduce auto fatalities, that clear testing protocols should be established, that the private and public sectors must work together, and that current safety assist technologies should be rapidly introduced on all new vehicles

International Road Assessment Programme. (2018). *Roads that Cars Can Read: Tackling the Transition to Automated Vehicles.* London: European Road Assessment Programme.

This work focuses on potential safety improvements from automated vehicles, and how infrastructure may need to adapt to maximize safety. It mentions that, if half of vehicles were autonomous, predictions suggest about a quarter of all road fatalities could be eliminated (this would happen around 2050-60). It mentions the necessity for "good and consistent signing and lining," both for AVs and other drivers. It also acknowledges that there is little knowledge of what sorts of collisions and accidents will become more common as AV use increases, but these may be different than what is common currently. The report also discusses how some safety measures now in place may become less needed (and less economically beneficial) for AVs as opposed to traditional vehicles (for example, roundabouts instead of stop signs).

International Transport Forum. 2017. *Managing the Transition to Driverless Road Freight Transportation.* Paris: International Transport Forum.

This report discusses the effects of driverless technology on trucks. It states that benefits of this technology, which could be as little as 10 years away, would include cost savings, lower emissions, and safer roads. It also states that there is set to be a massive shortage of truckers in the coming decade, but that this will probably not happen as soon as the technology is in place, and 2 million truckers could lose their jobs if the technology is rolled out in 2030. As such, it states that direct action will be needed in response to this, as traditional methods for dealing with unemployment will not be able to cope fast enough. The report recommends continuing testing these autonomous trucks, setting international standards for them, establishing a transition advisory board for the industry, and establishing temporary permits to ease the transition.

Jaller, Miguel, and Anmol Pawha. 2020. Analytical Modeling Framework to Assess the Economic and Environmental Impacts of Residential Deliveries, and Evaluate Sustainable Last-Mile Strategies. Report, Davis: UC Davis.

This UC Davis Institute of Transportation Studies report concerns strategies for reducing traffic and pollution caused by residential package deliveries (which have increased with online ordering). The researchers analyze different solutions including introducing micro-hubs, alternative delivery points, cargo bikes, and zero-emission vehicles. The study "found significant benefits from out-sourcing delivery, either in the form of customers picking up their packages at the collection points or by crowd-sourcing deliveries. In particular, the results show the benefits (reduced operating costs) of out-sourcing delivery, though these benefits may be realized at the expense of social costs in the form of additional externalities."

Joerss, Martin, Jürgen Schröder, Florian Neuhaus, Christoph Klink, and Florian Mann. 2016. Parcel Delivery – The Future of Last Mile. Report, McKinsey & Company.

A2016 McKinsey & Company report discusses the recent attention last mile parcel delivery has been receiving, due mostly to its significant costs (often more than 50 percent of total delivery costs). The report states that about 25 to 30 percent of consumers are willing to pay a premium for faster delivery (while the others choose normal delivery to save money). It predicts that, due in no small part to high labor costs (especially in higher wage markets like the US and Europe), 80 percent of packages will eventually be delivered by automated vehicles (including drones), and that this will happen in the next 10 years. It states that public opinion in developed countries is mostly (60% of the population) either supportive of or indifferent to this, and that support (or at least acceptance of) drones for delivery will likely increase in the future.

Journal of Commerce. 2021. Trucking Firms Betting on Autonomous Driving.

The Journal of Commerce published this article concerning increased investment from trucking companies in AV technology, spurred on by a desire to improve safety (and reduce costs of settling accident lawsuits), and to improve efficiency. The article mentions that some of America's largest truck carriers have invested in TuSimple, and that a wide variety of companies are also investing in the technology. Most of this notably concerns Level 1 and 2 automation, and increased safety features, however, as Level 4 or 5 automation is not being fully considered for immediate adoption at this point.

Kalra, Nidhi, and Susan M Paddock. 2016. Driving to Safety. Report, Santa Monica: RAND Corporation.

A 2016 report from the RAND Corporation addresses how much driving it will take to demonstrate AV safety. The report states that AVs would need to be driven hundreds of millions of miles to demonstrate reliability, and that this could take tens or even hundreds of years for many fleets. Therefore, the report concludes that innovation in testing will be required (in addition to just road driving testing). Even with this, the report states that there will still be uncertainty, and adaptive regulations will be necessary for gaining benefits from this technology.

Kharrazi, Sogol. 2020. Sustainable smart-parking management for connected and autonomous vehicles. Report, Stockholm: Swedish National Road and Transportation Research Institute.

The Swedish National Road and Transport Research Institute's 2020 report discusses the need for better parking management in urban areas, and "suggests a smart parking algorithm that can guide vehicles to the best parking lot in a parking area, minimizing travel time and maximizing chances of finding an available spot." The researchers compared a "BlindPark" algorithm (essentially, normal parking-seeking behaviors modelled) to the SmartPark system, and found that the SmartPark algorithm has a lower failure rate and gets vehicles to their destinations faster. The report concludes that "The outcomes of this project illustrate how recent advances in data sharing and aggregation among connected vehicles, and in sensor developments embedded within vehicles as well as parking infrastructures, hold a viable solution to the parking seeking problem."

Kim, Anita, Stephanie Fischer, Joshua Cregger, Aaron Jette, Sophie Jantz, Evan Sullivan, Jarred Myers, David Perlman, Emily Lawless, and Pepper Santalucia. 2019. Federal Highway Administration National Dialogue on Highway Automation: September 5-6, 2018 Freight Workshop Summary. Summary, Washington: Federal Highway Administration.

The summary of this workshop states key findings, such as the necessity to assess all automated technology in the context of safety and efficiency (the key priorities for freight movement), enhancing access to data on roads & hazardous conditions, constructing new infrastructure, and researching the impact on current loading patterns & infrastructure.

Kockelman, K., Boyles, S., Avery, P., Claudel, C., Loftus-Otway, L., Fagnant, D., . . . Stone, P. (2016). Bringing Smart Transport to Texans: Ensuring the Benefits of a Connected and Autonomous Transport System in Texas - Final Report. Austin: The University of Texas at Austin.

According to the abstract, "This project develops and demonstrates a variety of smart-transport technologies, policies, and practices for highways and freeways using connected autonomous vehicles (CAVs), smartphones, roadside equipment, and related technologies". The study intent is to maximize the benefit in improved driver safety, reduced congestion, and agency cost savings. The project's Phase 1, documented in this report, showcased DSRC-instrumented vehicles for wrong-way driving alerts, vehicle guidance, and road-surface condition monitoring demonstrations. It developed algorithms for more accurate vehicle-position information and real-time traffic flow monitoring. The study yielded statewide and national forecasts of fleet evolution, consumer preferences, and Texans' opinions of CAV policies and technologies. It also simulated various strategies for smart ramp merges and smart intersection and network operations with calculated delay reductions. The research also anticipated emissions savings from more thoughtful automated driving and crash savings from more conflict-aware driving, and analyzed the benefits of shared autonomous vehicle transit. Recommendations focus on the need for increasing TxDOT in-house expertise, simulating new systems, developing policy, and updating design manuals."

Lewis, Paul, Gregory Rogers, and Stanford Turner. 2017. *Beyond Speculation: Automated Vehicles and Public Policy.* Eno Center for Transportation.

This research paper states that fully automated vehicle technology is developing rapidly, and many robotic driving functions are already in place. It mentions that many states already have policies in place for these vehicles, and that the federal government is following in this as well. It makes recommendations for how policy can be best

enacted in the areas of certification, liability and insurance, cybersecurity and data ownership, infrastructure and funding, vehicle connectivity, federal safety programs, environmental programs, research investment, and workforce development.

Litman, Todd. 2020. *Autonomous Vehicle Implementation Predictions.* Victoria: Victoria Transport Policy Institute.

The abstract states, "This report explores the impacts of autonomous (also called self-driving, driverless or robotic) vehicles, and their implications for transportation planning. It investigates how quickly such vehicles are likely to develop and be deployed based on experience with previous vehicle technologies; their likely benefits and costs; how they will affect travel activity; and their impacts on planning decisions such as optimal road, parking and public transit supply. This analysis indicates that Level 5 autonomous vehicles, able to operate without a driver, may be commercially available and legal to use in some jurisdictions by the late 2020s, but will initially have high costs and limited performance. Some benefits, such as independent mobility for affluent non-drivers, may begin in the 2030s or 2040s, but most impacts, including reduced traffic and parking congestion, independent mobility for low-income people (and therefore reduced need for public transit), increased safety, energy conservation and pollution reductions, will only be significant when autonomous vehicles become common and affordable, probably in the 2050s to 2060s, and some benefits may require prohibiting human-driven vehicles on certain roadways, which could take even longer."

Machek, E., Burkman, E., Crayton, T., Cregger, J., Fischer, S., Pierce, S., . . . Thomas, A. (2018). *Strategic Transit Automation Research Plan.* Washington: Federal Transit Administration.

The FTA report largely concerns automation in public transit rather than freight, but provides insights into policy issues. For instance, although funding and policy constraints may play a role, there is also a reasonable unwillingness to risk public funding or to undertake new operational models without federal leadership and guidance. This report defines a five-year Strategic Transit Automation Research Plan that will establish a research and demonstration framework to move the transit industry forward. Key components of the Plan include conducting enabling research, identifying and resolving barriers to deployment, leveraging technologies from other sectors, demonstrating market-ready technologies, and transferring knowledge to the transit stakeholder community.

Manheim, Marvin L, John H Suhrbier, Elizabeth D Bennett, Lance A Neumann, Frank C Colcord, and Arlee T Reno. 1975. Transportation Decision-Making: A Guide to Social and Environmental Considerations. Report, Cambridge: MIT and Transportation Research Board.

Dating back to 1975, this NCHRP report discusses how highway agencies are gradually becoming transportation planning agencies responsible for movement of passengers and freight, while also considering social, environmental, and economic effects. It includes basic findings such stating that issues of social equity must be taken into account in a planning process (that it is "as much a political process as it is a technical one," and that differential effects, or who gains vs who loses, must be given attention.

Meyer, Gereon, and Sven Beiker. 2020. Road Vehicle Automation 7. Report, Cham: Springer.

This is a lengthy and comprehensive report on all different aspects of road vehicle automation, including discussion of a 2019 symposium. It essentially combines multiple reports concerning topics covered in the symposium.

Part one covers the public sector, including the SIP-adus (Strategic Innovation Promotion – automated driving system for universal service) program in Japan (which addresses achieving "Society 5.0," or something further developed than the information society, and the role of automated driving in achieving this). The section also includes a report on regulation in Australia, which is currently lacking, and how this needs to address control safety, insurance, and data.

The second part covers business models and operations, with reports addressing issues such as the wide variety

of operational businesses needed to provide infrastructure and servicing for AVs, as well as the technologies linking individual vehicles and network operations. It also includes a report on low-speed autonomous shuttles.

Section three discusses "users and human factors," with reports addressing consumer acceptance as well as what consumers generally expect from AVs; many of these find consumer skepticism towards automated vehicles in several countries (one report focuses on Germany). Another report argues for the need to listen more closely to consumer skepticism and not regard consumers as simply ill-informed ("not just top-down salesmanship," as the report puts it). The final report of the section discusses addressing AVs and "vulnerable road users" (such as cyclists and pedestrians).

The fourth section concerns "vehicle systems and technology development." Much of this concerns testing, with reports on improvements in simulation and developing technology to prevent cyberattacks (using humans, machines, sensors, and infrastructure together).

The last section concerns policy and planning, including city planning for issues concerning AVs and policy benchmarks. One report also addresses the issue of ethical algorithms for AVs in cities.

MIT Technology Review. 2021. Why Sidewalk Delivery Robots Still Need Safety Drivers.

This very brief summary points out that delivery robots are limited by their sensors and computers (due to using cheaper ones to keep overall costs down), and cannot cross a street in half of cases, for example. As such, operators are still employed to help these robots in difficult situations, and this is not expected to change soon.

Montebello, D., and Schroeder, J. (2011). *Cost of Pavement Marking Materials.* St. Paul: Minnesota Department of Transportation.

Pavement striping and marking is a critical issue in FAV deployment. This Minnesota DOT report presents information on the various types of pavement marking materials available to inform educated decisions on appropriate pavement marking materials. The report assembles information on pavement marking material terminology, the various types of pavement marking materials, their durability and their retro-reflectivity. There is also a list of best management practices that can be implemented to enable an agency or community to get the most value for its money. The information covered in this report is condensed into an easy to follow table. The report indicates that for low volume roads (AADT of 10,000 or less) a conventional product (paint) may be the most cost-effective material. For roadways with higher volumes (AADT of 10,000 or more) a more durable product (epoxy or tape) may be more cost-effective and may reduce worker exposure to traffic.

Motro, M., Kim, T., Kalantari, R., Park, J., Oza, S., Ghosh, J., . . . Nair, G. (2019). *Communications and Radar-Supported Transportation Operations and Planning (CAR-STOP) - Phase 2: Final Report.* Austin: The University of Texas at Austin.

The abstract for this report states, "This project designs a conceptual framework to harness and mature wireless technology to improve transportation safety, with a focus on frontal collision warning/collision avoidance (CW/CA) systems. The framework identifies components of the technology and its capabilities, and how these components can be integrated to improve transportation safety."

National Academies of Sciences, Engineering, and Medicine. 2020. Advancing Aerial Mobility: A National Blueprint. Report, Washington: The National Academies Press.

Advanced aerial mobility, or the increase of air services to areas not normally served by aircraft, is being helped along by new technology, including computer sensors and development of electric aircraft according to this report from the Aeronautics and Space Engineering Board. This has the potential to fulfill lots of different needs, including increased transportation, package delivery, medical supplies, etc. according to the report. It states that NASA could play a key role in this by establishing partnerships with cargo logistics providers and manufacturers (and working

together with the goal of deploying drone cargo delivery within three years). It also recommends that NASA work together with the FAA to accommodate these new aircraft and integrate them in current airspace. The report claims that the US is in a unique position to lead these developments, but that barriers include safety, security, social acceptance, environmental impacts, and regulation, among others. It recommends that NASA work together with other agencies to address these concerns.

National Academies of Sciences, Engineering, and Medicine. 2020. Airports and Unmanned Aircraft Systems, Volume 3: Potential Use of UAS by Airport Operators. Report, Washington: The National Academies Press.

Volume 3 of this 2020 Booz Allen Hamilton report for the Airport Cooperative Research Program concerns the rapid introduction of UAS systems and their effects on safety and other factors at airports. The report seeks to identify the potential for this technology to be used at airports, safety concerns and how to mitigate them, and stakeholder coordination. It states that "The introduction of UAS will pose safety, economic, operational, regulatory, community, environmental, and infrastructure challenges to airports. These risks are further complicated by the dynamic nature of UAS technological development. Experiences and lessons learned from recent major aviation system changes demonstrate the critical importance of ensuring that airports have the resources needed to avoid adverse impacts and maximize benefits as early as possible."

National Academies of Sciences, Engineering, and Medicine. 2020. Guidebook for Managing Data from Emerging Technologies for Transportation. Report, Washington: The National Academies Press.

A pre-production document from NCHRP and not a final report, the introduction to this document states "This guidebook provides guidance, tools, and a big data management framework, and it lays out a roadmap for transportation agencies on how they can begin to shift – technically, institutionally, and culturally – toward effectively managing data from emerging technologies." According to the document, this process involves eight steps, which are to develop an understanding of big data, identify a use case and an associated pilot project, secure buy-in from at least one person from leadership for the pilot project, establish an embryonic big data test environment, develop the pilot project within the big data test environment (or "playground"), demonstrate the value of data to other business units and executive leadership, and establish a formal data storage and management environment.

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. 2020. Impacts and Opportunities Around Land Use and Automated Vehicles and Shared Mobility.

Part 9 (the final part) of a series from NCHRP and TRB on preparing for AVs and shared mobility concerns land use and the impact on housing and telecommunications. The report found that AVs will impact land use most in urban areas, specifically regarding parking, curb use, and access (a shift regarding curb use from parking to curb management is highlighted). It also reviewed research regarding 5G networks (which may be needed to support AVs), and states that these could end up "leading to more land use conflicts in urban areas, heavy investment requirements in rural communities, and a much higher level of regulatory involvement." According to the report, research suggests that a reduced need for parking will lead to more land being available for other uses, including affordable housing, and that there may be less need for future infrastructure investment if AVs can use current infrastructure more efficiently.

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. 2020. Impacts of Automated Vehicles and Shared Mobility on Transit and Partnership Opportunities.

Concerning transit, a common theme in research is increased access to transit thanks to AVs and shared mobility, particularly through making additional forms of transit such as paratransit and circulator services easier to deploy, and that there is potential for partnerships between different forms of transit (ride sharing, buses, etc.). Infrastructure planning for future transit hubs will have to account for both privately owned AVs and shared ones going forward. The report mentions that traditional definitions of "public transit" will need to be updated as AVs are introduced to account for increasing use of ride sharing AVs and non-traditional forms of transit. It also mentions

that the number of driver positions will significantly decrease, putting many people out of work.

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. 2020. Implications for Planning and Modeling.

Part 8 of 9 of the same series addresses transportation and planning and modeling. The report found that discussion of AVs in plans is "not yet the norm," but is "increasing dramatically." It identifies planning for uncertainty (especially regarding infrastructure) and accounting for "zero occupancy" and other AV issues as key aspects that should be addressed in planning. One issue the report mentions as unknown is "the impact of this technology on the location decisions for households and businesses." It states that issues regarding uncertainly about timing and phasing of AVs present a problem for planners, and that "Understanding the infrastructure sequencing needs is essential for the development of a well-designed rollout of new technologies for transportation." The report also highlights issues regarding "fleet transition and mixed fleet planning" that will need to be addressed as AVs are rolled out.

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. 2021. Infrastructure Enablers for Automated Vehicles and Shared Mobility.

Regarding infrastructure, this report finds that "For the most part, the research does not focus on a particular infrastructure element, but rather a combination of general infrastructure enablers and impacts." Much research concerns lane markings, traffic signals, and road signs, which will need to be readable for AVs. Increased digital infrastructure for reporting data may also be needed (in addition to current reliance on user-reported data). The report states that there has been virtually no research into long-term impacts of AVs on infrastructure. It further states that "Among the areas where research has shown the largest impacts are: setting regulatory policy, encouraging pilot developments, identifying work zones, and data frameworks." It also mentions that high-speed, long-distance AVs (such as truck platoons and commercial AVs) are likely to require the largest infrastructure changes (dedicated lanes, etc.).

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. 2021. Maximizing Positive Social Impacts of Automated Vehicles and Shared Mobility.

In addressing social impacts, this report highlights the importance of powering AVs with electricity and deploying them in shared use models for maximum social benefit (as this would allegedly reduce pollution, congestion, and VMTs most significantly). It recommends that policies should put in place "measurable goals" surrounding these benefits. The report also highlights once again the importance of increasing accessibility through AVs and shared mobility, and the importance of including people who are disabled or otherwise have trouble accessing transportation throughout the planning process. It also once again highlights the importance of addressing issues with job impacts, and of public engagement throughout the decision-making and implementation process.

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. 2020. Models for Data Sharing and Governance for Automated Vehicles and Shared Mobility.

The section of the report on data sharing identifies key points such as the need to more specifically address anticipated uses for data, the fact that new regulations may make data collection for AV safety standards difficult, and how data usage will affect the public perception and acceptance of AVs. It also discusses the potential for shared data to increase "equitable deployments" of AVs, but states that there will be a need to adapt to regulations (and to adapt the regulations to AV technology) going forward, and that this could cause issues. The report also states that data collection can inform assets such as infrastructure and maintenance needs, and that "The opportunity for research to better understand the value of data and to align such research with the identification of use cases for data from AVs and shared mobility platforms can help inform risk assessments and consumer outreach and education."

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. 2020. Potential for Impacts of Highly Automated Vehicles and Shared Mobility on Movement of Goods and People.

According to the freight section of this report, most research for freight movement on highways currently concerns fuel efficiency and platooning. This research shows that AVs will likely be significantly more fuel efficient than current trucks. The report states that "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," and expects additional curb use issues to be at the forefront of last-mile delivery related issues. It recommends that planners "Consider how to leverage technology and potential pricing, delivery prioritizations and curb management techniques to manage transportation of both goods and people." It also highlights issues surrounding congestion and right-of-way for automated delivery vehicles, and states that more research is needed regarding implications for the workforce.

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. 2020. Prioritizing Equity, Accessibility, and Inclusion Around the Deployment of Automated Vehicles.

Section 5 of the same series concerns accessibility issues and how AVs will relate to topics such as complete streets, the Americans with Disabilities Act, and AI and facial recognition technology. The report concludes that AV technology could potentially increase transportation access significantly, but that barriers including "affordability, service provision in less profitable areas, physical accessibility considerations, and access to information in an increasingly digitized world" need to be addressed in order to fully benefit in this way. It also states that technology such as facial recognition must be used in a way where it does not allow for discrimination. The report mentions that "Without proper planning and policies, certain groups could see little benefit from smart mobility strategies while at the same time bearing the brunt of its negative effects," through inequities in AV infrastructure between neighborhoods and potential increased VMT, among other issues. It highlights the importance of considering equity and ensuring that research be participatory for all parties concerned in further development.

National Academies of Sciences, Engineering, and Medicine. 2019. Renewing the National Commitment to the Interstate Highway System: A Foundation for the Future. Report, Washington: The National Academies Press.

This 2019 Committee for a Study of the Future Interstate Highway System report concerns the major challenges to America's Interstate Highways, including refurbishing infrastructure before it becomes unsafe, updating capacity for increases in traffic (many highways were designed not anticipating current traffic levels), making sure the system is positioned to serve growing communities, adapting to technological changes, and coming up with equitable and efficient funding. The report states that increased investment will be necessary not only to maintain infrastructure, but to accommodate increases in traffic. It recommends reinforcing federal funding for this, including increasing the federal fuel tax & ensuring it continues to rise with inflation.

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. 2021. Safety Scenarios and Engagement During Transition to Highly Automated Vehicles.

This section highlights many key safety concerns, starting by highlighting the importance of testing safety in scenarios that vehicles may actually encounter. The report states that "While there appears to be some movement in releasing incident information and even sharing safety scenarios developed by OEMs and start-ups, most research on testing remains proprietary." It also states that "The roles and responsibilities in creating, adopting, and enforcing regulatory safety standards follow traditional federal, state, and local allocation of responsibility," further stating that regulations should be able to be put in place and enforced by those who are traditionally responsible for them. It mentions that test track or road tests will likely take too long to complete, so research suggests that this "coupled with test safety scenarios" will be more efficient. Although demonstrations have benefits, the report states that these "do not address managing safety in an operational environment that includes different levels of automation and different vehicle types."

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. 2018. Transportation Research Circular. TRB Forum on Preparing for Automated Vehicles and Shared Mobility.

The AV forum was launched in early 2018 to encourage research for developing these technologies for their maximum benefit, and TRB has published this white paper to summarize what was discussed in the forum. Topics of discussion include the wide variety in potential outcomes for AVs; for example, it is possible they will significantly improve congestion and reduce emissions (when combined with EV technology), or it is possible they will significantly increase congestion and emissions due to increased VMT. Forum participants also stressed the importance of increased safety from AVs (especially concerning winning over the public). The participants concluded that research priorities include models for data sharing, transition safety scenarios, state and local policies, infrastructure and social needs and impacts, impacts on shared mobility, and effects of AVs on land use, among others.

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. 2019. TRB Forum on Preparing for Autonomous Vehicles and Shared Mobility.

This is a summary of discussions at this TRB forum, held in July 2019 in Orlando, FL. Key takeaways from discussion include the difficulty of predicting economic impacts, and that these have often been underestimated and based on "common sense" assumptions rather than actual research. More research is needed into specific scenarios and actual models rather than assumptions, user acceptance and economic/safety benefits, and impacts on the environment, curb use, jobs, and transit, among many other issues.

National Academies of Sciences, Engineering, and Medicine. 2019. Zero Emission Vehicles: Forecasting Fleet Scenarios and their Emissions Implications. Report, Washington: National Academic Press.

This portion of an NCHRP Project 25 task attempts to quantify changes in pollutants from the adoption of electric and fuel-cell vehicles. It takes into consideration different levels of public enthusiasm for these vehicles (covering all "Advanced Technology Vehicles," or ATVs). It mentions that drivers are enthusiastic about ATVs for their potential HOV-lane access, reliability, and reductions in fuel costs, but that barriers include higher purchase costs, lack of access to charging, lack of knowledge, and resistance to new technology (among other factors). The report takes into account different scenarios regarding infrastructure efforts, and whether or not incentives for purchasing zero-emission vehicles (ZEVs) are used. The report found similar findings in estimated emission reductions across these different scenarios.

National Association of City Transportation Officials. 2019. *Blueprint for Autonomous Urbanism: Second Edition.* New York: National Association of City Transportation Officials.

The Blueprint "identifies decisions that cities, and government at all levels, must make to reach a people-focused autonomous future that is based on safety, public good, equity, and sustainability. Increasingly, policy makers are realizing that the autonomous future must be guided by thoughtful, bold, transformative public policy and street design practice that reduces driving and vehicle miles traveled (VMT) and offers mobility and opportunity to everyone, not just those in cars." It warns that, "Automation without a comprehensive overhaul of how our streets are designed, allocated, and shared will not result in substantive safety, sustainability, or equity gains. By implementing proactive policies today, cities can act to ensure that the adoption of AV technologies improves transportation outcomes rather than leading to an overall increase in driving."

National Center for Sustainable Transportation, UC Davis. 2019. User Perceptions of Safety and Security: A Framework for a Transition to Electric- Shared-Automated Vehicles.

The Institute of Transportation Studies at the University of California, Davis published this white paper covering research into public perception around AV safety, and what can be done to improve that perception. It describes itself as a "call for clarity not consensus on terminology, theory, approach, and methods." It states that questions surrounding whether or not different potential users have different risk constellations surrounding AVs are all too often unanswered in current research. It suggests framing questions regarding risk constellations surrounding AVs, EVs, and SVs, what they are and how these people form them, and how they will shape potential adoption or rejection of the technology going forward. The white paper also concludes that "continuing efforts to hear alternative perspectives, promote multi-disciplinary research, and incorporate user participation in imagining

e-SAVs may resolve personal risk constellations of e-SAVs to assure their design, deployment, and operation in ways that assures broad uptake of e-SAVs seen to be safe and secure."

National League of Cities. (2016). *Autonomous Vehicles: A Policy Preparation Guide.* National League of Cities.

This report explores how cities can best prepare for autonomous vehicles, including developing their own regulations. The NLC makes four main recommendations: first, meeting with constituents and stakeholders now and educating them on the process (as autonomous vehicles are already being used in some capacity); second, involving the right people in policy discussions, including technology developers and members of the local community; third, making their voices heard regarding federal and state regulations (they must communicate issues that are important to them); and fourth, start adapting infrastructure and computing capacity for AVs now to avoid issues in the future.

National Safety Council. 2019. Position/Policy Statement: Automotive Safety Technology.

The National Safety Council, a non-profit organization dedicated to promoting public health and safety, has issued a statement regarding safety technology (Level 1 or 2 automation; not full AV technology). According to the statement, "The National Safety Council supports the mandatory or voluntary adoption of new automotive safety technologies in vehicles to help reduce crashes of mitigate the impact of injuries and fatalities resulting from the operation of motor vehicles. Because of the rapid rate of introduction of these technologies and the risk of driver confusion, NSC also supports education programs to ensure the driving public knows what these technologies do and how to use them appropriately. Additionally, NSC supports additional research into potential unintended negative safety consequences that arise as a result of the introduction of new technologies."

National Science and Technology Council. 2020. Ensuring American Leadership in Automated Vehicle Technologies. Report, Washington: US DOT.

The US DOT published this report in 2020 on what will be necessary to ensure that America continues to be a leading AV developer. The report establishes three core interests: protecting users and communities (including safety, security, privacy, and mobility), promoting efficient markets (including remaining "technology neutral," protecting American innovation, and modernizing regulations), and facilitating coordinated efforts (promoting consistent standards and polices and a consistent federal approach).

National Transportation Safety Board. 2017. National Transportation Safety Board Aviation Incident Final Report. Accident Report, National Transportation Safety Board.

This is a NTSB report on a collision between a helicopter and a privately-operated drone, which resulted in minor damage and no injuries. This was due to the drone pilot flying the drone beyond the line of sight and where regulations prohibited it. It highlights the importance of drone regulations and the growing concern of drone and aircraft collisions as private drones (which can be operated by anyone regardless of knowledge) become more common.

Neubauer, K., Fleet, D., Grosoli, F., and Verstynen, H. (2015). *Unmanned Aircraft Systems (UAS) at Airports: A Primer.* Washington: National Academies of Science, Engineering, and Medicine.

The 2015 NAS primer is designed to give airports an analysis of unmanned aircraft systems, and how they would be used, as UAS are rapidly developing and growing. The report argues that integrating large unmanned aircraft that use runways will not be too difficult, and that these can operate safely in the current airport environment. It also mentions that most UAS operators will be located at an airport, so an important part of integrating these systems is ensuring communications between UAS operators and pilots/air traffic controllers. It also argues that, due to current regulations regarding permits for UAS operators, these operators will need to work closely with airports to give airports a reason to obtain the necessary permits and attract more UAS businesses.

Nodine, E., Lam, A., Yanagisawa, M., and Najm, W. (2016). *Naturalistic Study of Truck Following Behavior.* Washington: US Department of Transportation.

Volpe conducted this study of truck following behavior to better understand how trucks follow other vehicles in the real world, with the ultimate goal of supporting FHWA in the development of automated truck platooning applications. Volpe quantified how closely trucks follow other vehicles on freeways, and the safety impact of different headways. Key results from this 2015 study showed that truck drivers generally follow other vehicles at much shorter headways (around 2 seconds) than are recommended in CDL driver handbook, and that vehicles rarely cut-in between two trucks who are following at a distance of 40 m or less.

Norman, M. R. (2019). *Transformational Technologies in Transportation.* Washington: Transportation Research Circular.

This recent TRC report addresses research into automated vehicles and their impacts on society. It states that these vehicles provide great opportunities for meeting societal goals, but that this success is far from guaranteed, and dependent upon good research. It argues that these technologies are developing very rapidly, but that time frames for research can vary significantly. One key takeaway is that "Collaboration among the public, private, and academic sectors is key to meeting the twin objectives of providing needed answers in a timely manner while still protecting the credibility of our research." Another is that "There are a number of steps that TRB can take, including providing more opportunities for collaboration among the stakeholders through TRB convening activities such as this Forum, conferences, standing committees, and research panels."

North American Council for Freight Efficiency. 2020. Run on Less Regional. Executive Summary, North American Council for Freight Efficiency.

An executive summary of this 2020 report from the North American Council for Freight Efficiency concerns reducing fuel costs for regional trucking using new technologies, and covers the results of a road show to demonstrate these technologies. The summary states "The goals of this report are: (a) to help the industry understand the growing segment of regional haul, (b) to demonstrate that 8.3 MPG is possible for Class 8 trucks performing regional haul (compared to the national average of 6.0 MPG), (c) to highlight the technologies and practices that make ultra-low fuel consumption in regional haul possible, and (d) to explore the opportunities of emerging technologies such as electric trucks, hydrogen, and connectivity."

Northwestern University, 2020. Daily Load Planning Under Different Autonomous Truck Deployment Scenarios.

According to the abstract of this report, also for the 2021 TRB Annual Meeting, "This paper presents and tests modified service network design formulations that account for five levels of truck automation in a daily load planning setting." It focuses on two different models for daily operations. Both use historical daily load data, but the first focuses on "re-optimization of pre-booked loads and new requests," and the second on "optimization of new requests only." According to the abstract, "Results show that the cost savings achieved with re-optimization (Option 1) compared to insertion (Option 2) increase with more demand variability; this outcome is consistent across all fleet mixes. When most of the loads are new arrivals, the computational time saved with insertion is less attractive than the possible cost savings achieved with re-optimization. With daily re-optimization, most of the plan changes adjust the terminals visited by the load compared to just changing the dispatch and arrival times along the load's path."

Northwestern University, 2020. Examining the Potential of Autonomous Trucks in a Less-than-Truckload Context.

Published for the January 2021 TRB Annual Meeting, this report examines the effects of driver regulations on network planning for trucking companies, and analyzes the effects of lessening these regulations to create a model for potential savings and increased efficiency from autonomous vehicles. The study found that "the driver return to domicile requirement has a more significant contribution to cost than the hour of service regulations," and that

"Under the current fully manual fleet situation, the driver cost is the main determinant of routing choice compared to the other cost components (vehicle, fuel and handling costs). Results suggest that the potential savings to be achieved with autonomous truck deployment are both monetary and possibly environmental with the reduction of empty miles traveled."

Oak Ridge National Laboratory. 2021. Analysis of Variability in Heavy Truck Braking Systems.

According to this study from the Oak Ridge National Laboratory, truck stopping distance is important for truck platooning so trucks with a longer stopping distance are placed in front of those with a shorter stopping distance. However, there can be significant variability in this stopping distance depending on conditions. This study found that stopping distance for disc/disc brakes was shorter than that for drum/drum or disc/drum brakes. It also found that tractors with a GVWR of 50,000-55,000 lbs had the greatest variability in stopping distance (compared to both the lower and higher categories), but that those with a GVWR between 45,000 and 50,000 lbs had the shortest stopping distance. The report notes that these tests were performed under ideal conditions so bad weather and other factors will almost certainly increase variability, but states that these conclusions are still relevant for truck platooning, especially regarding brake types.

Perkins, Lucy, Nicole Dupuis, and Brooks Rainwater. 2018. Autonomous Vehicle Pilots Across America. Report, Washington: National League of Cities.

The National League of Cities published this report in 2018 concerning AV pilot programs. The report asserts that "the age of autonomy is here". As with many other reports, it argues for cooperation between governments in order to implement these programs (it states most action is taking place on a local level). It concludes that cities have an opportunity to shape policy on these issues, and that they should serve as facilitators for these pilot programs. The report also states that they must engage the public throughout the process, and lists many examples of cities that the organization feels have done this successfully.

Pike, Adam M, and Paul J Carlson. 2018. Evaluation of the Effects of Pavement Marking Characteristics on Detectability by ADAS Machine Vision. Report, College Station: National Academies of Sciences, Engineering, and Medicine.

Prepared for NCHRP by the Texas A&M Transportation Institute, this 2018 report concerns advanced driver assistance systems (ADAS) and what these systems require in terms of pavement markings in order to work properly. These include lane-departure warning and lane-keeping assistance, and have become standard on new vehicles. These systems use cameras to work properly (to determine where the lane actually is), but markings up to this point have been designed only with the driver's eyes in mind. Tests of various pavement markings show that the contrast level of the markings must be higher in order to be detected, and the report also notes that daytime sun glare severely reduced the effectiveness of these systems, especially in wet conditions (so a higher pavement marking contrast would be necessary). In other words, the camera sees the road similarly to how a human does, and can be inhibited by the same sorts of visibility issues.

Port Technology International Team. 2020. NYK successfully tests remotely navigated tugboats. Article, Port Technology International.

Japanese shipping company NYK has successfully tested an automated, remotely operated tugboat in Tokyo Bay, according to this May 2020 article. The carrier wants to launch remote navigation by 2025, and will attempt to work on issues surrounding ship-to-shore communications and continue testing in cooperation with the Japanese government (with the ultimate goal of developing autonomous ships).

PwC Belgium and Agoria. 2018. A Drone's Eye View – Overview of the Belgian UAV Ecosystem & the Development of Commercial Drone Applications in Belgium. Report, PwC Belgium and Agoria.

A Belgian report from PwC Belgium and Agoria covers all different (mostly civilian) drone uses in Belgium,

including inspections, farming, and a large variety of other applications. The report concludes that, with initiatives started, different players must work together for drones to reach their full potential. It recommends that new regulations should serve to facilitate this development (though it mentions privacy and other concerns), and states that realizing drone technology to its full potential will create new jobs and prosperity.

Raddaoui, Omar, Mohamed A Ahmed, and Sherif M Gaweesh. 2019. Assessment of the Effectiveness of Connected Vehicle Weather and Work Zone Warnings in Improving Truck Driver Safety. Report, Laramie: IATSS Research.

The abstract of this 2019 report from the International Association of Traffic and Safety Sciences states that "the frequency and severity of work zone crashes involving large trucks in rural freeways are alarming. Lack of compliance with the instructions provided at work zones results in increased crash risk. In-vehicle advanced warning systems enabled by Connected Vehicle (CV) technology have the potential to prompt appropriate driver response, make navigation more predictable, and improve overall work zone safety." This study simulated poor visibility or bad weather situations and determined that CV technology was easy and helpful to drivers and had a promising effect on safety, although it acknowledges a slight potential to increase driver distraction.

Ravich, Timothy M. 2017. Evolving Law on Airport Implications by Unmanned Aerial Systems. Report, Washington: The National Academies Press.

The Airport Cooperative Research Program published this 2017 "Legal Research Digest," which analyzes much of the controversy surrounding the increased use of drones, both for civilian and military use. The rapid increase in drone use has led to lots of issues concerning safety, privacy, speech, arms, search and seizure, executive power, national security, and many others. Many regulators are struggling to keep up with how fast the technology has become common, but airports may also gain benefits from drones (such as terminal or airfield inspection, traffic management, emergency response, construction, aircraft maintenance, and many others). The report states that airport managers have improved safety by educating operators and local communities on many of the issues, even as lawmakers have struggled to keep up. To quote the conclusion, "Combining community engagement with traditional insurance has provided a pathway for airports to operate safely and profitably as today's airports perhaps transition into tomorrow's droneports."

Resilient Navigation and Timing Foundation. 2016. Prioritizing Dangers to the United States From Threats to GPS: Ranking Risks and Proposed Mitigations. Report, Resilient Navigation and Timing Foundation.

The Resilient Navigation and Timing Foundation put together this 2016 report on GPS security. The report states that GPS signals are exceptionally weak despite their ubiquity. It identifies that the greatest risk is from jamming, either by criminals, terrorists, or governments. It states that most risk mitigation efforts are focused on only one vector and do not actually mitigate most risks. It concludes that the most effective mitigation efforts are requiring operators of critical infrastructure to be able to operate for 30 days with no GPS signal, and establishing backup capability for GPS systems.

Roberts, Jack. 2018. Autonomous Trucks Could Radically Transform US Logistics Within a Decade. Opinion, HDT Trucking Info.

HDT Senior Editor Jack Roberts cites a report claiming autonomous trucks will be delivering goods with no drivers in them within eight years on Interstate Highways in this 2018 article. The report claims that this transition will begin with wide-spread truck platooning (Level 3 automation) by 2020 (now past). Trucks will exit for local deliveries and in bad weather or visibility conditions now past.

Roberts, Jack. 2019. Is Autonomous Tech Taking a Time Out? Opinion, HDT Truck Tech.

A 2019 opinion piece by HDT Senior Editor Jack Roberts mentions that developments in Level 4 automation technology are taking "longer than expected" (or stalling). Level 2 and 3 automation is moving quickly ahead, and that this will bring great benefit to truck drivers soon, while Level 4 or 5 automation is likely a very, very long ways

away.

Roberts, Jack. 2018. Money and Manpower: Autonomous Trucks' Two Transparent Trends. Opinion, HDT Truck Tech.

A 2018 opinion piece by HDT Senior Editor Jack Roberts states that automated technology will be adopted by trucking companies faster than most predict due mostly to financial factors. He predicts that the wage increase to $15/hour for all Amazon employees will have effect on the whole industry, in that it will increase the wage standards for workers and make using automated technology to reduce the number of workers needed more attractive to companies. He also states that the current (and increasing) shortage of truck drivers will have a similar effect.

Roberts, Jack. 2019. Q&A: Anthony Levandowski on the Future of Autonomous Trucks. Interview, HDT Trucking Info.

HDT Senior Editor Jack Roberts conducted this interview with AV developer Anthony Levandowski, who answers questions regarding his significant work with Google and other companies. He states that he has recently turned to working on the truck market. He emphasizes that hopes that trucks could jump straight to level 4 automation in the near future are not at all realistic, though he does state that the technology is moving quickly. For the time being, he is focused on improving safety equipment in trucks (lower level automation). He is also noted for completing a cross-country San Francisco to New York City drive without any driver input, and states that it will be a very long time before concerns about job loss from autonomous vehicles will actually play out.

Roof, Katie, and Spencer Soper. 2020. Amazon Buying Zoox May Save $20 billion, put Tesla on its Heels. Article, AJOT.

Amazon was attempting to purchase AV startup Zoox, according to this 2020 article. Shipping costs for Amazon are expected to reach $90 billion in coming years, so using AVs could save the company significant amounts of money, according to the article. Other companies are interested in investing in Zoox for the same money-saving reason. Amazon has also invested in other AV developers, and the article questions whether Tesla warrants the investment it has been receiving as an AV developer.

Savage, Mark. 2019. Highly Automated Commercial Vehicles – Government Planning. Presentation, Colorado State Patrol.

Deputy Chief Mark Savage of the Colorado State Patrol assembled this PowerPoint presentation discussing past commercial AV tests and where regulations currently stand. The presentation emphasizes regulatory inconsistency across state lines as a major issue. It emphasizes first and foremost safety and responsibility to communities, including workforce considerations. It highlights the importance of cooperation, including with unlikely partners, to develop a consistent regulatory framework (stating that the technology is probably not yet fully understood). It also emphasizes a need for a "Balance between progress and economic development with a firm commitment to safety."

SmartGrowth America. 2013. Complete Streets – Local Policy Workbook. Workbook, Washington: SmartGrowth America.

This workbook from the organization SmartGrowth America heavily promotes the idea of "complete streets," or ones which include space and are safe for bicycles and pedestrians in addition to just cars and trucks. The workbook does not attempt to present a single model, but instead mentions a variety of policy issues and questions that the organization believes committees tasked with making streets "complete" should concern themselves with (it is literally a workbook, as it has space to write these answers). It includes lots of sample language from various policy plans put in place in cities around the US.

Spak, J., Clark, G., & Heidt, J. (2018). *RBC Electric Vehicle Forecast Through 2050 & Primer.* RBC Capital

Markets.

FAVs are not necessarily EVs, but the two concepts are developing in parallel. This report (which dates from 2018) states that, in 2017, battery electric vehicles (BEVs) accounted for 0.8% of global vehicle demand; it predicts that this will increase to 7.5% globally by 2025, driven mostly by new regulations. By 2050, the report predicts demand will have risen to 66%, driven more by consumers as battery costs come down and the vehicles become more cost-effective (it predicts demand will be higher in Europe than in the US). It also predicts BEVs will account for 35% of all vehicles in operation by 2050. It argues that, as research and development costs come down, financial opportunities will become greater for automakers, and that suppliers need to be investing in new technologies (batteries, etc.) now rather than later in order to be ready for a decrease in demand for parts for traditional vehicles.

Staff. 2015. Bendix Launches Wingman Fusion Driver Assistance System. Article, HDT Trucking Info.

This 2015 article concerns Wingman, commercial vehicle systems company Bendix's driver assistance system, launched the same year. Technologies combined in this system include radar, camera, brakes, and SafetyDirect. These technologies are used together to deliver automatic braking to avoid collisions (especially in vehicle lines or stopped traffic, with the goal of avoiding pileups), and also to send overspeed alerts (cameras can read speed limit signs). The developers, however, acknowledge that this technology is by no means a replacement for alert and safe driving.

Stinson, Jason, and Mark Lambert. 2020. How do you develop critical ADAS infrastructure systems? Presentation, Campbell: Renovo and Parasoft.

A 2020 PowerPoint presentation from Renovo Auto, an automotive data platform, and Parasoft, an automated software company, details the components of AV driving systems, both onboard and offboard vehicles, and how these companies are going about developing them. The presentation details the "create, store, and deliver components" (for example, sensors, storage for the data from these sensors, and application for driving systems), and lays out patterns for developing, testing, and eventually deploying technology in compliance with ISO regulations.

Studdard, Daniel. 2020. ATA Releases Results of Latest Driver Compensation Study. Presentation, Atlanta: Atlanta Regional Commission.

This is a 2020 news release covering the American Trucking Association's latest report, which states that average driver pay rose by almost $6,000 between 2017 and 2019. This reflects a shortage in drivers (so more pay & benefits being offered to attract workers to the industry), though the report speculates that this could become a more popular line of work following the COVID pandemic (as many unemployed workers will be seeking something reasonably well-paying).

Swift Navigation. 2017. High-Precision GNSS Autonomous Driving Localization Test White Paper. White Paper, San Francisco: Swift Navigation.

Swift Navigation, a San Francisco-based software company, published this 2017 white paper. The summary states "This white paper presents the results of performance testing Swift Navigation's advanced automotive positioning solution. This system is comprised of Swift Navigation's Starling™ software navigation engine, running on top of Swift Navigation's Piksi™ Multi Real Time Kinematics (RTK) GNSS Receiver hardware, receiving network corrections via cellular Internet. This system was tested in open-sky conditions on an 8-mile route in San Francisco, California. The circular error probability (CEP) was as follows—the CEP50 positional accuracy for the run was 1 cm and the CEP99 was 35 cm. These data demonstrate the breakthrough centimeter-level localization potential of this new, high-precision GNSS product offering for autonomous driving from Swift Navigation, Inc."

Tan, H.-S., Huang, J., Bu, F., Dicky, S., Nelson, D., Liang, T., . . . Zhang, W.-B. (2017). *Vehicle Assist and Automation Demonstration Report.* Washington: Federal Transit Administration.

This FTA report mostly concerns buses instead of freight vehicles. Sponsored by the United States Department of Transportation, this project aimed to demonstrate the technical merits and feasibility of Vehicle Assist and Automation (VAA) applications in bus revenue service. The VAA Demonstration project was carried out through the four phases of design, development, deployment, and operational tests. In the deployment phase, system performance and reliability testing were conducted first at a test track and then on an operational route in Eugene, Oregon. After operational testing without passengers, revenue service at Lane Transit District commenced. Data from revenue service showed that the VAA system met its performance goals, specifically that lateral deviation was substantially smaller under automated operations than it was under manual driving."

Texas A&M University and San Diego State University. 2020. Real-World Use of Automated Driving Systems and Their Consequences.

This 2020 report from the Safe-D National UTC (published by Texas A&M and San Diego State Universities) attempts to address how AV technology will actually be used (or misused) in real-world deployment (versus testing). The researchers investigated "naturalistic driving data" from 50 owners of partially automated vehicles. This research found that, in over half of "safety-critical-events," or SCEs, these owners misused the automated technology ("e.g., engaged in secondary tasks, used the systems not on highways, or with hands off the wheel"). The report also found that, in 13% of these incidents, the automated driving systems "neither reacted to the situation nor warned the driver," and that drivers feel more comfortable completing other tasks while driving with the technology present. It states that these findings will hopefully help with developing AV interfaces that can address real-world issues regarding AV use and user expectations.

The Coming Age of Autonomy: How Robotics Will Reshape the Future of Logistics. Supply Chain Quarterly. (2019).

This private sector report discusses autonomous vehicles, their potential in logistics, and how companies and others need to plan for using this technology and presenting it to the public. According to the report, "While some question the necessity of investing in autonomous vehicles, the potential for this nascent technology to create value and solve some long-standing logistical problems is undeniable. We will need to plan and prepare for the resulting disruption in business processes, operating costs, and economic models." The report continues arguing that "Autonomy—the ability to make decisions and take action without human intervention—promises to make a major positive impact on supply chains," but that "If companies want to gain meaningful benefits from autonomous technologies, they will have to rethink both their operating models and their value propositions."

TRIP. (2019). America's Rolling Warehouses: Opportunities and Challenges with the Nation's Freight Delivery System. TRIP.

According to this report, "The amount of freight transported in the U.S. is expected to increase significantly as a result of further economic growth, changing business and retail models, increasing international trade, and rapidly changing consumer expectations that place an emphasis on faster deliveries, often of smaller packages or payloads." It argues that current infrastructure and systems could have trouble handling this increase, and that increasing capacity at infrastructure bottlenecks (for example, increasing highway capacity, creating truck-only lanes, and increasing intermodal connectors) will be essential. It also argues that project planning must be streamlined, and institutional challenges must be relieved in order to meet this demand, and states that more permanent and reliable funding for the Highway Trust Fund will be critical.

UC Berkeley. 2011. Investigating the Potential Benefits of Broadcasted Signal Phase and Timing (SPaT) Data under IntelliDrive. Report, Charlottesville: University of Virginia.

To quote the abstract of the 2011 UC Berkeley Institute of Transportation Studies report, "This report identifies the transportation applications that could be implemented if real-time data about traffic Signal Phase and Timing (referred to as SPaT data) could be broadcast for signalized intersections and received by vehicles. These applications can support improvements in both safety and mobility of arterial driving. Preliminary estimates are

provided of the potential benefits that could be gained from these applications if all vehicles and signalized intersections were equipped. Actual benefits will of course be scaled down based on actual market penetrations. Finally, some of the practical considerations involved in implementing SPaT messaging from signalized intersections are addressed, based on recent experimental experience."

UC Davis, February 1, 2021. User Perceptions of the Risks of Electric, Shared, and Automated Vehicles Remain Largely Unexplored.

This two-page policy brief from UC Davis summarizes research into public opinions regarding the safety of getting into a self-driving vehicle with strangers (in a shared AV system), and what further research is needed to work towards widespread public acceptance. It discusses "personal risk constellations," or each person's perception of risks involved, and states that different demographics are more or less accepting of shared rides and AVs. For example, women are generally less enthusiastic about both AVs and shared rides than are men. It concludes that more research should be put into understanding the wide variety of individual reasons why potential users are hesitant regarding shared AVs in order to better promote them to the public and increase acceptance.

Union of Concerned Scientists. 2017. Maximizing the Benefits of Self-Driving Vehicles. Policy Brief, Cambridge: Union of Concerned Scientists.

This 2017 policy brief from the Union of Concerned Scientists states that AVs have potential to increase safety, accessibility, and convenience, but may use more energy and add to congestion. It concludes that, in order to achieve their maximum potential, six main points must be established: make transportation safer for everyone (aside from just drivers), cut pollution, integrate the vehicles with mass transit (to reduce congestion), equitably increase access to transportation across all demographics, support transitions for displaced workers, create a framework for sharing and protecting data, and create more livable cities with more efficient use of infrastructure.

United States Government Accountability Office. 2021. Unmanned Aircraft Systems.

The Government Accountability Office concludes that the "FAA could strengthen its implementation of a drone traffic management system by improving communication and measuring performance" in this 2021 report concerning the UAS traffic management ecosystem (UTM). This is a complex system to develop, and the FAA is working on it with NASA and UAS stakeholders. The report concludes that the FAA needs to provide more information on next steps for implementation to stakeholders as these stakeholders need this information to make plans for implementing UAS. It recommends that "The Administrator of the Federal Aviation Administration should provide stakeholders with additional information on the timing and substance of future UTM testing and implementation efforts, using FAA's UTM website or other appropriate means" and that "The Administrator of the Federal Aviation Administration should develop performance goals and measures for its UTM implementation plan." The report states that the DOT largely agreed with these recommendations.

University of Michigan, 2020. Investigating the Potential of Truck Platooning on Energy Savings: An Empirical Study On The US National Highway Freight Network.

Conducted primarily by the Department of Engineering at the University of Michigan (with some collaboration from the University of Illinois at Chicago), this 2020 report seeks to analyze real-world potential for increased fuel economy from truck platooning. It states that creating a real-world model is necessary, as this may differ from the results found from "ad-hoc platooning." The study analyzed truck itineraries to schedule platoons at locations where they are possible, stating in the abstract "By analyzing the numerical results obtained, this study quantifies the importance of scheduled platooning in improving trucks' fuel economy. Furthermore, the allowable platoon size, schedule flexibility, [and] fuel efficiency all play a crucial role in energy savings." The report concludes that "The cost-benefit analysis provided in the end suggests that the energy-saving benefits can offset the investment cost on truck platooning technology."

US DOT Volpe Center. 2020. Blockchain for Unmanned Aircraft Systems. Report, Washington: US DOT.

This 2020 US DOT report concerns Blockchain, defined here as "an immutable, time-stamped digital ledger that is distributed and managed by a cluster of computers and allows digital information to be distributed but not copied." According to the report, Unmanned Aircraft Systems (essentially drones) have begun serving very important missions (including carrying medical and sensitive military supplies), so blockchain technology can be used to keep them secure. Blockchain is already used for cockpit voice recorders and other trust/integrity issues. The report concludes that, as drones become more common, more traffic systems for controlling them will be needed, making blockchain an important part of security for these systems and the further implementation of drones.

US Department of Transportation, 2021. Driving Automation Systems in Long-Haul Trucking and Bus Transit.

The US DOT prepared this report to Congress, which seeks to address job-loss related issues from automated trucks and buses. The report states that, since job loss issues are not expected until Level 4 or 5 automation is reached, these issues will not even exist for a very long time. Even when they do it will take a long time before the technology is ubiquitous and replaces existing fleets, allowing for a transition period for out-of-work drivers. It claims that "If workers experience displacement as a result of automation adoption, existing U.S. Department of Labor (DOL) programs offer retraining and other general career services." The report also concludes that "natural turnover" in the trucking industry, specifically, most drivers being older and getting closer to retirement, and a lack of interest in truck-driving among younger people, will decrease the amount of involuntary job loss that occurs, and that new jobs will be added across industries due to lower costs and increased efficiency from AVs.

US Department of Transportation. 2021. Macroeconomic Impacts of Automated Driving Systems in Long-Haul Trucking.

The US DOT sponsored this study by the Volpe National Transportation Systems Center and the Centre of Policy Studies at Victoria University in Melbourne. The study explores different macroeconomic scenarios depending upon different rates of AV technology adoption. The report summarizes the findings of the study by stating "The results show that automation of the long-haul trucking industry is expected to bring welfare enhancing productivity enhancements to the economy. Assuming that occupational turnover rates remain as they are, these positive economic impacts would not be accompanied by forced lay-offs under the slow and medium adoption scenarios. Only under the fast adoption scenario are there short-lived, small magnitude lay-offs."

Washington State Transportation Commission. (2018). *Autonomous Vehicle Work Group: Framing Washington's Transportation Future.* Olympia: Washington State Transportation Commission.

This report discusses autonomous vehicles in Washington State, and the findings and recommendations of a work group assigned to study them. The work group recommends preemptively adapting local regulations to "prevent unnecessary roadblocks to deployment of autonomous vehicles," promoting "self-certification" to increase technology development, enhancing infrastructure to accommodate AVs, putting liability on AV manufacturers, and making sure data needed for AVs is secure. It also mentions a recommendation for a "Health Impact Assessment of AV technologies, with emphasis on identifying disproportionate impacts on disadvantaged populations."

West, D. M. (2016). Moving Forward: Self-driving Vehicles in China, Europe, Japan, Korea, and the United States. Washington: Brookings Institution.

This work describes where self-driving vehicles currently stand, and analyzes what is needed to develop them further. The conclusion states, "… the technology underlying semi- and fully autonomous vehicles is well-developed and poised for commercial deployment. Major automotive companies and software developers have made considerable progress in navigation, collision avoidance, and street mapping. But in each country, there are budgetary, policy, and regulatory issues that need to be addressed in order to gain the full benefits of autonomous vehicles. Governments can accelerate or slow the movement towards self-driving vehicles by the manner in which they regulate. The study notes that, as of 2016, there was uncertainty over "who or what is in control" and what constitutes proper control. The authors called for national guidelines on road trials, driver rules, control expectations, and legal liability. From an outside standpoint, work needs to be done to overcome obstacles such as

poor infrastructure, bad weather, spectrum limitations, hacking, and public acceptance.

WSP. 2017. Navigating Uncertainty: Background Paper to the Draft 2041 Regional Transportation Plan. Report, Toronto: Metrolinx.

WSP prepared this 2017 report for Metrolinx, a transportation agency in Ontario, concerning transportation futures in the Toronto-Hamilton area. The report addresses six different alternative scenarios, which are rapid adoption of emerging technologies, rapid growth of core areas, extreme climate change, on-demand economy, user pay economy, and economic decline. The section on emerging technologies concerns widespread AV adoption, delivery drones, and robotics and automation. The report addresses possible issues associated with this such as more "super commuters," more trips (including ones without people), an increasing income inequality gap, and more vehicle miles travelled.

Xing, Yan, Susan Handy, and Giovanni Circella. 2020. Experiencing Pilot Demonstrations Helps Individual Acceptance of Self-Driving Shuttles. Policy Brief, Davis: UC Davis.

This UC Davis National Center for Sustainable Transportation report discusses local self-driving shuttles, such as the one operated on the university's campus in 2019. The report states that survey results point to high acceptance of these shuttles, and that experience and familiarity with AVs in general leads to greater public acceptance and fewer safety fears. Enthusiasm for these services is important for their acceptance, and the study also shows that younger people, people of color, and women are likely to be more accepting and enthusiastic about the shuttles.

Yeakel, Skip. 2019. Moving America Forward – Next-Gen Truck Freight Transport. Presentation, Greensboro: Volvo.

This is a 2019 Volvo presentation on autonomous trucks. The presentation states that Volvo's primary concerns surround Automated Driver Assistance Systems (ADAS), or lower-level automation. Much of this is achieved using radar and cameras together to achieve collision and lane departure warnings, as well as automated braking. Volvo is also currently testing truck platooning, including gap control and braking. The presentation mentions that higher levels of automation (level 4) are currently only being considered for confined areas (ports, mining, construction sites, and refuse), and that more considerations for transporting hazardous materials and a change in regulations to allow for more highway testing will be necessary for this to develop further.

Zickuhr, K., Stahl, E., & DuPuis, N. (2016). Cities and Drones: What Cities Need to Know About Unmanned Aerial Vehicles. National League of Cities.

This report concerns drones (UAVs), and their effects on cities. It discusses current FAA regulations, which notably do not include "flight altitude, flight paths; operational bans; or any regulation of the navigable airspace." The FAA has said consultation on these is "recommended." As such, according to the report, local governments will likely end up being responsible for a good deal of regulation as drones become more common, which they almost certainly will. The FAA's recommendations make for good guidance now, though the report states that the federal regulatory environment for drones will almost certainly change as they are used more. The report concludes that, "Regardless of whether cities follow the suggestions in this municipal action guide or chart their own course, local leaders should consider the technological horizon and set clear expectations regarding the approved usages and limitations of drones in their communities."

Zmud, J., Goodin, G., Moran, M., Kalra, N., & Thorn, E. (2017). *Advancing Automated and Connected Vehicles: Policy and Planning Strategies for State and Local Transportation Agencies.* Washington: The National Academies of Science, Engineering, and Medicine.

This study looks at both the positive and negative effects of autonomous vehicles, and discusses desirable outcomes and recommended policies to pursue those. The report argues in favor of increasing AV testing (and making it legal across the board), modifying driver training and standards, and moving to increase public awareness

of the risks and benefits. It also argues for a no-fault approach to insurance and liability, and that CVs and AVs should be promoted for their environmental and safety benefits through giving them priority for lane, signal, and parking use. It also acknowledges that "Technology direction may change, consumers may not adopt certain products, and any number of global economic or environmental drivers could alter the policy course."