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16. Abstract The Texas Technology Task Force was formed to help TxDOT to remain at the forefront of innovative transportation, by serving as a cross-functional advisory dedicated to providing guidance on essential strategies, innovation, and communication tools for emerging technologies. The Task Force, together with TxDOT, maintains the Emerging & Advanced Technology Portfolio, and has developed a Technology Utilization Plan (TUP) to serve as the fulcrum between technology discovery and implementation. The TUP has been developed in three phases including (1) technology prioritization and evaluation, (2) capturing best practices and lessons learned, and (3) developing recommendations for technology utilization and advancement. This report provides findings from phase three.		
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THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

Technology Utilization Plan

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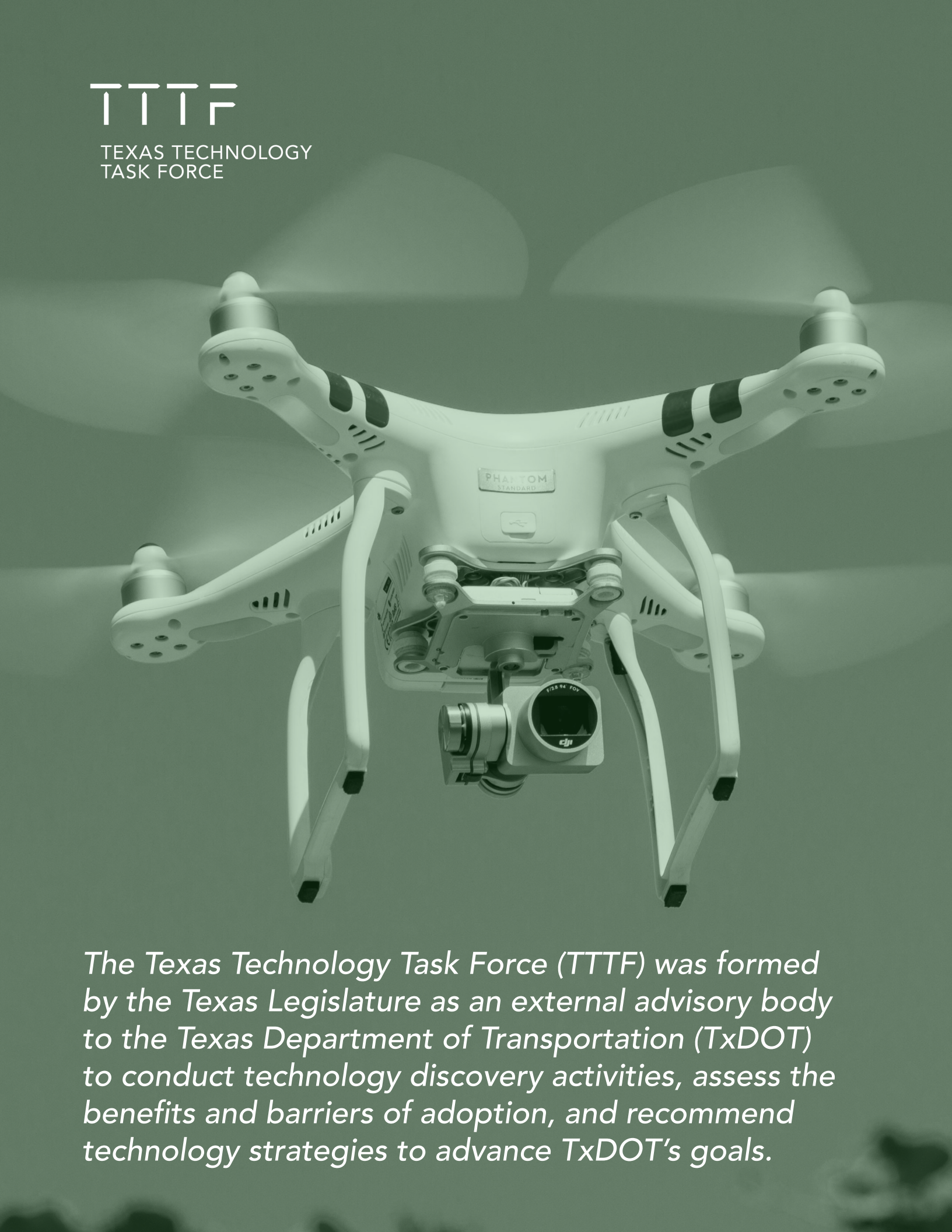
TTTF

TEXAS TECHNOLOGY
TASK FORCE

2020 TECH UTILIZATION PLAN

TTTF

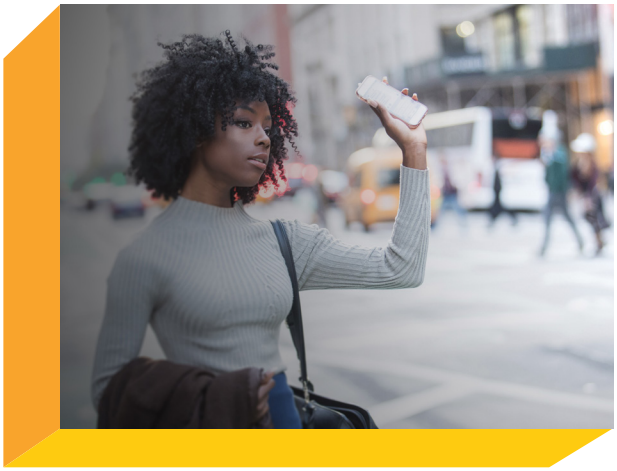
TEXAS TECHNOLOGY
TASK FORCE



The Texas Technology Task Force (TTTF) was formed by the Texas Legislature as an external advisory body to the Texas Department of Transportation (TxDOT) to conduct technology discovery activities, assess the benefits and barriers of adoption, and recommend technology strategies to advance TxDOT's goals.

AT A GLANCE.

AUTOMATED VEHICLES, CONNECTED VEHICLES, ELECTRIC VEHICLES, UNMANNED AERIAL SYSTEMS, BIG & OPEN DATA, MOBILITY-AS-A-SERVICE




electric
drive

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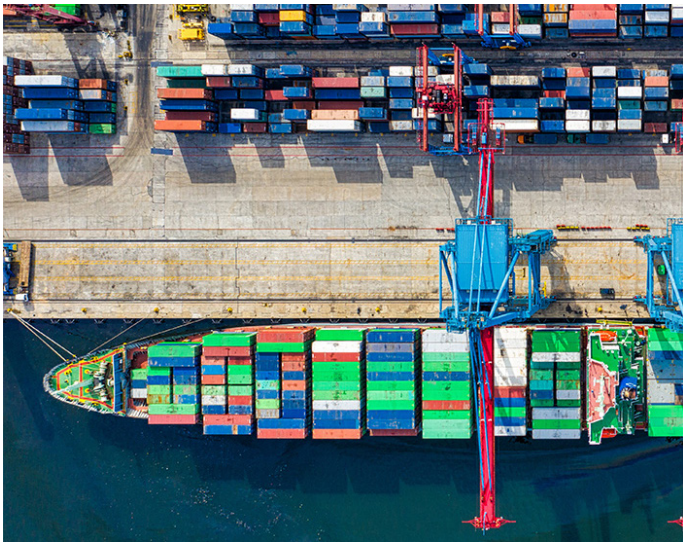
The safe integration of transformational technologies into the transportation system and public agencies requires strategic planning efforts that align technologies and innovation with agency goals, assess deployment barriers, and analyze trade-offs and resource requirements. This report, which is Part III of the Technology Utilization Plan, provides information on lessons learned in technology deployment and recommendations for implementation and advancement in Texas.

Texas at a Pivotal Moment

Texas is in a period of great change: in the midst of an economic uptick and drastic population growth, the State is making strides in technological advancement. Understanding the implications these technologies will have on the transportation system in Texas is pivotal for the State to continue supporting such multifaceted growth.



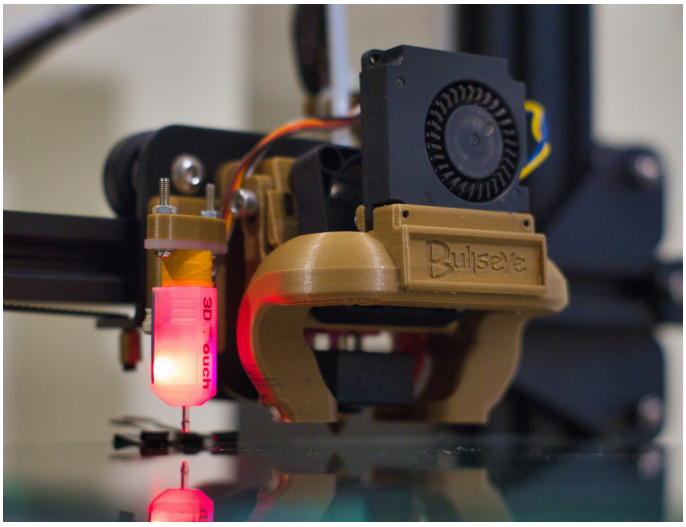
Population and Economy

Texas is experiencing historic population growth, a result of various job opportunities and a pleasant climate. The Texas Office of the State Demographer estimates the state will double its population by 2050. The fastest growing regions of the State are in urban and even more so in suburban counties of the large cities. As of 2019, two of the top-five fastest growing cities in the nation by number were in Texas, in Fort Worth and San Antonio. Trends show an urbanizing state, as between 2010 and 2050, 90% of the population growth is expected to be in urban areas. However, not all regions of the state are seeing such benefits, as 29 Texas counties are expected to lose population in this same time period, predominantly in rural areas of the state. Expanding economies in health, energy, and tech sectors are only some of the drivers of the growth Texas is seeing. The Texas economy shows little sign of slowing; between 2005 and 2015 the state ranked second in percent GDP growth in the nation. With this growth comes an increased demand in servicing this economy and the necessity for proper planning. Already, over $1.6 trillion and 1.2 billion

tons of freight are moved on Texas highways annually, and freight traffic is expected to increase by 78% by 2040.

Technology

Technological advances in the areas of telecommunications, supply chain, and international movement are all changing the transportation landscape in Texas. The emerging technology of 5G communication is one that shows great potential for connected vehicle (CV) systems. CVs offer great benefits for safety and efficiency for drivers, as the vehicles have the ability to communicate with each other and with roadside devices installed in roadway infrastructure. Currently many CV systems are set up to use DSRC radios, though the emergence of 5G offers benefits such as improved interoperability, a wider bandwidth, and increased security. Other technologies, such as 3D printing, have the potential to greatly alter the supply chain. 3D printing allows products and prototypes to be made much more easily, at a lower cost, and closer to the consumer. Rather than shipping parts from only a single manufacturer, parts can be created and shipped from various distribution centers.



Freight-related improvements being made at the state level may impact Texas greatly, as efficiencies achieved at the Texas/Mexico border have the potential to generate both economic and environmental benefits. Already in use are weigh-in-motion and dimension-in-motion systems, which allow freight trucks to weigh in without stopping. As wait times continue to lag, further efficiencies are of great priority.

Consumer Preferences

Just as companies are capitalizing on these technologies, consumers are similarly demanding what is now possible and available to them. Shipping speeds have now greatly increased and many retailers have begun to offer same-day shipping, including Amazon, Target, Walmart, and others. Constant demand for faster and more efficient delivery is putting a significant strain on the supply chain. Some predictions describe the standard changing to a "demand chain," where production is localized and immediate rather than produced in one central facility. An emerging technology to meet this demand is being called X2C, or delivering "X" to customers. A significant undertaking already under way, companies are looking at X2C solutions such as autonomous ground vehicles or drones that can service the last-mile delivery.

Constraints on Public Resources

The State of Texas has an expansive road and infrastructure network that already requires continued updates; expanding the network to service the greatly increasing population requires substantial resources. One constraint that the state faces is the lowered return from the federal Highway

Trust Fund. The Highway Trust Fund is the recipient of the federal fuel tax revenues, at 18.4¢ per gallon. This fund supports road construction and other surface transportation projects, including mass transit. Texas is technically the only "donor" state to the Fund at present, receiving only $0.95 for each dollar contributed. Additionally, the 18.4¢ tax has not been updated since 1993, even as the buying power of the dollar has fallen roughly 40% by 2016. According to the Texas Transportation Plan 2040, keeping Texas's various transportation modes in "a good state of repair" will require $547 billion in funding through 2040. Texas drivers drove about 100 million more miles in 2016 than in 2010, drastically increasing wear and tear of the roadways.

Strategic Planning for Technology

Strategic utilization of technology has the great potential to address many inefficiencies in our transportation system and create many other improvements. To properly implement emerging technology, however, it must be understood and planned for as comprehensively as possible. Such preparation calls for a three-pronged approach: awareness of investment trade-offs, understanding of potential unintended impacts of these technologies, and integration of these systems into daily life. These three components, which underlay creation of the Technology Utilization Plan, are outlined here.

Promoting Awareness & Education

Keeping abreast of technological developments benefits planners because even a baseline understanding may reveal potential applications of a new technology to an existing challenge. Additionally, an in-depth education in these technologies may point to unexpected applications, sparking additional benefits and potentially offshoots of further tech advancement and creativity.

Understanding Impacts & Trade-offs

It is vital to understand a new technology holistically, by taking a deep dive to anticipate both beneficial and harmful impacts. Transportation in particular is a comprehensive and multifaceted area; mobility itself relies on interconnections, so changes in one mode would likely affect other modes as well.

Facilitating Safe & Appropriate Integration

Technology development is worth little without effective integration. Planners must understand the variety of impacts new technologies could have, such as how their implementation might reduce or increase the need for other services. To facilitate integration, the budget for investments may need to be adjusted.

Texas Technology Task Force

Texas Technology Task Force

The Texas Technology Task Force was formed as an external advisory body to the Texas Department of Transportation (TxDOT) to conduct technology discovery activities, monitor existing technologies, and bring awareness about new ones. The following summarizes the Task Force's origins, mission, activities, and relationship to other innovation efforts within TxDOT.

Task Force Origin

The 83rd Texas Legislature (2013) issued a mandate to TxDOT to establish a technology task force to monitor and advise on emerging transportation technologies. The Texas Technology Task Force formed following this mandate with a deliberate composition of subject matter experts across industry, research institutions, and public agencies with extensive knowledge in vehicle automation, telecommunications, big data, innovative funding and partnerships, transit, freight, long-range and strategic planning, and additional areas of expertise. Task Force membership is dynamic; although it has remained relatively unchanged, it undergoes periodic review to ensure that the right mix of expertise is included to capture perspectives on new technologies and innovative processes.

Mission & Activities

The Task Force has designed its activities to advance the mission of transformational technology discovery, stakeholder engagement, coordination and planning with other state agencies, and developing strategic recommendations for technology advancement. The Task Force activities are planned around its organizing principles of People, Portfolio, Plans, and Process. Each of these principles and corresponding activities is described below.

People

The Task Force activities provide a platform to engage various stakeholder groups on technology awareness and planning. These stakeholder groups include the following:

Transportation leadership and policymakers - Texas Transportation Commission, TxDOT Administration, elected official and their staff, Governor's Office.

TxDOT staff - practitioners from across all TxDOT divisions, including but not limited to freight, traffic, strategic planning, information management, long-range planning, legislative affairs, fleet management, and research & technology implementation.

Public agencies - other state agencies such as the Department of Motor Vehicles, Department of Public Safety, the Texas Department of Insurance, Texas Commission on Environmental Quality, Public Utilities Commission, local public agencies, metropolitan planning organizations, transit authorities, federal agencies, etc.

Industry experts **-** subject matter experts from automated driving systems, telecommunications, information & technology, data management and mining, transportation network companies (TNCs), freight and logistics, etc.

Portfolio

The Task Force developed and maintains the Emerging Technology Portfolio as a tool for tracking new and maturing technologies that are expected to be transformative to transportation. The Portfolio is a dynamic list that group technologies into the following technologies: next-generation vehicles, infrastructure & construction, materials & additive manufacturing, information & communications, service-based platforms, and other technologies. A full list of technologies in the portfolio is shown in Figure 1.

For technologies in the Portfolio, the Task Force maps transportation applications and use cases, assesses alignment with transportation goals, identifies barriers to implementation, and determines maturity. The Portfolio informs the composition of the Task Force, meeting topics, and white papers. The Task Force considers which technologies may be competing, complementary, or evolving at different paces. The Task Force draws upon information from subject matter experts (individuals with experience and deep technical understanding of technology processes, implementation, and research and development), and industry reports to develop the list of technologies for the Portfolio. The Emerging Technology Portfolio serves as the basis for the technology discovery process, technology evaluation and prioritization, and major components of the Technology Utilization Plan.

Plan

The Task Force develops several documents that are intended to assist in TxDOT's planning activities. The first is the annual issuance of technology white papers on critical topics. Three to five white papers are developed each year in order to provide timely information on innovative technologies, policies, or programs. The Task Force selects white paper topics based on input from the Task Force activities with TxDOT staff and industry experts, focusing on areas in which there is critical interest and a number of outstanding questions. The white papers are composed in a manner to serve as a mechanism to bring the most-up-to-date information to TxDOT and other stakeholders and inform strategies in the Technology Utilization Plan. Elements of the white papers contain, but are not limited to, information on technical details of technologies and their real-world applications, potential business models or markets, political and societal trends bearing an impact on technologies, identification of opportunities for utilization and adoption in Texas, and case studies on ongoing trials or pilots, when possible.

Next the Task Force develops and maintains a Communications & Stakeholder Engagement Plan that characterizes stakeholder groups, such as elected officials, other state agencies, TxDOT divisions, industry sectors, the public, etc., and defines, at a minimum, appropriate messages, informational materials, and communication channels. The plan outlines proposed methods of outreach and involvement of various stakeholders throughout the strategic planning process.

The final planning document is this Technology Utilization Plan, which is intended to serve as a strategic guide on the anticipation and inclusion of advanced technologies for the Texas transportation system and within TxDOT. The Task Force works to continually familiarize itself with ongoing efforts within TxDOT to create an Emerging Technology in Transportation Plan. Where possible, the Task Force has developed the Technology Utilization Plan in a manner to supports the development of the Emerging Technology in Transportation Plan. Further, the Task Force will continue to work with TxDOT staff on an as-needed basis to support the development of the Emerging Technology in Transportation Plan. The Task Force formed the Technology Utilization Plan through a multi-step process that draws from all of its activities and includes, but is not limited to, elements such as technology market forecasting, evaluation of benefits and barriers, technology maturation requirements and planning, lessons learned from early trials, and technology adoption strategies. The Technology Utilization Plan aims to define a technical end-state enabled by technology adoption over time. The Plan identifies opportunities for TxDOT to use advanced technology to reasonably meet existing and anticipated goals in the near and long term.

Figure 1: Emerging Technology Portfolio

Next Generation Vehicles and Energy

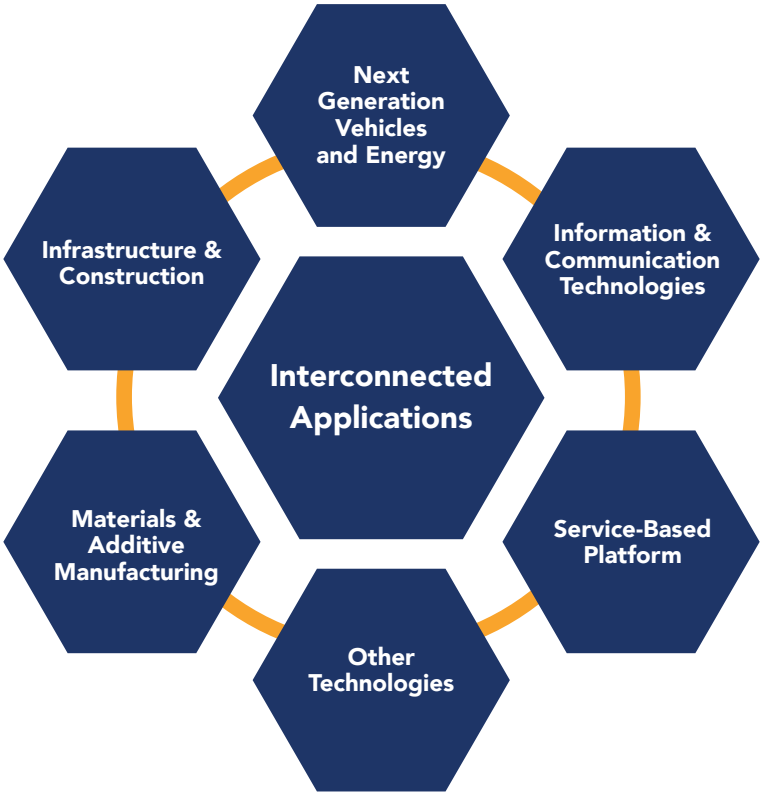
- Automated Vehicles
- Connected Vehicles
- Electric Vehicles
- Unmanned Aerial Vehicles

Information & Communication Technologies

- Crowdsourcing
- Blockchain
- Big & Open Data
- Cybersecurity
- RFID
- Cloud & Edge Computing
- Data Standards & Interoperability
- Machine Learning & AI
- Telecommunications

Infrastructure & Construction

- Infrastructure Enhancements
- Construction Techniques
- Solar Powered Highways



Materials & Additive Manufacturing

- Self-Healing Pavements
- Nanotechnologies
- 3D Printing

Service-Based Platform

- Mobility on Demand
- Micromobility
- Transportation Subscription Services
- freight Brokerage
- Uber Elevate
- Last Mile Delivery

Other Technologies

- Robotics
- Virtual/Augmented Reality
- Hyperloop

Process


Summary of technology effects on insurance claim frequency

PROCESS

The Task Force meets regularly with TxDOT staff to determine internal technology questions and priorities. The Task Force hosts meetings quarterly at TxDOT headquarters to engage industry subject matter experts through deep-dive presentations, panel discussions, and roundtables. These meetings also provide an opportunity for Task Force members and TxDOT staff to discuss technologies; address open questions; formulate recommendations for additional research, implementation; or generate new policies, procedures, or programs to advance technology in Texas.

Figure 2 shows how Process drives the Task Force's People, Portfolio, and Plan activities.

The Technology Utilization Plan has been developed over three phases: 1) evaluation of benefits and barriers to technology adoption, 2) synthesis of best practices and lessons learned, and 3) delivery of technology utilization plan with recommendations. Figure 3 shows the successive phases with timelines for each.

More detail on these phases is provided below.

Phase I: Priority Technologies & Assessment

Phase I focused on prioritizing technologies in the Emerging Technology Portfolio. Input was provided by Task Force members, TxDOT staff, and industry experts. Six priority technologies were selected and include:

1. *Autonomous vehicles*
2. *Connected vehicles*
3. *Electric vehicles*
4. *Mobility-as-a-service*
5. *Unmanned aerial systems*
6. *Big & open data*

It was also recognized that augmented reality, blockchain, Hyperloop, and 5G telecommunications were important technologies to continue to monitor closely.

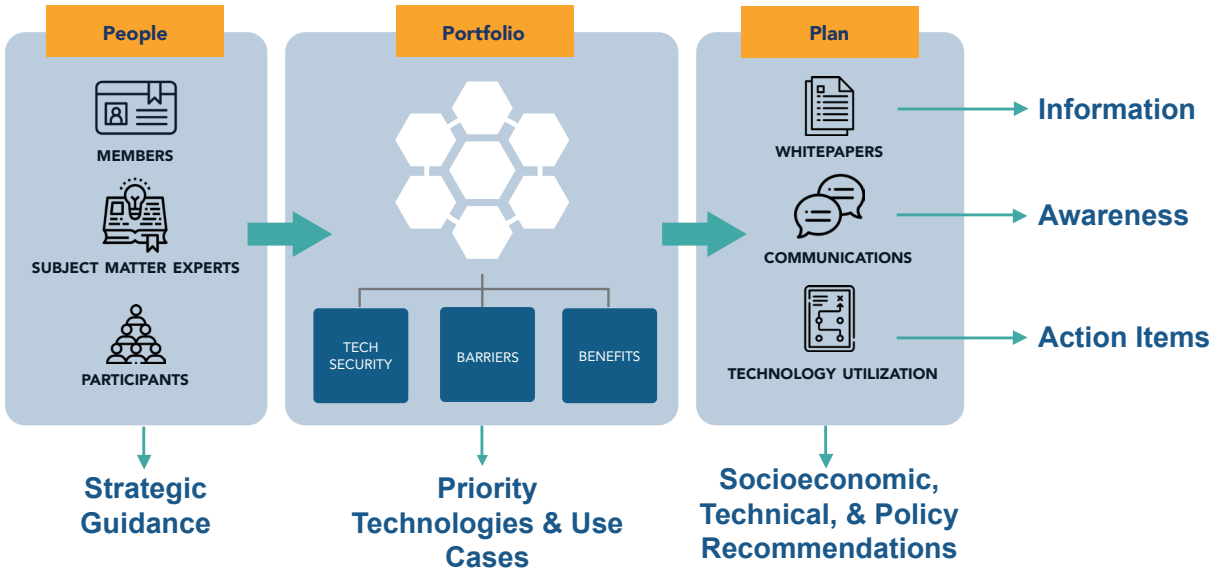


Figure 2: Task Force People, Portfolio, Plan, and Process

Phase II: Best Practices & Lessons Learned

Phase II focused on collecting best practices and lessons learned for technology and innovation deployment, helping to identify methods, programs, and technical implementations that can be leveraged by fast following agencies for replication. Best practices and lessons learned are sometimes gathered by official external agencies that conduct reviews and evaluations, or are sometimes realized from reflection and interviews with practitioners participating in pilot programs.

Best practices differ from lessons learned in that they often loosely meet the following criteria:

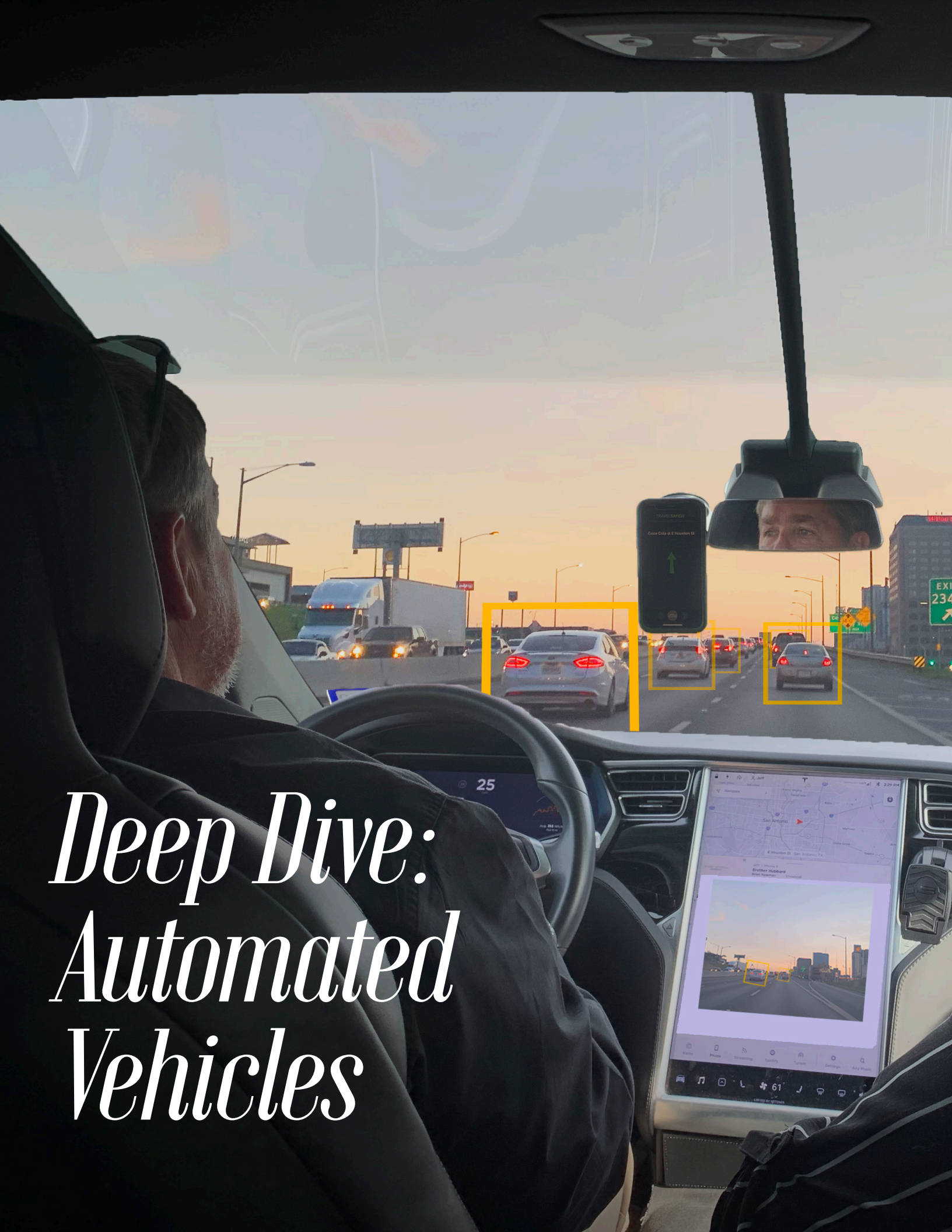
- Measurable – meaning that goals and objectives are clear and that progress toward them can be measured.
- Successful – not only are there good results, but the pilot program progresses toward achieving its goals more than similar pilots.
- Replicable – the method or program is structured and documented clearly enough so that it can be reproduced elsewhere.

Lessons learned captured both the positive and negative experience of projects and draw from reflections from individuals performing or participating in the project. Lessons learned can be used to improve future projects and future stages of current projects. Lessons learned from key interviews and case studies are provided for each of the top six priority technologies in later sections of this plan.

Phase III: Readiness Evaluation & Recommendations

Phase III focused on developing recommendations and actions for technology advancement. Examples may include allocating resources such as funding for technology deployment, crafting regulations and policies, providing user training, conducting research, or keeping the status quo. Recommendations for each of the top six priority technologies are provided in later sections of this plan.

Figure 3: Technology Utilization Plan Phases and Timeline



Deep Dive: Automated Vehicles

AUTOMATED VEHICLES

Automated vehicles (AVs) have the potential to shift how people and goods travel within a community. As AVs progress in maturity, the safety, mobility, and public health benefits are becoming more apparent. The most promising of these benefits is the increase in road safety, with an expected reduction in vehicular fatalities and crash severity, enabling Texas to achieve its road to zero.

Maturity Scale

Concept — Operational

KEY TAKEAWAYS

Short-Term. Create a public education campaign and materials.

Long-Term. Develop a funding mechanism to coordinate public and private investments.

Featured Case Studies

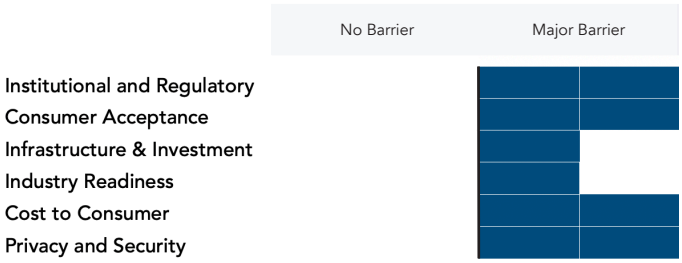
- Nuro AI
- Waymo Public Education Campaign
- Automated Bus Consortium

Readiness Index	Policy	Deployment	Research	Public Education
7	⚙	⚙	⚙	!

Legend: ! =High Priority ⚙ =Needs Work — = Not Urgent

GOAL ALIGNMENT

BARRIER ASSESSMENT



USE CASES

Automation within vehicles has allowed for a variety of uses and applications for these vehicles. As the following use cases illustrate, these applications cover not only personal mobility but also freight and transit.

- **Last-Mile Delivery.** AVs can provide contactless delivery utilizing smaller vehicles designed for on-street operations.
- **Long-Haul Freight.** Middle-mile and remote operations can be used to control multiple vehicles, allowing for increased platooning and efficiency.
- **Sidewalk-Based Personal Delivery Devices.** Small robotic devices allow for delivery of groceries or prescriptions into food deserts and areas with limited access.
- **Personal Vehicles.** Wider public adoption can lead to potential increases in accessibility for those who have traditionally not been able to drive as well as productivity efficiencies for commuters.
- **On-Demand Passenger Services & TNC Fleets.** Create new options for transit operations with greater route flexibility and servicing of vulnerable populations.

Analysis: Automated Vehicles

In the last few years, AVs have seen increased attention from state legislatures, agencies, and researchers. To encourage innovation, Texas has taken an open and welcoming stance to promote and attract on-road testing. Due to this openness, the state does not require any notification to be made for any on-road testing activities. To determine the state of practice within Texas, the state's readiness was analyzed based on current legislation, deployments, research activity, and public education. In the gap analysis that was conducted, it was found that the first three mentioned need work, while the public education component should be the highest priority. Through the state-of-practice review, and discussions with stakeholders, priorities to focus on were determined. Among these priorities are better notification of testing activities, creation of funding opportunities, research activities into human factors and accessibility, and the need for public education tools. Two case studies have been chosen to focus on safety standards and public education.

Case Study: Nuro AI

Key Takeaways: Nuro was the first to be granted an exemption from FMVSS standards. The current pilot is deployed in Houston, with recent expanding partnerships to allow for increased on-road testing, including delivery of groceries and prescriptions.

Launching its first pilot in August 2018, Nuro has developed a low-speed AV designed for local goods delivery. Partnering with grocery stores, Nuro uses its vehicle platform to conduct grocery delivery to local communities. To operate as safely as possible, Nuro's vehicle does not transport people, and is restricted to operations of less than 25 mph, meaning the vehicle is classified as a low-speed vehicle. For residents in qualifying zip codes, after ordering their goods online, a time for delivery can be scheduled with Nuro's vehicle delivering to the resident's curb.

Partners

Initially launching as a company in 2016, Nuro quickly began creating partnerships to provide driverless grocery delivery. The first of these partnerships were with Toyota and Kroger. Utilizing modified Toyota Prius vehicles at the beginning of its pilot program in Scottsdale, Nuro quickly transitioned to its own R1 vehicle. The pilot provided delivery to a single zip code within the area, after partnering with Kroger for pickup at its local Fry Food store. This partnership with Kroger has continued into Nuro's latest deployment in Houston. In the past year, Nuro has announced a further partnership in the Houston area with Domino's Pizza.

Technical Details

Nuro's pilots currently use modified Toyota Prius vehicles and the R1 vehicle platform, with plans to convert to the utilization of the R2 vehicle. The R2 vehicle was specifically designed to operate as a highly automated, driverless, low-speed goods delivery vehicle. As such, it is restricted to operate at no more than 25 mph, with the majority of operations taking place around 15–20 mph. As it was designed for the sole purpose of goods delivery, it was not

fitted with a steering wheel or foot pedals. Due to its design, Nuro applied for and was granted the first US exemption for an AV, as of February 2020, from the Federal Motor Vehicle Safety Standards (FMVSS), allowing Nuro to operate the vehicle without these two otherwise standard safety features.

Continuation and Scaling

Utilizing information learned from pilot tests, Nuro is continuing to develop its on-road vehicle. While the pilot tests in Scottsdale, AZ have ended and no longer deliver groceries, Nuro continues to test its vehicles in the Scottsdale area. Within Texas Nuro has committed to continued operational testing in Houston, highlighted by the announcement of the partnership with Dominos. Other recent partnership announcements have included Walmart and CVS Pharmacy, to deliver groceries and prescriptions, respectively. It was also recently announced that Nuro has been granted permission to test its vehicle within the State of California. To further strengthen its position in Texas and further expand its pilot, Nuro should focus on partnering with HEB, which has approximately 320 stores within Texas.

In order to expand into more localities, and handle the variety of deliveries that will occur, Nuro has begun looking into scaling up its vehicle. This scaling-up will potentially allow for operations at higher speeds, around 35 mph. With increased operational speeds, the vehicle will be able to travel on an increased number of roads, expanding its operational environment limits and reaching more residents in an area.

Lessons Learned

Looking into Nuro's pilots and operations reveals some key lessons learned. The first involves their exemption from the FMVSS. The exemption was granted to specific portions of the standards in which not complying with those standards would not adversely affect the safe operation of the Nuro vehicle. To continually monitor and assess the safety of the exemption granted, USDOT has stipulated that a detailed report be submitted every 90 days. This report is to include mileage driven, detailed descriptions of any changes to the vehicle's operational design domain (ODD), and detailed descriptions of any incidents and interactions with law enforcement. These conditions show that while exemptions are granted, subject to specific items in the FMVSS, the safety of the vehicle will continually be monitored by USDOT and the exemption can be revoked at any time based on safety information provided.

Another lesson learned was that partnering with various companies is important to the expansion of testing. The partnerships that Nuro created allow for increased testing in a wider range of zip codes. This increased testing supports the advancement of Nuro's platform by providing operational information on how the vehicle handles differing environments within its ODD.

Case Study: Waymo Public Education Initiative

> *Key Takeaways: Waymo's initiative focuses on providing information on the basics of self-driving vehicles, and their specific technology. Information included in the initiative was presented to various road*

users, including other drivers, pedestrians, cyclists, first responders, etc.

Recognizing the need for the public to be educated on AVs, Waymo has created the "Let's Talk Self-Driving" initiative. The initiative website includes not only news sources for articles discussing AV innovations, but also articles discussing how AVs think and operate. The goal of including these resources and articles is to highlight and advance safety around AV and vehicles. Important to the advancement of AVs, partnerships are also highlighted between advocacy groups.

Public Outreach and Education

To provide information for the public on AVs, the Waymo initiative site is broken up into four main sections: 1 self-driving basics, 2) Waymo technology, 3) community impacts, and 4) resources. The first of these sections, self-driving basics, starts with a discussion on the level of automation, providing details on the driver's role and the functions that are controlled by the vehicle. This discussion is then followed up with a section that covers how self-driving cars think and work, highlighting the *sense*, *plan*, and *execute* stages. Because AVs have the potential to change the way people travel, mobility and accessibility are discussed, with Waymo's rider support, accessible mobile app, and braille labels being used as examples of how Waymo is thinking of accessibility.

Along with the general overview of AVs and how they function, the initiative site also focuses more specifically on Waymo's technology. With data protection and cybersecurity increasing in importance over the last few years, this site section discusses what would happen should the vehicle be hacked or encounter a a cybersecurity breach. Along with cybersecurity, assurance of AVs' safety has been a crucial topic within the AV realm. To show how AVs are safe, simulation, closed course testing facilities, geographic fencing, and the use of backup systems are discussed in order to increase confidence in the safety of these vehicles.

The "Let's Talk Self-Driving" initiative also discusses the community impacts of AVs in terms of passengers, cyclists, first responders, pedestrians, and other drivers. Looking specifically at the efforts for first responders, it should be noted that Waymo developers have taken care in programming the vehicle to recognize first responders and pull over. To allow for the sharing of information with first responders during on-road testing, a toll-free hotline was created to provide 24-hour communications with specialists. Along with the hotline for first responders, on-site training is also conducted to help police and other emergency personnel identify and be able to access a Waymo vehicle during an emergency situation.

Partners

In the development of the public education initiative, Waymo involved numerous partners, including automobile associations, foundations, and safety advocacy groups. Among the safety advocacy groups that Waymo has partnered with are the National Safety Council and the Red Means Stop Traffic Safety Alliance. Foundations that have been partnered with include Foundation for the Blind, Foundation for Senior Living, and Mothers Against Drunk Driving. To help stay informed about partner activities, news and stories related to AV activities are linked on the Waymo site.

Lessons Learned

On-road testing of AVs is increasing, with the exact number of deployments unknown. To help the public understand how these vehicles work, and the environments they can operate within, education campaigns are needed. An assessment of Waymo's initiative yields a few lessons learned. The first of these is the need to provide basic information on how these vehicles work, including descriptions of the role of the driver and vehicle at different levels of automation. Providing information on the role of the driver is important, as with increased automated functions on vehicles, misconceptions around what these vehicles can control has also increased.

While drivers should be informed on the automated functions of vehicles, a wide range of other road users should also be aware of AV parameters. Included in these groups should be first responders, as in the event of a vehicle emergency these responders must have the information needed to ensure a quick and appropriate resolution of any issues.

To craft and provide the information needed for diverse road users, working with a wide variety of partners is essential, to ensure that a unified message can be presented to the public.

Case Study: Automated Bus Consortium

Key Takeaways: Use of third-party managers can provide a streamlined process for the funding and procurement of emerging technologies, including AV platforms. Cooperative research and pilots among agencies can provide opportunities for diverse project scopes, including retrofitting existing vehicles, vehicle fuel types, and route types. Partnerships with agencies in both rural and urban areas can provide extensive knowledge sharing and insights, which can accelerate the deployment of automated buses and other emerging vehicle automation technologies.

The Automated Bus Consortium is a collaboration of transit organizations and departments of transportation organized to investigate the implementation of automated bus projects across the US. The consortium was created to promote the deployment of full-size, accessible automated buses in order to demonstrate automated technology in live service environments. Through the pilot deployments, the consortium leverages new technologies to improve transit service in the following areas: safety, reliability, operating efficiency, and customer service. Through the proposed deployments, it is expected that the consortium can accelerate automated bus technologies, reduce planning and procurement costs, and share lessons learned with other members.

Partners

To cover the widest possible range of environments, the consortium is made up of transit organizations from across the US. These include organizations on both the west and east coasts as well as the southeast. As such, the organizations cover not only highly urbanized areas, such as Dallas and Los Angeles, but also rural areas, such as the Huron area in Michigan. One of the benefits of the consortium for members is the use of resources to speed up the funding and procurement process for pilot

deployments, as AECOM was brought on to be a program manager.

Program Scope

Using AECOM as a program manager, the Automated Bus Consortium allows for members to bring forth and propose projects that are beneficial to their services and highlights a use of automated technologies. The consortium is designed for the procurement and use of between 75 and 100 full-sized, full-speed automated buses to be utilized across the various pilot deployments. Some of the proposed projects include shorter routes to help connect existing transit stations to airports, such as the proposed Love Field Connector in Dallas, or help connect two existing transit stations, such as the proposed MARTA route in Atlanta. Other proposed pilots include rural routes to better connect citizens to vital goods, such as pharmacies and grocery stores. These deployments were expected to take place by 2022 but could see delays due to the ongoing pandemic. One of the biggest benefits expected from the pilot deployments is the transfer of lessons learned between the member agencies, allowing for increased deployment of automated technologies.

Final Recommendations

As seen in the case studies above, AVs offer a number of opportunities for deployments in a variety of environments and uses. From these case studies, two recommendations have been drafted, a short-term and long-term recommendation focusing on areas in which Texas can advance understanding and deployments of AVs.

Short-Term

As the case studies highlighted, more pilot deployments and AV testing are being conducted not only on Texas roadways but across the country. This increase in on-road testing has magnified the need for public education. While those working in the AV arena are aware of how these vehicles operate, a lack of public education on AVs has caused confusion within the public. Due to this lack of knowledge, it is common for the public to place too much trust in the automated functions of these vehicles, which can lead to crashes and unexpected operations. To curb any potential accidents caused by placing too much trust in automation, public education on the various levels of automation and what those mean in terms of self-driving functions can be used to raise awareness. Along with education on the levels of automation, public education campaigns should focus on providing drivers and other road users information on the role of the driver at each automation level.

Long-Term

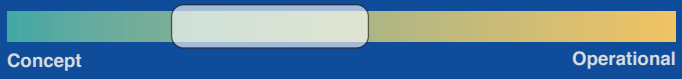
In order to advance innovation, Texas has taken an open stance regarding attracting AV developers and deployments. To continue this stance on promoting innovation, and to stay ahead of other states, a long-term funding mechanism should be developed to encourage developers to deploy in Texas and allow municipalities to invest in AV infrastructure. Currently there are local-led efforts (such as NCTCOG's work in this area) to provide funding for AV-related projects but a state-level funding mechanism could provide not only a larger pool of funds and funding mechanisms but also help create a more uniform process.

Deep Dive: Connected Vehicles

CONNECTED VEHICLES

Connected vehicles (CVs) enable the transfer of information between vehicles, connected roadside infrastructure, and other road users. With real-time information and driver notifications such as work zone warning, freight signal priority, and wrong-way driver alerts, CV technology can improve both safety and efficiency on the roadway. With major projects underway, Texas is well-positioned to deploy and scale operations.

Maturity Scale - C-V2X



Maturity Scale - DSRC

KEY TAKEAWAYS

Short-Term. Expand the network of connected corridors.

Long-Term. Conduct dual testing of DSRC and C-V2X technologies to ready the infrastructure.

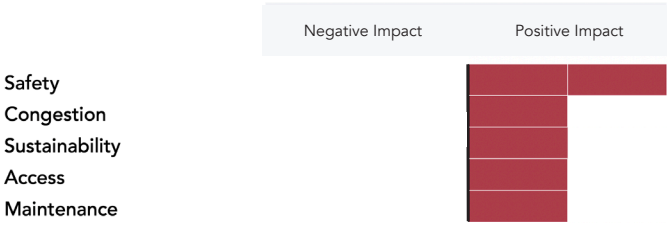
Featured Case Studies

- New York City Pilot Program
- Tampa Bay Connected Vehicle Pilot
- Utah DOT 5G Deployment

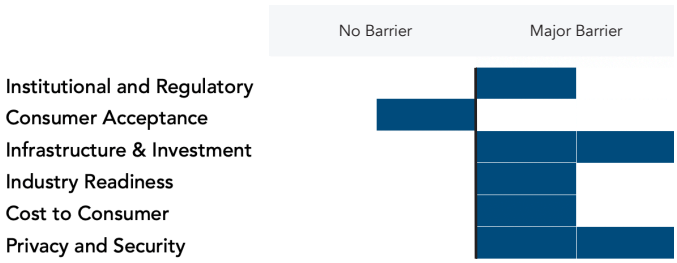
Readiness Index	Policy	Deployment	Research	Public Education
7 DSRC	!	!	⚙	⚙
4 C-V2X				

Legend: ! =High Priority ⚙ =Needs Work — = Not Urgent

GOAL ALIGNMENT



BARRIER ASSESSMENT



USE CASES

CV technology offers several benefits regarding safety of roadway users and pedestrians as well as efficiency of traffic patterns that can result in reduced accidents and decreasing congestion.

- **Advanced Safety Warnings.** Roadway users can be given notice of slowdowns or other hazards ahead in advance of what is visible to the driver.
- **Fleet Management.** Fleet managers can tap into information to improve fleet operations that can result in improved efficiency and productivity.
- **Pedestrian and Cyclist Detection.** CVs can detect and communicate with pedestrians/ cyclists via cell phone connection to protect vulnerable road users.
- **Connected Roadway Infrastructure.** Roadside units (RSUs) can communicate messages related to work zones, curve warnings, and road weather conditions.
- **Connected Transit.** Connected transit can communicate with traffic signals and request additional time to promote on-time transit and improve safety.

Analysis: Connected Vehicles

Connected vehicles (CVs) communicate information between other vehicles (V2V), infrastructure (V2I), and other connected devices like mobile phones (V2X). CV technology provides warning messages of roadway slowdowns, obstructions, and other hazards. CV messages can promote roadway safety and encourage decreased traffic congestion. Texas supports a quickly growing population, particularly in urban centers, which further stresses the existing transportation network, resulting in rising congestion and increased opportunities for collision. CV technology utilizes two communication platforms: DSRC and Cellular 5G communication, which is still developing today. The FCC has designated a portion of the 5.9 GHz band to DSRC, but in response to limited deployment of DSRC, efforts are under way to dedicate a portion of this spectrum for 5G communication. Roadside units (RSUs) and onboard units (OBUs) are two of the most important pieces of infrastructure necessary for CV deployment. CVs transmit information on position, speed, braking status, and the like. This platform has the potential to increase safety and decrease congestion on the roadway.

Case Study: New York City CV Pilot Program

> *Key Takeaways: The New York City DSRC-based CV pilot program is a substantial undertaking that has deployed one of the densest networks of DSCR radios for V2V and V2I applications. It has helped to advance safety applications for pedestrians and vulnerable road users.*

New York City was chosen as one of three deployment sites by the USDOT intelligent transportation systems. As part of a three-phase process, New York City ultimately plans to install up to 8,000 vehicles with V2V connectivity. This pilot is expected to be one of the largest CV deployments upon completion. This project is being conducted in three phases, beginning in 2015 with Phase 1's concept development and implementation. Phase 2 worked to design, build, and test wireless in-vehicle, mobile, and roadside technology; Phase 3 then serves as the evaluation period. The project will encompass three distinct areas in the boroughs of Manhattan and Brooklyn, ultimately connecting about 5,800 cabs, 1,250 city buses, 400 commercial fleet delivery trucks, and 500 city vehicles, including 310 signalized intersections and several RSUs.

Program Scope

CV technology is being utilized as a tool to help New York City reach its Vision Zero goal. Thus, this program is particularly focused on safety applications. These applications provide drivers with alerts so that the driver can take actions to avoid a crash or reduce the severity of injuries or damage to vehicles and infrastructure. The goal of this project is to show that the benefits realized justify the continuation of the operation and to encourage drivers to equip their vehicles with CV capabilities, thus increasing the benefits to all. Phase 1 began in September 2015 and concluded in September 2016, representing the planning phase. This included the concept of operations, system requirements, safety plans, benefits evaluation plan, security management plan, and deployment plan.

Phase 2 began September 2016, and ran for 48 months (although planned to last only 20 months). This phase included detailed design, field equipment development and procurement, software development, and integration and installation of the in-vehicle devices and the roadside infrastructure. Phase 3 began in September 2020 and is scheduled to end in November 2021; this phase includes an operating period where the applications will be active and providing alerts to the drivers. The project installed CV technology in 700 city buses, 5,000 City-owned vehicles, and 1,000 taxis, representing about 1 million miles of travel per day. Additionally, approximately 300 RSUs were installed. The city is working with a pedestrian advocacy groups and will be deploying two pedestrian-oriented applications. One will support the visually challenged at intersections, and the other will determine potential conflicts between pedestrians in crosswalks and approaching CV-equipped vehicles.

Metrics and Evaluation

The NYC deployment will include a configurable data collection application that will be used to evaluate the benefits of the system and allow USDOT to evaluate the overall system operation.

Lessons Learned

The New York City DSRC-based CV pilot program has already resulted in many lessons learned, including the need for pre-testing in roadway environments to ensure adequate sky visibility for signal communications, the importance of repeated testing of applications in testing environments, and the critical need for high quality training for participants.

Case Study: Tampa-Hillsborough Expressway Authority CV Pilot

> *Key Takeaways: The THEA CV Pilot provided a novel applications of DSRC CV technology in a unique reversible lane environment. The pilot advanced mobility applications and also advanced cybersecurity for vehicle elecommunication networks.*

Chosen as one of three CV pilots under the USDOT Connected Vehicle Pilot Deployment Program, the Tampa-Hillsborough Expressway Authority (THEA) is in the process of implementing multiple CV applications throughout downtown Tampa. This four-year effort began in September 2015, when USDOT awarded THEA $17 million. In 2016, the project entered its second phase, including design, testing, and deployment. The third phase began in 2018, and involved full-scale operation of CV technology throughout downtown Tampa. The applications for this pilot are to address morning backups, wrong-way highway entry, pedestrian safety, transit signal priority, streetcar conflicts, and traffic flow optimization. This pilot is working to install 1,600 OBUs on private cars, buses, and streetcars, as well as 40 RSUs downtown.

Technical Details

THEA has several partners as part of this pilot, including HNTB, Siemens, the University of South Florida Center for Urban Transportation Research, and Global5 Communications.

Siemens was one of the original project partners whose work included developing RSUs and the city's Transportation Management Center (TMC). HNTB was responsible for organizing aftermarket devices like backup cameras and OBUs, which ultimately included Navari, Sirius XM, and Insignia. Every vehicle is provided with a unique identification, which is used to bundle data and send it to the TMC. Then the data is compressed and stored in the master server. The data is available to the TMC after about 24 hours. There are no data-sharing agreements in place, though it is understood by users that the information created is going to be used for research. Drivers willing to install this service in their vehicles were recruited via their toll tag accounts. The units were installed in rearview mirrors and display messages.

Lessons Learned

Thus far, this project has revealed that V2V applications are much easier to implement on paper than in practice. Participants reported that their real-world, on-road experiences with the application differed from the demos that were given. For example, the pedestrian applications were found to be too dependent on the phone in use, and were ultimately scrapped.

Further, some limitations were found in the connected display as some groups weren't able to add a tablet because another screen was not allowed. Further, challenges arose where participants' rearview mirrors were considered "too intelligent" and installing the CV services created conflicts with the existing tech in the mirror, thus hindering existing functionality. With this technology there was concern about an overload of messages appearing in the driver's line of sight; thus, messages such as "speed advisories" were prioritized.

Case Study: Utah DOT 5G Deployment

> *Key Takeaways: The Utah DOT is partnering to launch a cellular-base network using information from the emerging V2X environment. The DOT's traffic operations center can use the data to improve roadway safety and mobility, while state policymakers can apply it to infrastructure decisions.*

As part of a $50 million agreement between the Utah DOT and Panasonic, announced June 25th, 2019, Utah would roll out an expanded CV platform. This platform will improve roadway safety and mobility, and data gathered from this platform can be used for future infrastructural decision-making. Panasonic is using their CIRRUS CV data platform, which works with both DSRC and Cellular V2X. This partnership is an opportunity to scale up work to expand existing CV infrastructure in Utah. Phase one includes the installation of infrastructure at 40 sites and in 30 state-owned vehicles. Later phases will include 200 sites in up to 2,000 vehicles.

Funding and Business Model

Deploying this platform involves four main components: implementing additional RSU deployment, deploying tech in fleet vehicles for information gathering, building a variety of V2I software applications to leverage

data, and creating a cloud-based data analytics, processing, and storage system. Panasonic's CIRRUS CV platform supports data sharing among transportation departments, network operations centers, and vehicle information systems. This data is made available to third-party developers. For safety, vehicles change their "signatures" at randomized intervals and CIRRUS anonymizes data. Panasonic has already worked with the Colorado DOT to deploy 1,500 miles of fiber optics and 100 RSUs along a stretch of I-70. Though only phase one is currently planned, this UDOT deployment is expected to roll out in five phases over the next 5 years.

Lessons Learned

A new paradigm needs to take place in transportation for successful CV deployment, where both road operators and the vehicle industry need to be committed to continued collaboration and synchronized goals.

Final Recommendations

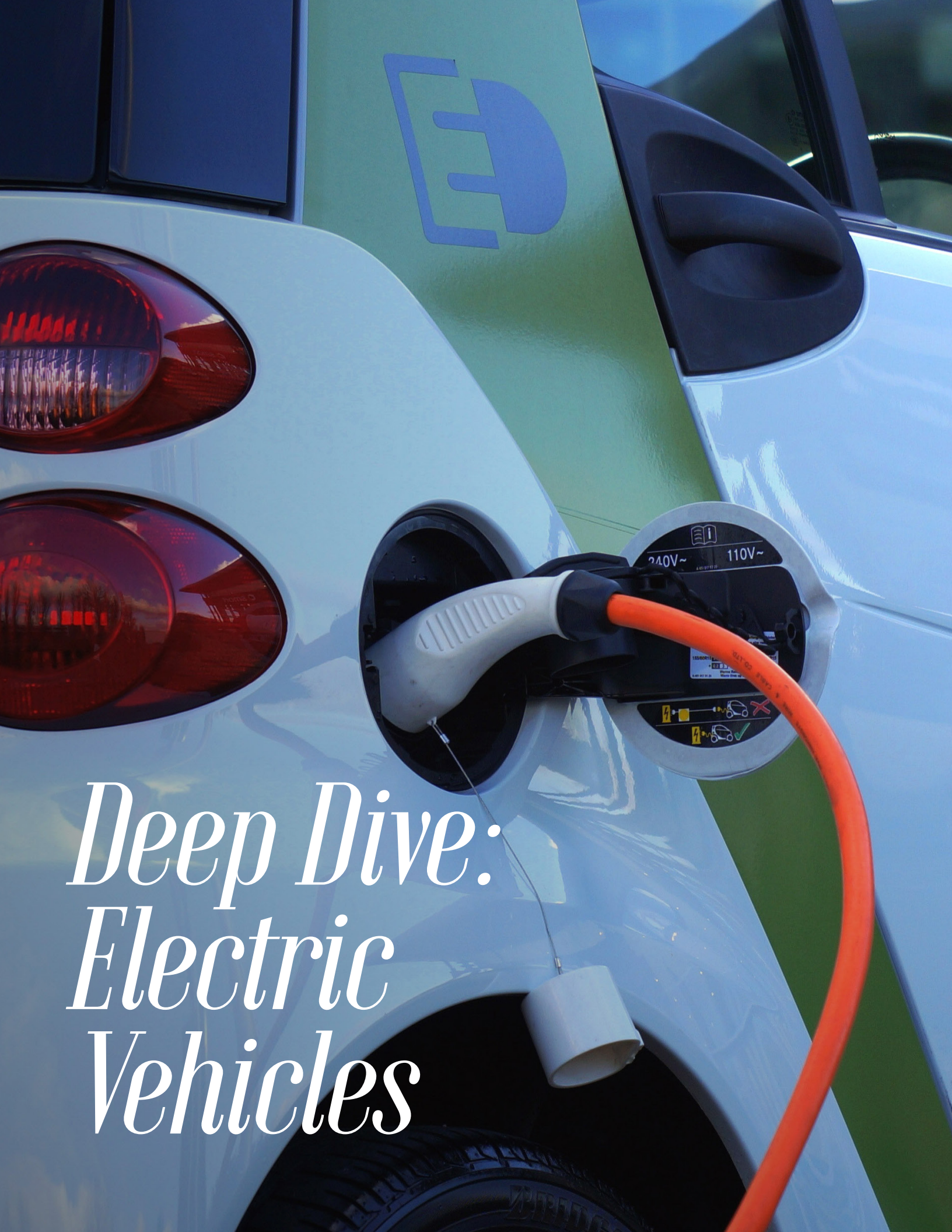
Short-Term

Short-term recommendation for Texas include the need to closely follow and learn from the Texas Connected Freight Corridors project. Once CV applications have been proven in highway and freight environments, they can be expanded. Texas agencies should also continue to monitor developments and technology advancements between DSRC and cellular communication technologies, as they are rapidly changing.

Several local agencies (City of Austin, City of Frisco, etc.) are deploying limited CV applications. At a statewide planning level, Texas should learn from and document best practices from these trials. Texas agencies should also keep informed on security and data needs.

Long-Term

Long-term recommendations include the need to build a network of connected corridors that offers both DSRC and cellular communications to accommodate the leading technology of the future or accommodate their coexistence. Recommendations also include the need to keep informed on standards and advancing technology so Texas is not behind when a dominant technology is found. Finally, it is recommended to establish joint funding mechanisms for CAV initiatives.



Deep Dive: Electric Vehicles

ELECTRIC VEHICLES

Anticipating reductions in the cost of battery production, electric vehicles (EVs) are said to reach parity in cost with traditional combustion engine vehicles before 2030. With the rollout of additional charging infrastructure, EVs can reduce greenhouse emissions and bring sustainability benefits to personal mobility, freight, and transit. Capitalizing on its strong energy sector, Texas has the opportunity to accelerate EV adoption by electrifying its fleets to capture a rapidly growing economic market.

Maturity Scale

Concept — Operational

KEY TAKEAWAYS

Short-Term. Electrify fleets and consider impacts to transportation funding.

Long-Term. Develop a statewide plan for siting charging infrastructure along major corridors, transit hubs, and local establishments.

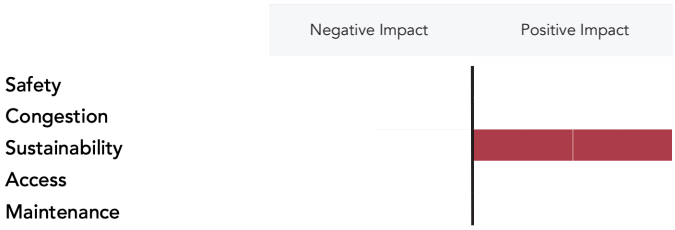
Featured Case Studies

- DART
- City of Denton Municipal Fleet
- General Motors

Readiness Index	Policy	Deployment	Research	Public Education
8	⚙	!	⚙	—

Legend: ! =High Priority ⚙ =Needs Work — = Not Urgent

GOAL ALIGNMENT



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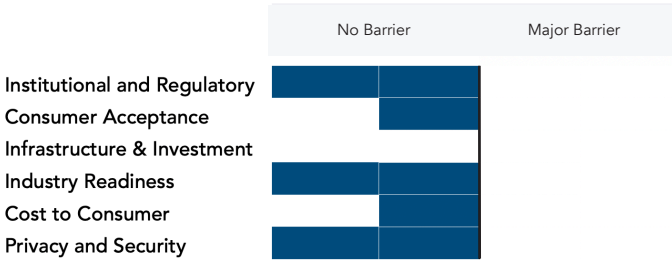


USE CASES

EVs have the potential to alter every sector of the transportation system, from personal mobility to freight. This shift will be aided by battery technology evolution and will need to coordinate with the electric grid.

- **Battery Technology.** Battery research and development is making significant strides to reduce costs, improve performance, and capitalize upon recycling opportunities.
- **Personal Vehicles.** Wider public adoption and at-home charging will drive infrastructure expansion, impact the grid, and create new jobs.
- **Public Transit.** Texas transit agencies are electrifying their fleets to reduce emissions and install charging infrastructure that can serve the general public.
- **Freight Vehicles.** Last-mile and short-haul freight are becoming electric to take advantage of economic savings.
- **Grid Resilience.** Expanded deployment of EVs will both increase demand on the electric grid and generate new, innovative resilience opportunities.

Analysis: Electric Vehicles and Alternative Fuels

Battery technology has greatly expanded in recent years, and in the next ten a drastic expansion of EV batteries is expected to occur. These advances will also bring about cheaper development and sale costs for EVs, whose prices are expected to drop to meet those of combustion vehicles before 2030. States across the country are preparing for this expansion of EV use and the necessary accompanying infrastructure, within all modes of transportation, including personal vehicles, transit, and fleet vehicles. EVs can bring benefits and flexibility to the transportation sector, as they can be charged almost anywhere—at home, at the office, or on the road. The expansion of charging infrastructure requires significant planning and coordination among several agencies necessary for implementation and operation. These include electricity providers, utility commissions, charging infrastructure providers, and leadership across jurisdictional boundaries. Texas has some incentives for alternative fuel use adoption on both the city and state level. Texas can utilize existing efforts by the four clean cities coalitions, including San Antonio, DFW, Houston-Galveston, and Central Texas. These plans can guide the goals and scope of a statewide or regional EV charging platform. There are four power grids that provide and manage electricity for the state; the largest of these is the Electric Reliability Council of Texas (ERCOT), which provides 85% of the state's electricity. Proper coordination and planning between municipalities and grid operators is pivotal for a successful deployment. By planning for more

affordable battery technology, greater prevalence of charging infrastructure, and improved grid resilience, Texas will be able to best prepare its EV ecosystem for the future.

Case Studies: DART and Proterra

Key Takeaways: Electric fleets are becoming an increasingly higher priority for transit authorities. Early deployments can provide critical information on performance, charging and logistics, and lifecycle costs.

Beginning July 2018, Dallas Area Rapid Transit (DART) acquired and deployed seven electric Proterra buses. The cost was offset by a $7.6 million grant from the Federal Transit Administration (FTA) low- or no-emission vehicle deployment program to help defray upfront costs. Announced in 2015, within a year that program dispersed more than $54 million nationwide. FTA grants have also assisted many other major metropolitan centers in purchasing EVs, totalling over $84 million

in funding that included $2 million in funds for VIA Metropolitan Transit in San Antonio. Each bus costs roughly $970,000, which is nearly twice the cost of natural gas buses, though proponents argue this cost is more than made up in maintenance and gas savings. DART began using these electric buses on the D-Link, route 749, which connects the convention center and Southwestern Medical District/Parkland stations, among other destinations. Major organizers throughout this project were DART, Oncor (electric provider for the DFW area), the City of Dallas (to coordinate placement of charging infrastructure on public land), and Proterra to provide the buses.

Technical Details

When preparing for this deployment DART commissioned the Texas A&M Transportation Institute to conduct a study before and after deployment of these vehicles, beginning 6 months before deployment and concluding 6 months after, in October of 2019. When looking at similar routes to the D-link, which was used as a sort of test route within the downtown area, the study revealed some savings with these EV buses, largely due to energy consumption. The study assumed at least 12 years in operation. This cost saving was further refined by avoiding charging during peak demand.

The D-link is an 8-mile route, and currently the system has five electric chargers, two of which are overhead fast-chargers stationed at the Convention Center Station. These fast-chargers enable the buses to charge via roof-mounted charging docks while waiting for customers, and reach a 90% charge in only 10 minutes. Then, at night or during maintenance activities, these buses can plug into one of two plug-in depot chargers that are located at the bus operating facility. Initially, DART hosted ChargePoint chargers, though for increased capacity and more reliable systems they were eventually replaced with Proterra, which increased capacity 20 to 30%.

Continuation and Scaling

DART has significant plans for the future expansion of electric bus and system infrastructure, coordinating grid impacts, longer-range buses, and charging infrastructure. Beginning the next phase likely by 2022 or 2023, there is some discussion of obtaining smaller vehicles, particularly fuel-support vehicles. Planned for 2025 is a more comprehensive scheme to replace roughly 85 buses with EVs if they meet the determined range requirements. While D-link operations proved the utility of an EV bus, DART is looking to acquire Proterra's long-range buses moving forward. Beyond expanding the number of buses, DART is collaborating with Oncor to establish both efficient charging times and best practices for meeting charging needs as fleet size expands. In expanding public charging infrastructure, DART is looking to create a model similar to that of San Francisco, who partnered with Tesla for its EV fleet expansion.

Lessons Learned

DART gained much experience through the "learn as you go" deployment. While Proterra offered field representatives, DART chose to conduct its maintenance activities in-house to become familiar with the new

technology. Other lessons learned include:

- The smaller scope of the D-link pilot provided valuable insights for a larger-scale future deployment.
- DART is collaborating closely with Oncor to assess grid impacts of a wider deployment.
- DART's forward-looking leadership enabled a successful integration of electric technologies and has well prepared the agency for the future.

Case Study: City of Denton, TX

Key Takeaways: The City of Denton is advancing knowledge of EV fleet ownership and management. The City's alternative fuel investment and plans are aimed at, among other objectives, addressing carbon emissions from transportation sources.

The City of Denton began their efforts for alternative fuel vehicles beginning in the early 2000's with hybrid vehicles. Beginning 2013 the City purchased their first plug-in EV, and expanded this fleet further in 2018. These vehicles are currently used for community services, as department staff move around the city. For example, meter-reader staff use these EVs to travel to work sites. What makes the City of Denton unique in its deployment of these vehicles is the use of their own electricity for charging them, which essentially allows the City more control over their own charging rates, and the network as a whole.

Continuation and Scaling

Initially, ensuring infrastructure was in place was one of the largest challenges the City of Denton faced, as the city offered few charging facilities. The city council has been a driving force for these EV adoptions, and the City has seen great success, including cost effectiveness, as maintenance costs are greatly reduced. Further, users enjoy the driving experience. Both a supportive city council and promising outlook on cost prospects make further EV adoption enticing on the municipal scale. As a more comprehensive network citywide for charging would be helpful, the next step is to expand services and infrastructure to all city facilities. EV use has been more challenging in some departments, including those that use pickup trucks. Moving forward, for the state to play a more helpful role would be to expand EV infrastructure on state-level corridors.

Lessons Learned

For a city beginning to install this EV infrastructure, understanding what all goes into charging infrastructure is particularly helpful. Cities should use a blueprint or some common method for implementation. Almost all of the push occurred at the city level; a state-level initiative may be helpful for creating such a blueprint. Beyond the installation aspect, users also should be educated on the benefits and use of this infrastructure, to overcome concerns such as range anxiety. In Denton, overall it was found that users liked the EV driving experience. The state is working to install a corridor EV infrastructure expansion of the network, which will ease implementation for cities.

Case Study: San Francisco MTA + ChargePoint

Key Takeaways: The SFMTA and ChargePoint partnership offers a pathway to advancing the transit authority's transition to electric busses by providing charging infrastructure and management software for better operational efficiency.

As part of a Federal Transit Administration (FTA) Bus and Bus Facilities Infrastructure Investment Program, the San Francisco Municipal Transportation Agency (SFMTA) was awarded $3.6 million late 2018. SFMTA oversees all ground transportation within the city, and this grant can provide funds to modernize bus facilities, support critical operator training, and begin development of new EV infrastructure to set the stage for future expansion. In 2019 SFMTA announced a partnership with ChargePoint to support the agency's transition into EVs. Part of this grant is working to renovate the Woods Bus Yard, which will implement utility upgrades that prepare for this fleet electrification, which will have funds matched by funds from SB 1 State of Good Repair Funding. These EVs are expected to hit the streets in late 2020.

Technical Details

Renovation of the Woods Bus Yard will support 99 electric buses, and with ChargePoint's assistance the foundation will be set to pave the way to the transformation of their entire 800-plus bus fleet by 2035. This project includes nine ChargePoint Express Plus DC fast charging stations, with power that is supplied by nine ChargePoint Power Blocks. These charging blocks can be configured in a way that can grow incrementally as demand increases. This flexibility allows for a range in the amount of EV buses, but also the type of fleet, including trucks. In terms of operation and management, ChargePoint will also provide the software solutions to manage the fleet, as well as the project management for installing all EV infrastructure of the site.

Final Recommendations

Short-Term

Short-term recommendations include the need to keep informed on national legislation regarding right-of-way charging regulations. In addition, as alternative fuel vehicles become more popular, decision-makers will need to evaluate and consider alternative transportation revenue sources to replace fuel tax revenues. Finally, agencies should plan to include electricity under the definition of vehicle fuel to maintain funding sources.

Long-Term

Long-term recommendations include the need to keep informed on evolving battery technologies and infrastructure requirements, as these will have a considerable influence on adoption rates. Agencies should continue planning and adjusting alternative revenue sources, and ensure major corridors and feeder routes are equipped with operational charging infrastructure.

Deep Dive: Unmanned Aerial Systems

UNMANNED AERIAL SYSTEMS

Unmanned aerial systems (UAS) stand to significantly impact every facet of the transportation sector. Drone technology is being developed for a wide variety of uses, including public safety, freight, and passenger travel. Whether it is natural disaster response or delivery of critical supplies, Texas is looking to the sky to eliminate major inefficiencies and constraints associated with ground travel.

Maturity Scale

Concept — Operational

KEY TAKEAWAYS

Short-Term. Coordinate state and local agencies to prioritize use cases in public safety and package delivery.

Long-Term. Investigate air space management for wide-scale operations.

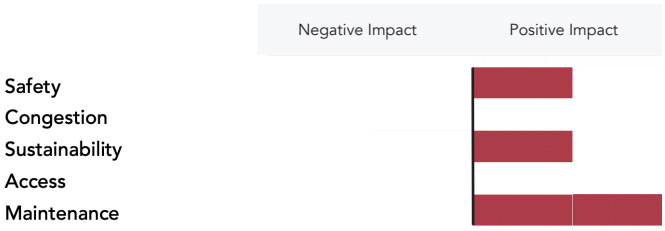
Featured Case Studies

- NCDOT
- Prime Air Delivery
- Zipline

Readiness Index	Policy	Deployment	Research	Public Education
6	⚙	!	⚙	!

Legend: ! =High Priority ⚙ =Needs Work — = Not Urgent

GOAL ALIGNMENT



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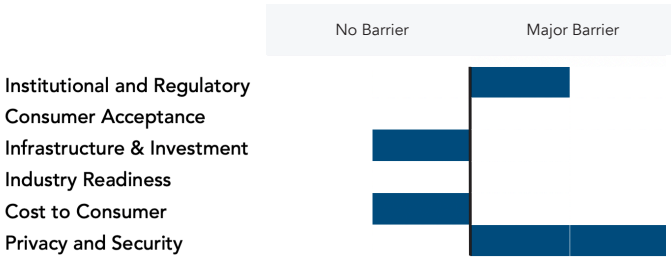


USE CASES

The versatility of UAS provides a wide array of technology applications to consider in the near future. Drones offer a diverse array of benefits across transportation, public safety, and medical sectors.

- **Last-Mile Package Delivery.** Packages can be delivered more quickly and efficiently, eliminating contribution to local traffic.
- **Traffic Incident Reconstruction.** Drones equipped with LiDAR technology are being used for incident reconstruction.
- **Infrastructure Inspections.** For bridge and rail, drones may be used to inspect critical assets.
- **Medical Supply Delivery.** UAS may be deployed for medical purposes, expediting the delivery of critical supplies and operations such as blood transfusions.
- **Urban Air Mobility.** Companies are designing vehicles and business models for urban air mobility to carry passengers between key destinations within the city, having implications for congestion and land use.

Analysis: UAS

The versatility of drones provides a wide array of tech applications for public agencies to consider. Drones are being developed for uses spanning from on-demand mobility to public safety. UAS differs from ground vehicles in that the regulatory landscape is rather nebulous. The Federal Aviation Administration (FAA) announced Part 107 in 2016, a set of rules and certification required for commercial drone operation in the U.S. Part 107 set operating parameters for drone use including a maximum weight of 55 lbs, maximum altitude of 400 feet above ground level, and maximum ground speed of 100 mph. Most notably, Part 107 limits drone usage to daylight hours, requires that UAS remain in the line of sight of the operator at all times, prohibits flying over people, and requires operators to yield right-of-way to other aircraft. While personal use is common, public and private agencies are still navigating what policies and uses are most relevant and effective for UAS deployment.

Case Study: NCDOT

Key Takeaways: NCDOT and its Aviation Division are leading the way in organizing at a state level to safely deploy drones for public agency applications and managing the airspace.

The North Carolina Department of Transportation (NCDOT) first considered UAS as an emerging technology in 2013, initially studying agricultural use cases. In 2014, NCDOT created an aviation division with programs and initiatives specifically for unmanned aerial devices/systems. The aviation division identified a wide array of use cases, including job site documentation, hurricane response, and traffic incident reporting. By identifying use cases, NCDOT was able to identify limitations in the technology.

One of NCDOT's objectives was to discern what regulatory power the state had in relation to unmanned aerial devices. While the FAA retained control over air space, NCDOT was able to regulate ground safety, privacy, and controlled take-off and landing on state property. By identifying regulatory power at the outset, NCDOT was able to build a strong framework of policies that paved the way for drone deployment.

In 2016, NCDOT began requiring commercial and government drone operators to obtain a state permit. The license program requires that operators must have a valid airmen certificate from the FAA, successfully complete a knowledge and safety exam, be at least 16 years old, and register their UAS with the FAA.

In 2018, North Carolina was selected as one of 10 participants in the FAA's UAS integration pilot program. The pilot program is an opportunity for state, local, and tribal governments to partner with the private sector in order to study and collect data on the efficiency of drone programs. NCDOT's participation in the program entails using UAS to deliver medical supplies, provide food delivery service, and conduct infrastructure inspections.

Partners

NCDOT established an array of partnerships that allowed the agency to successfully

develop and deploy UAS initiatives in a relatively short amount of time. When NCDOT began researching drones in 2013, it was an exploratory attempt to decipher the limitations and opportunities of emerging technology. UAS quickly became a bigger priority due to the technology's versatility and potential. To make a successful drone program, NCDOT decided to focus on personnel, education, and research, creating a special division for UAS and aviation in 2014. This legitimized the agencies goals and allowed NCDOT to discover and develop relevant use cases, and in turn develop better policies and develop a dialogue with the FAA.

As part of the FAA's UAS pilot program, NCDOT has collaborated with private companies in order to improve UAS operations. For example, NCDOT partnered with Apple to integrate Apple Maps and T-Mobile to access the company's 4G LTE network. Other industry partners include Matternet, Zipline, UPS, and WakeMed, which collaborate to develop and research UAS delivery of medical supplies. NCDOT has also worked with federal and state agencies like the FAA and North Carolina State Highway Patrol (NCSHP) to develop use cases, such as traffic incident reconstruction and infrastructure inspections.

Metrics and Evaluation

NCDOT collaborated with NCSHP's Collision Reconstruction Unit (NCSHP-CRU) and the Governor's Safe Highway Program to research the capability and potential for UAS and traffic incident response. Prior to the study, NCDOT and NCSHP-CRU reconstructed collisions utilizing time-consuming methods that resulted in extended highways closures and travel delays. The study aimed to explore the possible benefits of deploying lidar-equipped UAS to digitally reconstruct the crash site. The agencies conducted a simulation experiment in which two teams from the NCSHP-CRU worked to clear a simulated crash site using the traditional method and UAS respectively. NCDOT was able to determine that UAS was capable of reconstructing the scene to a comparable level as traditional methods and that UAS took much less time to do so. By creating a data-driven evaluation of the potential use case, NCDOT was able to prioritize drone operations for traffic incident reconstruction.

Lessons Learned

NCDOT has developed a robust program for UAS deployment. It has established a model framework of policies and operational protocols. It is uniquely positioned to do so as the DOT has oversight on operational permits. NCDOT is leading the way in identification of relevant transportation system use cases and forms partnerships with research and industry partners to leverage knowledge.

Case Study: Prime Air Delivery

> *Key Takeaways: The limited trial of package delivery by drone from Amazon in Las Vegas is one of the earliest of its kind. Many unknowns exist, and it is expected that package delivery is still a far-off applications.*

Amazon plans to deploy UAS as a means of last-mile package delivery in Las Vegas, NV. In 2019, Amazon announced that its Prime Delivery effort had been issued a

special airworthiness certificate from the FAA allowing the company to operate its MK27 unmanned aircraft in authorized flight areas.

The one-year approval, with the opportunity for renewal, allows Amazon to test non-commercial deliveries.

Technical details

The MK27 drone will be able to fly up to 15 miles and deliver packages under five pounds. Amazon has identified that roughly 75 to 95% of the company's deliveries fall within these constraints.

The drone is able to detect hazards when airborne, utilizing a combination of thermal cameras, depth cameras, and sonar. Onboard computers can automatically identify obstacles and avoid them with machine learning models. The rotors are fully covered, serving as wings during sustained flight. The drone has six degrees of freedom, rather than the typical four, which allows for more dynamic and deliberate flight.

Lessons Learned

Despite innovative tech and industry dominance, Amazon Prime Air delivery has yet to materialize. Executive shakeups, project delays, and the onset of the pandemic have made the future of the project uncertain.

Case Study: Novant Health and Zipline, Inc.

> *Key Takeaways: Zipline and similar companies may provide critical just-in-time delivery of medical supplies using drone delivery—especially in traffic incident and injury scenarios.*

Novant Health, in collaboration with Zipline and NCDOT, has launched drone operations for personal protective equipment (PPE) delivery in response to the Covid-19 pandemic. The venture is the first to receive a Part 107 exemption from the FAA, allowing UAS to fly in airspace previously restricted to manned aircraft. The drones follow two routes between Novant Health's emergency drone fulfillment center in Kannapolis and a medical center in Huntersville. The 32-mile flight is currently the longest approved route for delivery drones in the US. It is also the first emergency drone operation to help respond to the pandemic.

The drones deployed by Novant Health carry loads up to four pounds, travel up to 80 mph, and have a total range of travel of 100 miles. Over the next two years, the partnership plans to provide a blueprint for more resilient, responsive healthcare logistics operations. The venture also plans to expand beyond PPE delivery and carry out commercial deliveries at the local level.

Partners

Zipline, Inc. has successfully delivered medical supplies outside of the US since 2016. The company began delivering blood via UAS in Rwanda in 2016, partnering with civil aviation authorities to develop a successful model. Since then, the company has expanded operations to Ghana, delivering blood, vaccines, and medicines; Zipline currently has plans to expand operations to India and the Philippines by the end of 2020.

In 2019, Zipline partnered with the US

Department of Defense in order to develop UAS operations for disaster response purposes. The company delivered hundreds of mock blood samples throughout 2019, testing UAS operations across a series of disaster simulations. With the onset of the Covid-19 pandemic, the company's skills were put to the test. The company partnered with Novant Health, NCDOT, and the FAA in order to deploy emergency drone operations in North Carolina. The partnership has fast-tracked FAA exemptions from Part 107, allowing long-distance, high-speed operations in previously restricted airspace. This is significant as the partnership is the first and only Part 107 exemption, making the North Carolina operation a unique test case. Over the next two years, Zipline plans to develop a blueprint that will alter healthcare logistics. The company also plans expand operations to commercial deliveries, potentially creating a model for successful package delivery drone service nationwide.

Lessons Learned

Part 107 exemptions are possible for compelling public agency use cases. Emergency UAS operations can be a jumping off point to develop further operations. The policy landscape is still changing and will continue to do so as adoption increases and technology matures.

Case Study: Texas Department of Public Safety (DPS)

Key Takeaways: The Texas Department of Public Safety has established a robust UAS program that delivers many critical emergency and safety services. It is a model program, and DPS is helping other Texas public agencies with their drone deployments. In 2018, Texas DPS launched its Public Safety UAS program. The department deploys UAS for search and rescue, disaster response, crash reconstruction, and communication tower inspections, among other uses.

DPS has partnered with Dronesense to integrate software into UAS operations. Dronsense software collects data, streams video pilot feeds in real time, and allows DPS to manage its UAS assets across the state. The administrative tool generates reports for financial and legislative purposes, and serves as a common platform for state and local agencies, creating easy collaboration across boundaries.

Continuation and Scaling

Going forward, DPS has identified several needs for a successful program. Better training and accountability should be prioritized in order to ensure that PDS operators are ready to pilot UAS once an emergency strikes. As the program expands and more drones are in operation, there is a need to deconflict airspace, ensuring that UAS and other low flying aircraft, such as medical helicopters, are able to detect and avoid each other. Lastly, DPS identified the need for the clarification of legal terms, such as surveillance.

Lessons Learned

The extensive experience and expertise of the Texas DPS has shown how critical it is to have established protocols, training, and accountability. Tracking, monitoring, and managing UAS assets requires high quality software for camera feed viewing, logging,

and tracking. There is a need to develop strong policy frameworks on privacy, security, and safe operational procedures.

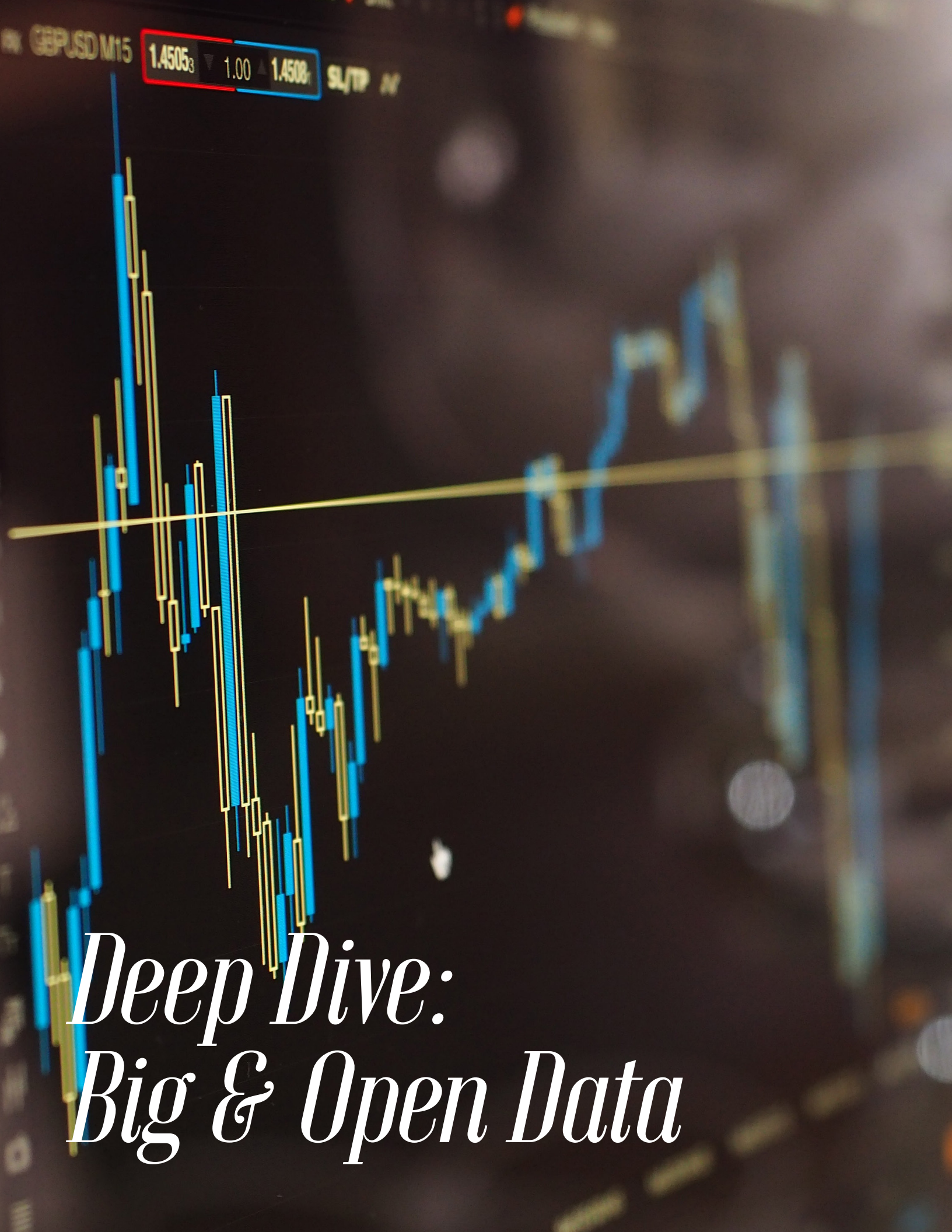
Final Recommendations

Short-Term

In the short term, TxDOT should identify and prioritize use cases for deployment of UAS technology. The versatility of drones provides a wide array of tech applications for TxDOT to consider in the near future. This includes passenger drone efforts by on-demand mobility services, as well as freight applications for last-mile package delivery. Other relevant use cases to consider include traffic incident mapping and reconstruction, as well as other auxiliary traffic and public safety uses.

Long-Term

In the long term, TxDOT should investigate the changes that will stem from broad use of UAS technology. Some examples include air space management, infrastructure changes needed, and impacts to the traditional transportation network. Currently, air space regulation of drone traffic is nebulous and it is unclear what the impacts to infrastructure or the network will be. TxDOT should follow the growth and adoption of the technology while paying special attention to regulatory changes by federal and state actors.



Deep Dive: Big & Open Data

BIG & OPEN DATA

In the field of transportation, data can be used to analyze and model people's travel behaviors in order to improve transportation networks and systems. Combining data from different sources – location-based service (LBS) data from smartphones, road network maps, GPS data from vehicle and navigation applications, land use data, and census demographics – can reveal key insights into travel patterns. To capture these benefits, Texas needs a process to assess, prototype, and integrate new sources into its data management practices.

Maturity Scale

Concept — Operational

KEY TAKEAWAYS

Short-Term. Develop and implement a framework to evaluate opportunities to use big data to achieve organizational goals.

Long-Term. Generate privacy principles, standards, and ultimately a culture of privacy across all programs.

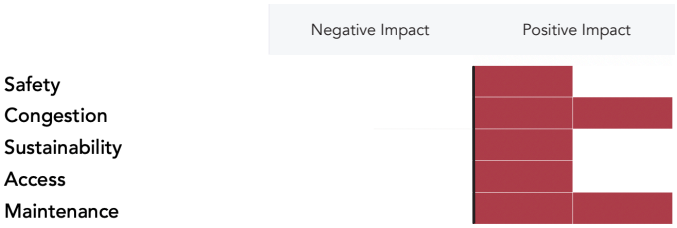
Featured Case Studies

- Waycare
- City of Seattle Privacy Principles

Readiness Index	Policy	Deployment	Research	Public Education
7	!	⚙	⚙	!

Legend: ! =High Priority ⚙ =Needs Work — = Not Urgent

GOAL ALIGNMENT



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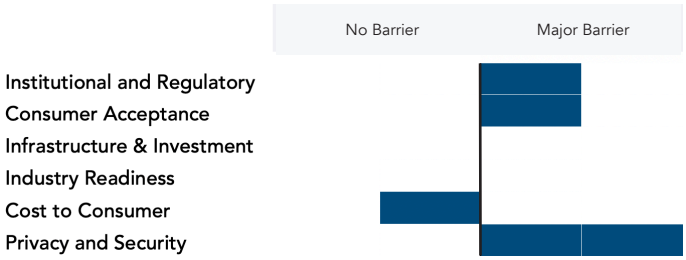

USE CASES

Data can be used to address key goals of transportation departments such as decreasing congestion and increasing safety. However, in order to be effective and to gain the trust of Texans, data privacy and cybersecurity must remain priorities.

- **Big Data for Traffic Operations.** Data can be used to decrease road congestion and increase road safety by predicting potential incident areas.
- **Predictive Data Analytics for Planning.** New demographic shifts and technology adoption rates can inform planning decisions.
- **Data Privacy.** Implementing a strategic and replicable process for collecting, storing, and sharing data across an organization is necessary to manifest a culture of privacy.
- **Cybersecurity.** Cutting-edge data security technology is vital to keep data safe and secure as it is collected, stored, and shared.

Analysis: Big Data and Artificial Intelligence

Data can be used to track performance related to key transportation network goals in areas such as safety, efficiency, and access. However, there are also some risks to consumers associated with having their mobility data collected, stored, and, in some cases, shared. Even when data is aggregated, sophisticated methods can often be used to match a user's identity with their location. These risks have sparked a robust conversation around data privacy, security, and consumer protections in relation to new transportation technologies.

The transportation data analytics technology is ready to be fully implemented in Texas. The case studies below will demonstrate how TxDOT can develop partnerships and processes in order to effectively implement data analytics to measure progress towards its goals of safety, access, and efficiency.

Case Study: Waycare + Las Vegas Traffic Management Center

> *Key Takeaways: Public agencies can begin to develop processes that allow and incentivize inter-agency collaboration. Learning can come from limited implementations or pilot data analytics program. Review of results and iterating based on findings allows for incremental learning.*

Waycare, a technology company focused on AI-driven mobility solutions for cities, partnered with the Regional Transportation Commission of Southern Nevada, Nevada Highway Patrol (NHP), and the Nevada Department of Transportation on a pilot project to identify roads at high risk for accidents and reduce crashes. The program resulted in a 17% reduction in primary crashes on a key I-15 corridor. Waycare uses in-vehicle information and municipal traffic data to analyze dangerous road conditions in real time. When a risk is identified, the partner agencies used methods such as dynamic message boards and high-visibility positioning of NHP officers. In addition, when accidents did occur, the agencies were able to identify incidents 12 minutes faster using the real-time data that Waycare collected and analyzed.

Partners

Inter-agency collaboration was key to the success of implementing Waycare's data analytics system effectively. The NHP is a division of the Nevada Department of Public Safety, which coordinates law enforcement activities across the state. NHP shares a dispatch location with the Regional Transportation Commission of Southern Nevada's Freeway and Arterial System of Transportation (FAST). FAST monitors and controls traffic in the southern Nevada region. Although the agencies were housed in the same location, they used different software systems. Waycare was able to provide a common, shared platform so NHP and FAST could share real-time information in order to respond to roadway incidents in an expedient and prepared manner.

Continuation and Scaling

In 2019, NHP built on the success of the 2018 program described above by leveraging funds awarded through the NSC Road to Zero grant program to use the Waycare platform to identify and deploy five strategic traffic management sites. These sites are elevated, protected platforms built in high-visibility locations along I-15 and US-95 and used to deter speeding and prevent traffic incidents. Using new funding sources and the predictive analytics software from Waycare, NHP was able to iterate, expand, and scale its original data analytics concept to cover more corridors.

Lessons Learned

- Develop processes that allow and incentivize inter-agency collaboration.
- Implement and pilot data analytics program or solution, review the results, then iterate based on your findings.
- Leverage learnings from pilot projects to expand to other corridors or contexts.

Case Study: Data Privacy in Seattle, WA

Key Takeaways: The foundation for an effective organization-wide data privacy program is the development of privacy principles through a collaborative process with internal and external stakeholders. The principles can only be operationalized when the necessary resources are allocated for the program.

Seattle is a leader in data privacy on the municipal level. In 2014, community advocates and city council recognized the need to make privacy a key value as the city invested in new "Smart City" technologies and began to collect data to quantify how citizens were using public space and public infrastructure.

Privacy Principles

Seattle is a leader in data privacy on the municipal level. In 2014, community advocates and city council recognized the need to make privacy a key value as the city invested in new "Smart City" technologies and began to collect data to quantify how citizens were using public space and public infrastructure. The city council and mayor came together to address data privacy risks and build trust with their constituents by hiring a Chief Privacy Officer and create a Privacy Advisory Committee. The committee, made up of stakeholders from business, journalism, activist groups, cybersecurity firms, and Washington University faculty, collaborated with city staff to craft a set of privacy principles. The principles include:

1. We value your privacy
2. We collect and keep only what we need
3. How we use your information
4. We are accountable
5. How we share your information
6. Accuracy is important

Once the principles were created, the city council and mayor adopted them in a city ordinance and designated resources to operationalize them across 38 departments of Seattle's city government. The privacy team performs risk analysis, consultation, and works with all city departments to mitigate privacy risk. The office of privacy has been integrated into all purchasing, project management, and program

development activities. The keys to Seattle's success in implementing and operationalizing these privacy principles have been conducting interdisciplinary team building, allocating significant resources towards this effort, and creating a culture of data privacy and security with ambassadors who work in each department. They create accountability and transparency by informing citizens what data they collect and issuing quarterly reports that communicate their progress towards living out the privacy principles.

Lessons Learned

- The foundation for an effective organization-wide data privacy program is the development of privacy principles through a collaborative process with internal and external stakeholders.
- The principles can be operationalized only when the necessary resources are allocated for the program.

Final Recommendations

Short-Term

Develop and implement a framework and rubric to evaluate opportunities to use big data to achieve organizational goals. Based on the implementation of select pilot projects, create an implementation plan to scale those particular use cases along multiple corridors across the state. This approach will create a process and pipeline for best use cases and opportunities for impact.

Long-Term

TxDOT has the opportunity to generate momentum following the security event in the spring to rethink and retool their approach to privacy and security. Following best practices around organization governance of data privacy, first take stock of privacy and security norms and protocols across the agency and develop an intradepartmental task force to develop privacy values, standards, and ultimately a culture of privacy across all programs. This effort will require coordination within multiple internal divisions and public engagement with stakeholders in industry and academia. Create a process that embraces innovation and nimbleness, while also providing built-in checks and balances when adopting new technologies or programs.

Deep Dive: Mobility-as-a-service

MOBILITY-AS-A-SERVICE

The concept of Mobility-as-a-Service (MaaS) includes planning for and buying mobility services based on consumer needs instead of buying the means of mobility. The realization of this concept requires a single app or website where users can plan trips using a variety of modes and purchase the tickets for each of those modes with a single account. To meet the variety of consumer needs, Texas can take steps to integrate multimodal transportation options into a single platform.

Maturity Scale

Concept — Operational

KEY TAKEAWAYS

Short-Term. Facilitate a working group to collaborate and share MaaS approaches across the state.

Long-Term. Scale resources to transit services for MaaS pilot projects.

Featured Case Studies

- Houston ConnectSmart
- Central Ohio Transit Authority (COTA)
- Kansas City Area Transit Authority (KCATA)
- Congestion Pricing

Readiness Index	Policy	Deployment	Research	Public Education
3	⚙	⚙	!	⚙

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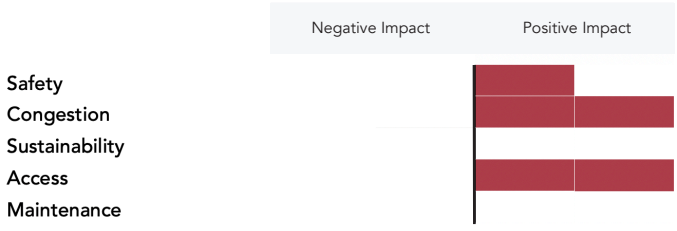

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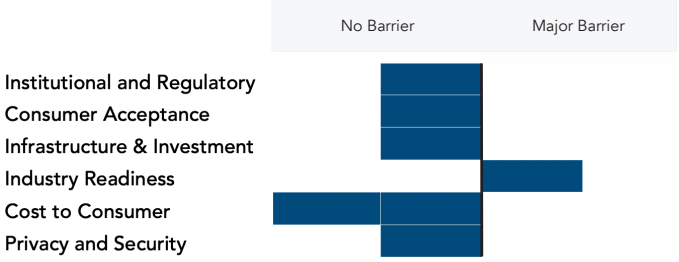

USE CASES

MaaS envisions a system in which residents do not need to own a car to meet their travel needs; instead, they can use a variety of modes to complete trips via one interface that allows for comprehensive trip planning and integrated payment.

- **Trip Planners and Integrated Payment.** Trip planning and integrated payment systems provide a more seamless, streamlined solution for customers to access multiple mobility services.
- **Zero Fare Transit.** Zero fare transit offers mobility services to users without traditional fares.
- **Congestion Pricing.** Drivers pay a fee in order to access certain dense areas of a city in order to decrease congestion, among other positive outcomes.
- **Public-Private Partnerships.** Transit providers can partner with TNCs or others to offer paratransit services ansd integrated planning and payment systems.

Analysis: Mobility-as-a-service

The concept of Mobility-as-a-Service (MaaS) has been described by Dr. Maria Kamargianni as one that includes "buying mobility services based on consumer needs instead of buying the means of mobility." The realization of this concept requires a single app or website where users can plan trips using a variety of modes and purchase the tickets for each of those modes with a single account. MaaS envisions a system in which residents do not need to own a car to meet their travel needs; instead, they can use a variety of modes to complete trips via one interface which allows for comprehensive trip planning and integrated payment. With the USDOT rollout of the Complete Trip–ITS4US Deployment Program, it is clear that the concept of complete trip planning will begin to become more of a priority in the US context. Designed to address the lack of transportation options for all, the Complete Trip program will "provide more efficient, affordable, and accessible transportation services for people with disabilities, older adults, and other underserved communities." The pursuit of a MaaS program in Texas with innovative partnerships and technologies will make the state competitive in securing resources through Complete Trip–IT4US. Like most jurisdictions across the country and the world, Texas may not have the technological capacity or readiness from the private sector to fully implement a comprehensive MaaS solution; however, in the short term, the adoption of integrated trip planning technologies is a realistic goal. Long-term solutions should aim to include integrated payment in addition to integrated trip planning.

Case Study: Integrated Trip Planning; Houston ConnectSmart

> *Key Takeaways: Marketing and outreach of new technology is key in order to influence individual travel behavior and congestion; data gathered from adoption can be used for planning purposes.*

Integrated trip planning systems are strategies that TxDOT and other public and private organizations providing transportation options can use to provide a more seamless, streamlined solution for customers. For example, TxDOT Houston partnered with Metropia, a mobile computing technology company, to integrate Active Demand Management and Transportation Systems Management and Operations with multi-modal demand and mobility management. The goal of this integrated system is to enhance the safety, reliability, and efficiency of Houston's regional transportation system by reducing congestion and maintaining quality of life and economic vitality. The ConnectSmart app provides users with currently available and emerging mobility options within a single, convenient platform. The ability to chain together those services, including bus, taxi, rideshare, light rail, bikeshare, and more—right within the app—will increase user access to all local modes for a seamless experience. It also provides data to TxDOT Houston about how people are planning trips and choices they make related to travel behavior.

The positive outcomes of the ConnectSmart program include strengthening partnerships among Houston regional transportation agencies; allowing users to discover sustainable mobility options; increasing opportunities to proactively influence the traffic network and conditions; providing real-time system information like travel times, delays and crashes; and optimizing special event and work zone management through real-time push alerts.

Lessons Learned

- Marketing and outreach of new technology is key in order to influence individual travel behavior and congestion.
- Data gathered from adoption can be used for planning purposes.

Case Study: Integrated Payment; Columbus

Key Takeaways: key challenges include coordinating policy, governance, inancial management, and acquisition. Management of the integrated system will require additional resources for COTA, including hiring additional staff to monitor the system and analyze performance.

In 2019, the Central Ohio Transit Authority (COTA) launched the COTA Connector, a mobile app that allows riders to transfer money from a bank or credit card to a "Connector account" that can be used to purchase pay transit fare. Riders can scan the Connect app on their smart phone on the bus fare box to pay for the ride. COTA Connect was implemented as a way to attract more choice-oriented riders, who indicated that they would be more likely to ride transit if there were a cashless payment option. The integrated payment system has the added bonus of expediting the boarding process, which can reduce delays and help to ease traffic congestion. COTA also provides an option for riders who do not have access to a smart phone, called a "Connector Smart Card", which they can load with cash in person, online, or over the phone. To pay a fare, riders swipe their pre-loaded Connector Smart Card at the fare box. With this system, commuters can identify whether bus, train, or Lyft would be faster and can also utilize other options, such as scooter or bicycle, to make last-mile connections and pay within one application.

Lessons Learned

- Key challenges include coordinating policy, governance, financial management and acquisition.
- Management of the integrated system will require additional resources for COTA, including hiring additional staff to monitor the system and analyze performance.

Case Study: Kansas City Area Transit Authority

Key Takeaways: The rationale for the program was based on the view that transportation service should be accessible for all riders, not just downtown riders. Communicating the program as "Zero Fare" instead of "Free Transit" was pivotal in gaining support for the initiative.

In December 2019 the Kansas City, Missouri city council voted unanimously on a free-

fare bus transportation plan that will cost the city approximately $8–9 million annually. The goal, as stated by the Kansas City mayor, is to "build up a culture of bus riding." Past experiments of free transit in the United States took place in the 1970s and 1980s with cities like Denver and Austin experimenting with subsidized transportation. While the experiment increased ridership, it did not change how frequently people traveled by car, nor did it increase mobility for residents who were unable to transport themselves or pay for public transit. It is unclear how this change will impact ridership, given that most studies, like the one produced by Transit Center, indicate that the top priority for most transit riders is how frequent and reliable a system is, not its price. However, the free fare program in Kansas City was based on an equity framework, values that the mayor and transit authority CEO support. The policy was embraced after the zero-fare downtown street car project was implemented four years prior. This catalyzed the rationale that all transit riders, not just those who live or work downtown, should have access to zero-fare transit as well.

Funding Model

The total cost for KCTA to implement zero-fare service will be around $8 million per year. The 2020 city budget designates $4.8 million to support zero-fare transit. The plan is to make up the difference through private funding, of which at least $1 million has been secured through sponsorship by BlueCross Blue Shield.

Continuation and Scaling

The city is rolling out zero-fare service incrementally as funding allows, so that they can monitor ridership and make sure they are able to support a possible increase in ridership. So far, fares have been eliminated on one fixed-route bus as well as for student and veteran riders.

Lessons Learned

- Communicating the program as "Zero Fare" instead of "Free Transit" was pivotal in gaining support for the initiative.
- The rationale for the program was based on the view that transportation service should be accessible for all riders, not just downtown riders.
- The greatest challenge for this program is securing adequate funding.

Case Study: Congestion Pricing

Key Takeaways: Congestion pricing is a tool that is being explored in a handful of communities in the US. While it may be helpful to change travel behavior, concerns about equity remain unaddressed.

The concept of congestion pricing is to charge a fee to drivers who want to access roads in certain dense areas of a city, with an aim to decrease congestion, speed travel, fund and improve public transportation, reduce air pollution, and achieve better public health outcomes. London, Stockholm, Milan, and Singapore have implemented congestion pricing and American cities such as New York City, Seattle, and Los Angeles are considering congestion pricing policies of their own.

New York City

The New York State Legislature and Governor Andrew Cuomo proposed and agreed to charge a fee for motor vehicles entering Manhattan south of 61st street as soon as January 1, 2021. The Metropolitan Transportation Authority's Triborough Bridge and Tunnel Authority (TBTA) would implement a congestion pricing program in partnership with the New York City Department of Transportation. The Regional Plan Association published a report that outlines two options for congestion pricing in New York City. The first option is a "Flat Fee" model where drivers would pay $6.12 to enter the busiest part of Manhattan between 5am and 11pm. The zone would include every street south of 60th Street. The second option is a "High Peak Period" model, which would charge drivers up to $9.18 during the busiest times of the morning and evening. In both models, trucks would be charged more because they cause more traffic and pollution. Taxis and ride share would be exempt from the model because they already pay a congestion pricing surcharge as a part of their existing operating agreements. Proceeds from the congestion fees will go towards capital projects for subways and buses, as well as Metro-North and Long Island Railroad improvements.

Seattle

Seattle is considering four different models for congestion pricing: cordon pricing, area pricing, fleet pricing, and road usage pricing. Cordon pricing entails charging drivers as they cross a certain boundary. Area pricing is a pricing program in which drivers are charged when they enter an area in addition to another charge based on how long they continue to drive within that area. Fleet pricing is a model that sets different fees for different types or classes of vehicles. For example, commercial vehicles could be charged a different rate than private vehicles or taxis. This model could be used in tandem with other pricing programs. The fourth model, known as the road usage charge, is a mileage-based fee, which would charge users based on VMT rather than crossing a certain boundary or zone. This model, however, would be hard to enforce or scale.

Los Angeles

Los Angeles is considering a congestion pricing model in which drivers are charged a $4 dollar fee during rush hour if they

enter the city's most gridlocked areas—the space between two intersecting freeways in western LA and eastern Santa Monica. The money raised from the fee would be used to increase mobility via transit and subsidize access to the area for low-income drivers. The study conducted by the Southern California Association of Governments (SCAG) found that incoming traffic to the tolled areas would decrease 9% during rush hour. Similar decreases were found in travel times and greenhouse gas emissions, with each dropping about 20% from current levels. The study acknowledges the political barriers to implementing congestion pricing in Southern California and cites polls showing only 30 to 40% of respondents are favorable towards congestion pricing.

Final Recommendations

Short-Term

Create a survey targeted to transportation professionals across the state to gauge interest and agency capacity for MaaS solutions. For interested agencies, help facilitate a working group in the "communities of practice" model to share approaches across the state.

Long-Term

In an article called "A topological approach to Mobility-as-a-Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals," Sochor, et al. enumerate four typologies of MaaS integration, which build off of each other: 0—no integration; 1—integration of information; 2—integration of booking and payment; 3—integration of the service offer, including contracts and responsibilities; and 4—integration of societal goals. This framework provides the basis for TxDOT to develop a strategy to encourage adoption of policies and technologies that advance Texas from 0 to 4. Different cities in Texas are currently between the 0 and 1 MaaS typologies. In order to encourage movement into levels 2, 3, and 4, TxDOT and other public agency partners can set policy and allocate resources in order to create an environment where MaaS may be viable in the future—for example, tactics such as the revision of fiscal policies and the redistribution of subsidies towards transit on a municipal and state level. They can support the diffusion of MaaS by providing exemptions from congestion charges, altering parking regulations, and allowing shared cars to travel in bus lanes, among other policy shifts. Furthermore, they can use their influence with cities in order to encourage integration of MaaS into local policy objectives by employing tactics such as using dynamic road charging in dense areas.

CONCLUSIONS

Texas transportation is rapidly evolving and emerging technologies will continue to play a significant role in generating safety, mobility, and economic benefits. In particular, the Texas Technology Task Force has identified six technologies: automated vehicles, connected vehicles, electric vehicles, unmanned aerial systems, big data and artificial intelligence, and mobility-as-a-service - with transformative potential. For each technology, the Task Force has conducted an assessment of goals and barriers, synthesized lessons learned from case studies, and proposed recommendations on technology utilization pathways. The Task Force will continue to monitor trends and developments related to these six technologies as well as new additions to the emerging technology portfolio, publishing updates on an annual basis. Overall, the Task Force and Technology Utilization Plan will serve as strategic resources as TxDOT considers different technology investments.

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