North Central Texas Council of Governments

PURDUE UNIVERSITY

KITTELSON & ASSOCIATES

AV2.1 MARKET ANALYSIS REPORT

AV2.1: Conduct a Planning Process to help the North Texas Region Prepare for Automated Vehicles and Related Technologies

August 2, 2022

AV2.1 Market Analysis Report

AV2.1: Conduct a Planning Process to Help the North Texas Region Prepare for Automated Vehicles and Related Technologies

Prepared for:
North Central Texas Council of Governments
616 Six Flags Drive
Arlington, TX 76011

Prepared by:
Kittelson & Associates, Inc.
100 M Street SE, Suite 910
Washington, DC 20003
202.450.3710

Project Manager:
Abby Morgan, PhD
Associate Engineer

Project Principal:
Gibran Hadj-Chikh
Senior Principal Planner

Authors:
Abby Morgan, PhD, PE, John Hicks, AICP, Rachel Grosso, Sean Laffey, PE, Richard Dowling, PhD, PE, Shannon Warchol, PE, Alek Pochowski, PE, Gibran Hadj-Chikh, (Kittelson & Associates); Darcy Bullock, PhD (Purdue University)

Contract Number TRN6551
Project Number 25425

August 2, 2022

Prepared in cooperation with the Regional Transportation Council, NCTCOG, and the Texas Department of Transportation.

CONTENTS

INTRODUCTION

Technology impacts all aspects of transportation, and these technologies are ever evolving. North Central Texas communities will need to incorporate emerging technologies into the planning process.

Why is NCTCOG completing this study?

Automated transportation solutions are part of the long-term transportation strategy for North Central Texas Council of Governments (NCTCOG).

NCTCOG is preparing for emerging transportation technologies through a three-phase Automated Vehicle 2.0 (AV2.0) program. AV2.0 will advance the North Texas region through planning, partnerships, and investment into new transportation technologies like automated vehicles (AVs).

The first phase of the AV2.0 program is *AV2.1: Conduct a Planning Process to Help the North Texas Region Prepare for Automated Transportation & Related Technologies*. This project will develop guidance for local agencies to proactively plan for the effects of emerging transportation technologies. This understanding and readiness will help the region apply for federal, state, or local deployment funding to deploy or support new technologies.

What information does this report provide?

The AV2.1 program focuses on emerging technologies that are expected to change the way people and goods move or to require different infrastructure or policy needs to support the new technology.

This Market Assessment Report inventories the status and trends in emerging transportation technologies, highlights likely applications and timelines for adoption for the technologies, identifies potential challenges to greater deployment, notes potential challenges to ensuring the technology is equitably available to all citizens, and identifies opportunities for public sector involvement.

When envisioning the AV2.1 program, NCTCOG used the following terminology:
"Automated Vehicle" or "AV" refers to both connected and autonomous vehicles. The term is inclusive of technologies that are precursors to the introduction of AVs, such as emerging modes of micromobility and rideshare, and related to AVs, such as vehicle-to-infrastructure technology."

In this market assessment, we differentiate between these different technologies to give agencies guidance on the differing applications, status, impacts, and challenges. This report covers a variety of emerging transportation technologies, including:

- Micromobility
- Aerial Mobility
- Emerging Vehicle Technologies
- Highway Systems Technologies
- Parking System Technologies
- Integrated Technologies
- Data Guidance

Look for this symbol to quickly find Texas-specific deployment or application information.

Overall Project Relationship

This report is part of Task 3 which encompasses an assessment of existing transportation challenges within the region (Task 3.1 Existing Conditions Report), planned improvements, and an analysis of adoption trends for automated transportation (Market Analysis Report). The analyses performed under Task 3 will serve as the basis for scenario development and strategy recommendations (Task 6 AV Best Practices Handbook) in the following tasks.

Key findings

Technology is changing rapidly. The impacts of technology on our transportation system, land use, and travel patterns will be significant. The planning process should be flexible to adjust to changing technologies, business models, regulatory frameworks, and market conditions. NCTCOG should plan for applications of technology, rather than specific technologies, which may change over time.

Lay the groundwork early. Engage with the NCTCOG regional stakeholders to understand common challenges, build partnerships, and establish strong stakeholder relationships to deliver transportation access needed today while preparing for future technological changes.

Manage the increase in the quantity of data. Emerging transportation technologies are already producing very large amounts of data, which will likely only increase over time. Public agencies will need to develop new data management approaches to collect, analyze, manage, share, and utilize data to understand and improve the transportation system.

Plan for multiple possible future scenarios. The impacts of many new technologies are currently unknown. Many technologies are still in the research and development stage. Until the technologies are in the hands of the general public in real-world use, and until the sustainable price point of the new technologies or services is known, the long-term, real-world impacts will be unknown. Planning agencies like NCTCOG need to consider multiple potential future scenarios and frequently measure system performance to monitor trends and learn how these new technologies are impacting North Central Texas communities and roads.

VEHICLE TECHNOLOGIES

Innovations in vehicle technologies can be generalized in the following categories: **A**utomated, **C**onnected, **E**lectric, and **S**hared-Use (or **ACES**).

- Automated Vehicle (AV): AVs are equipped with sensors that allow them to operate with little to no human input. These sensors include cameras, RADAR, LiDAR, computer vision, GPS, or CV technology. There are several levels of automation. Lower levels of automation assist the driver but still require the human driver to perform most functions of the driving task.
- Connected vehicle (CV): CVs are vehicles that can communicate with other vehicles, infrastructure, or other wireless technologies.

A Note on Terminology

"Clear and consistent definition and use of terminology is critical to advancing the discussion around automation. To date, a variety of terms (e.g., self-driving, autonomous, driverless, highly automated) have been used by industry, government, and observers to describe various forms of automation in surface transportation. While no terminology is correct or incorrect, [USDOT] uses 'automation' and 'automated vehicles' as general terms to broadly describe the topic, with more specific language, such as 'Automated Driving System' or 'ADS' used when appropriate."

- USDOT, AV3.0: Preparing for the Future of Transportation

- Electric vehicle (EV): The topic of electric vehicles (EV) covers the changeover from liquid fuel powered internal combustion engine (ICE) vehicles to electric motor-powered vehicles (EVs). EVs may get their power from batteries or fuel cells burning hydrogen. Some motor vehicles may be hybrids, using gasoline powered internal combustion engines to supplement the electric motor and/or the battery.
- Shared-Use Vehicles: Shared mobility includes mobility services used by multiple travelers for a variety of trip services. Travelers may share the same vehicle at the same time for a trip (like ridesharing, sometimes called "pooled" rides) or share a vehicle one after the other (like carsharing or even bikesharing). Shared mobility can include:
    - Ridehailing (or ridesourcing): Services provided by Transportation Network Companies (TNCs) such as Uber and Lyft, which connect drivers with riders requesting a ride through a mobile application. These trips can be made individually or shared (pooled) between multiple rider requests.
    - Micromobility: Small, lightweight vehicles operating at speeds typically below 20 mph and operated personally by the user. These may include bikesharing, scootersharing, and other services. Chapter 2 provides details on micromobility.

- Carsharing: Services providing members with short-term access for vehicles. The vehicles may be required to be picked up and dropped off at the same spot or can be parked and left at the destination. Some services also allow car owners to rent out their personal vehicle when it is not being used for others to use.
- Ridesharing: Often commute-based, this includes services such as carpooling where the driver and rider share a common destination.
- Microtransit: Services connecting travelers through a mobile application and offering flexible and dynamic routes. Travelers may have to walk short distances to dynamic pick-up zones depending on other travelers' requests for rides in the area.[1]
- Public Transit: Publicly owned fleets of buses, trains, ferries, facilities, and rights of way.[2]

Applications

Automated – AVs are being developed for person and goods movement applications. Both light and heavy vehicles are being developed or retrofitted with sensors and automated driving systems (ADS). These vehicles include, passenger cars, low-speed automated shuttles, transit buses, trucks, sidewalk delivery robots, and aerial drones. Manufacturers are even considering automated motorcycles, though that technology is not expected to be widely available soon.

Automation in trucking is being developed and tested for several specific applications. Several years ago, *platooning* was the focus of several truck manufacturers (like Daimler Trucks) and system developers (like Peloton). Platooning is when vehicles closely follow a lead vehicle. The lead vehicle could be automated or human driven. However, industry focus seems to have shifted away from platooning to full automation with few announcements about platooning in recent years from Daimler Trucks and others, although Locomation did recently announce a 500-truck platooning pilot based in Nashville.[3] Platooning continues to remain a focus for military applications where one human driver can lead a platoon of unmanned trucks.

Automated truck applications currently being developed include yard applications (such as moving containers on a port or rail yard), business-to-business deliveries of goods on regular routes (such as between distribution centers and stores), remote logging or mining applications, as well as highway driving applications.

Automated last-mile delivery is another new opportunity for freight automation. For example, UPS is testing package delivery drones. Last-mile delivery robots are being tested by Amazon Scout, Starship Robotics (DoorDash), Postmates Serve, FedEx Roxo (Walmart, Pizza Hut), Nuro (Walmart, CVS), Refraction AI, and more.

Connected – CVs can share travel and safety information to drivers through in-vehicle messaging. There are potential safety applications when CVs can communicate with other vehicles, for example, they can help a driver to "see" around blind spots, activate emergency braking sooner, detect vulnerable road users who can communicate with the CV. CVs can share data to infrastructure or traffic management centers about traffic, pavement, or weather conditions to inform maintenance and operations. Additionally, CV manufacturers can provide aggregated, anonymized data on crash incidents as well as near-miss events such as harsh braking, harsh acceleration, lane departure warnings, etc. Insights from this data can proactively point to hotspots within the traffic system that may pose safety concerns. Data use and applications from on-vehicle sensors and communications with infrastructure are detailed in Section 5 Highway Systems Technologies and Section 8 Data Guidance.

Electric – Electrification of cars, buses, trains, trucks, construction vehicles, UAVs (unmanned air vehicles), airplanes, helicopters, and maritime vessels are all seeing significant research and development, but for the sake of brevity, this discussion will focus only on electric cars. Among electric cars, this discussion focuses on battery-powered cars, which have reached greater market penetration than fuel-cell-powered cars. Battery-electric vehicles have greater potential to reduce greenhouse gas emissions and criteria pollutants (carbon monoxides, nitrogen oxides, ground level ozone, sulfur dioxide, particulate matter, and lead) for light-duty vehicles than plug-in hybrids.

Shared-Use – Shared mobility, enabled by emerging technologies, is providing new innovative ways to transport people and goods. In general, shared mobility tends to be most effective in medium- to high-density or mixed-use environments, or near public transit or other destinations for first- and last-mile connections. Research has suggested that shared-use transportation modes require a minimum level of population, household density, mix of uses, transit users, and walkability to be a viable option.[4] Shared mobility can also be leveraged for goods delivery, for example pairing on-demand passenger rides with package or food deliveries.

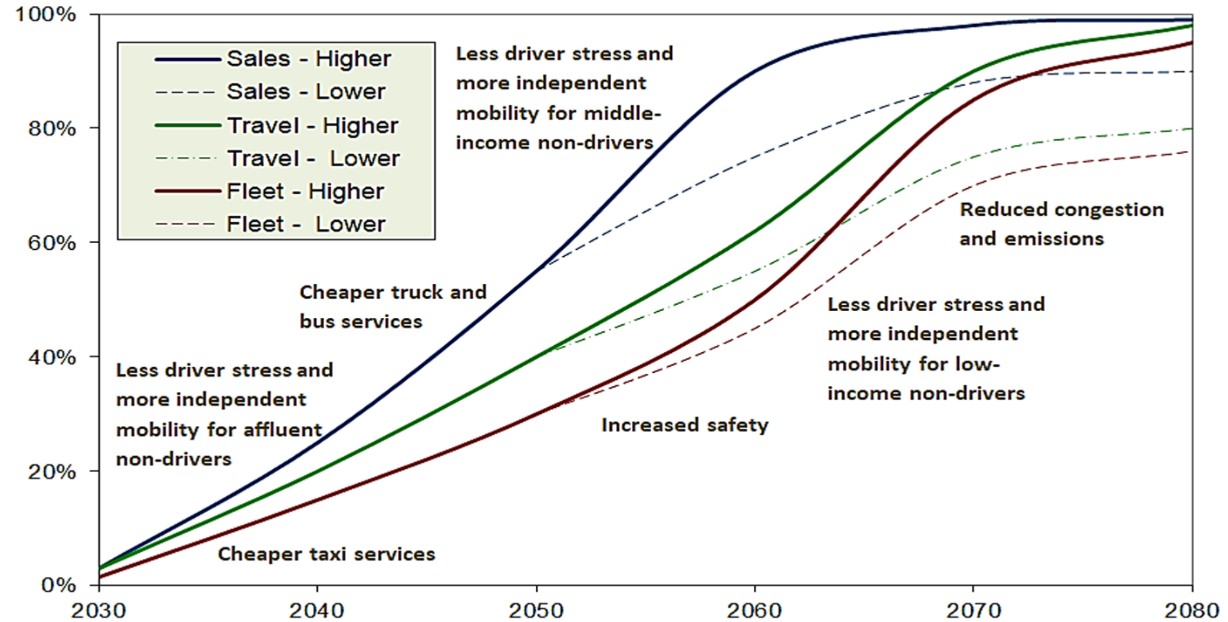
Status

Automated – Some advanced safety technologies are available today. Advanced driver assistance systems are standard or optional features on many new passenger, transit, and freight vehicles. Technologies such as lane keeping assist, blind spot warning, forward collision warning, and automatic emergency braking help drivers avoid crashes or slow down to reduce the severity of a crash.

High levels of automation are being tested only in fleet use. Automation testing without driver input is being conducted mostly in highway driving applications or low-speed, suburban applications. However, some testing is starting that focuses on rural roads and dense urban streets. Currently, no highly automated vehicles are available for purchase by members of the public. Personal mobility with AVs is currently being tested in transit applications and in robotaxi service concepts.

Figure 1 shows a conservative, yet realistic forecast for AV sales, travel, and fleet adoption in the U.S.[5] The Victoria Transport Policy Institute anticipates that AV applications for personal travel that impact safety and mobility may not be achieved until the 2040s or 2050s when AV fleet penetration rates near 40%. This is the horizon timeframe that transportation decision makers are currently planning for. Starting from when AVs become available, it may take another 40 years or more until we see high fleet penetration rates of AVs that could increase roadway capacity to reduce congestion or vehicle emissions.

The greatest uncertainty in planning for AVs today is the sustainable price for these technologies. To be transformational, AVs will need to offer service that is faster, cheaper, more reliable, or more accessible than a traveler's current modes of transportation. Another unknown for AV planning is the ultimate use cases (e.g., will AVs be individually owned or used only by fleets like robotaxis).



This analysis suggests that it will be at least 2045 before half of new vehicles are autonomous, and 2060 before half of the vehicle fleet is autonomous. Significantly faster deployment will require scrapping many otherwise functional vehicles that lack self-driving ability. Some benefits, such as reduced driver stress and independent mobility for affluent non-drivers, can occur when autonomous vehicles are relatively costly and rare. However, most benefits, such as independent mobility for moderate-income non-drivers and affordable taxi and micro-transit services, can only be significant if they become common and affordable, and some benefits, such as reduced congestion, will require dedicated lanes to allow platooning.

Source: Todd Litman (2022). *Autonomous Vehicle Implementation Predictions: Implications for Transport Planning*. Victoria Transport Policy Institute.

Figure 1. AV Market Penetration Projections

The AV-friendly legislative environment in Texas and the large freight hubs attract AV developers to test their automated fleets in Texas.[6] Dallas-Fort Worth is a hub for a number of AV truck fleet companies. In 2017, Texas state legislature passed SB 2205 that allows self-driving cars on the state's roads and driveways if they follow traffic laws and have video recording devices and insurance.[7] The City of Arlington approved a resolution to allow private companies to test and deploy robotic delivery devices in a real-world setting.

Local agency automated mobility pilots in North Central Texas include:

- Frisco Drive.ai Automated Vehicle Pilot [8]
- Arlington milo Low-Speed Automated Shuttle Pilot [9]
- Arlington Drive.ai Automated Vehicle Pilot [10]
- Aurora/Toyota autonomous ride-hailing fleet testing to prepare for 2024 deployment[11]

Established long-term deployments in North Central Texas include:

- Arlington RAPID Automated Microtransit Pilot with Via [12]
- Skylink - DFW Airport Automated People Mover

Automated freight testing and commercialization efforts in North Texas includes:

- Kodiak Robotics, TuSimple, Aurora, and Waymo are developing and testing automated trucking in the Texas Triangle (triangle formed by three of the state's main cities: Dallas-Fort Worth, Houston, and San Antonio.
- Starship Robotics sidewalk delivery bots are being tested by UT-Dallas to deliver in Frisco, Plano, and Richardson and Southern Methodist University in Dallas.[13]
- Gatik has expanded autonomous truck operations to Texas, focusing on moving goods from large distribution center to retail locations.[14]
- AllianceTexas' Mobility Innovation Zone (MIZ) provides a facility for testing and innovation of many new technologies, including automated trucking and unmanned aerial system (UAS) testing.[15]

Texas A&M University is leading the new USDOT-sponsored *Autonomous Vehicles for All* research program, which focuses on connected and automated vehicles for rural areas as well as dense city traffic involving motorists, cyclists, and pedestrians

Connected – Connected vehicle (CV) applications allow vehicles to communicate with other vehicles, vulnerable road users, infrastructure, central networks, and the cloud. These CV applications are referred to as Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Pedestrian (V2P), or Vehicle-to-Everything (V2X) technologies.

The best example of connected vehicle technology in practice today is Transit Signal Priority systems, where buses communicate with traffic signal to request priority and the signal will grant priority if the bus is running late. Emergency signal priority/preemption is a similar example.

Additional CV technology applications have been tested in large-scale deployments, such as *Safety Pilot* (Ann Arbor, MI) and the *CV Pilot Deployment Program* (Tampa, FL, New York City, NY, and Wyoming). These programs experienced varying degrees of success in deployment the CV technology. In all these cases, the vehicles in the deployments were equipped with after-market communication devices, as CV technology is not yet standard equipment in vehicles.

There are several examples of Connected Vehicle technology being tested in Texas:

The TxDOT Texas Connected Freight Corridors project is deploying connected vehicle technology on I-35, I-45, and I-10 and in more than 1,000 commercial vehicles to reduce truck-related crashes and reduce time trucks spend in congestion.[16]

The City of Arlington is testing multiple CV technology applications, including:

- Red-light violation warning application.
- Driver information alerts, such as pedestrian proximity, upcoming school zones, and approaching fire trucks.
- Enlighten advance traveler information system providing drivers with real-time signal data, anticipated wait time, and suggested travel speed.

NCTCOG is pursuing a freight vehicle optimization project to improve freight vehicle movement efficiency and reliability in the region. The project will identify main freight routes in the region and combine providing trucks with Green Light Optimized Signal

Advisories with adjustments to the signal timing plans along these routes to provide priority to trucks. The project will cover up to 500 intersections in the region.

NCTCOG's 511DFW (www.511dfw.org) serves as the single source for real-time, comprehensive regional traveler information. 511DFW provides information to freight companies and to drivers on traffic conditions on freeways and major arterials. CV technology could enable the 511DFW travel information to be shared directly to vehicles for driver information sharing or automated driving system route planning.

Wejo is a data provider that collects data over the cellular network from some connected vehicles, including GM. A recent study in Indiana, Ohio, and Pennsylvania found that approximately 4-5% of the vehicles in the states were providing speed data to Wejo.[17]

A Note on Recent Changes to Connected Vehicle Communications: In 2020, The Federal Communications Commission (FCC) decided to phase dedicated short-range communication (DSRC) out of transportation communication and to reallocate its spectrum to cellular vehicle-to-everything (C-V2X) and unlicensed uses (e.g., WiFi).[18] Agencies that previously invested in DSRC technology must transition to C-V2X solutions. Meanwhile, standards to support using C-V2X with 4G/LTE or 5G communications are still developing, as are the 5G networks.

Electric – As of 2019, there were 1.2 million EVs on the road in the United States. Sales of EVs in the US that year accounted for less than 2% of new car sales in the US. The number of EVs sold in the US soared 80% between 2018 and 2019.[19] The Electric Reliability Council of Texas (ERCOT) and Bloomberg New Energy Finance estimate nearly 20% of the light duty vehicle fleet will be electric by 2037.[20]

Toyota has a large presence in the region with its North American headquarters in Plano, TX and may build a new $1.29 billion factory for hybrid and fully electric vehicles in the state.[21] General Motors is also planning to build a new EV factory in Fort Worth, Texas with production starting in 2023.[22]

Tesla is building its second US manufacturing plant, Gigafactory Texas, in Austin, Texas. It is due to open in late 2021 reaching full production in 2022. It will focus on Tesla's Cybertruck, the Semi, as well as Model 3 and Model Y cars.[23]

Electric vehicle manufacturers Polestar and Karma also have dealerships and Kandi automotive has a headquarters in Grapevine, Texas.

Dallas-Fort Worth Clean Cities Coalition provides electric vehicle registration data by vehicle model, county, and city in North Texas (www.dfwcleancities.org/evnt). As of March 29, 2022, there are 43,072 electric vehicles in North Texas. Westlake, Texas has the highest percentage of all registered vehicles in a city with 5.56%.

Shared-Use – As of 2020, shared mobility options are widespread. Across North America there are 100 regions with bikeshare, 105 regions with dockless micromobility, 295 regions with carshare, and 435 regions with ridehailing.[24] The market for shared mobility is constantly evolving, with carsharing first deployed in the early 2000s, bikeshare and ridehailing in the late 2000s and dockless mobility in the past few years.

- Data Collection. Data from shared mobility providers is critical for public agencies to understand traveler behavior and the impact of emerging modes have on the transportation system. Private mobility providers often collect data such as trip origin and destination but managing large amount of new data streams and establishing data sharing agreements with private operators remain a key barrier for many public agencies. Some agencies have implemented policies requiring providers to share specific types of data in order to operate in the area. There has also been an increased emphasis on data standardization, such as the Mobility Data Specification (MDS) and General Bikeshare Feed Specification, to facilitate consistent data formats and data sharing practices across multiple cities and providers.[25]

- Policies. Agencies have implemented a variety of policy frameworks to regulate new shared-use modes. The policies can include changes to right of way allocation policies, such as parking rules, pick-up and drop-off zones, and signage and pavement marking. Some agencies also require shared mobility operators to be permitted, charging application or per-device fees to cover costs for the city.

  In Texas, House Bill 100, passed in 2017, requires TNC companies to pay annual fee, obtain a permit, and perform background checks on drivers. The bill overrode some more strict local regulations requiring fingerprinting of TNC drivers and prevented all local regulation of TNCs.[26]

- Partnerships. Many agencies have established public-private partnerships with shared mobility providers to enhance transportation service. These partnerships can include first and last mile connections, with public agencies subsidizing rides to or from public transit stops. As part of the agreement, agencies and private providers can incorporate traveler information into their respective app or website to provide travelers with both public and private options all in one convenient place and enable seamless transfers. Other partnerships are focused on supplementary service to fill gaps in the transportation system, where traditional public transit may not be viable.

  Public agencies have partnered with shared mobility providers to provide more flexible on-demand service for paratransit customers, low-density areas or in off-peak or late-night periods when public transportation is limited.

  For example, Dallas Area Rapid Transit conducted a Mobility on Demand pilot in 2017-2019 with a microtransit provider and TNC to provide more transit trip choices for riders in a low-density area that was difficult to serve.

Impacts

Travel Cost – Automated vehicles could reduce the *time cost of travel* for drivers who experience less stress riding in an AV compared to driving a car. In the future, automated vehicles might reduce the *monetary cost of travel* by reducing labor costs, system efficiency, or vehicle operations and maintenance costs. Currently, automated vehicle costs are too high for personal use. As a result, fleets and service providers are leading the testing and deployment.

Electric vehicles are also expected to reduce the *monetary cost of travel*. Initially, electric vehicles may have a higher up-front cost compared to internal combustion engine vehicles. According to Kelley Blue Book, the average price for an electric vehicle is $56,437, compared to the overall industry average of $46,329 for all vehicles including gas and EVs. Tax credits can help to offset this higher upfront cost.[27] As electric vehicle production rates increase and as battery technology continues to improve, their upfront costs will decrease.

Annual maintenance costs of an EV are about two-thirds that for gas powered cars. Charging costs can be one-half the cost of gasoline for the same miles driven. *Car And Driver* concluded that for the first 3 years of ownership, there was no significant difference in costs of owning a gas-powered vehicle or an EV (the uncertainty and variability of the costs were greater than the difference between them). Battery replacement costs were not considered.[28] However, over the lifespan of a car, EVs cost about $5,000 less. The operations and maintenance cost savings of EVs could be greatest for those who drive more—meaning underserved communities currently burdened with the highest conventional transportation costs due fuel and maintenance costs could see the most benefit.[29] Manufacturer deals, federal tax credits, and charging fees can dramatically change the cost comparisons. The U.S Department of Energy provides a vehicle cost calculator to compare vehicles based on average daily driving distance, annual mileage, and other driving characteristics.[30]

For shared-use mobility, studies show the services reduce annual household transportation costs, car ownership, and vehicle miles traveled—potentially reducing both the *monetary cost of travel* and the *time cost of travel*.[31]

Mobility – Vehicles that are both connected and automated could increase roadway capacity. They might increase capacity by following at shorter headways, reducing delays at green lights due to distracted driving, harmonizing speeds to reduce stop and go traffic jams, reducing gap acceptance for turns over human drivers, and potentially reducing crash-related delays due if they help to reduce the number or severity of crashes. Demand is likely to increase if the time cost of travel decreases either because capacity increases or as driver level of stress reduces. Vehicle miles traveled (VMT) could increase as demand increases or because AVs or shared-use vehicles are making empty or zero-occupancy trips. Local agencies may need to control the increase demand with policies that discourage increased VMT. Changes to the built environment (i.e., density supportive of transportation and housing goals, improved accessibility to transit, modernization of land use and zoning laws) are among the most significant and critical factors in reducing VMT. Road- and parking-pricing policies can have a significant impact on VMT while providing revenue for infrastructure maintenance in proportion to use. Examples of policies that impact VMT are mileage-based pricing strategies as an alternative to the gas tax for electric vehicles, congestion pricing in dense urban centers, demand-based parking, etc. Early benefits may begin in the 2030s (such as independent mobility for affluent non-drivers). Most impacts of automation (such as reduced traffic and parking congestion, independent mobility of low-income travelers, and safety) are not expected to begin until AVs become more affordable and widely adopted in the 2040s or even 2060s.[32]

With no significant difference in operating costs, electric vehicles are unlikely to increase or decrease auto travel or affect mode choice. There will likely be some minor effects on long-distance driving for trips that exceed the range of the vehicles. Parking may be affected by drivers searching for and choosing parking lots and garages with charging facilities (and something to do while waiting for the vehicle to charge) rather than parking on a street without plug in capabilities.

For shared-use, shared mobility can improve mobility by extending the reach of public transit, through first and last mile connection or supplementary service in late-night periods or in low density areas. New shared modes provide opportunities to fill gaps in the existing transportation networks and facilitate multimodal connections by travelers.

Land Use & Street Design – EVs will place a premium on vehicle parking facilities with plug-in capabilities. Highway oases combining supercharging capabilities and some activity that lasts about 30 minutes (fast food, etc.) will be preferred by EV drivers. EV drivers will also likely need expanded home charging capabilities, including apartment homes.

The continued increase in shared-use modes and operators will likely increase competition for curb space and right of way. If car ownership declines, traditional parking demand will drop further. This offers an exciting opportunity for infill. Existing surface parking lots and parking structures can be redeveloped as pick-up/drop-off areas, grand entrances, and new developments. Additionally, AVs will benefit from dedicated curb access to avoid double-parking or illegal drop off maneuvers. AVs will also benefit from clearly marked or limited-access pathways through parking lots and garages to reduce the number of potential conflicts and increase vehicle operating speeds. Ford and Bosch have announced an automated valet parking demonstration in Detroit. A pilot is currently underway at DFW International Airport to test automated parking of vehicles with existing autonomous parking capabilities after they drop off passengers at the terminal. Some vehicle owners will have their vehicle drop them off at the drop-off zones, and the vehicle will park autonomously. Some manually driven vehicles still require parking facilities. Considerations for local agencies include:

- Preserve interior parking for manually driven parking, while converting parking on the far exterior of a site to AV-compatible parking
- Plan simple, well-marked routes from drop-off areas to AV-compatible parking
- Install plug-in charging stations at manual parking locations nearest storefronts or pedestrian access points
- Install inductive charging stations in pick-up zones and in AV-compatible parking areas

Agencies will need to develop plans and policies to manage existing and emerging modes, including curb space management and parking policies. Street designs may also include physical integration of shared-use modes through mobility hubs to facilitate seamless multimodal transfers.

Safety – Automated and connected vehicles have the potential to be safer than human drivers because the automated driving system is always attentive, can process and respond to situations faster than a human driver, and can communicate with other vehicles or roadside equipment to get safety-related traffic information that isn't available to a human driver.

TxDOT hopes emerging vehicle technology like CVs and AVs could reduce fatalities in 2050 on all public roads by as much as 51% (expected) to 85% (optimistic).

EVs should have similar crash rates as internal combustion vehicles. Though EVs might reduce the risk of crash injury severity in some scenarios due to a lower center of gravity (created by the weight and placement of the battery) or increased resistance to impact penetration. The Tesla Model S received the highest crash rating and raised the bar for side-impact crash testing due to the added structural strength of the battery.[33]

Industry is currently advising agencies that street design practices do not need to be tailored to automated or connected vehicles. Adopting USDOT's Safe System approach builds multiple layers of protection for all road users to prevent crashes in the first place and making crashes less severe when they do occur. This holistic approach includes:[34]

- Safer Roads: Design roadway environments to encourage safer behaviors and facilitate safer travel for all road users
- Safer Vehicles: Expand the availability of vehicle systems that help to prevent crashes
- Safer Speeds: Promote safer speeds though appropriate roadway design and enforcement
- Safer People: Encourage safe, responsible behavior by people using our roads
- Post-Crash Care: Enhance crash response and prevent secondary crashes through traffic incident management practice.

Flammable liquids like gasoline leaking from crashed ICE vehicles will not be a concern for EVs. Additionally, EVs reduce the risk of carbon monoxide poising from ICE vehicles accidentally left turned on in garages or other enclosed spaces. However, vehicle fires from damaged batteries may be an issue. Training from the National Fire Protection Association is available to teach first responders how to deal with EV battery fires.[35]

For shared-use, it has been well documented that helmet usage is low among bike- and scooter-sharing users. Agencies will need to consider policies to encourage helmet usage, incentivize mobility companies to conduct safety outreach, and prioritize providing safer places to ride to encourage good riding behavior (see micromobility chapter for more information).

For ridehailing, regulatory agencies may consider safety policies, including certification procedures and background checks for drivers to ensure rider safety. However, in Texas, state law HB100 specifies regulations of TNCs is an exclusive power of the state and may not be regulated by local entities.

Equity – The early adopters of EVs have tended to be young, high-salaried people. However, as economies of scale enable manufacturers to sell a wide range of high- to low-priced EVs, the equity effects of EVs should be similar to those of internal combustion engines, with the added benefits of lowered air and noise pollution levels in the vicinity of highways and streets. Equity considerations for EVs are needed for each use case to ensure all users have access to convenient charging infrastructure to meet their needs. Examples include:

- **Economic equity** for disadvantaged or low-income communities, including payment options for unbanked users and prioritizing charging location sites in these communities and near small or minority-owned businesses. Low-income households and underserved communities could see the most benefit from EVs, because they are currently burdened with the highest conventional transportation costs due gas car fuel and maintenance costs.
- **Geographic equity** for all types of communities, including considerations for different needs for urban versus rural users.
- **Disability equity** for drivers with disabilities.
- **Home Charging equity** for all types of use cases, including charging stations at multi-unit dwellings, single-family homes without garages, and areas with street parking.

For shared-use mobility, access to the services often requires a smartphone and a credit card. GoGo Grandparent lets people use Lyft, Uber, DoorDash, and Instacart without using a smartphone. GoGo users dial a phone number and select a menu option to request a ride or place a delivery order. The GoGo Guardian service notifies selected family members of the riders' trips and provides real-time updates.

Through a partnership with the City of Arlington, the Via on-demand ridesharing service provides a customer service phone number and prepaid card (reloadable with cash at local convenience stores) as booking and payment options.

Equity solutions don't have to be high-tech. Creating a more accessible transportation system will provide more equitable service to people in wheelchairs, people with visual or hearing disabilities, and travelers with limited English proficiency. Shared-use provides an opportunity to provide alternative mobility choices to underserved populations, but agencies will need to incentivize or require providers to provide services on web-based applications, options for unbanked travelers, and accessible vehicles for people with disabilities.

Environmental Sustainability – Vehicle emissions can be divided into two general categories: air pollutants (which contribute to smog, haze, and health problems) and greenhouse gases (GHGs, such as carbon dioxide and methane). EVs running on only electricity have zero tailpipe emissions, but emissions may be produced by the source of electrical power, such as a power plant. EVs are already have lower emissions than gas cars on a well-to-wheels basis – meaning all emissions related to fuel production, processing, distribution, and use - and should improve further as the necessary additional power generation for charging EVs can be obtained from renewable sources.[36] EVs also reduce water pollution by reducing motor fuel and oil leaks compared to internal combustion engine vehicles. Reducing the demand for fuel and oil can also reduce the risk of spills. Vehicle emissions are only one of the adverse environmental impacts that come from dependence on cars (ICE or electric). The extensive roadway infrastructure to accommodate vehicles increases runoff, worsens the urban heat-island effect, and increased particulate matter pollution resulting from tire and pavement wear. EVs reduce vehicle tailpipe emissions, but the transition to EVs should be coupled with policies to reduce environmental impacts of overall vehicle infrastructure and dependence on cars.

For shared mobility, impacts may be somewhat mixed. Shared modes have been shown to reduce greenhouse gas emissions by reducing car ownership, encouraging connection to public transit, and reducing vehicle miles traveled in personal vehicles. However, some studies have also shown that ridehailing in some cities such as San Francisco can actually worsen congestion in urban centers.[37]

Cities will likely need to consider comprehensive Transportation Demand Management (TDM) strategies or congestion pricing policies to achieve the benefits of shared mobility and mitigate potential externalities.

Challenges and Opportunities

Challenges	Opportunities
Automated	

Challenges	Opportunities
Bringing together new stakeholders. The private industry is leading automation and logistics innovation.	Local agencies need to be part of the conversations to learn what is coming, what the impacts could be, and how the transportation system can support this innovation to meet regional goals and needs. NCTCOG and its partners can ensure a seat at the table by inviting industry partners to participate in the planning process.
Agency investments. Agencies are trying to plan for investment needs for future AVs when the technology is still being developed.	AV developers recommend roadway owners and transportation system operators support AV development by maintaining lane striping on roads and sharing accurate data and information about lane and road conditions, such as construction work. FHWA has awarded demonstration grants for the Work Zone Data Exchange (WZDx) Specification to enable infrastructure owners and operators to make harmonized work zone data available for third-party use. NCTCOG launched a Situational Awareness application and WZDx initiative in 2022. The intent is to make travel safer and more efficient through access to work zone location and activity data. The project aims to share data on work zones with vehicles to help automated driving systems and human drivers navigate work zones more safely. The active WZDx data feed currently lists feeds from TxDOT.[38]
Curb management policies. AVs might need special planning for parking access and drop off.	AVs may lead to a reduction in parking demand and an increase in curbside drop-off space. Local agencies may need to rethink their planning and design standards to support AV technology. If parking demand decreases due to AVs (or ridehail), agencies might need to repurpose underutilized parking facilities and on-street parking.

Challenges	Opportunities
Uncertain impacts. The long-term impacts of AVs are unknown until the vehicles are in the hands of consumers and the sustainable costs are determined. It remains unclear how consumers will interact with AVs (e.g., may be shared robotaxi fleets or in the long term could be personally owned). Currently, costs are artificially subsidized for consumers. Sustainable business models and pricing models remain uncertain but will influence how AVs are used by consumers.	Scenario planning can estimate impacts of multiple potential AV scenarios. For example, AVs could reduce the monetary cost of travel and the time cost of travel, which could cause an increase in demand for travel and overall vehicle miles traveled.
Land use. Current land use patterns and built environment are often designed for the personal car. Existing land use patterns could limit benefits of emerging technologies like automated vehicles.	Technologies alone cannot solve inhospitable land use patterns. Agencies should consider how changes in land use (e.g., walkable, bikeable, shorter trips) may encourage different forms of transportation and gain maximum benefits from emerging transportation technologies.
Rural areas. Initial AV development and testing has not focused on roadway operating conditions unique to rural areas. Wildlife crash risks present additional challenges along rural roadways.	Rural testing is the focus of two new pilot studies: University of Iowa's *Rural ADS* (Automated Driving System) research and Texas A&M's *Autonomous Vehicles for All* research.
Connected	
Lessons Learned. CV technology is still advancing. It is important to learn from past deployments.	The USDOT documents success stories and lessons learned from past large-scale deployments.[39]
Funding. CV technology is expensive, especially if vehicles need to be equipped for pilot testing.	NCTCOG's Transportation Improvement Program (TIP) identifies projects to enhance communications for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) applications, infrastructure maintenance, and digital installations in the right of way. Long-range plan improvements include both infrastructure installations and projects to modify driver behavior.

Challenges	Opportunities
Broadband Access. Some communications and data sharing systems that support connected and automated vehicles may rely on cellular communications or high-speed internet access, which can be especially limited in rural areas. For example, a Yellowstone National Park AV shuttle deployment was forced to mail hard drives between the deployment and data analysis locations because the internet speed could not support the large digital data sharing.	Broadband expansion programs, such as the grant funding in the Infrastructure Investment and Jobs Act (2021) support broadband expansion, including middle-mile fiber networks needed to support cellular communications.
Timeline. Planners have anticipated CV technologies for years, yet vehicle manufacturers still have not equipped vehicles as standard with this technology. Current uncertainty is leading to technology adoption delays.	The auto industry never embraced dedicated short-range communication (DSRC) radios and is shifting toward cellular communications. This will be supported by the larger communications industry's push toward faster cellular communications for streaming services and Internet of Things connectivity.
Electric[40]	
Affordability. Consumers perceive electric vehicles to be somewhat more expensive to purchase than the equivalent ICE (internal combustion engine) vehicle. However, consumers recognize that EVs are cheaper to own and operate once purchased.	Affordability is driven primarily by vehicle manufacturing economies of scale but can be assisted with federal and state tax credits for new vehicle purchases. The US EPA estimates that the cost of operating an EV is roughly one-third less than that of ICE vehicles. The difference in purchase prices between EVs and ICE vehicles is expected to diminish as more EVs are produced and sold.

Challenges	Opportunities
Battery Replacement Worries. Consumers are most concerned about the longevity of the EV's battery and the eventual cost to replace it.	These are primarily technical issues where the private sector is already well motivated to find an answer. The public sector can expedite this research by offering manufacturers tax credits for research into improving battery life or battery range. State agencies might encourage their university researchers to form public/private partnerships or establish research centers to research battery life issues, lower battery replacement costs, and battery range issues. States can leverage available funding from the Infrastructure & Investment Jobs Act (IIJA) for deployment of EVs and infrastructure, including $10.3 billion for grid- and battery-related investments.
Public Charging Concerns. The lack of public charging facilities is a primary concern. According to the Department of Energy there were in 2019 about 22,000 public EV charging stations in the US, compared to 162,000 gas stations. The *number* of EV charging or alterative fueling stations is not the only challenge. The *placement* or *location* of stations needs to consider equitable access for all communities, especially underserved communities as well as drivers with ADA accessibility needs.	Tesla has been aggressive about installing its patented charging stations at shopping centers and other high activity centers. Public agencies through regulations, tax incentives, and grants can encourage the placement of public charging stations in highway oases and major retail and employment centers to improve distribution and access throughout the region. The IIJA includes $7.5 billion for EV charging and alternative fuel infrastructure, including $2.5 billion for the Charging and Refueling Infrastructure Grant Program and $5 billion for the EV Charging Formula Program. In Texas, the Texas Emissions Reduction Plan (TERP) offers funding through the Alternative Fueling Facilities Program.
Equity and Affordability. ICE vehicles and electric vehicles are expensive to own and operate. Low- and moderate-income households spend disproportionate amount of household incomes on transportation in car-dependent environments.	Replacing ICE vehicles with EVs alone does little to improve equity and affordability of transportation. Agencies may consider coupling the transition to EV with efforts to expand accessible transportation options, including public transit, walking, biking, and micromobility to reduce dependence on automobiles.

Challenges	Opportunities
Range anxiety and charging deserts. Some EV drivers can feel uncomfortable about not being able to find a charging location. Charging deserts can occur on long distances of roadway with no charging stations available.	Agencies can make data-driven decisions for placement of charging infrastructure – and collaboration across borders. Coordinate with adjacent states so agencies don't end up duplicating efforts nearby or having charging deserts at the border. Two recent studies demonstrate potential data-driven approaches, including using connected vehicle data to assess EV investment opportunities.[41,42]
Shared-Use	
Increased VMT. Shared-use vehicles have been shown to increase Vehicle Miles Traveled (VMT) from deadheading – empty vehicles traveling from the drop off of a passenger to the pick-up of the next. In addition, ridehailing customers have opted for solo rides over pooled ride options. In many suburban or rural locations, shared rides are not offered by ridehailing companies. Since the start of the pandemic, many ridehailing companies have even stopped offering shared rides in urban areas. If shared automated vehicles lead more users to shift away from public transit, VMT could further increase.	Policies, especially in denser areas, should prioritize more efficient modes (such as public transportation, walking, and biking). Pricing mechanisms or travel demand management strategies could discourage deadheading miles and encourage shared-use vehicles to complement transit. For example, VMT and congestion could reduce if single-occupancy standard vehicle commute trips are replaced by trips connecting riders on DART with a short, shared AV ride to the office.[43]
Safety of riders. Safety for pooled ridehailing riders has been a concern, including travelers mistakenly boarding the wrong with drivers impersonating Uber or Lyft rides, and health risks for multiple people in the vehicle during the COVID-19 pandemic. For AVs, some riders will have concerns about riding in a shared vehicle without a human operator to monitor passenger safety.	Encourage operators to ensure safety of pooled riders through validation and confirmation of drivers and riders before each trip starts. Encourage operators to follow local COVID-19 safety protocols. Agencies and service providers will need to monitor safety and user comfort to determine how to address rider safety during shared AV rides.

Challenges	Opportunities
Technologies and business model shifts. Shared-use operators business models are constantly evolving with mergers, acquisitions, and changes in operational models. Changes and emergence of new modes can occur faster than public policy can respond to.	Agencies should focus planning efforts on applications of technology, rather than specific technologies or vendors, which may change over time. Agencies may also conduct needs assessments to understand which business models meet specific community needs and scenario planning to understand how these models might change in different future scenarios.
Data sharing. Scoping and negotiation of public-private partnerships and data sharing agreements can be a barrier to implementation. Private operators can be reluctant to share certain types of data with agencies due to security, privacy, and proprietary concerns.	Agencies should require shared mobility operators use common data specifications to facilitate easier sharing of data. In addition, agencies should develop detailed data management strategies and build staff expertise to prepare for the collection, storage, and/or analysis of large amount of data.

References

[1] Transit Cooperative Research Program. Shared Mobility and the Transformation of Public Transit
[2] Shared Use Mobility Center. Shared Use Mobility Reference Guide
[3] Freight Waves. Locomation signs up 3rd trucking company for its autonomous technology
[4] Shared Use Mobility Center. Shared Use Mobility Reference Guide
[5] Victoria Transport Policy Institute. Autonomous Vehicle Implementation Predictions: Implications for Transport Planning
[6] Fleet Owner. Autonomous truck testing heats up under the Texas sun
[7] Texas. S.B. No. 2205
[8] The Dallas Morning News. Why are Frisco's autonomous vans moving to another North Texas suburb
[9] City of Arlington, milo Pilot Program Closeout Report
[10] MyArlingtonTx. "Arlington Concludes Successful Pilot Program with Drive.ai"
[11] Dallas Innovates. Aurora Unveils Ride-Hailing Test Fleet, Gives Toyota Execs an Autonomous Ride Toward DFW Airport
[12] City of Arlington, RAPID
[13] NCTCOG. Progress North Texas 2020: Connecting the Dots of Regional Transportation.
[14] Tech Crunch. Gatik expands autonomous box truck operation to Texas with $85 million in new funds

[15] Alliance Texas. Mobility Innovation Zone
[16] TxDOT. Texas Connected Freight Corridors
[17] Purdue University. Estimation of Connected Vehicle Penetration on US Roads in Indiana, Ohio, and Pennsylvania. Journal of Transportation Technologies
[18] Federal Register. Use of the 5.850-5.925 GHz Band
[19] The Edison Electric Institute, EEI Electric Transportation
[20] Bloomberg New Energy Finance. Electric Vehicle Outlook 2021.
[21] Dallas Morning News. Texas one of several likely locations for Toyota's next $1.29 billion U.S. battery plant.
[22] Detroit Free Press. GM forms 2 new partnerships that will create new factories in US.
[23] Wikipedia, Giga Texas
[24] Shared Use Mobility Center. Shared Mobility Counter
[25] UC Berkeley Transportation Sustainability Research Center. Mobility on Demand Planning and Implementation: Current Practices, Innovations, and Emerging Mobility Futures
[26] Texas Tribune. Uber, Lyft return to Austin as Texas Gov. Abbott signs ride-hailing measure into law
[27] CNBC. Here's whether it's actually cheaper to switch to an electric vehicle or not – and how the costs break down
[28] Car And Driver. EV vs. Gas: Which Cars Are Cheaper to Own?
[29] Interstate Renewable Energy Council (IREC) Paving the Way: Enabling Equitable Electric Vehicle Shared Mobility Programs
[30] US DOE Alternative Fuels Data Center Vehicle Cost Calculator
[31] Shared Use Mobility Center. Shared Mobility Benefits Calculator.
[32] Victoria Transport Policy Institute. Autonomous Vehicle Implementation Predictions: Implications for Transport Planning
[33] Inside EVs. A Detailed Look at How Tesla Makes Incredibly Safe Electric Cars
[34] U.S. Department of Transportation. What is a Safe Systems Approach?
[35] National Fire Protection Association. Electric Vehicles
[36] U.S Department of Energy. Alternative Fuels Data Center
[37] San Francisco Country Transportation Authority. TNCs and Congestion
[38] U.S. Department of Transportation. Work Zone Data Exchange
[39] USDOT. Connected Vehicle Pilot Deployment "Success Stories and Lessons Learned"
[40] MyEV. Overcoming The Hurdles to Widespread Electric Vehicle Adoption
[41] Journal of Transportation Technologies. Analysis of Electric and Hybrid Vehicle Usage in Proximity to Charging Infrastructure in Indiana
[42] ITE Journal. Using Connected Vehicle Data for Assessing Electric Vehicle Charging Infrastructure Usage and Investment Opportunities
[43] Transport Policy. Can sharing a ride make for less traffic? Evidence from Uber and Lyft and implications for cities

AERIAL MOBILITY

Aerial mobility is an emerging concept envisioning a futuristic multi-use air transportation network for passenger mobility, cargo delivery, and emergency management. Historically, aerial vehicles with an onboard pilot have been used to transport passengers and cargo long distances. Compared to existing aviation services, aerial mobility typically refers to smaller, highly automated, lower altitude vehicles for shorter distances. Recent developments in aerial mobility technology and airspace regulations offer new businesses and the average consumer the opportunities to utilize the airspace.

Key definitions in the aerial mobility field include:

- Urban Aerial Mobility (UAM): an emerging concept envisioning a safe, efficient, accessible, quiet, and multi-use air transportation for passenger mobility, cargo delivery, and emergency management within or traversing a metropolitan area.[44]
- Rural Aerial Mobility (RAM): an emerging concept envisioning a safe, efficient, accessible, quiet, and multi-use air transportation system for passenger mobility and cargo delivery within or traversing rural and exurban areas.[45]
- Advanced Aerial Mobility (AAM): builds upon the UAM concept by incorporating use cases not specific to operations in urban environments, such as commercial inter-city operations; cargo delivery; public services; and private or recreational vehicles.[46]
- Unmanned/Uncrewed Aircraft Systems (UAS): the unmanned aircraft and all the associated support equipment, control station, data links, telemetry, communications, and navigation equipment necessary to operate the unmanned aircraft.[47] Note that the unmanned aircraft can still be operated by a remote pilot. In the future, unmanned aircraft may become autonomous.
- Electric Vertical Take-off and Land (eVTOL): an electric propelled aircraft that can hover, take off, and land vertically (similar to a helicopter).[48]

Applications

As of October 2021, uncrewed aerial vehicle use has been limited in the US. Public and private partners have tested cargo deliveries while local passenger movement has not been tested. Aerial vehicles have been used to inspect bridges and airplanes with special permission from the Federal Aviation Administration (FAA).

Once moving cargo and passengers through the air within or traversing a metropolitan area becomes a standard procedure, the aerial mobility industry is expected to grow. Industry experts expect regular air shuttle services along specific routes to be operational by 2028.[49] Estimates anticipate that the aerial mobility market capitalization can grow from $16.81 billion in 2025 to $110.02 billion in 2035 showing the potential explosive growth of this market.[50]

Aerial vehicles can be controlled by an onboard pilot (like a traditional plane), a remote pilot (also called an unmanned aircraft), or autonomously (by a computer without any human interaction). The US allows onboard piloted and remote piloted vehicles but not autonomous vehicles as of October 2021. Most tests being conducted in the US utilize remotely piloted vehicles, but these tests build a foundation so these vehicles can become autonomous.

Status

In 2020, policies impacting aerial mobility were changed to begin paving the way for deployment and implementation. First, the FAA NextGen Office released Concept of Operations for Urban Air Mobility (ConOps 1.0) to describe the operational environment it envisions to support the expected growth of flight operations in and around urban areas. The US Department of Transportation (USDOT), the FAA, and the Office of the Secretary of Transportation (OST) also released an amendment to Title 14 of the Code of Federal Regulations (CFR) Parts 11, 21, 43, and 107: *Operation of Small Unmanned Aircraft Systems Over People*. This document allows for the operation of small, unmanned aircraft systems over people at night under certain conditions beginning March 16, 2021. This rule is significant because it shows that policies are adapting to new inputs from existing stakeholders and increasing demands for operational flexibility.

The aerial mobility sector has advanced in the last several years through private partnerships, acquisitions, and certifications. Key private company milestones include Flirtey completing the first fully autonomous FAA-approved urban drone delivery in the US in 2016; Google receiving the first air carrier certification ever given to a drone company in 2019; UPS Drone Delivery receiving full Part 135 certification from the FAA in 2019 which allows UPS to deliver goods beyond the visual line of sight (BVLOS) of the remote pilot; Uber Elevate, acquired by Joby Aviation, teaming up with Hyundai in 2020 to promise cargo deliveries by 2026 and air taxis by 2028; and Amazon winning FAA approval for its Prime Air drone delivery fleet in 2020.

In Frisco, Wing is partnering with Walgreens to pilot "store-to-door", on-demand aerial delivery. This pilot is the first commercial drone delivery service in a U.S. metro area.

To help aerial mobility grow in a controlled fashion with the community's support, NCTCOG has developed multiple working groups and training resources for public agencies, private companies, and the general population. The working groups bring public and private partners together to discuss aerial mobility policies and concerns. The public outreach and education efforts aim to connect NCTCOG with all levels of the public and inform them about aerial vehicle use, what it will be used for, and what it will not be used for. These efforts also aim to train individuals for job placement in the industry.

In addition to the working groups, Texas has been advancing aerial mobility by working with NASA and other government agencies to:

- consider how emerging cargo-carrying drone and passenger-carrying air taxi services can best be included in their civic transportation plans
- create a Mobility Innovation Zone proving ground in North Texas
- set up low-altitude airspace monitoring service in Arlington;
- and allowing Flytrex to deliver food in DFW.

Impacts

Aerial mobility applications can impact travel cost, mobility, land use and street design, safety, and environmental sustainability.

Costs – The costs for aerial mobility can be incurred by a private aerial vehicle company, the government, and an individual user. The costs for the company can include paying for the aerial vehicles and any taxes and fees that come with operating an aerial mobility company. The cost for the local government can include the price for building, operating, and maintaining new infrastructure (e.g., vertiports) and staffing employees to keep the UAS network running. The costs paid for by the individual user can include the price to ship goods or take a taxi ride.

The anticipated near-term cost for an aerial ride is $6.25 per mile but is expected to drop to $2.50 per mile in the future.[51] A taxi ride in a surface automated vehicle is expected to cost around $1.60 per mile, making the aerial transportation option more expensive.[52] In 2021 in Dallas, a Yellow Cab charged $2.25 for the initial fare plus $1.80 per mile making a one mile trip by taxi costs $4.05 and a two-mile trip costs $5.85 while an Uber costs about $2.00 per mile, with a minimum fare of $8.00. When the cost of the passenger's time is considered, aerial transport may become more competitive with ground transport due to the ability to avoid typical rush-hour congestion on roadways. Volocopter, an eVTOL vehicle manufacturer, expects its aerial vehicles to cruise at 110 miles per hour, have a range of 60 miles, and carry a payload of 660 to 880 pounds.[53]

Mobility – Aerial mobility is anticipated to impact the movement of cargo and people.

- *Rural aerial mobility (RAM)* can seamlessly link isolated communities like island towns to other communities. RAM also offers a redundant mode of transportation to these communities if traditional infrastructure connections such as roads, bridges, or ports are washed out.
- *Urban aerial mobility (UAM)* can relieve congestion in urban areas because cargo and passengers can be transported into, out of, and within a city without using crowded roads and bridges.
- UAM and RAM fall under the *advanced aerial mobility (AAM)*, which incorporates operations in urban, suburban, and rural environments, such as commercial inter-city operations, cargo delivery, public services, and private or recreational vehicles.

Land Use & Street Design – For aerial mobility to be successful, a network of locations where aerial vehicles will take off and land will need to be established, which can impact land use. Vertiports will need to be in convenient but safe locations for passenger travel. Locations where packages can be dropped off also need to be considered (i.e., can packages be delivered to rooftops, into buildings, or can the curb space be redeveloped for deliveries). Government agencies like NASA have developed a model that identifies the best locations for vertiports that can be used as a foundation for locating vertiports in the region.

Safety – Aerial vehicles present a safety concern for the public if there is a vehicle crash or if the system fails. To ensure the system is being safely developed, all failure scenarios need to be considered and mitigation strategies need to be implemented. Weather, cyber security, and airspace security may also impact aerial mobility. Airspace management needs to be built to be flexible so contingency plans can be implemented whenever unexpected bad weather is encountered, system elements fail or are attacked, or non-cooperative air traffic enters an airspace region normally occupied by cooperative traffic.[54]

Aerial mobility can also improve societal safety by supporting emergency management missions such as air ambulance, emergency supply delivery, organ transport, crash investigations, and search and rescue operations.[55]

Environmental Sustainability – The aerial mobility network can impact the environment, but steps are being taken to mitigate these impacts. Most futuristic aerial vehicles are electric powered (e.g., eVTOL vehicles), using a potentially clean energy source. Electric vehicles are also quieter compared to liquid-fueled vehicles. The locations of vertiports can also impact the environmental sustainability of the aerial mobility networks. A Carnegie Melon University study found drone delivery accounted for 84% less greenhouse gas emissions than a diesel truck—it also used 94% less energy. The National Renewable Energy Laboratory (NREL) has launched a research partnership to determine energy costs, market viability, public acceptance, station distribution, accessibility, and environmental sustainability.[56] There is some initial research suggesting electric aerial mobility could be slightly more efficient energy consuming than an equivalent electric taxi performing the same trip with the same payload.[57]

Challenges and Opportunities

The initial challenges cities will face include security and safety, changes to the regulatory environment, flexibility, and scalability. Specific examples of challenges and opportunities to address them are discussed below.[58]

Challenges	Opportunities
Advanced aerial mobility will have to demonstrate the high safety levels expected by the public for modern air transportation systems.	Policies in the US and Texas ensure aerial vehicles are only allowed to fly in a controlled manner and in areas that will cause minimal harm if there is a crash. National and local policies are slowly being changed as more tests are complete. The NCTCOG Legislative and Policy UAS Safety and Integration Initiative Working Group should continue to provide policy recommendations and comments to the FAA and State government.
Emerging technologies present new cybersecurity risks and vulnerabilities that will have to be managed.	Aerial mobility network developers are focusing on security. Redundant systems will help reduce security risks. To further minimize risks, aerial vehicle policies implemented by the State of Texas and local entities such as airports should follow federal regulations but should still be flexible to meet local needs.
New products or services applying advanced aerial mobility must gain the trust and support of the public, taking into account multiple factors.	Local governments should work with the NCTCOG Education and Public Awareness UAS Safety and Integration Initiative Working Group to connect the community with public and private partners early on. These groups help educate the public and key stakeholders about aerial mobility policies and provide training for aerial mobility jobs.
Contingency management, the ability to manage the expected and the capability to recover	Resilience is being built into the aerial mobility network in a scalable manner as the industry expands. As the aerial mobility network grows, so will the resilience complexities.

Challenges	Opportunities
from the unexpected, will be a key to success.	Incorporating resilience from the start ensures an effective management and recovery system is used. NCTCOG should continue to work with the Testing and Integration Working Group to ensure impactful projects are beneficial for aerial mobility companies and the public.
Factors such as noise and visual impact from air vehicles on the environment and nonparticipants, as well as greenhouse gas emissions and any associated air pollutant emissions, will have to be minimized to acceptable levels.	Most aerial vehicles being developed are battery operated. Being battery operated helps dampen the noise these vehicles produce while also enabling the fuel source to come from a potentially renewable source. NCTCOG should continue to work with the aerial mobility vendors through the Testing and Integration Working Group to ensure vehicles being used in the state meet all the local environmental requirements.
New rules to accommodate the technology as well as to define its integration into the National Airspace System will have to be created.	Regulations are slowly being updated with input from private industry partners. This ensures regulations being passed are helpful for both the public and private industry. The NCTCOG Working Groups should review and comment on federal and state policies so meaningful, impactful, and implementable policies are passed.
Any successful approach to advanced aerial mobility will need the capability to scale as the market segments emerge and grow.	The aerial mobility system needs to be scalable for all stakeholders. Private industry partners need to work together, so the aerial system works for all companies, not just a few. The FAA needs to ensure they can regulate all aerial vehicles and their trips. NCTCOG should continue to test aerial vehicles and systems in both urban and rural areas and adopt successful practices that can be scaled.
Flexibility is critical with any disruptive new initiative as new use cases and operational concepts emerge.	The future of aerial mobility is not known. The existing system needs to be flexible so it can grow and bend to both public and private industry needs. NCTCOG can use its Working Groups* to bring stakeholders (e.g., government agencies and private aerial mobility companies) together to discuss what different areas need to do to integrate aerial mobility technologies so a safe, effective, and efficient aerial mobility system can be implemented.

*NCTCOG has multiple working groups within the North Texas UAS Safety and Integration Initiative that bring stakeholders together, including:

- Education and Public Awareness
- Legislative and Policy
- Training and Workforce Development
- Testing and Integration

References

[44] UC Berkeley Sustainable Transportation Research Center. Reimagining the Future of Transportation with Personal Flight: Preparing and Planning for Urban Air Mobility
[45] UC Berkeley Sustainable Transportation Research Center. Reimagining the Future of Transportation with Personal Flight: Preparing and Planning for Urban Air Mobility
[46] FAA. Urban Air Mobility and Advanced Air Mobility
[47] NCTCOG. North Texas UAS Landing Page
[48] UC Berkeley Sustainable Transportation Research Center. Reimagining the Future of Transportation with Personal Flight: Preparing and Planning for Urban Air Mobility

[50] Global News Wire. Advanced Aerial Mobility Market to Garner $110.02 Billion by 2035: Allied Market Research
[51] Booz Allen Hamilton. Urban Aerial Mobility Market Study
[52] Financial Times. The Questionable Economics of Autonomous Taxi Fleets
[53] EVTOL. Volocopter unveils VoloConnect, its longer-range eVTOL air taxi
[54] National Academies Press. Advancing Aerial Mobility: A National Blueprint
[55] UC Berkeley Sustainable Transportation Research Center. Reimagining the Future of Transportation with Personal Flight: Preparing and Planning for Urban Air Mobility
[56] https://www.nrel.gov/news/program/2022/advanced-air-mobility-takes-flight-with-new-partnership.html
[57] International Conference on Innovation in Aviation & Space to the Satisfaction of the European Citizens. Energy consumption and environmental impact of Urban Air mobility
[58] Booz Allen Hamilton. Urban Aerial Mobility Market Study

Micromobility

Under the umbrella of active transportation, micromobility is a specific term for mobility using small, lightweight vehicles operated by users at speeds typically below 20 mph. Examples include both human-powered and electric bicycles, scooters, skateboards, and cargo bikes. They can be privately owned or shared through a short-term rental program within a specified geographic region. Users can rent a micromobility vehicle using a smartphone app and pay with a credit or debit card through that app or through a SMS-text-based alternative for renting.

Micromobility is often described as a "first and last mile connection"—or as a mode of transportation intended for short trips in both distance and duration, [59] mostly in urban environments, to connect to public transit and other destinations.

Shared micromobility rental programs typically offer docked, dockless, or hybrid service. Docked service systems provide designated parking and charging locations for vehicles not in use. Dockless service systems allow users to start/end rides at any location and provide a re-balancing service that moves and charges devices. Hybrid models provide users with the choice of returning to a dock, lock to a public bike rack, or designated area out of the public right of way.

Applications

Micromobility technologies are used for both personal mobility applications and freight movement applications (such as cargo e-bikes) in the existing transportation system. Average trip lengths on bikes and scooters range between 0.5 – 2.0 miles, so micromobility is typically used in urban areas where trip distances are shorter. The range of electric assist devices can vary according to weight, speed, and topography, but e-scooters in today's systems have about 20+ miles per charge.[60] E-bikes typically are able to provide about 40-50 miles of range, riding at an average of 12 mph and low to medium rider effort.[61]

Status

Micromobility services launched in the US in 2008 as docked bikeshare systems. Micromobility began to explode across the country and the world in 2017, when smartphone location-based services enabled the first generation of dockless bikeshare systems. Docked and dockless e-scooter systems first appeared in the US in 2018. As of June 2021, US micromobility deployments included 66 docked bikeshare systems, 60 dockless bikeshare systems, and 214 dockless e-scooter systems (excluding systems limited to college or employment campuses).[62] While operations were significantly scaled back in many locations during the pandemic, the micromobility industry is projected to grow to be a $500 billion industry globally by 2030.[63]

The Dallas dockless vehicle program was paused in Fall 2020, but other municipalities within NCTCOG continue to operate micromobility programs, including Plano, Texas with Bird permitted to operate a maximum of 1,000 devices.

In the coming years, expected micromobility innovations include:

Accessible Micromobility Device Deployments – Providers are designing and deploying adapted designs, such as hand-powered pedal bikes, electric-powered wheelchair assist, seated scooters, and seated tandem bikes, to increase accessibility for people with disabilities.[64]

Alternative Charging Strategies – To combat the extra logistics and emissions of retrieving dockless electric vehicles and redistributing them after charging, providers are piloting dispersed infrastructure to charge batteries and swap them out on the grid network (by trained technicians) in Russia and parts of Europe.[65] Cities are also piloting designated charging station dock infrastructure for e-scooters and e-bikes to eliminate the need for expensive collection, charging, and rebalancing of fleets. There also efforts to automate the rebalancing process with technologies that allow operators to remotely operate devices and move them to a charging location or from a location where it's underutilized or blocking the right of way.[66]

Continued growth of e-commerce delivery and cargo bikes – The COVID-19 pandemic has caused accelerated growth of the e-commerce and delivery industry. The trend is leading some cities to shift freight management and good delivery strategies towards cargo bikes for shorter delivery trips instead of larger trucks.

Impacts

Micromobility applications can impact travel cost, mobility, land use and street design, safety, equity, and environmental sustainability. Coupling street design and public policy to shift mode choice from vehicles to "active" modes within the region may have significant impacts in terms of reduced congestion cost, reduced GHG and criteria pollutants (carbon monoxides, nitrogen oxides, ground level ozone, sulfur dioxide, particulate matter, and lead) emissions, and public health benefits from reduced sedentary travel.

Travel Cost – Micromobility services reduce the monetary cost and time cost of travel compared to car parking and walking. Dockless devices can also offer added point to point convenience and travel time savings over biking and transit. For each trip, dockless devices typically charge a $1.00 unlocking fee plus between $0.15-$0.39 per minute (equating to an average 12-minute scooter share trip cost between $2.80 and $4.70).[67]

In Fort Worth, the *Bcycle* docked bikesharing system costs $8 for a day pass and unlimited 60-minute trips.

Basic human-powered bicycles for commuters range in price from $100 to $900, e-bikes range in price from $300 to $3,000 and e-scooters range in price from $100 to $1,500 (with only several hundred dollars of annual maintenance and charging costs for personal e-scooters[68] and e-bikes[69]), compared to AAA's estimated annual cost of $10,000 for personal vehicle ownership.[70] For shared e-scooters and e-bikes with an average trip cost of $4.70, a twice daily commute over 250 working days per year is significantly less than personal vehicle ownership.

Micromobility providers are currently operating as loss-leaders and continue to be supported by venture capital, artificially lowering trip costs for the end user. As pandemic restrictions are lifted, losses for micromobility providers have been reduced. Micromobility services could play a critical role in providing alternative mobility options during the COVID-19 recovery period, but the long-term cost-sustainability of these business models remains uncertain. Micromobility also had a seasonal impact on usage and could be very sensitive to weather, usage could drop significantly when it encountered with wintry weathers. [71]

Mobility – Micromobility devices are most commonly used for first-mile/last-mile connections for both personal mobility and freight applications. These short trips can complement transit by connecting users with bus stops or transit stations for longer trips and can reduce short auto trips. The bike share system in Chicago was associated with a 26% increase in average bus stop ridership, and a 11% increase in average rail station level ridership.[72] With roughly 50% of car trips in the twenty-five most-congested US metro areas being less than 3.0 miles, micromobility devices have the potential to replace some of these short urban vehicle trips.[73] E-scooter travel patterns vary largely in different land use regions for both recreational and non-recreational trips. A recent study in Indianapolis showed that University campus and downtown central business district (CBD) areas had shorter and more direct E-scooter trips for commute purpose. These trips consisted of about 65% of the non-recreational trips analyzed by trip starts in these regions. Areas with restaurants, movie theaters, or parks had longer-duration travelled trips. [74] Thus, micromobility provides an opportunity to change the paradigm of private automobiles dominating public space allocation by enabling a shift toward a new era of mobility. Cities are leveraging micromobility to initiate this change. For example, car-free zones in Paris and Superblocks in Barcelona are naturally suited for micromobility options as a more speed-efficient way to get around as opposed to a personal vehicle.[75]

Some cities and mobility providers have integrated micromobility devices into existing travel apps to facilitate multimodal connections. Innovations in vehicle design may also help to expand mobility services to people with disabilities and other underserved communities.

Land Use & Street Design – Street and curb designs can create safe spaces for micromobility use and storage. Some agencies are updating street design guidelines and integrating micromobility into traditional active transportation planning and design. Others are rebranding the conventional bike lane to include e-scooters and other micromobility devices, separating road space by vehicle speed through striping or physical barriers, and reducing overall speed limits to create safer facilities for micromobility use.

Infrastructure to support the new technologies, such as designated in-street corrals, sidewalk docking points, traditional bike racks, painted parking zones, and geofenced corrals are needed to encourage organized micromobility parking behavior and to reduce accessibility issues surrounding parked devices blocking curb ramps and sidewalk space.

Future innovations in charging docks may also require additional sidewalk infrastructure. Cargo bikes could also require special parking, charging, and street design planning. Policies will need to be updated to address the various sizes of cargo bike and where they are allowed to ride. Infrastructure such as hubs where delivery companies can deliver packages to for cargo bikes to complete the final leg, overnight storage, charging infrastructure, or wider bike lanes may be needed to support cargo bikes.

Micromobility street design guidance is provided by:

- Institute of Transportation Engineers (2021), *Micromobility Facility Design Guide*
- Transportation for America (2021), *Parking & Street Design*
- National Association of City Transportation Officials (2019), *Guidelines for Regulating Shared Micromobility*
- C40 Cities (2020), *Cargo bikes: Safely delivery goods during the COVID-19 crisis and paving the way for a zero emission freight future*

Safety – Micromobility users are vulnerable road users, and several issues affect micromobility safety. First and foremost, over 80% of micromobility user deaths are a result of crashes involving motor vehicles.[76] Street design and land use policies can help create safer places to ride and lower speeds of motor vehicles to reduce safety risks for vulnerable road users. Safety of micromobility riders can also be impacted by the lack of personal protective equipment use among riders (particularly helmets) due to the spontaneous nature of many trips. Lack of control due to inexperience riding the devices and falls due to defects in paved surfaces like potholes can impact safety. Poor bicycle network connectivity and sidewalk riding also create safety risks for micromobility riders and pedestrians.

Equity – Micromobility equity concerns relate to where devices are located and who can access them. Local agencies can partner with providers to create geofenced zones and to set requirements for the minimum number of devices that a vendor must provide within each zone, as in Baltimore, MD's "Equity Zones" for their dockless vehicle pilot.[77]

The same vehicle location data that enables the geofenced Equity Zones can also provide agencies with routing and origin-destination information to study trends and identify locations for facility improvements.

Agencies increasingly require micromobility providers to have options for unbanked users and users without smart phones to unlock and rent devices, as in Portland, OR.[78]

Environmental Sustainability – Replacing vehicle trips with micromobility trips could reduce greenhouse gas emissions and criteria pollutants (carbon monoxides, nitrogen oxides, ground level ozone, sulfur dioxide, particulate matter, and lead).

Bikesharing is found to replace public transport most (41%), followed by walking (29%) and private cars/motorcycles (10%). Shared e-scooters are found to replace walking most (43%), followed by taxis/TNCs (22%) and private cars (13%).[79] The reduced vehicle use, and vehicle miles travelled would reduce emissions energy needed for travel compared to an internal combustion-engine. [80]

According to the EPA, transportation is responsible for 29% of U.S. GHG emissions. Providing more environmentally friendly choices is an important part of Mobility 2045: The Metropolitan Transportation Plan for North Central Texas. The plan supports goals of providing non-motorized or transit modes for all trips less than 2 miles and designing roadways to accommodate at least three modes of transportation.[81] In the Dallas-Fort Worth area, NCTCOG projects the regional cost of congestion to be about $12 billion per year and forecasts this rising to $27.2 billion in 2045. If the plan, programs, and projects listed in Mobility 2045 are not implemented, the cost could rise to $47.9 billion in 2045.[82]

Micromobility and the COVID-19 Pandemic – At the onset of the COVID-19 pandemic, many micromobility providers removed their devices due to health concerns, and the following months of lockdowns dramatically reduced ridership.[83] Since that initial dip, micromobility has rebounded considerably, being hailed as a crucial component of pandemic recovery in many places.[84]

"COVID was able to highlight **micromobility as an essential transportation service**, filling in where transit service stopped or where gaps existed and helping essential workers get to work"

- Samantha Herr, Executive Director, North American Bikeshare Association (NY Times)

Challenges and Opportunities

The initial challenges cities will face likely include safety concerns for users and other pedestrians, shifting mobility needs, and consideration of equity in business models. Specific examples of challenges and opportunities to address them are discussed below.

Challenges	Opportunities
Right-of-way obstructions impact mobility of people with disabilities, older adults, and other pedestrians and create "sidewalk clutter"	Consider lock-to requirements, enforcement regulations, parking zones, and additional parking infrastructure tailored to micromobility, including swapping existing on-street parking for a bicycle and scooter dock or storage rack. These policies should be coordinated among jurisdictions to avoid confusion on where devices may be used and parked. Cities can also develop performance-based criteria (such as implementation of a safe parking outreach program or response time to illegally parked devices) for operator permits and incrementally increase vehicle caps based on vendor performance.

Challenges	Opportunities
Safety. Collisions with vehicles are the most dangerous safety issue. Dangerous riding habits and low helmet usage are a safety risk for riders and pedestrians	Street design and land use policies can help create safer places to ride and lower speeds of motor vehicles to reduce safety risks and crashes involving vehicles. Collect additional data on helmet use, injuries, and accidents caused by collisions with vehicles, rider error, device malfunction, potholes, or illegal riding to conduct comprehensive safety evaluations. Cities can include safety data sharing and safety outreach to users as part of the operator permitting requirements or geofenced no riding zones or speed limits. Establishing strict speed limits or speed governor zones may also be considered for non-micromobility modes to reduce speeds of all vehicles in the same area. Implementing safer places to ride such as bike lanes can also help to discourage unsafe riding such as sidewalk or wrong way on street riding.
Lack of awareness of rules and regulations	Engage stakeholders to increase awareness for both users and non-users of micromobility. Agencies need to educate the public and law enforcement on micromobility policies and local jurisdictions should work with e-scooter providers to coordinate outreach to users.
High speed streets discouraging ridership	Update curbside management and public right-of-way policy to prioritize infrastructure investment that creates safe space for micromobility use and parking.
Changing traveler behavior due to COVID-19	Monitor traveler behavior changes including bus stop ridership, rail station ridership, urban vehicular parking, and trips, and micromobility origin/destination data to determine the impact of micromobility programs on local travel patterns and adjust policies and regulations to the "new normal" as necessary. After initial decline, some cities are experiencing rapid growth in micromobility use.[85]
Weather impacts. Devices and docking areas may not be suitable for poor weather conditions like snow and heavy rainfall	Establish weather-related operational procedures to ensure safe storage of devices during hurricanes or other major weather events. Cities should engage and coordinate with a variety of stakeholders such as public safety and public works departments for clear roles and responsibilities during these events.

Challenges	Opportunities
Cost Uncertainty. Micromobility business models change quickly, require a high initial investment, and to date have not generated a positive cash flow for investors	Use scenario planning when seeking to use mobility services and making decisions as technology, economic trends, regulation, and other factors are changing. Cities can consider how business models may change in the near and long term and what risks those changes pose (and applicable risk mitigations).[86] For example, cities may consider public-private partnerships to jump start a service with public agency financing initial start-up costs and perhaps subsidizing daily operating costs such as vehicle recovery and maintenance.
Equity. Micromobility services can be skewed towards those in wealthy neighborhoods and entertainment districts	Include performance requirements within Equity Zones, geographic areas where operators must operate a certain number of devices. Cities may also include equity criteria, such as providing options for the unbanked, people without smartphones, people with disabilities, and low-income travelers, in operator permit applications.
Rural/Suburban. Services not profitable in moderate to low density suburban areas	Right-size policies and regulations to lower density areas. For example, consider partnering exclusively with one provider in lower density areas to make operations more profitable, lower fees per device for operators, or a free-floating parking model to avoid long walks to and from parking zones.[87]

References

[59] Purdue University. Analysis of E-Scooter Trips and Their Temporal Usage Patterns
[60] Lime Bike. Electric Scooter Sharing
[61] Bosch. eBike Range Calculator.
[62] Bureau of Transportation Statistics. COVID-Affected Micromobility Changes Differ by City.
[63] McKinsey & Company. Micromobility' s 15,000-mile checkup.
[64] Fast Company. These 7 new accessible vehicles let people with disabilities access micromobility.
[65] Raido. Universal Charging Infrastructure.
[66] Tortoise. Shared Micromobility

[67] National Association of City Transportation Officials. 2020 Bikeshare Snapshot.
[68] Eridehero. How Much Money Can You Save by Using an Electric Scooter.
[69] Bicycle Volt. Electric Bike Maintenance Cost
[70] AAA. Sticker Shock: Owning a New Vehicle costs Nearly $10,000 annually.
[71] Purdue University. Impact of Weather on Shared Electric Scooter Utilization
[72] University of Wisconsin Milwaukee. Public Transit and Micro-Mobility: Identifying the Impacts of Bikeshare on Public Transit Ridership in the City of Chicago
[73] INRIX. Micromobility Potential in the US, UK, and Germany.
[74] Purdue University. Analysis of Recreational and Last Mile E-Scooter Utilization in Different Land Use Regions
[75] Tech Crunch. How Four European Cities are Embracing Micromobility to Drive Out Cars
[76] International Transport Forum. Safe Micromobility
[77] Baltimore City Department of Transportation. Baltimore City Dockless Vehicle Pilot Program Evaluation Report
[78] Portland Bureau of Transportation. Cash Payment E-Scooter Rental Options.
[79] Transportation Research. Mode choice, substitution patterns and environmental impacts of shared and personal micro-mobility, Transportation Research Part D
[80] Institute of Transport Research. Is micro-mobility sustainable? An overview of implications for accessibility, air pollution, safety, physical activity, and subjective wellbeing
[81] NCTCOG. Mobility 2045
[82] NCTCOG. 2019-2022 Transportation Improvement Program
[83] Smart Cities Dive. Will scooters survive the COVID-19 crisis?
[84] Smart Cities Dive. Micromobility 'here to stay' despite COVID setbacks: NACTO
[85] The New York Times. As E-Scooters and E-Bikes Proliferate, Safety Challenges Grow
[86] Federal Highway Administration. Mobility on Demand Business Models Scenario Planning Template
[87] Bloomberg CityLab. The Local Regulations that can kill e-scooters.

HIGHWAY SYSTEMS TECHNOLOGIES

Highway systems technologies include devices used to gather and disseminate data about the status of roadways and transit systems. They serve to detect, control, and inform users while they are traveling. Detection devices are critical to gather information used by dynamic control and information systems.

These devices can be located along the transportation network or at the Traffic Management Center (TMC). In some instances, devices gather and process data in situ, immediately using that information to dynamically adjust control or information devices. In other instances, devices send data to a remote location such as a TMC or private entity for processing. The data can then be used by staff in the TMC to deploy instructions to control and information devices.

Applications

Highway system technologies can be deployed at any point along the transportation network, in settings that are high speed and low speed; urban, suburban, and rural locations; for pedestrian, bicyclist, passenger, freight, and transit vehicles; and, on interrupted and uninterrupted segments. Regardless of their location, these technologies typically fall into one of three types of devices:

- Detection devices
    - Point Detection devices are typically devices such as loop detectors, cameras, radar and lidar used to characterize speed and volume. Occasionally they will be used for additional measurements such as estimating density, detecting queues, or detecting red light violations. In general, they monitor road traffic, but more and more devices are emerging to provide monitoring capability for bikes and pedestrians.[88]
    - Segment Monitoring are typically devices such as Bluetooth or Wi-Fi sniffing sensors that can be used to estimate travel time or origin-destination.[89,90] These are point detection systems that are deployed in at least pairs, and often times several dozen[90] to track vehicles between points to estimate travel time, delay, origins, and destinations.
    - Connected Vehicles can take a variety of forms ranging from dedicated short-range communication (DSRC)[91] to vehicles connected directly to the cloud.[92,93] Due to the extensive sensors on vehicles, these vehicles can provide a richer source of data than point detection.
- Control devices seek to manage conflicts between transportation users and often include multiple modes such as vehicles, pedestrian, transit, rail, and bicycles.[94]
- Information devices seek to inform users of critical location or directional information.

Status

While significant advancement has been made in the areas of detection, control, and information devices, the barrier to realizing benefits is the timeframe over which system wide adoption occurs.

Detection – *Point Detection* devices historically were statically located in the transportation network and reported data about many or all users at that location. Bluetooth, toll tags, and Wi-Fi detection devices have provided enhanced mobility data over segments and now provide for detection of single users as they move through the network. Infrastructure-based detection technology (such as loop and video detection) will likely be the preferred detection technology for traffic signal control for the next 30 years. However, these point- and segment-detection systems cannot scale to cost effectively provide the network-level data that cellular connected vehicle technology provides.

Currently, the North Central Texas region has more than 7,000 signal systems. Many use detection devices. There are also numerous detection devices operating at the segment level of arterials and along limited-access roadways.

Many states have used connected vehicle data for the past decade to assess system-wide mobility[93]. A recent study in Indiana, Ohio, and Pennsylvania found that approximately 4-5% of the vehicles in the states were providing speed data to Wejo at 3-sec reporting intervals with a latency of just under 1 minute.[95]

This CV data is being used for monitoring traffic signal efficiency,[96,97] as well as queuing on the interstates and associated hard braking[97,98] in Indiana and Texas.

Artificial Intelligence (AI) is currently in prototype and production stages for short-term traffic detection of queues and pedestrians as well as prediction of trajectories, used for traffic adaptive signal control, transit signal priority, and work zone management.[99]

Control – *Control Devices* typically refers to traffic signals, but other control techniques such as ramp metering, dynamic lane assignment, and reversable lanes are also used to a lesser extent. The fundamental requirement for efficient control is establishing an agency policy on what performance measures are important and should be focused on. There has been extensive work over the past decade in this space. Nevers et al.[94] provides an extensive summary of that work. Using information from detection devices, emerging control devices can dynamically adjust to account for events such as weather[100] or demand resulting from construction zone diversions.[101]

Integrated corridor management plans were developed for the US-75 corridor in Dallas, which allows for special incident signal timing plans.

AI monitoring and analysis of incoming detection information is at the research and development level with some prototyping.[102]

Use of AI for fusion of data gathered from detection devices can improve decisions made by control devices as well as information shared through information devices. It allows TMC operators to evaluate the full context of a situation without having to look at multiple data streams. This technology is currently in production.[102]

Information – Historically, *Information Devices* included devices such as static warning signs for upcoming curves or fog areas as well as static signs for special event traffic routing.

The North Central Texas region has a 511 system which informs road users of road and weather conditions. The traffic management centers in the area gather and disseminate information to road users – through 511 and dynamic message signs – and first responders. NCTCOG is planning a “data lake” deployment, which will allow for sharing of detection information across the region and state. This will enable control devices in a neighboring jurisdiction upstream of the detector to use the data and respond appropriately.

Emerging technology uses information from detection devices to allow for dynamic, remotely controlled information to be provided through dynamic message signs located throughout the network or in-device messages (through vehicle displays or phone apps). These messages provide real-time information such as transit arrival times, downstream incidents or congestion, and weigh station guidance.

Use of AI for fusion of data gathered from detection devices can improve decisions made by control devices as well as information shared through information devices. It allows TMC operators to evaluate the full context of a situation without having to look at multiple data streams. This technology is currently in production.[99]

Impacts

Travel Cost – Effective deployment of highway systems technology can result in reduced cost of travel time and greater reliability.

A recent evaluation of the Dallas US-75 integrated corridor management system resulted in reductions of person hours traveled between 0.06 – 1.41% during the peak hours. Travelers tended to utilize alternate routes but the expected shift between modes was not realized.[99]

Safety – Detection advances, such as intersection monitoring of conflicts, can provide increased understanding of safety concerns that are otherwise not visible from crash data alone.[103] Increased use of information devices, including in-device and on-road alerts, can provide advanced warning of hazardous conditions and allow agencies to prioritize upgrades much faster than if they wait several years for traditional crash data to accrue.[104] Changeable crash-ahead warning signs have been shown to reduce crashes by up to 44% while roadside close-following alert systems reduce rear end crashes by 6%.[105]

Equity – It is necessary to critically evaluate the source of data from detection devices to understand the equity impacts. Devices such as Strava, a phone application that tracks and aggregates pedestrian and bicycle travel, must be installed and activated on a phone for the trip to be tracked. This leads to capturing data from recreational users more than commuters. Similarly, advances in tracking individual vehicles or conveying information to individual vehicles through connected devices prioritizes occupants of newer vehicles equipped with the technology. Improvements in highway system technologies tend to benefit primarily single occupant vehicles, the predominant users of the highway system. Strategies that favor transit vehicles, other high occupancy vehicles, and non-vehicle users can partially compensate.

Environmental Sustainability – Strategies that make driving an automobile more convenient tend to increase driving demand, which increases air pollution, greenhouse gases, and fossil-fuel consumption. Focusing on improving mobility for non-motor vehicle and high-occupancy modes may mitigate these impacts, as would using environmental sustainability as an objective for automobile-focused projects. For example, optimizing the signal timing of a corridor for reduced emissions (typically achieved through reduced stops) can result in decreased carbon dioxide emissions on the order of 5-10%.[106] In addition, these strategies could reduce criteria pollutants (carbon monoxides, nitrogen oxides, ground-level ozone, sulfur dioxide, particulate matter, and lead).

Challenges and Opportunities

The initial challenges cities will face likely will be the large amount of data available, prioritization of device upgrades, and device interoperability. Specific examples of challenges and opportunities to address them are discussed below.

Challenges	Opportunities
Decision making. Increased access to detection devices can lead to decision paralysis when considering which data to purchase or use	NCTCOG should consider implementing an objectives-based performance management plan or assisting member agencies in deploying such a plan. This plan would be championed by management, engineers, and technicians, guiding staff and consultants to first determine the objective meant to be achieved with each project. Users would then critically evaluate which data source(s) and temporal/spatial extents of data would most inform decisions related to that objective.
Interoperability. Tens of thousands of detection, control, and information devices exist across NCTCOG. Upgrading all devices simultaneously is not practical or cost effective. Interoperability of devices is important.	Agencies should consider prioritizing device upgrades along corridors over isolated intersections. On limited access roadways, agencies should prioritize segments with known operational or safety challenges. When acquiring new devices (be it detection, control, or information), agencies should use performance-based specifications to increase the likelihood of interoperability between devices. Agencies should develop and implement communications standards as devices are upgraded to ensure interoperability across devices. NCTCOG should focus on investing in infrastructure-based detection needed for real-time control. For system wide monitoring, crowdsourced probe data is a much more scalable and cost effective approach.[107]

Challenges	Opportunities
Across-Agency Data Sharing. Devices are maintained by multiple agencies throughout North Central Texas leading to challenges in sharing data across agency boundaries.	The planned deployment of a "data lake" sharing system will alleviate some of these challenges, allowing control and information devices upstream of an incident to respond based on detection data gathered at the incident. NCTCOG can also work to educate agencies on the benefits of Waze Communities Partnerships and Work Zone Data Exchange (WZDx) programs as a means of sharing information across boundaries.

References

[88] FHWA. Traffic Detector Handbook: Third Edition
[89] Purdue University. Roadway System Assessment Using Bluetooth-Based Automatic Vehicle Identification Travel Time Data
[90] Purdue University. Estimating Route Choice and Travel Time Reliability with Field Observations of Bluetooth Probe Vehicles
[91] Ohio Department of Transportation. Setting The Stage: Technology White Paper.
[92] U.S. House of Representatives. Testimony of Darcy Bullock to the U.S. House of Representatives Committee on Science, Space, and Technology
[93] Purdue University. 2012 Indiana Mobility Report
[94] NCHRP. Performance-Based Management of Traffic Signals
[95] Journal of Transportation Technologies. Estimation of Connected Vehicle Penetration on US Roads in Indiana, Ohio, and Pennsylvania
[96] Transportation Research Board. "Deriving Operational Traffic Signal Performance Measures from Vehicle Trajectory Data
[97] Journal of Transportation Technologies. Longitudinal Performance Assessment of Traffic Signal System Impacted by Long-term Interstate Construction Diversion using Connected Vehicle Data
[98] Purdue University. Hard-braking event dataset for I-35, TX. Purdue University Research Repository
[99] FHWA. Integrated Corridor Management Analysis, Modeling, and Simulation for the U.S.-75 Corridor in Dallas, Texas – Post-Deployment Assessment Report
[100] Journal of Transportation Technologies. Leveraging Telematics for Winter Operations Performance Measures and Tactical Adjustment
[101] IEEE. Methodology for Applying Connected Vehicle Data to Evaluate Impact of Interstate Construction Work Zone Diversions
[102] FHWA. Summary of Potential Application of AI in Transportation
[103] National Operations Center of Excellence. Accelerating Vision Zero with Advanced Video Analytics: Video-Based Network-Wide Conflict and Speed Analysis
[104] J. Big Data Anal. Transp. A Proactive Approach to Evaluating Intersection Safety Using Hard-Braking Data.
[105] Elvik, R. and Vaa, T., Handbook of Road Safety Measures
[106] Travel Behavior and Society. Traffic signal Optimization in Disrupted Networks, to Improve Resilience and Sustainability. 2021.
[107] U.S. Department of Transportation, Federal Highway Administration. Innovator Newsletter

CURB SPACE MANAGEMENT TECHNOLOGIES

Demand for curb space has rapidly increased. The parking ecosystem in the North Central Texas region is made up of a diverse range of users, including personal vehicles, public transit, ride-hailing services, commercial deliveries, and new options such as shared micromobility. All these users increase the demand for already limited curb space. Parking system technologies can help increase the curb's functionality and improve safety and access for all travelers. While this chapter focuses on managing curb space, there are a variety of land use, policy, and pricing strategies under the umbrella of parking. These impacts and strategies are discussed further in the Vehicle Technologies and Integrated Technologies chapters.

Applications

Curb space management and parking system technologies are most common in areas where demand for the curb exceeds supply, and typically where on-street parking is metered. The three main applications for these technologies are:

- Special uses, including large event and entertainment venues, airports, and campuses
- Mixed-use developments, including downtowns or central business districts
- High-density residential areas, typically adjacent to mixed-use areas

Status

Parking Governance – In the NCTCOG region, parking regulations and enforcement are typically managed by local governments such as local departments of transportation, public works, or the police department. In many cases, different divisions or departments within these local governments set parking policies, enforce policies, and handle the adjudication. Other governance strategies include parking benefit or management districts, which are public or private management entities that manage parking spaces within a specific boundary and reinvest the parking revenues into improvements.

NCTCOG developed best practice recommendations for parking management and curb planning and could play a key role in facilitating a coordinated regional parking management approach.

Demand-Based Pricing and Time Limits – Establishing pricing and time limits for parking and curb usage based on demand can help distribute demand more evenly for parking. Parking demand management, traveling information sharing, and wayfinding can reduce situations where vehicles are circling a block with no parking available without knowing there are multiple available parking spaces on other nearby blocks. Raising prices for premium spots near popular destinations at peak times and setting time limits can also encourage more turnover of spots.[108] Prices, time limits, and allowed uses could change based on the time of day to best serve the demand for the curb (such as goods loading/unloading zone in the early mornings, passenger loading zone in evenings, and long-term parking overnight).[109] These strategies have been deployed by many cities, but determining prices, time limits, and allowed uses is an iterative process informed by constant evaluation and adjustment and the local context.

Data Collection – Before deploying parking system technologies, data collection tools evaluate conditions of a street, adjacent land uses, and how the curb is currently being used at different times of the day. The current data collection methods available include manual field observation, video data collection, citation data, or data from existing parking payment systems or sensors on parking usage patterns.

Reallocation of Space – Curb space management involves more than adjusting the cost of parking a private vehicle. Some cities have responded to increased demand for the curb by re-imagining street design and how space is allocated. For example, the curb space can be reallocated for other uses such as delivery zones, transit passenger pick-up/drop-off zones, Transportation Network Company (TNC) pick-up/drop-off zones, or geofenced boundaries, in-street corrals for dockless micromobility devices, or expanded pedestrian and bike facilities. Reallocating curb space by time of day, day of the week, and seasonally can help maximize the economic and social outputs of the curb space.

Consistent Enforcement – Enforcement is essential to managing the curbside and minimizing vehicles blocking facilities for people walking and biking. To date, the use of automated enforcement technologies, whether by pole-mounted license plate readers or vehicle-mounted cameras, has proven effective and unbiased in its application.[110] Effective June 2, 2019, per HB 1631, local authorities are no longer permitted to install or operate photographic *traffic signal enforcement systems*, or red light cameras, and use of evidence from photographic enforcement systems is prohibited, but automated parking enforcement with license plate readers is allowed.[111]

The City of Dallas uses automated license plate readers for parking enforcement, and a 2016 Downtown Parking Study in Plano recommended modernizing the city's handwritten system to be digital.[112,113]

Real-time Parking Availability – The technologies to provide real-time parking availability include mobile applications, websites, and signs to inform travelers and allow potential users to compare prices, find available spaces, and make informed decisions. Applications such as ParkMobile, which is operational in the Dallas area, also facilitate a variety of mobile payment options. These applications can highlight real-time sensor or zone-level predictive parking availability for all users and integrate the information into navigation apps. Public or private parking lots and garages can use these navigational parking applications supported by data sharing, partnerships with private providers, and periodic data checks for accuracy.

At DFW International Airport, for example, parking space sensors direct travelers to open spaces.

Partnerships – Cities might consider establishing partnerships with transit agencies; TNCs such as Uber, Lyft, and Via; delivery and logistics companies; and restaurant associations to meet passenger and good delivery needs. Many agencies have partnered with mobility providers to provide first-/last-mile connections or designated pick-up and drop-off zones for large events. Intergovernmental coordination within cities, such as between traffic engineering and planning departments, is important to consider all possible alternatives when designing special event traffic management, new curb space management strategies, street design, or space reallocation.

Impacts

Travel Cost – Parking technologies enabling delivery drivers to find open loading zones and loading docks more quickly can reduce truck shipping costs and improve reliability. For auto drivers, demand-based pricing of the curb space could mean higher or lower parking costs depending on the location and proximity to popular destinations. Costs to local governments to deploy, operate, monitor, and maintain parking management systems may also increase but can at least be partially paid for through local parking fees.

Mobility – Effective curb space management maximizes the efficiency of the space. There may be improved loading zone availability by reducing the amount of time occupied by non-commercial vehicles. For drivers, parking system applications can simplify their parking experience by providing accurate real-time information, a convenient parking payment process, and reduce the amount of time spent circulating for an open space. For ride-hail passengers, designated pick-up zones can provide a dependable, designated location to easily find a ride.

Land Use & Street Design – With a more efficient use of the existing curb space, these new technologies may enable agencies to dedicate less street space and less land to parked vehicles. Greater deployment of advanced parking system technologies might support greater densities of development. These new technologies might enable agencies to modestly reduce off-street parking requirements for new development by facilitating shared use of parking spaces.[114]

The City of Dallas Zoning Ordinance Advisory Committee (ZOAC) is in final stages of recommending revisions to parking codes in the city, including its parking minimums rules.[115] Outdated parking minimum requirements for new development have contributed to a large oversupply of parking that could be used for other land uses.[116]

Safety – Strategies such as pick-up and drop-off zones and goods delivery zones can improve safety for all users. It can improve safety for rideshare and transit passengers if they do not have to walk into the street to board a vehicle. There may also be a decrease in illegal parking, erratic and unpredictable motorist behavior, and double-parked vehicles blocking travel lanes or bike lanes.

Equity – Parking technologies that require the traveler to use payment methods other than cash to park the car (e.g., to use a cell phone and a credit card number) may be inaccessible for travelers who do not have the necessary devices or accounts. Public agencies could explore partnerships to provide cash payment options. Automated enforcement strategies also help reduce bias in the enforcement of curb space regulations.[117]

Environmental Sustainability – Parking management strategies that increase parking turnover and availability and provide real-time parking information can reduce congestion and emissions by reducing the time and vehicle miles traveled (VMT) of drivers searching for a parking or delivery spot. Implementing these strategies can provide opportunities for reallocating roadway space from dedicated on-street parking or motor vehicle travel lanes to dedicated transit lanes, separated bicycle facilities, or expanded sidewalk space to encourage permanent shifts to more sustainable travel modes.

Challenges and Opportunities

The initial challenges cities will face include evolving curb needs, limited real-time data for planning purposes, and traveler preferences and information sharing. Specific examples of challenges and opportunities to address them are discussed below.

Challenges	Opportunities
Evolving curb needs. Technology and curb space demand are evolving quickly, with existing and emerging modes increasing demand for curb space	Implement curb management strategies and plan for regular updates and adjustments based on new data or the emergence of new mobility options. For example, automated vehicles could impact demand for curb space and electric vehicles could have their own unique needs such as charging-equipped parking spaces.[118]
Limited real-time data for planning purposes. Lack of useful real-time data on parking occupancy and existing uses of the curb space. Manual data collection can also be costly for agencies.	Collect data on existing parking utilization and curb space usage. This effort, coordinated through NCTCOG, could continue to build on NCTCOG's Regional Parking Database.
Finding the right solutions. Determining which curb space management vendor solutions are viable for the NCTCOG region	Test multiple vendors for the same technology to ensure that the best in business serves the region. NCTCOG could establish a programmatic mechanism for piloting new technologies through a "sandbox" approach to test new technologies and ensure effective returns on investment.[119]
Communicating and incentivizing change. Strong traveler preference for single-occupancy vehicle parking	Conduct region-wide Transportation Demand Management to encourage alternative modes of transportation. NCTCOG should also develop a detailed outreach plan to effectively communicate with all stakeholders, with targeted messaging based on an understanding of common stakeholder concerns such as the removal of car parking. Local agencies may also consider policy changes, such as updating outdated minimum parking requirements or other incentives for developers to right-size parking capacity.

Challenges	Opportunities
Equity. Access to real-time information for those without a smartphone or credit card may be limited	Provide free public Wi-Fi for those without cell phone data plans, improved signage, or cash payment options for parking apps. Needs for people with disabilities should also be considered as part of any curb space management strategy.
Coordination and outreach. Lack of coordinated parking management systems across jurisdictions can be confusing for travelers	Establish regular coordination and communication between NCTCOG member agencies, including local DOTs (planning, operations, IT), public works, police departments, local businesses, and other stakeholders. NCTCOG could play a critical role in stakeholder identification, outreach, and coordination.

References

[108] District of Columbia. ParkDC Concept of Operations.
[109] North Central Texas Council of Governments. Curb Management Regional Planning Guide
[110] Governors Highway Safety Association & Kimley-Horn. Equity in Highway Safety Enforcement and Engagement Programs.
[111] Dallas Morning News. Dallas police to get 80 new license plate-reading cameras
[112] City of Dallas Department of Transportation. City of Dallas Parking Enforcement
[113] City of Plano. Downtown Parking Study
[114] National Cooperative Highway Research Program. Foreseeing the Impact of Transformational Technologies on Land Use and Transportation
[115] City of Dallas. Code Amendments (ZOAC)
[116] D Magazine. The City of Dallas Is Putting Parking Spots in Its Crosshairs
[117] Governors Highway Safety Association & Kimley-Horn. Equity in Highway Safety Enforcement and Engagement Programs
[118] NCTCOG. Dallas Midtown Autonomous Transportation System and Shared Parking Feasibility Study
[119] District of Columbia. ParkDC Concept of Operations

INTEGRATED TECHNOLOGIES

In addition to traditional public transportation options, today's mobility ecosystem includes a variety of new options including carsharing, bike and scooter sharing, ridesharing, goods delivery (such as packages and food), and Transportation Network Companies (such as Uber and Lyft). Travelers often need multiple fare cards, accounts, or smartphone apps to access services or information from different transit agencies, mobility service providers, or navigational apps. This can create barriers for some travelers, especially those who do not have access to a smartphone, cellular data plan, or bank account. Additional barriers are created when mobility information is shared in different apps – for example transit information, driving directions, or bikeshare/scootershare locations.

For travelers, the integration of technologies focuses on bringing together multiple mobility options in a region into a single platform, such as multi-modal trip planning, real-time information and navigation, and integrated payment applications to enhance personal mobility.

Cities can encourage and allow public and private mobility providers to assemble optimal trip planning, payment, and ticketing integration apps. The apps can be customized to regions, types of travel, and consumer segment through open data standards.[120] This approach allows various tools and integrated applications tailored for different mobility needs and preferences of individual regions or metropolitan areas. Examples of integrated mobility apps include the MovePGH app launched in Pittsburgh, which enables residents to pay for transit, rent micromobility devices, or rent a car under the umbrella of the Transit app.[121] The Regional GoPass is a great example of an integrated payment system that uses one ticketing account to pay for travel across the Trinity Metro, DART, and DCTA systems.

For agencies, the integration of technologies may also include more holistic, flexible land use design and innovative mobility management approaches like variable pricing or incentives to dynamically manage the entire mobility ecosystem and influence traveler behavior such as destination, time of day, mode, route, and facility choices.

Applications

Integrated mobility applications are most productive and cost effective in urban and suburban areas with higher density of development. In these areas, public transportation and other mobility options are typically more readily available for planning and booking multimodal trips or goods delivery. During peak demand, limited supply can lead to more frequent congestion and the need to manage transportation demand and use.

For rural areas or underserved populations, mobility options are often restricted by geographic barriers, trip purposes, high operational costs for providers, and a variety of eligibility restrictions.[122] For example, eligibility based on age, disability, and location can vary between ADA paratransit, dial-a-ride, or medical transit providers. Integrated applications can improve coordination among a variety of transportation providers such as paratransit/demand-responsive transit or volunteer driver programs to improve mobility for rural areas, older adults, and people with disabilities.

Status

There are a range of integrated mobility technologies. Personal mobility applications provide access to a variety of public and private mobility options in one application. There are varying degrees of integration with these applications, with some including integrated payment options within the app or others linked to a provider's app to complete booking and payment. For example, a traveler browsing options in a multimodal application may select a TNC option and be automatically redirected to the TNC app, with all trip details automatically filled in, to complete the booking of the trip.

Similar to personal mobility applications, Mobility as a Service (MaaS) applications, mostly piloted in Europe, integrate multiple mobility options in one digital platform. MaaS is characterized more as a marketplace, managed by a third party, bundling mobility options into personalized subscription plans. With the mobility subscription, travelers have seamless access to multiple modes. To date, MaaS applications have had limited success, struggling to overcome challenges integrating trip planning, booking, and payment for multiple modes and operators that are often competitors.

Cities and agencies can continue to build the foundations of an integrated mobility ecosystem by encouraging more data standards. Mobility data standards have been successful in the past, including the General Transit Feed Specification (GTFS) and General Bikeshare Feed Specification (GBFS). These data standards allow mobility providers to share their information in a standard format that can easily be used by a variety of apps. These standards will help make the applications more open and interoperable, encouraging the development of transportation planning or payment packages customized to regional consumer needs.[123]

The importance of data standards can be illustrated with the development of email. Whether someone is using Gmail, Yahoo, Outlook, or other software, and the message will be delivered because they were each built on a foundation of data standards to enable interoperability. For the mobility ecosystem, there will likely be multiple integrated applications available to travelers, tailored to regions, types of travel, and consumer segment.

While MaaS emphasizes mobility subscriptions and aggregation, mobility management or transportation system management is focused on managing the supply (mobility providers) and demand (traveler choices) within the transportation ecosystem. Transportation management platforms can streamline trip planning and booking rides across providers with different requirements.[124] Demand management strategies can shift traveler behavior and improve the operational efficiency of the entire transportation system.

Pricing can be used as a transportation systems management tool. Congestion pricing or dynamically priced managed lanes can help to optimize the mobility system, and shift traveler behavior. They may also be used to mitigate and disincentivize some potential negative impacts of TNCs and AVs such as increased VMT from vehicle deadheading (time spent between drop-off and the next pick-up).

Any policy for managing VMT focuses on strategies that shift the mode of travel to more VMT-efficient modes, reduce trip lengths, or reduce the need to travel. Better transit service and higher parking costs are examples of strategies designed to shift the mode of travel to more

VMT-efficient modes. Mixed-use development and other land development policies typical of Smart Growth are examples of strategies designed to shorten trip lengths. Teleworking and other policies that use technology to replace physical travel are examples of strategies that reduce the need to travel. The most effective VMT management policies address all three aspects of VMT: mode of travel (mode choice), trip length (trip distribution), and forgone trips (trip generation). Similarly, flexible land use design applications maximize the efficiency of the use of space during different times of day.

Personal Mobility Applications – GPS, wireless, and cloud technologies coupled with the growth of data availability and sharing are causing people to increasingly use smartphone transportation apps to meet their mobility needs.[125]

- **Integrated Mobility and Payment Applications –** These applications seek to provide a seamless multimodal travel experience by providing full booking services for trip planning and execution. Some multimodal applications also include payment across different modes and providers, but to date, integration is still limited.

  For example, travelers can use the GoPass® mobile app to plan, book, and pay for trips on a variety of Dallas public transit services (including Trinity Metro, DART, and DCTA systems), but not other private mobility providers. The Mobility on Demand (MOD) Sandbox project in Plano also demonstrated providing multimodal options and payment in one app but relied on "soft integration" meaning if a traveler chose a private mobility provider within the GoPass app, they would be redirected to the provider's individual app for booking and payment.[126]

- **Mobility as a Service (MaaS) Applications –** MaaS applications have been piloted around the world with limited success. The first MaaS application was launched in Finland with an app called Whim offering a universal application for mobility, emphasizing mobility aggregation and subscription services that bundle multiple services into a pricing package.[127] The bundled package can include a personalized menu of mobility choices, public transport, shared mobility, taxi, or any mode from a participating public or private provider. Travelers can use any service in their menu of options with no need for separate payments across modes or providers. The challenge as noted by the company's founder was "the modes are not designed to fit together, but you need to get them onto the same service, and somehow agree to that."[128] Pittsburgh has piloted the first U.S. MaaS app. The app has limited capabilities, providing payment options for public transit, bikesharing, and e-scooter trips, but car rental and carpooling still redirects users to individual apps. The application also does not include popular ridehailing apps like Uber and Lyft.

Coordinated Mobility Management – The role of traditional transit agencies is changing. With numerous mobility options to most customers other than traditional public transportation, transit agencies and public providers can collaborate with private mobility providers to become mobility managers of a multimodal transportation system that better serves traveler needs.

- **Travel Management Platforms –** Transportation services for seniors, persons with disabilities, and underserved communities often involve numerous public and private providers, eligibility restrictions, and reservation requirements. These technologies, sometimes referred to as *One Click/One Call*, provide streamlined trip planning, scheduling, and payment across services.

- **Integrated Corridor Management (ICM)/ Active Transportation Demand Management (ATDM) –** Integrated, active mobility management involves holistically managing the entire transportation system.[129] Strategies can include incentives, traveler information, or ITS to dynamically manage transportation supply and demand.

The City of Plano, for example, plans to use Transportation Demand Management strategies to address traffic congestion, safety, and system efficiency during periods of high travel demand, such as morning and afternoon rush hour.

NCTCOG also has deployed the GoCarma app that uses Bluetooth technology to automatically verify two or more travelers are riding together in HOV lanes. If two or more people are riding in the same vehicle, they may travel on the Dallas-Fort Worth area's TEXpress Lane System for a discount. On these roadways, drivers can either choose to pay a variable toll to travel on the TEXpress lanes or use the general lanes for free. HOV vehicles would receive a discounted toll during weekday peak periods. Applications like GoCarma could be leveraged in the future to provide additional dynamic pricing and incentives to optimize operations.

Flexible Land Use Design Applications – These applications facilitate flexibility in land use design in real-time by maximizing efficiency and use of spaces during both underutilized and peak periods. Applications could include peer to peer sharing of spaces during underutilized times, similar to peer-to-peer carsharing applications such as Turo or Getaround renting out personal vehicles when they are not being used or AirBnb maximizing utilization and revenue of excess residential space. For example, a restaurant that is open for only dinner service during the week might lease its tables during the day as a shared co-working space.

Impacts

Travel Cost – There could be significant travel time (such as reduced trip planning time and seamless multimodal transfers), or financial impacts (such as dynamic pricing or incentives providing discounts for off-peak travel and for choosing low-volume routes).[130] Another potential cost impact are VMT fees road user charges, a tax on the number of miles traveled by a vehicle. VMT fees may be applied to all vehicles or may be applied in different ways to certain vehicle types (like trucks) or to certain operating conditions (like an automated vehicle or ridehail vehicle not carrying any passengers). They may be administered annually, quarterly, or on a pay-as-you-go basis. VMT fees are being explored in several states to address the issue of declining revenue from fuel taxes as fuel economy increases. They are marketed as a simple switch from a "pay-per-gallon" to a "pay-per-mile" option that follows a "user pays" principle for infrastructure funding—thus allowing the state to receive revenue from hybrid and electric vehicles that contribute less or no gas taxes but still cause wear and tear on the road. VMT fees incentivize a reduction in the number of unnecessary vehicle trips and the length of trips taken, thus reducing GHG emissions and criteria pollutants (carbon monoxides, nitrogen oxides, ground level ozone, sulfur dioxide, particulate matter, and lead). However, the primary motivation to use VMT fees as a source of revenue is at odds with using them to disincentivize personal vehicle travel. There also could be significant cost savings for agencies in managing existing transportation supply and demand, rather than building roads to increase supply. Agencies will likely have to balance the combination of greater cost-effectiveness and convenience of emerging modes causing a shift to the more convenient or cost-effective mode. For example, congestion increased because of Uber and Lyft service in many areas due to increased demand.[131]

Mobility – Integrated technologies can improve access by providing a personalized menu of on-demand mobility options at travelers' fingertips as an alternative to private car ownership. These applications can encourage connections between public transit and other services to fill gaps in the existing system and provide access to on-demand e-commerce goods deliveries.

Land Use & Street Design – Flexible land use applications promote real-time approaches to land-use encouraging maximum efficiency in the use of space and reducing the need for parking in some areas. Incentivizing convenient, multimodal travel can reduce parking demand and help communities reimagine public space, such as converting underutilized parking space into affordable housing.

Safety – Coordinated mobility management can improve safety for travelers through a proactive, integrated approach for agencies to manage the system during special events, natural disasters, or crashes on a roadway. Dynamically shifting travelers to under-utilized modes can maximize efficiency and reduce the impact of the event.

Equity – Traditional paratransit trips can require complicated eligibility requirements and 24-hour advanced booking. Combination technologies can provide more convenient alternative mobility options for people with disabilities or older adults or can streamline the planning and booking process for specialized transportation services. There are additional equity concerns for people without smartphones, reliable internet service, and credit/debit cards in accessing integrated mobility technologies.

Environmental Sustainability – Through coordinated mobility management, agencies can shift travelers away from private cars, such as through incentives or dynamic pricing, resulting reduced congestion and emissions. Integrated mobility and payment applications also facilitate easier and more convenient multimodal trips as a competitive alternative to using a private car.

Challenges and Opportunities

The initial challenges cities will face likely will be technical, operational, and institutional barriers to integration. Integration of technologies, services, and operational practices touches upon each of these possible challenge areas. Specific examples of challenges and opportunities to address them are discussed below.

Challenges	Opportunities
Partnerships. Integration of public and private mobility options in one application	Explore opportunities for collaboration among modes and providers. Public-private partnerships can support a more multimodal transportation network that better meets traveler needs. Partnerships can extend the reach of public transit with supplementary service (such as first-mile/last-mile connections and late night/off-peak service) and provide additional mobility options for all.[132,133]

Challenges	Opportunities
Data management. Lack of data sharing agreements with private mobility providers due to privacy and proprietary data restrictions	Establish data management procedures that protect customer privacy and proprietary data generated by mobility providers. When requesting data from private mobility providers, agencies should narrowly tailor their data request, knowing what data they want to ask for and how they will use it. To incentivize data sharing, agencies may also consider including specific data sharing as a condition of obtaining operator's permits or offering fee discounts to private providers for sharing data.
Bringing the right people to the table. Potential opportunities for greater coordination between local agencies in the delivery of mobility services	Engage regional stakeholders, build a collaborative group, and integrate mobility management into regional plans and operations. NCTCOG can continue to build on existing regional coordination and active system management, which requires data collection and sharing. NCTCOG can expand efforts with local agencies to coordinate and share transportation data, beyond traffic signal data (such as signal phase and timing information) and traffic data (through the 511DFW/Waze data sharing project).

References

[120] Transit App. The Guide to Open Mobility-as-a-Service
[121] Move PGH Move PGH FAQs
[122] Intelligent Transportation Systems Joint Program Office. Mobility Service for All Americans (MSAA)
[123] Transit App. The Guide to Open Mobility-as-a-Service
[124] Intelligent Transportation Systems Joint Program Office. Mobility Service for All Americans (MSAA)
[125] FHWA. Smartphone Applications to Influence Travel Choices: Practices and Policies

[126] Federal Transit Administration. Mobility on Demand (MOD) Sandbox Demonstration: Dallas Area Rapid Transit (DART) First and Last Mile Solution Evaluation Report
[127] Shaheen, Susan. Mobility on Demand (MOD) and Mobility as a Service (MaaS) How Are They Similar and Different?
[128] The New York Times. Is an All-Encompassing Mobility App Making a Comeback?
[129] City of Plano. Comprehensive Plan 2021
[130] Gamification: Using Game Design Elements in Non-Gaming Contexts
[131] San Francisco County Transportation Authority. TNCs and Congestion
[132] UC Berkeley Transportation Sustainability Research Center. Three Ps in a MOD:" Role for mobility on demand (MOD) public-private partnerships in public transit provision
[133] Shared Use Mobility Center. Examples of Mobility on Demand Policies and Public-Private Partnerships to Increase Accessibility

DATA GUIDANCE

Data are critical elements of transportation planning. Low-cost sensors and personal data-sharing devices have proliferated, and their sensing and computational power has advanced. These changes have dramatically increased the volume, speed, and granularity of data available from public and private sources. According to a McKinsey estimate, connected cars create up to 25 gigabytes of data per hour.). Automated vehicles are anticipated to generate around 4 terabytes of data every hour as they move throughout a city—and this excludes data associated with booking travel, parking, and other transactions associated with automated transportation systems.[134, 135] For agencies to maximize the value of data, they will need to consider new strategies for managing data capture, analysis, and storage, as well as rethink how they engage with public and private partners who serve as sources of data in the automated transportation ecosystem. Agencies will also need to address how they will protect Personally Identifiable Information (PII) that may be transmitted, handled, or stored by their data systems. For example, trip journey data (how individuals or goods get from Point A to B) can include many pieces of PII that can be combined with other data to develop recognizable travel patterns to identify individual travelers. Agencies are both *consumers* of data when they use data to make informed transportation policy decisions and *managers* of data and, therefore, responsible for ensuring protection of the public interest and privacy in the collection, use, and storage of data.

Applications

While the sources and applications of data to automated transportation are limitless, there are four dimensions to data management and utilization that warrant special attention.

- **Crowdsourcing and data sharing** – The most successful applications of new data sets provide a feedback loop between users and application developers, allowing products and services to respond quickly to changes in user needs. In crowdsourcing applications such as Waze and Moovit, users are encouraged to contribute their own input to a data set, enriching it with insights that may not have been possible using conventional data capture techniques. Data sharing applications include open data platforms where data compiled from different agencies and regional stakeholders are made available to one another and third parties, allowing each stakeholder to enrich their own data and applications.
- **Vehicle-to-Everything (V2X)** – V2X technologies allow for data sharing among vehicles, transportation infrastructure, and other road users. This data can be used to optimize personal and regional travel, as well as generate traffic operations data that can inform capital planning and programming decisions. Much of the data generated by V2X systems are not publicly available and must be obtained by subscriptions to third-party solutions such as HERE or INRIX (who, in turn, are partnered with the Original Equipment Manufacturers (OEMs) selling the vehicles).
- **Cloud, Fog, and Edge Computing** – The volume of data generated by automated transportation systems will make it increasingly difficult to transmit and process data quickly enough to allow for responsive decision-making from a centralized traffic control center. The on-premises data storage systems used by agencies may be unable to scale up quickly or cost-effectively enough to meet increasing data needs. New data architectures will be needed that can take advantage of cloud solutions (off-premises, large-scale data storage and analytics), edge solutions (data analysis performed in the field at the sensor, reducing the lag time associated with transmitting data for analysis to a control center), and fog solutions (strategies that filter data needs between the edge and the cloud). The evolution of data solutions will necessitate a rethink of how Traffic Management

Centers (TMCs) are operated and maintained. The increased volume and speed of data may require TMCs to transition from traditional on-premise data storage and analytics to data architectures better optimized for interfacing with large volumes of sensors in the field. While machine learning may supplement (or ultimately replace) many activities currently carried out by TMC staff, machine learning may also generate new staffing needs or require re-training for existing staff to operate and maintain advanced traffic management systems.

- **Data analytics** – New analytic systems ("Big Data" solutions, such as IBM Watson) have been developed to take advantage of the volume, variety, and speed of data being generated by modern systems. Such analytic systems represent a paradigm shift from traditional data-processing applications (like spreadsheets) and will require new investments in training, software, and data management strategies to take advantage of their full benefits.

Status

Each of the applications listed has been in commercial use for at least ten years and is being employed by multiple public and private entities. Examples of other regional agencies with advanced data management strategies include:

- **Regional Integration of Intelligent Transportation Systems** – The Los Angeles Metro[136] system supports real-time data sharing between freeway, traffic, transit, and emergency service agencies to improve management of the Los Angeles County transportation system.

In the North Central Texas Region, NCTCOG has defined a Regional ITS Architecture to guide future deployment and to develop a roadmap for multi-agency systems integration.

- **Mobility Data Specification (MDS)** – MDS is a data-sharing standard to streamline transportation data sharing across agencies and operators. First developed in Los Angeles in 2018, MDS is now widely adopted by cities across the country. The intent of MDS is to provide a standard data sharing format to give cities valuable access to real-time data to better plan for micromobility and give private providers consistent data formats across different cities. Due to privacy concerns, the Open Mobility Foundation recommends implementing strong data management and protection practices and policies in conjunction with adoption of the MDS.[137]

In Dallas, the updated dockless vehicle ordinance states any operator "shall comply with the MDS standard and cooperate with the city in the collection and analysis of aggregated data concerning its operations."

- **Data Sharing Requirements** – Public agencies in Chicago[138], Portland[139], and other cities have established ordinances and other regulations requiring TNCs to share activity data to understand how their operations may be affecting transportation infrastructure.

In Texas, HB100 specifies cities can request data sharing from mobility providers (such as TNCs) and voluntarily enter into data sharing agreements but cannot pass specific regulations requiring data sharing.

Impacts

While the potential impacts of advanced data strategies are unlimited, the core impacts that can be anticipated and how local agencies can position themselves to take advantage of the benefits are summarized below.

Travel Cost – Sharing data can help travelers and mobility providers lower their costs or increase revenues by understanding tradeoffs in route, scheduling, and direct costs of their transportation (fuel, fare, tolls, and parking). Agencies may consider participating in regional open data platforms to maximize availability of data to mobility partners (which could help them reduce operating costs or maximize revenues).

Mobility – Shared data (especially V2X data) can improve mobility by giving travelers real-time information on traffic conditions. Agencies can identify opportunities to maximize data being communicated from transportation facilities to travelers via investments in ITS and V2X infrastructure.

Safety – Shared data (especially V2X data) can alert drivers, pedestrians, and cyclists to hazards on the roadway. The volume and quality of data on safety issues can help agencies identify where to invest in safety systems and capital improvements. Agencies should develop strategies to disseminate real-time safety data via V2X and other ITS infrastructure to benefit travelers and to monitor safety data from multiple modes over time to inform future safety investments.

Equity – New data strategies may offer opportunities to identify equity challenges that can be addressed. On the other hand, communities without access to smartphones or internet services may be left behind unless considered in data and transportation planning. Agencies will need to engage with affected communities (such as low-income, minority, limited English proficiency) to understand their needs and to identify strategies for allowing all travelers to participate in data-enabled transportation services.

Resiliency – Improved data strategies can allow transportation providers to adapt to future disruptions in the market from natural disasters like tornados, hurricanes, or pandemics. Agencies may begin to engage with first responders and emergency management agencies to understand what transportation data could be provided to them to improve response times.

Data Architecture – New data strategies will require significantly more data storage than available from conventional, on-premises data management strategies. The volume of data being captured and analyzed will require new investments in telecommunications. Agencies' data architecture strategies will need to evolve with data needs, including involving both traffic engineering and IT staff in discussions of data transmission, storage, and analysis needs.

Security – Many devices used by agencies and transportation providers are now equipped with the ability to communicate with one another, either intentionally or unintentionally. This creates vulnerabilities in public infrastructure that can be exploited by bad actors. Agencies can coordinate with IT and cybersecurity staff to assess vulnerabilities in existing sensor networks and data systems and explicitly consider cybersecurity when designing and implementing transportation projects and programs.

Privacy – Participation in data-sharing strategies has the potential to expose information participants may not want to make public. New strategies will be needed to make sure agencies, private interests, and individuals are able to control the amount of information they are willing to share as part of a larger data ecosystem. These strategies may include focusing collection on only what data are necessary from stakeholders to fulfill the needs of the transportation solution, or exploring the potential of data marketplaces, which are being developed to allow participants to explicitly decide what types of data they are willing to share.

Challenges and Opportunities

Challenges	Opportunities
Forming new partnerships. Advanced data management strategy requires a willingness to partner with both public and private stakeholders.	Agencies should consider how to develop a data management framework that allows them to partner with others to collect, maintain, and analyze data (or consider joining existing regional partnerships, especially if such partnerships include participation from key transportation partners.) Local agencies can look for opportunities to recruit local entrepreneurs and academic institutions to create new uses for agency-generated data, as this may result in useful consumer applications of agency data while supporting local economic development.
Ongoing cost requirement of third-party solutions and procurement. Many third-party solutions for data and data storage are based on subscription services rather than one-time purchases. Agencies can be locked into proprietary data vendor solutions.	Agencies should consider how they budget for ongoing data needs and consider how their procurement policies can be adapted to encourage new data sets to be piloted on projects before being adopted agency wide. Procurements should also ensure open data standards with private vendors.
Cybersecurity. Intelligent Transportation Systems and V2X technologies increasingly depend on linkages to privately owned assets, creating potential vulnerabilities created by new assets (including sensors, communications systems, and software).	Agencies should consider developing cybersecurity plans to protect their assets and data, and procurement policies should be updated to require all contractors to prove how their systems would adhere to such plans.
Agency resources. Lack of capacity of public agencies to manage large amounts of data	Agencies should begin to strategically build capabilities and staff expertise around data management, including data analysis and evaluation of data quality from private vendors.

References

[134] Statista. Big Data on Wheels
[135] NACTO. Blueprint for Autonomous Urbanism. 2019
[136] LA Connect-It. Regional Integration of Intelligent Transportation Systems (RIITS)
[137] Open Mobility Foundation. About MDS
[138] City of Chicago. Chicago Data Portal – Transportation Network Provider Trips
[139] City of Portland. 16.40.240 TNC Operating Responsibilities and Prohibitions

CONCLUSIONS

Transportation technology is evolving, and the planning process must evolve along with them to integrate emerging technologies into planning activities. NCTCOG is preparing for emerging transportation technologies through the Automated Vehicle 2.0 (AV2.0) program, including this market analysis report that documents the latest developments in a range of emerging transportation technologies, describes potential applications and adoption timelines, and identifies deployment challenges and opportunities for public agencies to proactively consider.

Build the foundation. This market analysis report helps equip public agencies with a broader agency, community, and stakeholder understanding of opportunities with emerging technologies. This understanding is part of proactive groundwork to build readiness through planning, partnerships (both public-private and inter-agency), and investment. Laying the foundation sets NCTCOG up to pursue funding opportunities to deploy or to support new technologies.

Match applications of technologies with community needs. With a baseline understanding of the technologies, agencies can engage with stakeholders and partners to identify specific transportation challenges facing North Central Texas and to determine which technology applications may help solve the challenges. Taking a needs-based approach can help agencies ensure they utilize technology applications to address transportation challenges. In other words, use technology as a tool to solve transportation problems, rather than forcing a technology deployment where there is not a need.

Technology is changing. Think holistically and plan with an eye towards the future. Emerging technologies will likely have significant impact in North Central Texas. The Market Analysis demonstrates the ever-evolving and somewhat unknown future of emerging transportation technologies. Nimble planning processes that adjust to changing technologies, business models, regulatory frameworks, and market conditions will be critical. Local agencies should also consider integrating plans for numerous applications for technologies. For example, when planning for EV infrastructure needed today, consider possible future applications such as hubs for micromobility, electric cargo bikes, or sidewalk delivery robots.

Develop strong data management practices. Emerging transportation technologies are already producing very large amounts of data, which will likely only increase as deployments and adoption increases. With more data comes an unprecedented opportunity to better understand and improve the transportation system, but it will likely require public agencies to be better equipped to collect, analyze, manage, and share data.

Plan for multiple possible future scenarios. The impacts and adoption timeline of many new technologies are currently unknown. Public agencies like NCTCOG need to consider multiple potential future scenarios. Given the uncertainties, NCTCOG should plan for applications of technology, rather than specific technologies, which may change over time. NCTCOG should also frequently measure transportation system performance and monitor trends in emerging transportation technology development and adoption.