7. Transportation Technology and Innovation

Introduction

In 2016, NCTCOG (North Central Texas Council of Governments) established an Automated Transportation Program in response to the acceleration of the trend toward automation of highway transportation. Such automation may have a significant impact on the transportation system, providing both challenges and opportunities for improvement. This chapter expands on the previous edition by describing not only the rise and impetus of vehicle automation, but also the emergence of connected vehicles and the constellation of related technologies. It also touches on the growing importance of broadband internet in facilitating innovative solutions to transportation issues like air quality and accessibility. This chapter also outlines policies designed to ensure that connected and automated vehicles and other technology solutions will be deployed in a way that best serves North Central Texas.

Mobility 2045 Update Supported Goals

Improve the availability of transportation options for people and goods.

Support travel efficiency measures and system enhancements targeted at congestion reduction and management.

Ensure all communities are provided access to the regional transportation system and planning process.

Encourage livable communities which support sustainability and economic vitality.

Ensure adequate maintenance and enhance the safety and reliability of the existing transportation system.

Pursue long-term sustainable revenue sources to address regional transportation system needs.

Provide for timely project planning and implementation.

Develop cost-effective projects and programs aimed at reducing the costs associated with constructing, operating, and maintaining the regional transportation system.

Transportation Technology Policies and Programs

The Mobility 2045 Update includes the following policies to guide attainment of transportation technology goals:

TT3-002: The region will develop and implement data sharing best practices that are project- and outcome-focused, serve the public interest, and comply with privacy and cybersecurity requirements, without infringing upon private sector proprietary information requirements.

TT3-006: The region will support automated vehicle and related transportation technology deployments that advance the goals of the Mobility 2045 Update by fostering public-private partnerships among local transportation authorities, technology developers, and commercial/industrial hubs.

TT3-007: The region will support consistent and high-quality maintenance and operations of its transportation system, including utilization of new technologies which offer a cost-efficient method of linking asset management to data collection.

TT3-010: The region will pursue its goal of becoming a "Region of Choice" by exploring emerging mobility technologies which offer new modes of transportation and those which enhance existing modes of transportation.

TT3-011: New transportation technologies must be deployed in a manner consistent with Mobility 2045 Update goals of providing the public with a transportation system that is equitable, protects the safety of all users, offers the public more travel options, is well maintained and operated, is environmentally responsible, and prepares the region for innovations in transportation and mobility infrastructure that will accelerate its future economic development.

TT3-012: The region will prepare for future innovations in both transportation and infrastructure by developing analytical tools capable of assessing traditional transportation projects against alternatives such as new mobility technologies, C-V2X (connected vehicle-to-everything) innovations, more effective use of existing assets, and demand management tools.

TT3-013: The region will work with educational institutions at all levels to develop workforce training solutions to prepare area residents for job opportunities in the emerging transportation technologies sector, to pursue funding opportunities, and to support deployments of automated vehicles and other emerging transportation technologies.

TT3-014: The region will prioritize the safety of all transportation system users in and through the deployment of emerging modes of transportation such as e-scooters, e-bikes, automated vehicles, and delivery robots through the use of strategic technology, design, and policy solutions.

The Mobility 2045 Update also includes the following programs to reach transportation technology goals:

TT2-006: AV2.0

TT2-007: Freight Optimization

TT2-008: North Texas Center for Mobility Technologies

TT2-009: Connected Vehicle Data for Operations

TT2-010: Workforce Development

TT2-011: Emerging Transportation Technology Deployments

TT2-012: Innovation Grants for Local Partners

Additional details on these programs can be found in the **Transportation Technology** appendix.

Programs

By continuing to monitor developments in the transportation sector and engaging with the public and regional partners, NCTCOG will plan for and adapt to the three related developments that are advancing transportation technology and service models: automation, electrification, and shared mobility.

While much of this work will take place in the ordinary course of designing, building, and operating roadways and other parts of our transportation system, in April 2017, the Regional Transportation Council approved approximately $2.5 million to fund projects to advance automated vehicle technology and prepare the region for automated vehicles. These projects include:

- Two pilot programs for low-speed automated vehicles.
- Use of IH 30 between Dallas and Fort Worth as a test corridor for high-speed automated vehicles.
- Further development of the data infrastructure to support automated vehicles.
- Support for the next-generation people mover system using automated vehicle technology.

Transportation Technology and Innovation Program

The TTIP (Transportation Technology and Innovation Program) is NCTCOG's response to the future. To prepare for the future while shaping an envisioned future for North Central Texas, the program is built along three LOE (lines of effort):

LOE 1: Transportation Technology and Innovation: Catalyzing technology development and deployments

LOE 2: Connectivity and Innovation Workforce: Expanding broadband access/usage across Dallas-Fort Worth—necessary to make connected vehicle-to-everything available to all and promote telecommuting and other virtual connections—and building next-gen transportation workforce via "agile curricula."

LOE 3: Connected Vehicle-to-Everything and Transportation Data Infrastructure: Data infrastructure to support connected vehicle-to-everything, leverage Cloud to improve operations, and level the playing field through regional licensing/programs giving all local partners access to emerging connected vehicle data tools.

Seven project categories fall within these levels of effort, as described in **Exhibit 7-1**.

AV 1.0/2.0

TTIP follows in the footsteps of previous work and shares the DNA of preparing for the future of transportation by improving conditions for drivers and transit users, today. The initial period of TTIP's work is split into AV1.0 ("Automated Vehicles 1.0") and AV2.0. The work in AV1.0 centered around two main efforts: automated vehicle deployments and data sharing. Both efforts yielded strong successes: from 2016 to 2019, multiple automated vehicle deployments occurred (and are still occurring) throughout North Texas. Data sharing involved several elements. First, TTIP staff worked tirelessly to recruit local partners to join the open data sharing initiative launched through Waze, known as the Connected Citizens Program (now Waze for Cities). During this time, NCTCOG also awarded data sharing grants as a way to help selected cities improve their traffic data collection and sharing capabilities.

Exhibit 7-1: Transportation Technology and Innovation Program Level of Effort Project Categories

Project Category	Description	Lead If Applicable
Regional Innovation	Competitive grant program for transportation-related innovative projects	Regional partner driven
Emerging Vehicle Pilots	Continuation of AV2.2/2.3 but encompassing wider range of vehicle types	NCTCOG driven
Broadband/ Communications	Improve broadband access/virtual connections to jobs, education, medicine	
Workforce/Universities	Next generation transportation workforce development; build Dallas-Fort Worth tech talent base in transportation	
Connected Vehicle Data Infrastructure	Getting infrastructure data (e.g., road closures, crashes) to automated vehicles/connected vehicles to improve operations	
Cloud-Based Roadway Optimizations	Build on freight optimization tech platform to improve vehicle flows/operations on roadways (e.g., transit signal priority, green light speed advisories)	
Connected Vehicle Data Platforms for Partners	Regional licenses so all local partners can access data platforms to improve safety/operations; extensive training	

As a phase of characteristic program activities, AV2.0 also includes automated vehicle deployments and infrastructure enhancements. Multiple automated vehicle deployments have launched across Dallas-Fort Worth, including cities such as Arlington and Frisco. Notably, Dallas-Fort Worth has become a nationally-significant hub for automated freight technology. Self-driving trucks are already operating on our highways.

Finally, an important project that rounds out the work of AV2.0, is the Dallas-Fort Worth Freight Optimization Project. This is a pilot initiative to use emerging Intelligent Transportation System technology to detect and prioritize truck movements at signalized intersections near freight hubs in an effort to develop more responsive methods of coordinating truck and vehicle movements near freight centers.

Why Connected and Automated Vehicles?

In recent years, automated vehicle developers and transportation network companies have viewed several challenges facing the existing transportation system as opportunities for technological and business innovation. The developers of automated vehicles have identified two things that roadway operators can do to optimize the operations and safety of automated vehicles. First, well-maintained roads with good quality lane striping are key to successful operations. Second, by sharing accurate information about changes to roadway conditions as a result of events, such as lane closures for construction work, roadway operators can help improve the operation of automated vehicles. It is noteworthy the actions that will advance the successful operation of automated vehicles will also improve the operation and safety of human-driven vehicles.

Reduction in Economic Gains

While the highway system delivers benefits to society, it has not advanced in any significant way for the past half century. Highway speeds remain about where they were in the past. Consistency has not improved regarding the time it takes to travel the same route from day to day, known as travel time reliability. Traffic congestion levels remain high despite billions of dollars in investment in new or expanded highways. While construction of the Interstates delivered substantial economic benefits because the Interstates offered a significantly improved form of highway travel, fewer economic gains are delivered by most highway investments today that add capacity to the Interstate Highway System and similar expressways.

Transportation Costs and Accessibility

Transportation is the second-highest cost for many households. The average cost of owning and maintaining a vehicle is roughly $10,000 per vehicle per year.[1] In auto-dependent areas such as North Central Texas, households may need multiple vehicles for household members to access jobs, healthcare, shopping, entertainment, and other needs. In low-income areas, transportation costs can eat up as much as a third of the household's income.[2] The costs associated with vehicle ownership make it difficult for some households to pay for other necessities or to invest in education or entrepreneurial efforts that will help the household advance up the economic ladder. The US Department of Transportation has found that North Central Texas has the highest percentage of households that own one or more vehicles of any major metropolitan region in the United States.[3] Some studies have indicated this region also has relatively high levels of income inequality and low levels of social mobility, which may be a partial function of the high cost of transportation for low-income households.[4]

[1] US Bureau of Labor Statistics, 2017, *Economic News Release: Consumer Expenditures 2016*, https://www.bls.gov/news.release/cesan.nr0.htm

[2] The University of Texas at Arlington Center for Transportation Equity, Decisions, & Dollars, 2017, *Equity Analysis of Dallas Mass Transit*, https://ctedd.uta.edu/dart

[3] Federal Transit Administration, 2013, *Evaluating Transportation Equity: An Intermetropolitan Comparison of Regional Accessibility and Urban Form*, https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Report_No._0066.pdf

[4] Pew Research Center, 2015, *In greater Dallas area, segregation by income and race*, http://www.pewresearch.org/fact-tank/2015/06/29/in-greater-dallas-area-segregation-by-income-and-race; Simek, P., D Magazine, 2017, *Dallas' Poverty Problem Explained in a Single Map*, https://www.dmagazine.com/frontburner/2017/03/dallas-poverty-problem-explained-in-a-single-map; Nicholson, E., Dallas Observer, 2015, *Dallas Inequality in 22 Maps*, http://www.dallasobserver.com/news/dallas-inequality-in-22-maps-7559829; City of Dallas Human & Social Needs Committee, 2017, *November 6, 2017 [meeting recording]*,

Some of the region's residents face constricted access to mobility due to their inability to drive because of their age or abilities. The number of these residents will grow between now and 2045 as the population of individuals aged 65 and older increases.[5]

Inefficiency of Private Vehicle Ownership

There are inefficiencies and costs associated with private vehicle ownership. Despite their high cost, vehicles sit idle for over 90 percent of the time.[6] Vehicles are designed to carry multiple people but carry a single person on most trips. This low occupancy, or vehicle load factor, is much lower than the load factors on bus, rail, and air transportation vehicles. The need for parking facilities to accommodate large numbers of vehicles requires the use of large amounts of land and other resources. As many as eight parking spaces per vehicle may be available.[7] These spaces, like vehicles themselves, sit empty most of the time. In some urbanized areas, parking spaces and roads together may take up over 25 percent of the land, creating impervious surfaces that prevent rainfall from being absorbed, potentially increasing flooding.

At the same time, personal vehicle ownership appears to be preferred by many and has some efficiency benefits, namely, immediate access to vehicular transportation.

Safety

Vehicle safety has improved over the long term, due largely to incremental improvements in vehicle design such as air bags, and improved highway design such as expressways with good pavement markings and generous space for lane merging. Despite this trend, vehicle crashes remain a public health problem and impact the economy. Future crash, injury, and fatality totals will likely vary due to changes in population and transportation modes but remain an important factor in the transportation system.

The costs of vehicle crashes are high. In a 2015 study, the National Highway Traffic Safety Administration estimated that crashes imposed direct costs of $242 billion and indirect costs of $594 billion on the US economy in 2010. Direct economic costs were equal to approximately 1.6 percent of US gross domestic product.[8]

Highway safety performance in the United States has lagged behind the performance of other developed countries in recent years.[9] Between 2010 and 2018, the United States was one of only 4 out of 30 developed countries that saw an increase in the number of vehicle occupant fatalities.[10] With respect to pedestrian fatalities from vehicle crashes, the United States had the worst performance of all 30 developed countries, with an increase of over 40 percent in pedestrian fatalities over the 2010 to 2018 period, when most countries saw a decrease in pedestrian fatalities.[11]

In recent years, automated vehicle developers and transportation network companies have viewed the challenges of economic gain, transportation cost and accessibility, inefficiency of private vehicle ownership, and safety as opportunities for technological and business innovation.

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https://dallastx.swagit.com/play/11062017-625; Dallas Morning News, *Five ways the American Dream is broken for Dallas' working poor*, https://www.dallasnews.com/opinion/editorials/2017/07/20/5-ways-american-dream-broken-dallas

[5] Office of the State Demographer, 2014, *Texas Population Projections, 2010 to 2050*, http://demographics.texas.gov/Resources/Publications/2014/2014-11_ProjectionBrief.pdf

[6] Morris, D.Z., Fortune, 2016, *Today's Cars Are Parked 95% of the Time*, http://fortune.com/2016/03/13/cars-parked-95-percent-of-time; The Economist, 2017, *The perilous politics of parking*, https://www.economist.com/news/leaders/21720281-average-car-moves-just-5-time-improve-cities-focus-other-95-perilous

[7] Chester, M., Horvath, A., & Madanat, S. 2010. Parking infrastructure: energy, emissions, and automobile life-cycle environmental accounting. *Environmental Research Letters*, (5)3, http://iopscience.iop.org/article/10.1088/1748-9326/5/3/034001/meta

[8] National Highway Traffic Safety Administration, 2015, *The Economic and Societal Impact Of Motor Vehicle Crashes, 2010 (Revised)*, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013

[9] International Transport Forum, Road Safety Annual Report 2020, https://www.itf-oecd.org/road-safety-annual-report-2020

[10] Id. at Figure 7

[11] Id. at Figure 8

Vehicle Automation and Related Developments

At the time the original Mobility 2045 was published, automated vehicles occupied the foreground in transportation innovation. However, since then, technologies related to the rise of automation have gained more traction and are moving to the fore of development and adoption. It is unclear, at this time, where these developments will go and their impact on the transportation system. North Central Texas should be prepared, however, for the possibility of significant changes between 2023 and 2045.[12]

While the actual impacts of widespread vehicle automation remain hidden from us, modelling conducted by a range of sources has identified some of the potential challenges that driverless cars might bring:

1. Automated vehicles take up as much space as standard vehicles, which means that swapping automated vehicles for today's vehicles will not reduce the space requirements—roadways and storage—for vehicles.
2. Introduction of new safety/security risks associated with automated driving technologies.
3. If roadways remain largely unpriced, automated vehicles may reduce the cost of distance by a significant margin, which will lead to more vehicle miles traveled.
4. It is not obvious that much of the public will shift to shared automated vehicles, which is one key way to manage possible increased vehicle miles traveled from automated vehicles.

These are some of the possible downsides of automated vehicles. Many possible upsides exist and are listed in the next sections. First, though, is a look at the bigger picture of transportation innovation trends shaping the future of how we move between places.

[12] Steven E. Shladove, "'Self-Driving' Cars Begin to Emerge from a Cloud of Hype," 'Self-Driving' Cars Begin to Emerge from a Cloud of Hype - Scientific American

Trends in Emerging Mobility Technologies

The new, durable transportation technology regime seems to be anchored around communications, mapping, and vehicle-generated data. Communications is the centerpiece of the new transportation innovation order. One could say this has always been the case. The existing roadway system relies on a complex web of physical and non-physical communications systems to operate freely. Physical systems (e.g., traffic lights, signs, paint) create the world of the road by which we are able to navigate. Meanwhile, the legal code establishing the rights, rules, and orders of driving is the invisible infrastructure keeping drivers in their lanes. Additionally, drivers rely on physical gestures, special driving tactics, and the tools of the vehicle (e.g., signals) to coordinate their movements further.

Thinking about the way drivers operate in this intricate communication network of visible and invisible systems allows us to fully appreciate the role that communications technologies are beginning to play in the future of driving. Three examples below highlight technology responses to these visible and invisible systems.

5G and Connected Vehicle-to-Everything. The direct communication between vehicles and between vehicles and infrastructure will rely on robust cellular networks capable of low-latency communication.

Emerging Technology Opportunities

Automated vehicle freight and shipping

North Texas boasts a giant inland port so automated freight and shipping is taking off in our region. This will only increase in the coming years and decades.

Automated delivery

A variety of automated delivery formats are in development or already in use across Dallas-Fort Worth. This ranges from small sidewalk delivery robots to larger golfcart-sized delivery bots. Automated delivery technology extends upward in size to vans and small trucks (e.g., Ford Transit).

Transit connections and transit-oriented development footprint expansion

Automated people-mover shuttles offer an exciting opportunity for expanding the footprint of transit-oriented developments. The typical transit-oriented development footprint extends out to a quarter-mile, but with a system of on-demand automated vehicle shuttles, that footprint could be extended outward to 2 to 3 miles.

Fiber network and 5G connectivity: broadband access for all

Transportation technology encompasses virtual travel, as well as physical travel. The amount of trips on the roadway systems is directly affected by the share of virtual travel taking place. The critical task in coming decades is providing access to reliable broadband available on a wider scale.

Vehicle data platforms: open-source data and asset management technologies

An entire ecosystem of connected vehicle data technology is springing up as automated vehicles continue to develop. These data platforms extend far beyond automated vehicle applications, however, to include open source mapping, incident reporting, and vehicle/driving behavior. Asset management technologies can now use artificial intelligence and video-based platforms to monitor, catalogue, and assess pavement conditions and roadway furniture.

Workforce development: Dallas-Fort Worth university strength in transportation

Vital to the successful implementation and safe deployment of new technologies is a well-prepared workforce. This ranges from top-tier research capabilities to high-skill mechanical and service trades which will be needed to support innovation and growth.

Edge Computing and Cloud Computing. This is a vital element in the success of a cellular communications order as it facilitates the ability for automated vehicles to communicate with each other in way that allows robot drivers to make decisions.

Mapping via Vehicle Data. Automated vehicles require up-to-date and highly accurate information about roadway rules and conditions. Data collected from vehicle sensors, analyzed using Artificial Intelligence/Machine Learning tools, and distributed to vehicles via the Cloud will be the key components of this system.

These three systems represent a shift from traditional transportation data-gathering tools, which were primarily installed and operated by transportation departments and used to convey information to human drivers. Instead, autonomous vehicle manufacturers, governments, and others will be harvesting extensive data from vehicles and using this information to guide both automated vehicles and human drivers as they navigate roadways. DOTs (Departments of Transportation) will contribute key information to this roadway data ecosystem such as up-to-date information about lane closures at construction sites and will license information based on vehicle sensor data rather than investing heavily in their own closed system of roadway sensors.

It has also become apparent that automated vehicle developers are not relying on DOTs to take responsibility for any of the driving tasks handled by automated vehicles. Today, DOTs provide streets and signage, but are not involved in the driving tasks handled by human drivers. Likewise, DOTs will continue to provide streets and signage for automated vehicles—perhaps in the form of digital road rules—but the driving tasks will be the responsibility of automated vehicles, not the DOTs. This development likely means that initiatives will have to shift away from US Department of Transportation and others from the public sector playing a central role in supporting automated driving (through public vehicle-to-vehicle and vehicle-to-infrastructure using dedicated wireless spectrum).

Vehicle Automation

Automation is well established in the transportation sector. Dallas Fort Worth International Airport, for example, has an automated people mover system. Buildings in the region have elevators that travel automatically. Much of the flight time for the commercial aircraft accessing Dallas Fort Worth and Love Field airports is done on autopilot.

There have been efforts to automate highway transportation for over a century. These efforts cover a spectrum that, at one end, features "smart vehicles" that are designed to perform all of the driving functions themselves, commonly known as "autonomous vehicles," and the other end of the spectrum features "smart highways" that direct vehicle operation. For purposes of the Mobility 2045 Update, the term "automated vehicles" is used to cover the whole spectrum.

There are multiple levels of vehicle automation (**Exhibit 7-2**), as illustrated by this Society of Automotive Engineers classification that was recently adopted by the US Department of Transportation.[13]

[13] https://www.sae.org/blog/sae-j3016-update

Exhibit 7-2: Levels of Vehicle Automation

SAE **J3016™** LEVELS OF DRIVING AUTOMATION™

Learn more here: sae.org/standards/content/j3016_202104

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	SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	**You are driving** whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			**You are not driving** when these automated driving features are engaged – even if you are seated in "the driver's seat"		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
	These are driver support features			These are automated driving features		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering **OR** brake/acceleration support to the driver	These features provide steering **AND** brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions
Example Features	• automatic emergency braking • blind spot warning • lane departure warning	• lane centering **OR** • adaptive cruise control	• lane centering **AND** • adaptive cruise control at the same time	• traffic jam chauffeur	• local driverless taxi • pedals/steering wheel may or may not be installed	• same as level 4, but feature can drive everywhere in all conditions

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In the past decade, automated vehicle developers have utilized improvements in computing power, sensors, and artificial intelligence to make strides toward rolling out vehicles with a high degree (Level 4) of automation. Auto manufacturers are developing and testing automated vehicles for street and highway use. These vehicles have the same general design as today's vehicles, but with additional sensors, computing power, and automated driving software.

Low-Speed Automated Shuttles

Low-speed automated shuttles are another important category of automated vehicles. These shuttles typically accommodate about 10 people, travel at up to 25 miles an hour, and have a service range of roughly two miles. They are currently being deployed in closed campus-like environments. Test deployments of such vehicles are now occurring on low-speed public streets.

Freight Sector

The freight sector has emerged as a key automated vehicles sector and North Central Texas is a center of development. A number of firms that have automated long-distance freight transportation have operations hubs in the region. Other developers that are locating in North Central Texas focus on automating vehicles in other segments such as business-to-business deliveries and freight yard operations. Others are automating last-mile deliveries with sidewalk delivery bots. Experts predict vehicle automation will proceed more quickly in the freight sector than in the human passenger sector.[14]

Teleassist, Teleoperation, and Robot Valet Services

Two other related technology advancements deserve mention. First, automated vehicle developers are increasingly using teleassist and teleoperations to supplement automated vehicles. In teleassist, remote operators respond to questions posed by the automated vehicle as it navigates through difficult situations such as an unexpected road blockage. Teleoperation involves the actual driving of a vehicle by a remote operator using a robust communications network.

The city of Arlington operates the Milo autonomous vehicle during events in the Entertainment District. (*Source: City of Arlington*)

The second advancement is robot valet services, namely having a vehicle park itself at a parking facility after its occupants disembark at a destination. Robot valet services can increase the storage capacity of parking facilities by approximately 20 percent and potentially eliminate the sometimes long treks to and from parking facilities. If robot valet technology becomes established, it may have significant implications for how both destinations and parking facilities are designed.

Automated Vehicle Public Policy

Automated vehicles are being actively developed around the world by auto manufacturers, tech companies, and universities. Governments at all levels throughout the world are supporting automated vehicle research and development, recognizing the

[14] Steven E. Shladove, "'Self-Driving' Cars Begin to Emerge from a Cloud of Hype," ['Self-Driving' Cars Begin to Emerge from a Cloud of Hype - Scientific American]

potential transportation and economic development benefits of such technology.

Most automated vehicle developers today are focused on developing autonomous vehicles, observing that it might take decades for the public sector to invest in the kind of roadside infrastructure necessary to allow semi-autonomous vehicles to run in full automation mode. Such developers have identified two key things the public sector can do to support the deployment of automated vehicles:

- Implement high roadway maintenance standards such as high-quality lane marking; this is essential in helping automated vehicles "see" roadway elements and navigate accordingly.
- Share the data governments have about roadways—especially road and lane closure information—to help support the safe operation of automated vehicles.

Within the next decade, and certainly by 2045, most of the vehicle fleet will have a direct high-speed connection to the internet. This connection will allow vehicles to share information about roadway conditions with each other. For example, a vehicle that encounters a lane closure can share that information with the mapping firms that provide real-time roadway information to automated vehicles. Such firms will update the maps for the automated vehicles approaching the lane closure.

5G wireless communication will allow fast communication among vehicles and between vehicles and internet-based services and software. It will be important that highways and streets have robust wireless coverage in order to support automated vehicle operation.

Vehicle Electrification

A global shift to electric vehicles appears to be under way. China and a number of European countries have committed to phasing out new internal combustion engine vehicles by 2045 or earlier. Reductions in the cost of batteries and other improvements have made electric vehicles more price- and performance-competitive with internal combustion engines.

Notably, California became the first state to require that by 2030 all light-duty automated vehicles must be fully electric.[15] Through similar legislation or incentives, this state might use automated vehicles to help accelerate the electrification of our vehicle fleet.

Electric powertrains support a wide variety of vehicle types, including automated shuttles and personal vehicle "pods" that may someday be automated. Electric vehicles whose forms and functions fill the gap between electric bikes and the standard automobile may be developed. These vehicle types will include the automated shuttles that are being deployed on a pilot program basis at sites around the world. For more on electric vehicles, see the **Air Quality** section in the **Environmental Considerations** chapter.

Shared Mobility

Shared mobility services, including car sharing, ridesharing, and bike sharing platforms, have emerged in the past decade, and have impacted the transportation system. These services have attracted consumers with the services' flexible and convenient mobility, powered by apps that handle ride hailing, payment, and navigation.

Shared mobility services have proven popular with consumers, and the market is growing. Where today, shared mobility services in the region cover well under 5 percent of all trips, it is forecast that by

[15] https://www.theverge.com/2021/9/24/22691410/california-autonomous-vehicles-zero-emission-2030-newsom

2030, a significantly greater percentage of all trips in the region will be handled through shared mobility services.[16]

Developers around the world are working with these three elements—automation, vehicle electrification, and shared mobility—to advance major changes to the surface transportation system. Most automated vehicles are being developed on an electric vehicle platform. Shared mobility services—not individual consumers—are likely to be the first big customers of automated vehicles. Unmanned electric vehicles in continuous operation deployed in fleets could offer mobility at a lower per-mile cost than today's privately-owned vehicle. Shared mobility services, where multiple users ride in the vehicle at any one time, could drive down the per-mile cost even more.

According to this vision of the future, the cost of automated vehicle services would drop below the cost of operating a personal vehicle. This would lead people to shift to a model of mobility as a service. Rather than investing in an expensive capital asset on wheels that sits idle most of the time, many people would prefer to pay for just the amount of mobility they need. Just as people book and pay for only the amount of airline travel they need rather than owning their own jetliner, they would be able to do the same with their surface transportation, namely, consuming just the amount of vehicular mobility they need. The consumers' cost-driven preference for lower-cost automated vehicles would increase the demand for automated shared mobility services and accelerate the transition to automated vehicles. Ultimately, more mobility would be consumed by more people at a lower per-mile cost and a greater level of safety than before. However, there is uncertainty in this popular vision of the future, as discussion in the next section.

Possible Impacts on Transportation System

A great deal of uncertainty is associated with automated vehicles. Automated vehicle technology would need to improve, consumers would have to accept riding in shared automated vehicles, and automated vehicle fleet operators would have to be able to develop a sustainable business model.

Despite progress, there is no assurance that automated vehicle technology will advance sufficiently to support pervasive Level 4 automation. There is no assurance that consumers will accept automated vehicles or embrace a shift from private vehicle ownership to mobility as a service. Likewise, there is no assurance that consumers will embrace multi-occupant vehicle shared mobility services that, with automation and electrification, can greatly improve the performance of the highway transportation system.

Just as there is no consensus about the timing and extent of the widespread adoption of vehicle automation, there is no consensus about the impact of automated vehicles should they be introduced successfully and embraced by consumers. Some of the anticipated impacts include:

- An increase in demand for mobility might result if automated vehicles can reduce the per-mile cost of mobility and eliminate the age and other requirements of a driver's license. As noted previously, the upward pressure on vehicle miles traveled and the North Central Texas roadway system could be mitigated, if not counteracted entirely, by shared mobility vehicles carrying multiple occupants.

[16] Morgan Stanley, 2016, *Shared Mobility on the Road of the Future*, https://www.morganstanley.com/ideas/car-of-future-is-autonomous-electric-shared-mobility; McKinsey & Company, 2017, *How shared mobility will change the automotive industry*, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-shared-mobility-will-change-the-automotive-industry; Deloitte University Press, 2016, *The future of mobility: What's next?*, https://www2.deloitte.com/content/dam/insights/us/articles/3367_Future-of-mobility-whats-next/DUP_Future-of-mobility-whats-next.pdf; The Boston Consulting Group, 2017, *By 2030, 25% of Miles Driven in US Could Be in Shared Self-Driving Electric Cars*, https://www.bcg.com/d/press/10april2017-future-autonomous-electric-vehicles-151076

- The land-use impacts of automated vehicles may be significant, depending on whether automated vehicles are deployed mainly in fleets or in the current model of private vehicle ownership. Possible impacts might include:
  - Reduced amount of land required to accommodate vehicle parking, freeing up the land for other uses.
  - Increased demand for housing in outlying areas by people who are willing to tolerate long commutes because they can do work while traveling in automated vehicles.
  - Increased demand for housing in higher density urbanized areas as people opt to end or limit their private vehicle ownership in favor of pay-as-you go mobility through automated vehicle fleets.
  - Increased clustering of housing and businesses because of the reduced need for surface parking.
- Building design may change because electric vehicles are able to operate inside enclosed facilities, allowing for in-building pick-up and drop-off zones; likewise, robot valet services may change circulation patterns at major destinations.
- Roadway design may change to accommodate automated vehicles. These changes might include:
  - Narrower lanes.
  - Heavier investment in infrastructure, such as fiber and small cells, which supports robust wireless communication solutions, such as 5G, that enable automated vehicles.
  - Road markings and other visual features to help automated vehicles better read the roadway path.
  - Electronic beacons to help guide automated vehicles and help reduce the distance between vehicles, increasing roadway capacity.
  - Reduced signage and dynamic message signs targeted at human drivers.
  - Dedicated lanes for special uses, such as automated vehicles or truck platooning, when trucks communicate with each other to coordinate their movements.
  - Accommodation of new vehicle types that emerge from the intersection of vehicle automation and electrification such as smaller vehicles that require less lane width.
- Gas tax revenues could drop faster than otherwise projected if automated vehicles, developed primarily on an electric powertrain platform, capture a significant share of trips. This could necessitate a fee associated with vehicle miles traveled or other tax to provide revenue to fund the building, maintenance, and rehabilitation of roads.
- Highway operations and planning could change as a result of the extensive data vehicles will gather and disseminate in real time. Such data, which will include video and Lidar, will allow emergency responders to assess the nature and severity of an incident before deploying emergency resources, potentially improving the quality of the response and reducing the costs associated with emergency response. Such data will be mined to identify roadway trouble spots, such as areas where vehicles are swerving or braking suddenly, that can be targeted for investments that improve safety. Such data can also assess the efficacy of roadway investments.
- Changes in transportation and land use policies and incentives, prompted by the public's support for active transportation options or the need to reduce carbon dioxide emissions, may reduce the demand for vehicle trips as people access more destinations using methods other than standard-sized vehicles.

The impact of automated vehicles on travel behavior is not known at this time. It is unknown whether:

- Automated vehicle technology will mature sufficiently to be widely deployed.

- Consumers will accept automated vehicle technology even if that technology matures sufficiently to allow for widespread deployment.
- The private vehicle ownership model will continue with the arrival of automated vehicles or whether consumers will embrace a mobility-as-a-service model where they pay for the mobility they need from mobility services providers rather than own their own vehicle.
- The evolution of vehicles to become places where drivers and other occupants can work, shop, and consume entertainment while en route will change the consumer tolerance for trips lengths and times.
- Automated vehicles will advance transportation equity by giving more people access to affordable transportation or whether the benefits of automated vehicles will be limited to more fortunate socio-economic groups.

These and other uncertainties make it impossible to confidently predict the deployment and impact of automated vehicles. What is certain is that after a stable operating model for the past half century, the highway transportation sector is being impacted by the same advances in digital technology that have transformed other sectors of our economy and society such as retail, banking, entertainment, and communications.

Technology and the Future

Broadband Internet

Broadband internet is of growing importance to transportation. The core elements affected by this important topic are access to the internet (see the **Social Considerations** chapter), physical infrastructure and the uses of internet for transportation (see the **Operational Efficiency** chapter), and the transportation-communications nexus (in this chapter). Broadband internet's importance is demonstrated by the following:

- Air quality benefits result from telework, which is the most prominent use of internet in transportation.
- The internet increases access in the same way railroads or planes have done in the past.
- Physical rights-of way are evolving to more than pavement, meaning urban environments will see more varied use of this public infrastructure in the future (incorporating fiber, solar panels, charging stations, etc.).

Virtual Travel: A New Transportation Technology Opportunity

The COVID-19 pandemic introduced many North Texans to "virtual travel" to their destinations. Using computers, software like Teams and Zoom, and broadband communications, many people worked, learned, received medical treatment, worshipped, engaged with family members, and the like virtually rather than via physical travel.

The pandemic also exposed inequities and challenges. Many jobs still require in-person attendance in the workplace. Many essential workers—disproportionally from lower income and minority communities—had to continue working in public settings.

A key purpose of the transportation system is to connect people to their destinations. As more people connect virtually to more of their destinations and activities, it becomes necessary to think of "virtual travel" as an emerging and likely growing complement of travel in physical space.

Such virtual travel may replace some trips. Telecommuting, for example, may be a valuable way to reduce demand for roadway travel at peak AM and PM periods, which is when most congestion occurs. However, it is better to think of virtual travel as a way to help people access more destinations and life activities in a given amount of time—some trips via physical travel and some trips via virtual means. Providing people with both modes of travel gives them access to more opportunities and activities than if they have access to only one mode.

Just as railroad tracks, expressways, and air space accommodated new modes of travel and allowed people to connect with more destinations, broadband-enabled virtual travel is an emerging form of transportation that will do the same. Regions that offer people robust options for both physical and virtual travel will likely fare better in the future than regions that offer their people just one. Virtual travel may turn out to be especially important in relatively low-density urban regions like North Central Texas where the financial and environmental costs of moving people in physical space are high.

The following elements will be important for virtual transportation to emerge as a robust travel mode, just as passenger aviation emerged, literally out of thin air, roughly a century ago.

Broadband Access: People need broadband access in order to utilize virtual transportation. Access requires broadband infrastructure, appropriate connectivity devices such as laptops and smartphones, and skills. The North Central Texas Council of Governments is actively working to facilitate broadband access through its transportation program.

Improved Virtual Tools: Developers are actively working to improve the quality of virtual connections via improved software and new devices such as virtual reality headsets. Such tools, enhanced by improved communications networks and improvements in robotics, will allow an increasing percentage of jobs to be performed remotely. These improved tools will allow more activities—from jobs to worship—to be conducted virtually in ways that make them attractive alternatives to travel in physical space.

Policies/Practices: Improved virtual travel tools and pervasive broadband access alone will not guarantee that virtual transportation will become a major travel mode. Policies and practices by both public and private entities will have to facilitate virtual travel as a way for people to access destinations and life activities. The Regional Transportation Council's adoption of a policy encouraging North Central Texas employers to convert at least 20 percent of their work-related trips to virtual travel is a step in that direction.

The impact of virtual travel on transportation on roads and transit in physical space is not yet known. As noted above, If virtual travel can become well established, it is possible the transportation system will provide the average person with access to more destinations—both physical and virtual—while demand for travel in physical space may moderate. Yet, preliminary indications from the pandemic suggest that people connecting remotely for professional work may actually take more short trips on a daily basis than they did when they traveled to an office.[17] The virtual transportation mode, in short, is likely to give people more choices and more opportunities, but not significantly change the existing demand for movement in physical space.

An Agenda for Future Mobility

An agenda for future mobility means staking out the broad outline of how to effectively solve transportation pinch-points of the future through applying the technologies we anticipate becoming widespread in the future. Even as technologies and possibilities are emerging, we must also consider likely constraints. Once we survey emerging technology and give thought to constraints, the Dallas-Fort Worth region can mark out its agenda.

[17] Bureau of Transportation Statistics, Daily Travel during the COVID-19 Public Health Emergency, https://www.bts.gov/daily-travel

Emerging Mobility Technology

The technology on everyone's mind is automated, self-driving vehicle technology. This is only a small part of the larger ecosystem of mobility technology. Much of the technology has been covered in this chapter above, but the wider phenomenon includes smart infrastructure systems capable of communicating with vehicles, cyclists, and pedestrians; connected vehicles communicating to each other and collecting large quantities of trip data; electric vehicles and new types of drive-trains; and even smart phones, which are fueling the boom in connected vehicle data right now.

Constraints Shaping the Future

Important constraints affecting the way these technologies are deployed now and in the future stem from the very nature of public right-of-way: Right-of-way is fixed and unlikely to see more than marginal capacity increases. Two broad ways to overcome this dilemma is to extend the right-of-way above and below grade—such as IH 35 through Austin or LBJ Expressway in Northeast Dallas. The other approach is to maximize the efficiency and utility of the at-grade right-of-way through technology solutions.

Another vital constraint facing infrastructure owners and operators has to do with funding. Trends suggest that due to efficient engine technology and growing popularity of electric vehicles, the traditional sources of surface transportation funding—gas taxes—may not have the momentum to provide needed maintenance funds in the coming decades. More on funding constraints can be found in the **Financial Reality** chapter.

Agenda for North Texas Technology Corridors

The arena for setting out our agenda is the public right-of-way, which includes two environments: the broader right-of-way and the travel-way on which traffic flows. What follows are principles for envisioning corridors of the future. These are corridors inclusive of multiple modes of travel, utilized for much more than merely travelling, and maximize safe and efficient transport through strategic, cost-effective technologies.

A keystone technology in this vision is vehicle automation, but it is important to realize that for the foreseeable future, "vision" will remain the primary form of perception for automated piloting. This includes everything from teleoperation, camera-vision, LIDAR, and radar. The implication is that a principle operative today will remain central to technology corridors going forward: Do what benefits drivers today to benefit drivers of the future, be they human or robot.

Drivers today need clear striping, consistent signage, and smooth roads to navigate effectively; pedestrians and cyclists must be seen and afforded a place. Automated driving systems, because such systems rely on vision navigation, operate optimally when afforded the same assets.

Beyond this primary principle, technology corridors adhere to these general principles:

1. Relieve capacity pressure on the system by increasing broadband access for virtual travel.
2. Leverage connected vehicle technologies as a means to facilitate roadway user charging.
3. Optimize the utilization of the public right-of-way, whenever feasible, for other uses with public benefit—e.g., solar energy banking, other forms of distributed energy generation, bioswales, and runoff water improvement.
4. Use technology solutions to improve capacity safely and efficiently before considering construction fixes.
5. Facilitate alternative fuel distribution along technology corridors such as fast-charging stations and hydrogen fuel cells.
6. Deploy technologies that foster safe, generous interactions between pedestrians and cyclists.

Equipped with these principles, the technology corridors will play a critical role in making North Texas a "Region of Choice."

Summary

The various technology developments discussed above will not, by themselves, alleviate many of the challenges associated with the current transportation system: affordability, safety, access, equity, and environmental concerns. In planning its transportation investments, the region must still ask basic planning questions; namely, will the transportation investment connect people to more destinations and opportunities, improve safety, promote equity, and advance environmental sustainability? Leveraging technology developments will follow and assist in achieving these broader regional goals into the future.