Connected and Automated Vehicle Infrastructure Needs for Automated Freight

Texas CAV Task Force White Paper
Subcommittee on Freight and Delivery

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Table of Contents

List of Figures

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Disclaimer

The contents of this white paper reflect the views of the Texas CAV Task Force members, who are responsible for the information presented herein. The contents do not necessarily reflect the official views or policies of the State of Texas or any Texas state agencies. The white paper does not constitute a standard, specification, or regulation, nor does it endorse standards, specifications, or regulations. This white paper does not endorse practices, products, or procedures from any private-sector entity and is presented as a consensus broad opinion document for supporting and enhancing the CAV ecosystem within Texas.

Texas CAV Task Force Charter

The Texas CAV Task Force was created at the request of Texas Governor Greg Abbott in January 2019. The Texas CAV Task Force is responsible for preparing Texas for the safe and efficient rollout of CAVs on all forms of transportation infrastructure.

The primary functions are:

1. Coordinating and providing information on CAV technology use and testing in Texas.
2. Informing the public and leaders on current and future CAV advancements and what they mean in Texas. This process includes reporting on the current status, future concerns, and how these technologies are changing future quality of life and well-being.
3. Making Texas a leader in understanding how to best prepare and wisely integrate CAV technologies in a positive, safe way, as well as promoting positive development and experiences for the state.

The Texas CAV Task Force is composed of a voting group of no more than 25 members and represents the full spectrum of CAV stakeholders.

Terminology Note

The Texas CAV Task Force addresses the full spectrum of connected, automated, and autonomous vehicles. An *automated vehicle* refers to a vehicle that may perform a subset of driving tasks and require a driver to perform the remainder of the driving tasks and supervise each feature's performance while engaged. A *fully autonomous vehicle* refers to a vehicle that can perform all driving tasks on a sustained basis. These definitions are still blurred in common discussions and language. Currently, the industry is developing automated vehicle capability while pursuing fully autonomous vehicles. The white papers generally use the term *autonomous* to refer to the vehicles with fully autonomous capabilities and the term *CAV* to refer to the grouping of connected, automated, and autonomous vehicles. Please see the "CAV Terminology" white paper for a full listing of terms and definitions used in this developing technology ecosystem.

List of Terms and Acronyms

AV	automated vehicle
CAV	connected and autonomous vehicle; also, connected and automated vehicle
CV	connected vehicle
C-V2X	cellular vehicle to everything
DSRC	dedicated short-range communications
ELD	electronic logging device
FCC	Federal Communications Commission
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	Federal Motor Vehicle Safety Standard
LSV	low-speed vehicle
MIZ	Mobility Innovation Zone
NHTSA	National Highway Traffic Safety Administration
OBU	onboard unit
PDD	personal delivery device
RSU	roadside unit
TCFC	Texas Connected Freight Corridors
TxDOT	Texas Department of Transportation
USDOT	U.S. Department of Transportation

Executive Summary

The freight network is at the heart of the Texas economy (Figure 1). In 2016, more than 2.2 billion tons of freight—19.7 tons per household and over 12,000 tons per business—moved within Texas, a volume that is anticipated to increase to over 4.0 billion tons by 2045 (1). By investing in smart infrastructure, maintaining an attractive regulatory environment, and taking a proactive approach to workforce development, Texas will improve roadway safety, optimize freight operations, and grow the Texas economy.

Source: Quintin Gellar—Pexels

Figure 1. The U.S. Freight Network.

The events of 2020 have accelerated the freight industry toward an automated future. With the rise of e-commerce and a demand for just-in-time deliveries, everything from packages and groceries to medications and last-minute school supplies could, in the future, be transported by connected and autonomous vehicles (CAVs). This acceleration presents an opportunity to reimagine the transportation infrastructure and identify improvements to support connected and automated freight while enhancing the safety and experience for all road users. For example, drivers could someday see truck platoons on the highway and even have the option to join the platoon as part of their daily commute. Additionally, the shift toward automation warrants a closer examination of changes needed to prepare the Texas workforce. In particular, there is a concern that current jobs in the trucking, manufacturing, and related industries may be displaced; however, there is strong analysis showing that the technology has the potential to instead boost productivity, attract a new generation of workers, and create new jobs. New skills and training programs can create jobs at a time when

Texas residents and businesses are retooling. By investing in smart infrastructure improvements and workforce development programs, Texas will be investing in accelerated economic competitiveness.

The Texas CAV Task Force Freight and Delivery Subcommittee sees the following as opportunities for the State of Texas related to freight and infrastructure:

- Prioritize roadway maintenance along CAV corridors, focusing on lane striping, pavement quality, and signage.
- Launch a cooperative research program targeted at research gaps for common infrastructure challenges such as work zones, forced merges, and transfer points.
- Expand the Texas connected freight network to include local roads, using the Texas Connected Freight Corridors project as an opportunity to develop critical applications, gain experience in connected vehicle technology, and formulate best practices for deployment.
- Invest in workforce development programs that upskill workers and create new educational pathways.

Introduction

The freight landscape is rapidly evolving. As new technologies and vehicle types continue to emerge, Texas's infrastructure and policies must keep pace. Many Texans rely on the freight ecosystem for their livelihoods. Connected and autonomous vehicle (CAV) technologies present significant safety and economic potential to the state. The Texas CAV Task Force represents a collaborative forum where the public and private sectors can work together to achieve success. In the wake of the COVID-19 pandemic, Texas must continue to make strategic investments in its freight infrastructure and workforce.

This white paper provides an overview of the ground-based freight ecosystem, highlighting challenges and opportunities in three environments:

- Long haul.
- Warehouses, distribution centers, and intermodal facilities.
- Last-mile delivery.

In addition, this paper examines shifts in the Texas freight workforce as the trucking industry evolves from a driver-based profession to a skills-based labor market. Finally, the white paper describes the infrastructure needs to enable connected freight capabilities and the potential safety benefits.

Ground-Based Freight

The advent of CAV technologies is transforming transportation. In particular, the freight industry is at the leading edge of the transformation, touting numerous research and development efforts on the ground and in the air. While several developments are taking place in unmanned aerial systems, the focus of this white paper is limited in scope to ground-based freight. The general consensus is that ground-based freight will advance at a faster pace than passenger services due to its simpler operating environment, for-profit business model, and quicker go-to-market strategy, providing early insights into infrastructure needs that could support automated vehicle (AV) operations more broadly. For instance, automated freight vehicles that are operating on limited-access freeways can provide information on lane striping, roadway geometry, and other roadway condition data. While navigating complex urban environments is more challenging, similar information-sharing concepts could be enhanced to yield insight into situations where there are more variables, such as avoiding pedestrians, yielding to bicyclists, and navigating signalized intersections.

In addition, automated freight is setting a positive example for conducting safe testing. Whether it is extensive training for those operating larger vehicles with heavier loads or proactively working with the residents to build awareness of personal delivery devices (PDDs) operating in local neighborhoods, the automated freight industry is taking precautionary measures to ensure safety. The following describes three basic infrastructure environments that compose the ground-based freight ecosystem.

Long Haul

Driving down the highway are thousands of long-haul trucks—Class 8 vehicles more commonly known as semis or 18-wheelers. Highly automated truck developers have focused on the middle mile—that is, the stretch of high-speed highway in between exits. Unlike passenger vehicles and PDDs, self-driving Class 8 trucks can be operated profitably mostly or exclusively on divided, limited-access highways, thus avoiding many of the pedestrians, pets, and bikes that make urban and suburban driving complex and unpredictable. So far, automation of short haul has not been a high priority. Larger trucks are hard to operate in dense urban environments, so the industry has left this task for experienced human drivers. With more lane miles than any other state and a booming population, Texas has prioritized the roadways that compose the Texas Triangle (I-10, I-30, I-35, and I-45) for CAV investments (Figure 2).

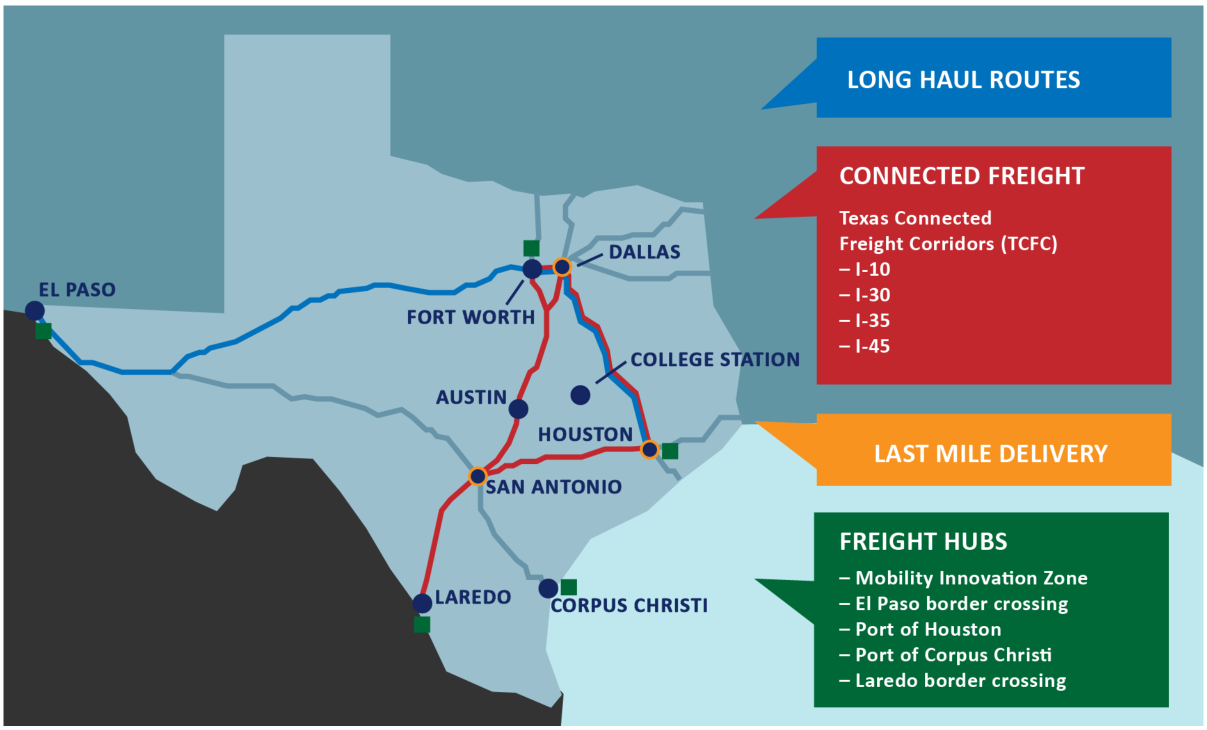

Figure 2. The Texas Triangle Connected and Autonomous Vehicle Activity.

Warehouses, Distribution Centers, and Intermodal Facilities

Along the supply chain are a string of warehouses, distribution centers, and intermodal facilities. In addition, Texas ports of entry—including seaports and border crossings—serve as tremendous hubs for freight activity. Increasingly, these facilities are co-locating to reduce drayage costs and accommodate increased freight volumes. Some automated freight developers are focusing on short-haul operations along routes that connect these facilities to one another or between distribution centers and retail customers. To spur investment, Texas can support CAV infrastructure in and around these nodes to create transportation-advantaged areas and attract companies to supply chain access.

Last-Mile Delivery

The final step in this process is last-mile delivery, which transports retail goods to consumers who are typically located at either home or work. Some last-mile delivery models are also connecting with consumers at convenient or central pickup locations such as community centers or downtown. The same features of the urban landscape that make it difficult to navigate are making it very lucrative to automate. To travel to each customer, the CAV must navigate a complex environment, so last-mile vehicles operate at lower speeds on local arterials, neighborhood streets, and sidewalks. Often operating in urban areas and pedestrian zones, last-mile delivery requires special infrastructure and regulatory considerations.

Texas: A Deployment Epicenter

In just the past five years, CAV testing has ramped up to include numerous connected and automated freight efforts. Operations are taking place along major highway routes, intermodal facilities, university campuses, local neighborhoods, and city sidewalks. What are the key factors behind this growing industry, and why Texas?

Clear Legislative Path

First and foremost, Texas offers a favorable regulatory environment for deploying CAVs. Governor Greg Abbott and the Texas Legislature have welcomed innovation, offering clarity where needed rather than requiring strict and overly burdensome regulatory and reporting requirements. This business-friendly path to deployment has put Texas at the leading edge, attracting many companies from California and other locations to both test and headquarter in the state.

More People, More Freight

Second, the Texas population is expected to grow from 28 million today to 55 million by 2050. It is estimated that 70 percent of the population will live in the four metropolitan areas of the Texas Triangle (Houston, Dallas-Fort Worth, Austin, and San Antonio), making it one of the largest markets in the country that operates under uniform regulations and is connected by high-quality infrastructure. In fact, if growth rates continue, Texas is set to surpass California in total population by 2045 (2). With more people comes an increased demand for goods, which is also expected to nearly double in the next 30 years.

Access to Talent

Third, Texas has a strong labor market with a robust technology sector. AV developers are choosing to headquarter or establish bases in Texas to take advantage of the access to both commercial driver license drivers and software engineers.

Education is another asset in Texas. There are opportunities to develop new curricula for K-12 schools to enrich learning in the transportation field, partner with community colleges to launch new certificate programs, and strengthen higher education programs with courses in CAV technologies. By continuing to invest in its workforce and education, Texas can remain at the forefront of job growth.

Partnership and Infrastructure

Finally, Texas infrastructure owners and operators have joined to approach CAV developers with a philosophy toward partnership. Recognizing that the Texas freight network is comprised of local, regional, and state facilities, public agencies are working alongside the private sector to develop common infrastructure standards, leverage CAV data to improve roadway maintenance practices, and prioritize investments. By sharing lessons learned and best practices, the Texas CAV Task Force is a collaborative model for identifying infrastructure enhancements to support CAV deployment.

The Freight Vehicle Lineup

Several connected and automated freight vehicle types are under development. Each vehicle is designed to operate in at least one of the following infrastructure environments: highway, local street, and sidewalk. Using a suite of sensors—lidar, radar, global positioning system (GPS), cameras, telecommunications, and other technologies—the vehicles are designed to steer, detect, and avoid obstacles while navigating safely to their final destination.

Automated Trucks

Traditional semi-tractor-trailer trucks that are Federal Motor Carrier Safety Administration (FMCSA) compliant are being automated to operate at highway speeds. The operation of highly automated trucks focuses on the part of the trip between entering the highway and exiting the highway with some extension off the highway to access warehouses, distribution centers, transfer hubs, and intermodal facilities. This has been referred to as the *middle mile* in some discussions. The highway environment has been identified as low-hanging fruit for automated operations because there is less complexity than urban streets. Highways do not have intersections, crosswalks, bike lanes, or street parking, which drastically reduces the variation in scenarios that a highly automated truck may encounter. In Texas, runs are being made regularly from El Paso to Dallas, between Dallas and Houston, and across I-10 beginning in California and ending in Florida. With increased technology, highly automated trucks can be safer and more fuel efficient and can transform the truck-driving profession.

Connected Trucks

Trucks may also be equipped with connected vehicle (CV) technology. Vehicle-to-vehicle communications enable trucks to platoon, where only the lead vehicle is driven by a human and the other trucks in the convoy rely upon GPS and sensor systems to follow. Vehicle-to-infrastructure communications can generate alerts such as “Work Zone Ahead” or give trucks priority at traffic signals by extending their green time. Currently, Texas is developing a set of CV applications that will enable truck drivers and operators to make better safety, routing, and business decisions. Furthermore, the trucking industry has integrated telematics to receive important alerts regarding traffic events and adverse weather. By combining technologies along the roadside and in the cab, Texas trucking can improve safety, fuel efficiency, and profitability.

Low-Speed Vehicles

For last-mile deliveries in urban areas, low-speed AVs are operating on-street at speeds up to 25 mph. The base vehicle is typically a full sedan or a purpose-built zero-occupant vehicle. Early use cases include grocery and medicine deliveries and will likely expand to other household items.

Personal Delivery Devices

For sidewalk-based deliveries, the two vehicle types for PDDs are wheeled and legged robots. Wheeled robots are the most efficient, perform well in structured environments, and are making improvements to traverse challenging surfaces. Legged robots have the advantage of navigating uneven surfaces, steps, and other obstacles. PDDs have load-carrying capacities ranging from 20 to 110 pounds and, in Texas, are restricted to a top operating speed of 10 mph in the pedestrian area and 20 mph on the side of the roadway.

Delivery Lockers

Mobile lockers are an emerging model in last-mile delivery with some companies developing purpose-built vehicles. The automated delivery vans typically operate on-street at speeds up to 60 mph and are customized to include 30–40 lockers. These vehicles are typically used to make multiple stops within a zone or may also be parked at a single location and serve multiple customers at the same time.

An Evolving Policy Landscape

Texas policy needs to ensure public safety while not hampering innovation. To mitigate policy uncertainty, Texas has focused on providing clarity and uniformity at the state level, has followed safety guidance at the federal level, and has relied on municipalities to issue permits and manage the curb space. The following highlights key issues for Texas to monitor in the arena of automated freight.

Federal

The U.S. Department of Transportation (USDOT) is committed to facilitating the next generation of transportation technologies. In particular, USDOT has published guidance documents referred to as AV 2.0 through 4.0, which describe the federal vision, regulatory authorities, research, priorities, and investments (3, 4, 5, 6). Significantly, in AV 3.0, FMCSA asserts its authority to take enforcement action if an automated system inhibits the safe operation of a commercial motor vehicle (CMV), while concluding that automated CMV operation is allowable under existing Federal Motor Carrier Safety Regulations (FMCSRs), assuming it can be compliant with the same operational requirements as a human-driven CMV. AV 3.0 also noted that FMCSA policy would no longer assume that the driver of a CMV is always human or that a human is necessarily on board, and that human-specific FMCSRs, such as drug testing and hours of service, would not apply to SAE Level 4 or 5 CMVs operating without a human driver. Furthermore, if FMCSA determines that state or local legal requirements may interfere with the application of FMCSRs, the department has preemption authority.

National Highway Traffic Safety Administration Exemptions. The National Highway Traffic Safety Administration (NHTSA) issues Federal Motor Vehicle Safety Standards (FMVSSs), which specify the design requirements for all motor vehicles. Before 1968, for example, not every vehicle had seat belts; the FMVSSs are responsible for requiring seat belts, airbags, and other safety measures. With AVs, however, some design specifications are no longer relevant. With no human driver, a steering wheel, brake pedal, and mirrors are no longer needed. Therefore, AV developers are applying to NHTSA for exemptions from the FMVSSs; at the time of this publication, some have been approved, while others remain pending. NHTSA has also announced a proposed rulemaking to update the FMVSSs with AVs in mind. Timely federal regulatory action is important to provide uniformity and support a growing CAV market.

Federal Motor Carrier Safety Administration Rulemaking. In addition to NHTSA's regulation of road safety and vehicle requirements of the FMVSSs, CMVs are also subject to the regulations of FMCSA. The FMCSRs focus on driver and carrier operations, including driver qualification, hours of service, vehicle inspections, financial responsibility, and other requirements that apply to the motor carrier industry. FMCSA has issued an advanced notice of proposed rulemaking related to the "Safe Integration of Automated Driving Systems-Equipped Commercial Motor Vehicles." The rulemaking is designed to update the FMCSRs in order to address safety, security, and privacy concerns relevant to automated driving systems.

Federal Communications Commission Rulemaking. In the world of CVs, there has been debate between two technologies:

- **Dedicated short-range communications (DSRC),** which has been proven to perform with such low latency that it can enable automated braking systems and other safety-critical applications.
- **Cellular vehicle to everything (C-V2X),** which uses the same network as a cell phone and has the potential for more ubiquitous coverage.

The Federal Communications Commission (FCC) has issued a ruling to reallocate the spectrum that is dedicated to transportation safety. While there was a 75-MHz allocation for DSRC, FCC has allocated the lower 45 MHz of the 5.9-GHz band for unlicensed operations such as Wi-Fi and allocated the upper 30 MHz for C-V2X operations (7). Existing DSRC implementations are able to continue operating in the upper 30 MHz; however, existing operations in the lower 45 MHz are required to cease operations after the one-year transition period. FCC is seeking comments on the appropriate transition paths for existing DSRC operations. Like many states with existing deployments, Texas is seeking a clear path forward.

State

Governor Greg Abbott and the Texas Legislature have demonstrated significant leadership in creating a business-friendly environment for CAV development. Specific to automated freight, three pieces of legislation signed into law by the governor are worth noting:

- **Senate Bill 2205** (effective September 1, 2017) specifies that AVs may operate on any public roadway, carry passengers, and operate without requiring a human to be present (8).
- **House Bill 1791** (effective May 18, 2017) allows trucks equipped with a connected braking system to platoon with one another (9).
- **Senate Bill 969** (effective June 10, 2019) provides a regulatory framework for PDDs that outlines rules for operation and specifies vehicle requirements (10).

As Texas continues to test and deploy new technologies, results and key findings can be summarized for the Texas Legislature for potential opportunities related to policy.

Local

In Texas, current legislation preempts local regulation of AVs. Municipalities do maintain regulatory authority over their curb space management practices, ensure compliance with traffic laws, and design the infrastructure and right of way. Cities such as Washington, DC, are testing systems that allow delivery drivers to reserve space at the curb to discourage double-parked vehicles that block traffic. The sidewalks are also becoming more congested as bicyclists, scooters, pedestrians, and PDDs compete for space. Cities are reimagining their rights of way to include dedicated lanes to minimize conflicts and ensure accessibility.

Long Haul

Trucks in Texas carry massive volumes of freight, so it makes sense that the majority of companies developing highly automated trucks have identified Texas as a proving ground. The state must strategically invest to maintain this edge.

The Challenge and the Opportunity

By far, the primary mode for moving freight is commercial vehicles. Over 700,000 truck trips are made daily in Texas, which is expected to grow to over 1 million by 2045 (11). This freight traffic relies on a robust roadway network.

Investing in highway infrastructure supports the economy by enabling safe and efficient transportation of goods. Developers have identified the middle mile, or entrance to exit on a roadway, as an ideal environment for the operation of highly automated trucks. Highways have limited intermodal interactions, which reduce the challenge of object identification and classification.

This is coupled with a national truck driver shortage, which continues to grow. In 2018, the driver shortage was estimated at over 60,000 drivers, with an expectation that it will grow over time (12). The average age of a commercial truck driver is 55 years old according to the Bureau of Labor Statistics, and the industry has trouble attracting a younger workforce (13). This means that, for now, highly automated trucks are unlikely to impact the existing employment of drivers and instead fill a gap between supply and demand. Additionally, the technology provides new jobs, which may be more attractive to the younger workforce.

Texas has become a hub for automated freight deployments, but the roads on which highly automated trucks must operate were designed long before the technology emerged. Through early deployments, the operators of highly automated trucks have identified challenges within the current infrastructure (Figure 3). The existing highly automated truck deployments demonstrate that they are capable of operating on the existing infrastructure, but consistent maintenance and infrastructure enhancements would enable broader deployments.

Some challenges are common across traditional and highly automated trucks. The three basic infrastructure needs where industry has reached consensus are:

- Consistent striping.
- Quality pavement.
- Standardized signage.

Faded or missing lane striping is challenging for vehicles that rely on striping to dictate the extent of a lane, uneven pavement can confuse the highly automated truck's sensors, and non-standardized signage is difficult for highly automated trucks to read and interpret. Addressing any of these challenges will also benefit human drivers. With regards to signage, long-haul trucks traveling routes that span multiple states are particularly challenged by signage variations that occur across state lines. In addition, some infrastructure challenges are more difficult for highly automated trucks to navigate reliably or do not have a current solution. Highly automated trucks find the following roadway environments challenging due to their unexpected and highly varied nature:

- Work zones.
- Lane closures.
- Forced merge points.

There are also unique challenges, such as the issue of how to navigate weigh stations and inspections without a driver present. The Commercial Vehicle Safety Alliance, in partnership with the Federal Motor Carrier Association, has been working to develop a consensus approach to inspection of highly automated trucks (14). These new methods are being crafted with industry input, and Texas could reinforce its position as a leader in this space by adopting them early on.

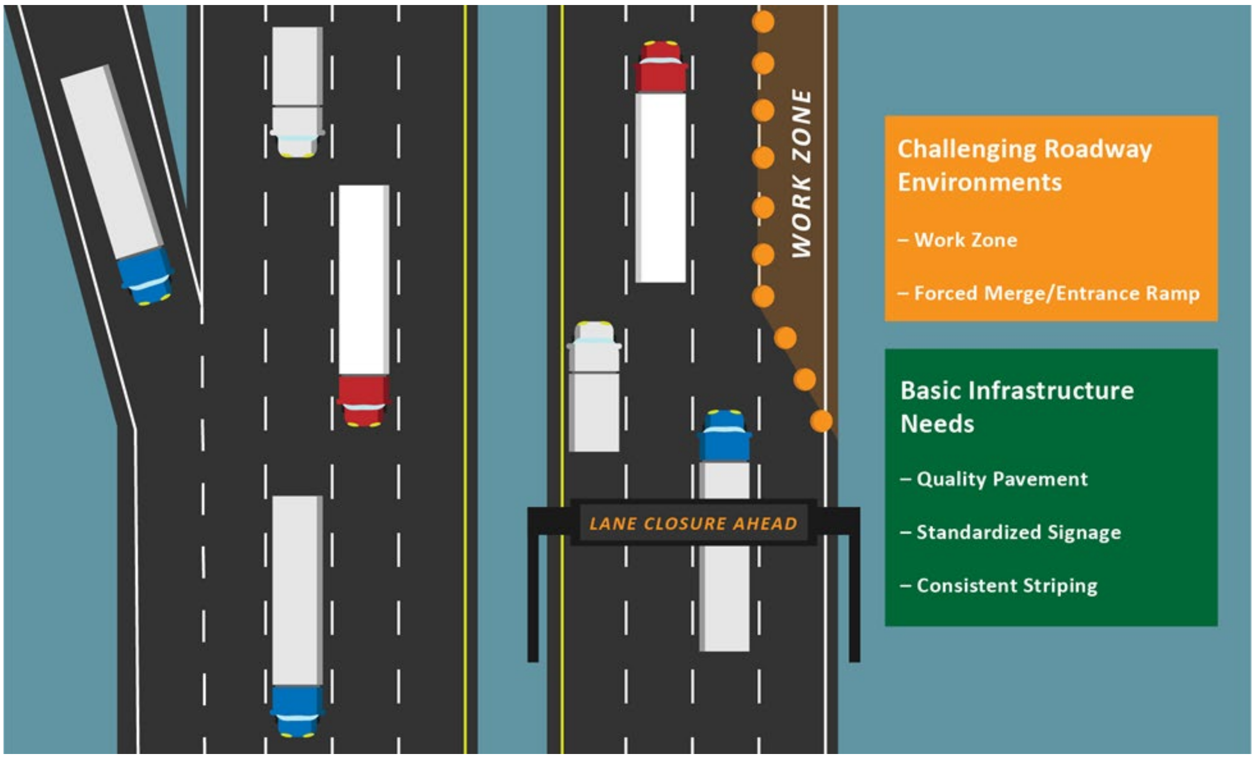

Figure 3. Roadway Environment Challenges and Basic Infrastructure Needs for Long Haul.

Infrastructure Close-Up

The operation of highly automated trucks focuses on the middle mile between entering the highway and exiting the highway. The highway environment has been identified as low-hanging fruit for automated operations because it has less complexity than urban streets. Highways do not have crosswalks, bike lanes, or street parking, which drastically reduces the variation in scenarios that a highly automated truck may encounter. In Texas, the interstate highways that compose the Texas Triangle are all highly used trucking corridors that provide access to the major metropolitan areas within the state. Multilane divided highways present an opportunity for highly automated trucks to focus on navigating the roadway environment without the complexity of intersections, tight corners, pedestrians, or bicyclists.

However, the highway environment does involve unexpected work zones, difficult-to-navigate forced merge points, faded or missing pavement markings, and no existing system for automated operations to transition to human operations for the more complex first and last mile. Addressing these challenge points would allow highly automated trucks to deploy broadly and boost the Texas economy.

Work Zones and Forced Merges

Highly automated trucks can be challenged in the work zone and temporary lane-closure arena by the need to navigate rapidly changing and unpredictable environments. Work zones are known to be challenging for both humans and computer-driven vehicles alike, with some new work even addressing the safety of construction workers as they are performing work. This reflects large value in finding ways to standardize the work zone environment and provide a safer environment for drivers, highly automated trucks, and work zone workers alike. One company operating highly automated trucks in Texas provided a powerful anecdote of how a truck can often get trapped in the right lane when approaching an unanticipated lane closure. To navigate around the closure, the truck must merge into the left lane. However, the left lane is clogged with drivers who do not provide a gap for the truck to merge. Class 8 trucks are bulky and require considerable time to merge, brake, accelerate, or otherwise maneuver.

The solution to this challenge is maintaining accurate information about work zones and lane closures that the highly automated truck operators can easily access. With advance notice, the highly automated truck can move into the left lane earlier and avoid the congested merging point closer to the work zone.

Similar to work zones, forced merge points (e.g., a lane ending or becoming an exit-only lane) require highly automated trucks to merge, which is one of the more complex tasks for any truck to execute. Entirely eliminating merge points is not feasible, but they should be well signed and give time for vehicles to merge into the next lane. Conversations with highly automated truck companies can guide the development of new entrance and exit ramp configurations as well as enhance signage protocols associated with work zones.

Lane Striping

Pavement markings designed to help drivers orient themselves and stay within set boundaries to avoid collisions are also important to the operation of some highly automated trucks. Faded or missing striping makes driving at night and during adverse weather more hazardous for human drivers. Even though most highly automated truck companies plan to be capable of operating without high-quality lane striping, faded or missing striping makes operation more difficult. Significant work has been done to ensure that standards are set for minimum retroreflectivity, but these standards were not designed for automated activity. In 2018, California elected to switch from 4-inch-wide to 6-inch-wide stripes, citing the better visibility for AVs as one of the motivators (15). Other work is being done across the country to explore methods for improving pavement striping. Generally, high-quality striping is a change that can be implemented rapidly at a relatively low cost that will benefit highly automated trucks and human drivers alike.

Even when high-quality striping is implemented, it must be maintained properly to remain effective in the long term. The procedures currently in place for Texas rely on a combination of driver reports and inspections. Driver reports provide some information but should not be considered comprehensive. A subset of lane miles is inspected each year, but this system does not catch all degradation in a timely manner. Texas needs to find a way to fill the gap so that faded and missing striping can be identified and remedied appropriately. Some highly automated truck companies have come forward to offer data to state agencies in support of road maintenance efforts. Since the trucks have multiple cameras and other sensors pointed at the roadway, they can provide valuable information on road quality to the Texas Department of Transportation (TxDOT). This concept has been explored broadly, but it would be valuable to invest in the development of a robust system for reporting maintenance events because this reporting tool will only grow in value as the deployment of highly automated trucks rises.

Transfer Hubs

Highly automated trucks that are built to operate on the highway need access to facilities that connect to the highway. Highly automated truck developers have announced plans to build transfer hubs and convert existing facilities where cargo can be dropped off by human drivers and connected to highly automated trucks (16). This type of facility will be essential to the success of highly automated trucks that aim to tackle the middle mile. This framework also highlights a continued need for human drivers for many years. Many highly automated truck developers have chosen to tackle the middle mile distinctly because of the simpler operational design domain and are not looking to navigate complex urban environments using autonomy in the near future. Texas can support the transfer hub concept by identifying facilities that are already connected to the highway network and can be repurposed or redesigned to work as a transfer hub. Rest areas, weigh stations, park-and-ride areas, truck stops, and truck parking facilities have been identified as potential locations for transfer hubs. If the facility is no longer in use, it can be fully converted. Otherwise, the space could be shared between the two activities. An important consideration when developing transfer hubs will be the need to keep human activity away from any area where highly automated trucks are operating to maintain safety and avoid confusion.

Opportunities

In the short term, Texas should focus on working with companies to exchange information effectively. Texas is investing in CV technologies that can provide up-to-date, lane-specific information on work zones and lane closures. Highly automated truck companies have also demonstrated a willingness to work with state and local partners to provide information on faded and missing striping.

In the long term, highly automated trucks will need to be considered part of a broader ecosystem. Many standards and procedures can be adjusted to incorporate the presence of highly automated trucks. Developing an effective transfer hub network will be essential to the success of middle-mile highly automated truck operations. As highly automated trucks spend more time on the road, they may find new concerns to be addressed. In summary, the Texas CAV Task Force sees the following opportunities:

- Refine infrastructure standards for lane striping, work zones, and lane closures with the needs of highly automated vehicles in mind.
- Prioritize research to address challenging roadway environments such as forced merges and entrance/exit ramps.
- Identify potential locations for transfer hubs and work with industry to pilot this solution.

- Encourage TxDOT and industry partners to work together in sharing information to benefit the operations of both organizations.

Warehouses, Distribution Centers, and Intermodal Facilities

As automation is incorporated into the freight ecosystem, major actors in the supply chain are co-locating to create transportation-advantaged zones that can attract and grow automated freight companies.

The Challenge and the Opportunity

The journey of cargo from manufacturer to customer contains many connections (Figure 4). At warehouses and distribution centers, cargo is sorted and packed into a new vehicle. These connections do not take place directly on the roadway but are critical to the efficient movement of freight and come with their own challenges. Intermodal facilities consist of ports, rail yards, and airports where the movement of goods transitions from one mode of transport to another. As the role of autonomous technology grows in the freight sector, these facilities are changing how they tackle drayage and management of vast quantities of cargo. Companies are changing how they think about moving their goods. For example, to meet its tight delivery timeline, Amazon purchased 20,000 vans, which cover the last-mile journey to a customer's doorstep. Even the U.S. Postal Service is experimenting with automated freight, shown by its 2019 long-haul test run of moving mail in a highly automated Class 8 truck from Phoenix, AZ, to Dallas, TX.

As the journey evolves, the connection points will shift with it. The location and scale of warehouses may look different in the future. Distribution centers will be located strategically to tackle the increasingly challenging last-mile delivery. This period of transition means that regions that are home to large amounts of freight activity can experiment with how facilities are structured in the future. The creation of freight hubs may become more common as the benefit of centralizing activity grows.

Figure 4. Warehouses, Distribution Centers, and Intermodal Facilities.

Infrastructure Close-Up

Cargo transitions take place most often at warehouses, distribution centers, and intermodal facilities. Companies use **warehouses** to store large quantities of cargo, located outside urban centers because the cost of space within urban regions is prohibitive. Manufacturers must maintain warehouses because they cannot perfectly align their production with consumer demand. Warehouses are expected to expand vertically as automation makes it easier to log the location of inventory and quickly retrieve product as needed.

Distribution centers are smaller facilities where individual orders are prepared and loaded for delivery to a consumer. These locations are typically located within the urban environment so that smaller delivery vehicles can make more trips to and from the location within a given day. The function of distribution centers remains important, but their location will need to be decided carefully to enable the operation of last-mile delivery vehicles.

Intermodal facilities are unlikely to relocate but will likely invest in automated technologies that can support drayage. These facilities can receive and distribute massive volumes each day, but to keep up with demand, they will need to operate efficiently. Connectivity allows trucks to report an early or late arrival so the queue can shift with roadway conditions.

An interesting example is in Fort Worth, TX, where AllianceTexas is launching the Mobility Innovation Zone (MIZ) to provide a proving ground for unmanned aerial systems and automated freight. The large scale of the facility allows for automated freight companies to determine what intermodal interactions will look like in the future. The MIZ has an industrial airport and a rail yard along with close proximity to I-35, allowing easy access to the highway network. This means the companies operating here can navigate interactions with two of the three most common intermodal transitions. The MIZ is also home to warehouses for companies, so movement from warehouses to distribution centers can be tackled. Freight hubs like the MIZ will likely become a popular way to pilot new technologies since the private ownership allows for flexibility to test rapidly, and collaboration with the public sector supports future growth to broader deployment. The public sector should foster efforts like these because they provide test beds to learn from. Lessons learned in the MIZ may be broadly applicable as automated technologies continue to grow. Additionally, the success of the MIZ would be beneficial for the freight ecosystem and the economy.

As companies integrate automated technologies into their delivery system, there will be changes at connection points within the journey of cargo from manufacture to delivery. More warehouses will be located close to highways so highly automated trucks can access them without navigating complex urban environments. As the space that warehouses occupy becomes more valuable, they could transition to a more vertical footprint to make use of the land companies own. Ports have a proven system for creating a digital inventory where the location of everything is maintained so that sorting a delivery of inventory and preparing a shipment both run more smoothly. The location of distribution centers will need to be carefully selected to allow access to consumers and to consider the needs of last-mile delivery vehicles. Last-mile delivery vehicles operate on a subset of the full roadway network, so distribution center location is critical to the ability to efficiently make deliveries.

Lastly, until automated technology is ubiquitous, automated technology will operate alongside human-operated systems. This will provide an interesting set of challenges where most structures are neither designed with only human operators or automated operators in mind. The supply chain structure will persist, but the connection points will transform alongside the changes occurring on the roadways to accommodate new highly automated technologies.

Opportunities

Warehouses, distribution centers, and intermodal facilities provide vital connection points along the journey of cargo. To continue growth, the Texas CAV Task Force sees the following opportunities:

- Monitor the changes in location and structure of facilities to understand how automation may impact land use in the long term.
- Support warehouses, distribution centers, truck stops, and intermodal facilities in creation of more test beds for automated freight technologies.

Last-Mile Delivery

Traversing the last-mile delivery leg is complex and dynamic, but increasing demand is fueling growth and pushing the development of automated delivery vehicles.

The Challenge and the Opportunity

Last-mile delivery involves transporting goods—everything from groceries and packages to meals and last-minute items—the final step to the customer's door. Last-mile delivery is both the most time-consuming and most expensive part of the delivery process, often costing over half of the delivery costs, because it involves multiple stops along a route that could be spread across several miles (17). Automating last-mile delivery offers significant value to Texas residents and businesses. First, the sector presents a tremendous boon to the Texas economy. Automated last-mile deliveries are forecasted to generate almost $50 billion in global revenue by 2030, according to a new report from Lux Research (18). Second, the COVID-19 pandemic has brought to light a public health benefit of contactless delivery. AVs are delivering groceries to seniors, meals to busy families, and medicine to those in need. Finally, automated last-mile delivery promises to reduce the per-parcel cost of last-mile delivery (19).

With increasing customer expectations for fast and free delivery, retailers and logistics partners are looking to new technologies such as CAVs to drive business improvements. However, these vehicles must navigate complex roadway environments that were not designed with the presence of CAVs in mind. Delivery robots operate in the street and on the sidewalk (Figure 5). It is challenging to operate on sidewalks without creating conflict between delivery robots and pedestrians. Operating on public roads requires higher speeds of travel and compliance with rules of the road. Delivery robots find signalized intersections particularly complex because of the interaction with pedestrians, bicyclists, and human-operated vehicles. While there is significant value in automating the last-mile journey, it is a difficult landscape to navigate and can be aided and accelerated with beneficial adjustments to infrastructure for more successful deployments.

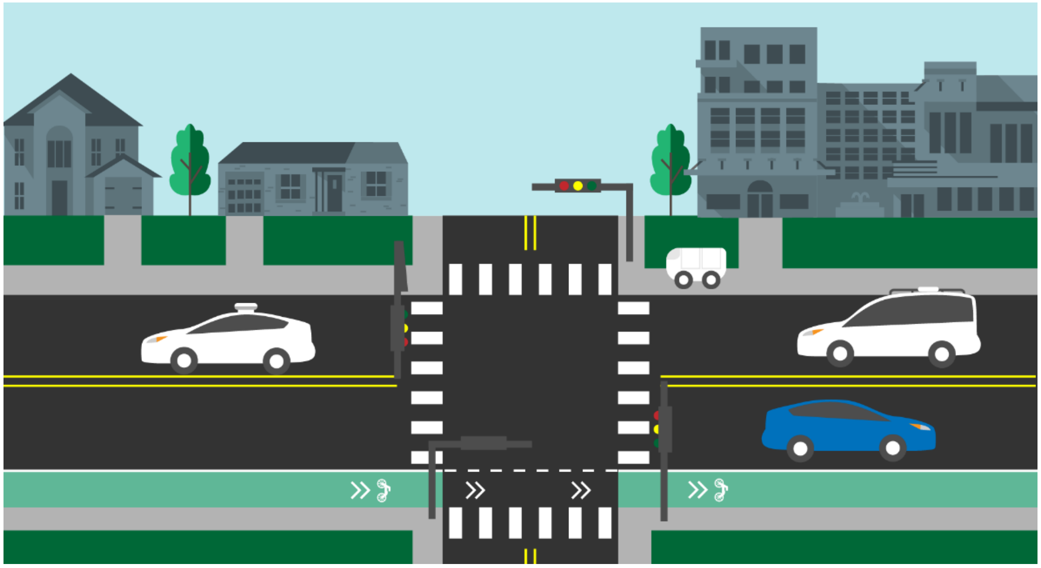

Figure 5. Challenging Roadway Environment for Last-Mile Delivery.

Infrastructure Close-Up

Personal Delivery Devices

PDDs typically use the existing sidewalk infrastructure to make small deliveries to the doorstep of a customer. The PDD, typically wheeled, must navigate around city infrastructure such as light poles and fire hydrants along with urban infrastructure such as benches, outdoor restaurant seating, menu boards, and others. In addition to static obstacles, sidewalks are a busy place in urban regions. The PDD may encounter pedestrians, dogs, bicyclists, or scooter users on a regular basis. While the PDD can govern its own behavior, it cannot control the behavior of humans with whom it must interact. PDDs must operate with an abundance of caution because they exist within a space designated for pedestrians. In many situations, the existing infrastructure may not be well suited for broad deployment due to challenges with accessibility, and interactions with humans have not been addressed.

Sidewalks are a critical part of the transportation infrastructure but can present a challenging operational environment. In urban environments, there are often missing sidewalks, curb cut variations, and obstacles that are difficult for wheelchair users and pedestrians alike. Companies operating PDDs on the sidewalk are programming their vehicles to navigate the complex environment; however, it is an evolving process.

During a pilot at the University of Pittsburgh, a PDD pilot was put on hold for a few days after a robot accidentally blocked a wheelchair user from accessing a curb cut. Recounted by Emily Ackerman in an article she wrote about her experience, “It didn’t move as the walk signal was ending. I found myself sitting in the street [...] blocked by a non-sentient being incapable of understanding the consequences of its actions” (20). The company in charge of the pilot took quick action and made sure the robot would not loiter in curb cuts, but the event made clear that it is difficult to avoid potential conflicts in the existing infrastructure.

More generally, a PDD cannot anticipate every event that it will encounter when expected to operate alongside humans. Companies are investing in remote operation capabilities, which could enable an operator to take control of the vehicle in an unexpected situation. Cities are also exploring new ways to allocate their rights of way, including a dedicated lane concept, although such a designation is by no means mandated, and companies are actively working to develop operational premises for the infrastructure conditions that exist today. As vehicles and operating conditions continue to develop, the industry could see significant changes to infrastructure development and use.

If provided, a dedicated lane for delivery robots would function similarly to a bike lane. Space would be set aside within the street or sidewalk specifically for PDD operations. Cities could also create slow lanes, where PDDs could share space with bicycles, scooters, skateboards, runners, and other slower-moving vehicles (21). While remaining vigilant, the PDD would be able to operate in the protected lane more comfortably without needing to share space with pedestrians or navigate unexpected obstacles. The challenge lies in identifying available space within the right of way to develop a network of dedicated lanes. This would require a shift in planning but could make the broad deployment of PDDs more feasible. In the future, a network of sidewalks could be designated for pedestrians and delivery robots. Creating a painted marking or sign could identify the presence of these delivery robots so that pedestrians are not surprised when they come upon one.

Automated Delivery Vehicles

Another strategy for tackling last-mile delivery has been the development of automated delivery vehicles that operate on roadways, typically along neighborhood streets. These vehicles must share the roads with cars, bicyclists, and scooter users. At intersections, the vehicle must be aware of pedestrians. Additionally, they are challenged in navigating unprotected left turns and instances of road work. While companies are improving the left-turn capabilities, public agencies are focused on providing clear signage and maintaining an accurate database of ongoing road work.

One company, Nuro, has deployed in Houston, TX, to provide grocery delivery service. The company was awarded an exemption from NHTSA to operate its vehicle on public roads without having a steering wheel or brake pedal. However, federal legislation classifies the vehicle as a low-speed vehicle (LSV), and therefore it cannot travel over 25 mph without falling into a new vehicle classification. This restriction limits the geographic reach of these delivery vehicles. The exemption applies to the requirements that an LSV be equipped with exterior and/or interior mirrors; have a windshield that complies with FMVSS No. 205, "Glazing Materials"; and have a backup camera system that meets the requirement in FMVSS No. 111, "Rear Visibility," limiting the length of time that a rearview image can remain displayed by the system after a vehicle's transmission has been shifted out of reverse gear.

Texas deployments could consider strategically expanding the geographic reach of automated delivery vehicles to address food deserts and provide access to healthy foods without requiring a car. However, the network in which these vehicles can operate is limited. Due to federal legislation, LSVs cannot go over 25 mph and, due to state legislation, are only allowed to travel on roads with a posted speed limit up to 10 mph above their maximum speed. In other words, LSVs cannot travel on roadways with a posted speed limit greater than 35 mph in Texas.

States can consider enabling LSVs to travel on roads with higher posted speeds in order to access more households. In the case of Houston, key roadways could be identified to create a network for the automated delivery vehicle. Appropriate signage could be posted so that drivers are aware of the delivery vehicle operating at a lower speed. By expanding access to customers, automated delivery vehicles could provide a way to learn about implementing CAVs on neighborhood streets that can provide valuable insights for infrastructure enhancements and additional services.

Opportunities

Last-mile delivery is complex, which means that Texas should be proactive in addressing concerns that prevent automated delivery vehicles from navigating the urban landscape. Rather than slowing down the adoption of these new technologies, Texas infrastructure owners and operators are seeking to accelerate their ability to integrate them. The Texas CAV Task Force has identified the following opportunities:

- Collaborate with last-mile delivery vehicle companies and cities to plan for future infrastructure needs, including designating a network of automated delivery roadways to address food deserts and establishing dedicated lanes for PDDs.
- Consider posting signage along automated delivery routes to create awareness of the automated delivery vehicles and support updates to the *Manual on Uniform Traffic Control Devices* where applicable.
- Support the development of policy that allows AVs to operate in state without inapplicable equipment requirements.

A Changing Workforce

Automation is disrupting the transportation workforce, but it does not have to mean that jobs will disappear. Preparing now for the changing workforce demands can enable Texas to mitigate worker displacement, create new jobs, and bolster its economy.

The Impacts of Automation

Several theories are predicting how and when automation will hit the transportation sector. One outcome is that transportation will follow the same fate as the manufacturing industry, permanently replacing jobs with more cost-effective machines. Or transportation may follow the path of the banking industry, transmuting workers into new positions and creating jobs that require new skills. When one in sixteen jobs in the state is directly supported by the freight sector, it is essential that Texas get it right. By investing now in workforce development programs, Texas can mitigate displacement and upskill its workforce.

The Current Driver Shortage

With over 172,000 people employed as truck drivers, Texas has more truck drivers than any other state—and yet there is a significant driver shortage. In 2018, the American Trucking Association estimated a shortage of 60,800 drivers with the potential to reach 160,000 by 2028 (12). Several factors contribute to the shortage; in its simplest form, fewer qualified drivers are applying while experienced drivers continue to retire, and more and more drivers are needed to fulfill the increased demand.

The current driver stock is aging out as the industry is growing. The industry is struggling to attract younger drivers, often pointing to the arduous lifestyle. The long stretches of travel take their toll, making it difficult to spend time with family, exercise, or eat healthy, and lead to high turnover rates. In addition, the pay structure is far behind the curve. While drivers' salaries have increased, they are still as much as 50 percent lower than they were in the 1970s when adjusted for inflation. Additionally, regulating drivers to 11 hours per day for driving and the more recent mandate requiring an electronic logging device (ELD) has continued tension between safety advocates and the trucking industry. Safety advocates consider ELDs to be a technology platform that prevents the falsification of records, minimizes violations of federal hours-of-service limitations, and improves safety by reducing driver fatigue. On the other hand, the mandate has exacerbated an already tightening labor market, and many truckers have left the business. The full safety and labor effects of the ELD mandate are still being studied, particularly the impacts to small carriers who are most affected by the mandate (22). At this critical inflection point, Texas has an opportunity to turn the driver shortage around by investing in the development of its workforce and looking for ways to attract a new generation.

Disrupted but Not Displaced

While the concern of job loss from automation is very real, the truck-driving profession is far from obsolete (23). First, the future of freight operations will continue to rely on the experience and expertise of truck drivers. Trucking companies are transitioning from a driver to an operator model where the human performs fewer and fewer driving tasks; currently, the human operator typically drives the first and last mile, takes over the vehicle if it encounters an unfamiliar situation, and loads/unloads the vehicle at its destinations. In the long term, drivers will likely retain responsibility for first- and last-mile segments, with highly automated trucks operating without a driver across the middle mile. Another model under development is remote operations, where a fleet would be monitored by humans and, if necessary, controlled from a central command center. In any scenario, companies will continue to rely on truck drivers with roadway experience to support operations in various ways.

Second, the changes in the trucking industry have the potential to attract a new generation of workers. Fully automated trucking will still rely on human drivers for short haul and driving in urban environments, creating more trucking jobs that allow drivers to stay close to home. Additionally, the opportunity to be a remote operator is a fundamental change to the truck-driving lifestyle that makes the profession more appealing. With the rise in e-commerce and population growth, Texas anticipates an increased demand for goods and therefore goods delivery.

Third, the pathway to full automation will be a gradual transition, and some tasks may never be automated. Within the near future, the truck driving experience will be enhanced with advanced driver assistance systems that assist with driving tasks like lane keeping and adaptive cruise control. The next wave of automation focuses on automating driving tasks in simple environments: the middle mile of long-haul trips, guided movements within warehouses, and last-mile deliveries in designated zones. Meanwhile, more complex tasks such as navigating through inclement weather, conducting safety inspections, handling freight, refueling, managing customer relationships, or changing a flat tire will still require a human touch. Disaster response is a specialized area that will continue to require manual operations. During strong storms or in the aftermath of a hurricane, Texas depends on experienced truck drivers to restock grocery shelves, deliver medical supplies, and evacuate residents. To accommodate the transition, Texas has an opportunity to proactively support truck drivers and other supporting industries with new skills and training.

A Growing Gig Economy

With the advent of smartphone technology, the way that people view and perform work has altered over the past decade. For example, DoorDash is a smartphone-app-based platform that lets customers order food to be delivered. The customer inputs an order from an area restaurant, and DoorDash offers the gig to its workers, who can choose to accept, deliver the food, and get paid. What is different about this model is that a gig worker is paid by the task, not by the hour or by a salary. Some of these companies, including DoorDash, are testing automated delivery. While there are concerns that companies are using more automated systems to reduce their reliance on human delivery drivers, the technology also presents the opportunity to support retail outlets by expanding customer deliveries and create new jobs. Automation has the potential to accelerate the need for and size of the gig economy (24). As the gig economy continues to grow, Texas can support workforce education and training programs to equip truck drivers and gig workers alike with new skills.

Education and Training

The future of trucking will offer new employment opportunities for today's drivers but will require a new set of skills.

Partnerships in Education

With a shared interest to invest in local talent, companies are forging partnerships with educational institutions and launching new training programs. For example, automated trucking companies are working with community colleges and vocational schools to create curricula, teach courses, and provide hands-on training with highly automated trucks. Then, the companies prioritize hiring graduates of the program to work at their testing and development centers. Texas can similarly encourage companies that are testing and operating in the state to partner with its school system to cultivate a talent pipeline in a growing industry.

The Bigger Picture

Automation will affect many areas of the transportation industry beyond truck drivers—other drivers such as bus drivers and taxi drivers but also other sectors such as repair shops, manufacturing, and automobile insurance. There are several opportunities to create jobs in industries that support trucking; and as trucking becomes more efficient, the economy grows. Drayage, for example, is a potentially complex environment where human jobs can be created. Texas needs to be proactive in its approach and to think holistically about the shifts that are under way. Existing workforce development programs may be leveraged to prepare for automation. In particular, the Texas Workforce Commission manages a Skills Development Fund and an Apprenticeship Program that could support transportation workers who are interested in acquiring new skills related to CAV technologies. As the state emerges from the COVID-19 pandemic, Texas can ease reentry for workers by providing training opportunities.

Opportunities

The progression of AV technology development is expected to accelerate over the next decade. The Texas CAV Task Force has identified the following opportunities:

- Prioritize upskilling for truck drivers and others who may potentially be displaced.
- Encourage companies that are testing in Texas to partner with local educational institutions.
- Integrate training in CAV technologies into existing workforce development programs.

Connected Freight

Information provided by CV technology is valuable to current human truck drivers and has the potential to enhance highly automated truck operations in the future.

The Challenge and the Opportunity

The freight ecosystem thrives on good information, and CV technology can provide better, more accurate information. Historically, truck drivers have gathered their information "through the windshield" and adapted their delivery schedule with changing road conditions. As companies rely more on just-in-time deliveries and consumers expect timeliness, the value of accurate and up-to-date information has grown, and companies are updating their practices to keep up. Increasing connectivity in the trucking arena has been transforming the availability of information that is available at the right time and place. As in the automotive industry, connectivity can be as simple as a 4G LTE cellular connection, which enables in-vehicle applications and information sources to provide information to drivers.

However, in the area of safety-critical applications, CV infrastructure enables trucks to communicate with infrastructure and other equipped vehicles on the roadway. This allows a crowdsourcing of updates on important conditions such as queues of stopped traffic, hazardous weather conditions, or work zones ahead. Texas already has extensive information on the location and timing of work zones, low-clearance bridge locations, and other infrastructure challenges. Deploying CV technology allows for the broadcast of this information, which will improve operations and subsequently boost the economy. Once more vehicles are equipped, there is potential to power the implementation of safety enhancement technologies, such as emergency electronic brake lights. CV technology has economies of scale, and it will take time to realize the full potential of the technology. It is important that Texas invests early on and does not fall behind. Additionally, some new intersection control innovations that may be necessary for enhancing CV operations include freight signal priority and the ability for PDDs to trigger pedestrian walk calls in order to cross intersections safely.

While Texas has begun investing in CV infrastructure, challenges exist to widespread adoption of the technology. Enabling this type of connectivity in the freight ecosystem has relied on instrumenting trucks with onboard units (OBUs) and installing roadside units (RSUs), with a corresponding challenge for the public sector in deciding how fast to deploy RSUs. Fleet owners have been hesitant to install OBUs because of the cost and the time required for installation with little return due to the lack of CV infrastructure. At the same time, public agencies want to deploy CV technology that will be used immediately.

Simultaneously, the spectrum is controlled at the federal level, and recent rulings by FCC have led to changes in the spectrum allocation. Existing DSRC licenses are able to continue operating in the upper 30 MHz; however, existing operations in the lower 45 MHz are required to cease operations after the one-year transition period. FCC is seeking comments on the appropriate transition paths for existing DSRC operations. FCC has embraced C-V2X and allocated bandwidth for those communications. Moving forward, the public and private sectors will need to work together to deploy CV technology at a similar pace so that there are adequate returns for both entities and with due consideration to the areas of information versus safety applications. CV technology ties back to automated developments, too. CV technology enables AVs to communicate with the road and other traffic. As of yet, it is unclear whether connectivity is essential to the success of automated freight or tangential. Automated freight developers have generally described connectivity as a “nice to have,” not a “must have.”

Infrastructure Close-Up

Texas has started building the CV ecosystem across a number of deployment projects. Cities have done small pilot deployments on local roadways to understand how CVs might fit into the existing network. TxDOT has developed standards for smart work zones, enabling them to broadcast information.

The largest CV freight project in the state is the Texas Connected Freight Corridors (TCFC) project, which will instrument the Texas Triangle. In addition, freight partners have joined the project and will equip their vehicles to communicate with the deployed RSUs. This project sets up a foundation for CV technology that Texas can build on to realize the potential benefits. Through these efforts, the state can develop standards, collect lessons learned, and identify high-value deployment locations. The adoption rate of OBUs will take time to increase, but the presence of RSUs makes acquiring a CV more appealing. Texas should continue to invest in building the network of RSUs and educate consumers on the benefits of CV technology.

RSUs and OBUs operate by transmitting and receiving information, which must be done over a common frequency for the two to make a connection. DSRC and cellular communications (C-V2X) have been the two most popular solutions for communications with implementations of both. While DSRC was operating on a 75-MHz spectrum in the 5.9-GHz band, a recent FCC ruling allocated the lower 45 MHz of the safety band to unlicensed usage and reserves the upper part of the bandwidth for C-V2X. Existing DSRC licenses are able to continue operating in the upper 30 MHz; however, existing operations in the lower 45 MHz are required to cease operations after the one-year transition period. FCC is seeking comments on the appropriate transition paths for existing DSRC operations (7).

The option of using the cellular network (C-V2X) is the most immediate alternative in any situation where DSRC is no longer viable. The network has existing coverage for a broad majority of the country and provides another option for quickly transmitting information. However, there are concerns about the ability for cellular communications to perform with the same low latency that DSRC can achieve, which enables high-value safety applications. The development of dual-mode devices has been explored and may provide a short-term bridge while DSRC is still allowed to operate. This shifting landscape has made the recent conversations surrounding CV technology more complex, but the FCC ruling provides a clear direction for the marketplace to advance in the future.

Opportunities

Texas has made great strides in putting together CV deployment projects early on and should continue to support the growth of this technology. CV technology is not among the highest priorities for highly automated truck companies because it only supplements operations, but there is still value in CV investments. The Freight and Delivery Subcommittee of the Texas CAV Task Force has identified the following opportunities for Texas:

- Expand the Texas connected freight network to include local roads, using the TCFC project as an opportunity to develop critical applications, gain experience in CV technology, and formulate best practices for deployment.
- Continue to discuss information-sharing opportunities with the private sector, including items related to geometry, signage, and safety.
- Work with the private sector to identify opportunities for increased CV connectivity and technology, and work with partners to identify high-priority applications and locations for future efforts.
- Provide information on executed and planned CV deployments to the public and educate them on the benefits of adopting the technology.

Summary of Freight and Delivery Subcommittee Opportunities

In summary, the Freight and Delivery Subcommittee of the Texas CAV Task Force has identified the following opportunities for Texas:

- Prioritize roadway maintenance along CAV corridors, focusing on lane striping, pavement quality, and signage.
- Sponsor research into gaps in common infrastructure challenges such as work zones, forced merges, and transfer points.
- Expand the Texas connected freight network to include local roads, using the TCFC project as an opportunity to develop critical applications, gain experience in CV technology, and formulate best practices for deployment.
- Continue to examine the potential needs for infrastructure enhancement and/or refinement, including items such as transfer points, changes to sidewalk design, and ways that multiple vehicle types can travel safety and cooperatively on the same infrastructure at different speeds.
- Continue to discuss information-sharing opportunities with the private sector, including items related to geometry, signage, and safety.
- Work with the private sector to identify opportunities for increased CV connectivity and technology and work with partners to identify high-priority applications and locations for future efforts.
- Provide information on executed and planned CV deployments to the public and educate them on the benefits of adopting the technology.

- Invest in workforce development programs that upskill workers and create new educational pathways.

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