Texas
Department
of Transportation

COOPERATIVE AUTOMATED TRANSPORTATION STRATEGIC PLAN

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EXECUTIVE SUMMARY

INTRODUCTION

The emergence of Cooperative Automated Transportation (CAT) technologies has the potential to fundamentally change the landscape of transportation: improving safety, mobility, multimodal connections and the environmental impact of transportation system.

By making strategic investments in the right technologies, TxDOT has an opportunity to leverage CAT technologies, such as connected vehicles (CV) and automated vehicles (AV), for the benefit of all Texans.

The Plan provides 35 strategies that seek to:

» Prepare TxDOT for emerging CAT technologies

» Maximize benefits of CAT

» Position TxDOT as a national leader in CAT technologies and innovation

WHO WILL USE THIS PLAN?

TxDOT, technology providers, agency partners and other stakeholders will use the plan to develop, deploy, implement and promote CAT statewide.

THE VALUE OF CAT TO THE STATE OF TEXAS

The statewide CAT program is an initiative set forth by TxDOT to integrate CV, AV and related emerging transportation technologies into the state's transportation system. CAT offers numerous potential benefits and improvements to accommodate rapidly growing transportation demands with the use of technology that maximizes the performance of transportation infrastructure.

THE PRIMARY BENEFITS ANTICIPATED WITH CAT IMPLEMENTATION INCLUDE:

SAFETY

- » Mitigate roadway crashes, 90% of which result from human error
- » CV Applications reduce rear-end collisions by up to 50%
- » Automation could eliminate 600 fatalities in Texas per year
- » CAT safety improvements can move Texas towards its Road to Zero fatalities goal

RELIABILITY

- » Numerous CAV applications target improving traffic flow management and stability
- » AVs can save travelers 50 minutes per day with increased throughput and less congestion
- » CV applications that dynamically respond to slow downs, route vehicles and preempt signals improve travel time by 20 - 40%

MOBILITY

- » CV applications enhance mobility for transit riders, pedestrians, freight vehicles, and vulnerable populations
- » AVs can improve access for Texas ~7 million disabled and older people

AGILITY

- » Participating in CAT initiatives offers agencies a role in the development and advancement of the technology
- » Investment allows for swift adoption of evolving technologies
- » Fostering workforce development will ease deployments and mitigate risks as well as attract and retain Texas's talent

VITALITY

- » CAT can reduce crashes, which cost Texans $38.4 billion annually
- » Congestion reduction with CAT can save the freight industry $9 billion per year across the nation
- » CAT offers broad potential benefits to the economy and workforce with enhanced transportation access

PLAN DEVELOPMENT

Development of the Strategic Plan began with broad information gathering, internally and externally. Meetings, interviews and workshops were held with TxDOT stakeholders to gather agency needs and desires related to CAT technology. External outreach was performed to provide industry-related developments and infrastructure owner/operator lessons learned on existing CAT deployments across the country. From these activities, TxDOT developed a mission, vision, and set of goals for CAT in the State of Texas providing direction for this strategic plan.

PROGRAM MISSION

Maximize the safe, reliable, and efficient movement of people, goods and data within Texas's multimodal transportation network.

PROGRAM VISION

Deliver forward-thinking transportation solutions, by implementing emerging technologies, to enhance quality of life for all Texans.

CAT PROGRAM GOALS

SAFETY: Support the implementation of CAT technology to improve safety for the traveling public and help achieve TxDOT's Road to Zero goal for zero roadway fatalities by 2050

RELIABILITY: Harness CAT technology to improve overall system dependability for both people and freight

MOBILITY: Emphasize CAT technologies that improve mobility and accessibility, allowing TxDOT's transportation system to reach its full potential

AGILITY: Support the ability to proactively and quickly respond to CAT technology

VITALITY: Provide economic benefit to the State of Texas and opportunities for leadership and innovation

STRATEGIES

This Strategic Plan identifies strategic initiatives that should be undertaken to

» Prepare TxDOT for the emergence of CAT;

» Maximize the benefits of CAT across Texas; and

» Position the agency as a leader in emerging technologies and innovation

FOCUS AREAS

POLICY: Legislation, standardization, institutional culture and practices

SYSTEMS READINESS: Potential for TxDOT digital and institutional systems to enable and enhance CAT

FISCAL RESPONSIBILITY: CAT implications for TxDOT funding, revenues, and budgeting

MULTIMODAL: Implications for CAT to impact travel of all manners and modes

COLLABORATION: Internal and external outreach, skill development and pursuing partnerships

MAINTENANCE & OPERATIONS: CAT implications for TxDOT's day-to-day functions of traffic management, maintenance and operations

INFRASTRUCTURE READINESS: Potential for the built environment to enable and enhance CAT

PROCUREMENT: Purchasing of goods and services necessary for CAT

RECOMMENDED STRATEGIES AND TIMELINE TO INITIATE

Category	Strategy	Immediate	Near-Term	Mid-Term	Long-Term
POLICY	01 Institutionalize TxDOT's CAT Program	●			
	02 Coordinate Emerging Technology Planning Initiatives	●			
	03 Implement Robust Security and Privacy Policies	●			
	04 Identify Regulatory Policies that May Impact CAT Implementation		●		
	05 Develop Statewide Guidance for CAT Project Planning and Implementation		●		
	06 Update Existing Design Manuals and Standards to Accommodate CAT Deployments		●		
	07 Explore CAT Impacts on Border Crossing Policies and Procedures			●	
FISCAL RESPONSIBILITY	08 Allocate Additional Budget for Modernizing TxDOT's Asset Management Program to Support CAT Technology Needs		●		
	09 Pursue Public-Private Partnerships for Technology Development and Deployment		●		
	10 Support the Pursuit of Federal Grant Funding for CAT Projects		●		
	11 Support and Provide Internal Funding for CAT Initiatives			●	
	12 Prepare for Changes in Revenue Streams Due to CAT Proliferation			●	
COLLABORATION	13 Expand TxDOT's Internal and External Conferences to Feature CAT		●		
	14 Continue to Support and Expand Partnerships with Research Institutions, Academia, Industry and Peer Agencies		●		
	15 Expand Workforce Capabilities with the Provision of CAT Training			●	
	16 Perform Outreach to Promote Internal and External Acceptance of CAT Initiatives			●	
INFRASTRUCTURE READINESS	17 Continue and Expand CAT Demonstrations/Deployments and Establish Innovation Areas			●	
	18 Prepare Traffic Management System for CAT Readiness	●			
	19 Provide Backhaul Communications for TxDOT Assets along Priority Corridors		●		
	20 Build Communications Readiness into Roadway Construction Projects			●	
	21 Support the Provision of Statewide Communications Availability			●	
	22 Strategically Allocate Space for EV Charging Infrastructure			●	
	23 Explore Design Options to Incorporate CAV Operations			●	
SYSTEM READINESS	24 Identify and Prioritize Use Cases for CAT Data to Inform Data Management Plans and Policies	●			
	25 Update Existing Data Management Strategies to Address the Unique Challenges of CAT and Capitalize on CAT Data Opportunities		●		
	26 Develop Common Data Standards and Influence their Widespread Adoption		●		
	27 Expand Upon Efforts to Create an Information Portal for Sharing CAT Initiative Information		●		
MULTIMODAL	28 Enhance Visibility of Vulnerable Road Users in CAT Project Areas		●		
	29 Explore CAT Applications that Benefit Multimodal Travel			●	
	30 Explore Next Generation Mobility Hub Concepts				●
MAINTENANCE & OPERATIONS	31 Deploy CAT Projects that Address Common Operational Scenarios		●		
	32 Explore CAT-Enabled Innovative Traffic Operations and Management Strategies		●		
	33 Identify CAT Impacts and Needs for Smart Work Zones			●	
PROCUREMENT	34 Incorporate CAT Design, Construction, Operations and Maintenance into Procurement Rules and Policies		●		
	35 Support Flexible and Agile Procurement Practices		●		

INTRODUCTION

Emerging transportation technologies have the potential to fundamentally change the landscape of mobility. Through early testing and development, Cooperative Automated Technology (CAT) has demonstrated the ability to create a substantial positive impact on safety, mobility, multimodal connections and the environmental quality of the nation's transportation system. The performance of these emerging technologies depends on the maturity of vehicle technologies as well as the physical and digital infrastructure that support their functionality. While the promises of technology represent a significant opportunity for infrastructure owners and operators, long-term success will depend on strategic investments in the right deployment scenarios. In May 2019 the Texas Department of Transportation (TxDOT) began the development of a CAT Strategic Plan and a CAT Program Plan for the State of Texas. These plans contain policies, strategies, pilot programs and deployments for emerging CV, and AV technologies.

Purpose of the Plan

TxDOT has always been a national leader in transportation innovation and research. To maintain TxDOT's position at the forefront of innovation, the agency must leverage its existing expertise and continue to understand and prepare for the full integration of CAT as a transportation solution. This CAT Strategic Plan offers an opportunity to articulate the goals of TxDOT's CAT program and identify strategies in the current landscape that support achievement of those goals. The plan is intended to serve as the foundation for statewide policy and procedural decisions related to CAT. It includes critical steps TxDOT should take to make thoughtful, strategic investments that prepare for the emergence of CAT technology; maximize the potential benefits of CAT, and; position the agency as a leader in emerging technologies and innovation. Additionally, this document provides an overview of the business case for pursuing a TxDOT CAT program, including the expected benefits and impacts of CAT technology. TxDOT, as well as the broad community of technology providers, stakeholders, and agency partners will use this plan to promote the development, deployment, and implementation of CAT statewide. As CAT technologies rapidly evolve this document will serve as a checkpoint against which future CAT efforts and initiatives may be evaluated to ensure continuous alignment with TxDOT's CAT mission and goals.

Key Terminology

Key terms that are used in reference to the CAT program and this Strategic Plan include the following. Term definitions are in accordance with the glossary of terms developed for the Center for Transportation Studies at the University of Virginia (UVA) Connected Vehicle Pooled Fund Study[1]:

- » **Automated Vehicles (AVs)** possess hardware and software collectively capable of performing some aspects of safety-critical control functions (e.g., steering, throttle, or braking) without direct driver input. AVs may use vehicle sensors, cameras, GPS, and telecommunications to obtain information in order to make judgments regarding safety-critical situations and act appropriately by effectuating control at some level. While AVs require human drivers to perform part of the dynamic driving task, self-driving and automated vehicles require little to no human intervention.

- » **Connected and Automated Vehicle (CAV)** encompasses the capabilities of both CVs and AVs.

- » **Connected Vehicles (CVs)** use wireless communications technology to enable cars, buses, trucks, trains, transportation infrastructure, smartphones and other devices, and the cloud to "talk" to one another, and share critical safety and mobility information.

- » **CV Applications** are built to take advantage of a connected vehicle environment. They serve a multitude of functions, such as leveraging sensors and safety messages to disseminate traveler information for route planning and guidance. The latest list of CV applications is provided on the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) website.

- » **Cooperative Automated Transportation (CAT)** is a cooperative ecosystem of physical and digital infrastructure and CAV technologies to enable the safe, reliable, and efficient movement of people and goods in a multimodal transportation network.

- » **Cybersecurity** is a broad term referring to the processes and practices designed to protect networks, computers, programs and data from attack, damage or unauthorized access.

- » **Dedicated Short Range Communication (DSRC)** is a communications protocol developed to address the safety-critical issues associated with sending and receiving data between vehicles and roadside access points.

- » An **On-Board Unit (OBU)** is a piece of hardware located in a vehicle to collect data from the vehicle and provide an interface through which CV and ITS services can be provided.

- » **Platooning** is a method of decreasing the distances between AVs by eliminating the distance needed for human reaction, primarily to increase the road capacity.

- » A **Roadside Unit (RSU)** is a transceiver, typically mounted along a road or pedestrian passageway, that broadcasts or exchanges data with OBUs in its communications zone.

- » **Transportation Systems Management and Operations (TSMO)** is an integrated set of strategies that optimize the performance of existing multimodal transportation infrastructure through the implementation of systems, services and projects. TSMO provides flexible solutions that preserve capacity while improving efficiency, safety and utility of existing and planned transportation infrastructure.

- » **Vehicle to Infrastructure (V2I) Communication** promotes the exchange of information between vehicles and infrastructure.

- » **Vehicle to Everything/Many (V2X) Communication** promotes the exchange of information between vehicles and various counterparts, including other means of transport, infrastructure, traffic management centers and various internet applications.

- » **Cellular V2X (C-V2X)** is a 3rd Generation Partnership Project (3GPP) standard describing a communications technology to achieve the V2X requirements.

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1   Park, H., Khattak, Z., Smith, B. (2018). Glossary of Connected and Automated Vehicle Terms Version 1. Retrieved from http://www.cts.virginia.edu/wp-content/uploads/2018/03/Glossary-of-CAV-Terms-Ver1.0-03052018-1.pdf

II
UNDERSTANDING TxDOT'S CAT PROGRAM

The statewide CAT program is an initiative set forth by TxDOT to integrate CV, AV and related emerging transportation technologies into the state's transportation system. The CAT program will promote the use of technology to achieve the overall mission and goals of TxDOT. Industry forces are currently propelling the deployment of CAT technology across the country, which will transform personal, freight, and public transportation networks whether agencies are prepared or not. The CAT program at TxDOT seeks to proactively integrate CAT into transportation projects, from planning, design and construction, to operations and maintenance, rather than reactively cope with its emergence.

While significant safety, mobility, social and environmental improvements are anticipated, CAT technologies will also pose financial, technical and institutional challenges, which are currently being discovered through CAV development efforts and studies across the country. CAT program champions will work towards implementing CAT technologies that tackle some of Texas's biggest challenges in the areas of safety, mobility, environment, and funding, while executing strategies to combat disruptive changes and impacts.

Business Case

BENEFITS

According to a 2019 report from the Texas Demographic Center, the State of Texas will see tremendous growth over the next several decades, with the population potentially doubling and reaching 54.4 million by 2050[2]. It will be difficult to solely address the demand of this population on the state's transportation network with traditional means of increasing roadway capacity (e.g. roadway expansion). In fact, the gap between population growth and transportation capacity has been demonstrated over the past several decades. Between 1990 and 2014, Texas saw a population growth of 55 percent while the total mileage of statewide roadway grew by only seven percent[3]. Continued expansion of this gap between travel demand and transportation capacity will compromise safety while increasing congestion and cost for the traveling public. CAT, if properly deployed, offers numerous benefits and improvements that could help accommodate rapidly growing transportation demands. CAT technologies can be used to maximize existing transportation infrastructure and driver performance.

2   You, H., Potter, L., Valencia, L., Geppert, J., & Huang, P. (2019). Texas Population Projections 2010 to 2050. Retrieved from https://demographics.texas.gov/Resources/publications/2019/20190925_PopProjectionsBrief.pdf

3   Williams, T., Wagner, J., Morgan, C., Hall, K., Sener, I., Stoeltje, G., & Pang, H. (2017). Transportation Planning Implications of Automated/Connected Vehicles on Texas Highways. Retrieved from https://static.tti.tamu.edu/tti.tamu.edu/documents/0-6848-1.pdf

CAT STRATEGIC PLAN

The primary benefits anticipated with CAT implementation include:

» improving **SAFETY** with a reduction in roadway crashes and fatalities;

» improving **RELIABILITY** dynamically mitigating recurring and non-recurring disruptions to transportation networks;

» enhancing **MOBILITY** and access for all Texans with the expansion of transportation options;

» supporting **AGILITY** by affording TxDOT the ability to adopt beneficial technology in a continuously evolving transportation landscape; and,

» improving **VITALITY** for the State of Texas with increased efficiencies and cost savings.
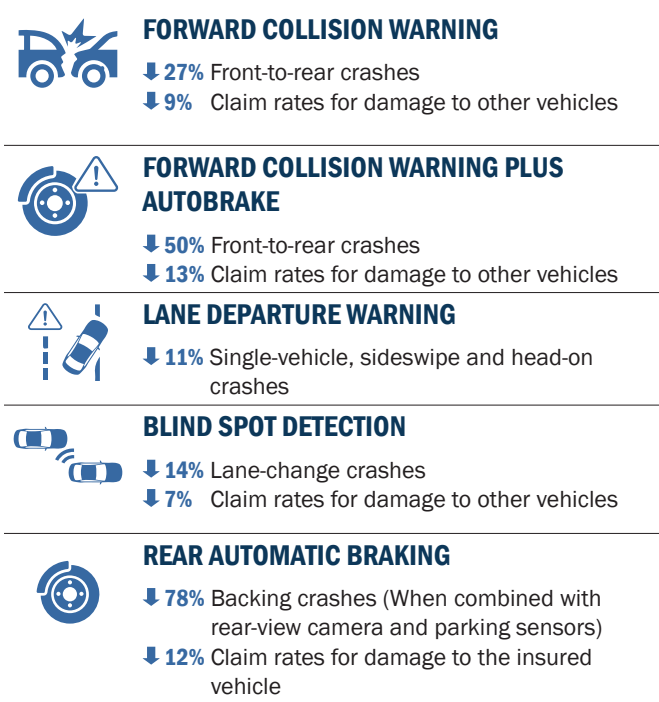
SAFETY

With 3,587 roadway traffic fatalities in 2019 alone, Texas has had at least one roadway fatality every day since November 7, 2000. The Texas Transportation Commission and TxDOT are committed to investing in engineering practices that will make Texas roadways safer and put an end to this heartbreaking streak. On May 30, 2019, TxDOT adopted a goal to end all fatalities on Texas roads by 2050, known as the "Road to Zero." Investment in CAT technology has great potential to help with achieving this goal.

The National Highway Traffic Safety Administration (NHTSA) estimates that **human error contributes to more than 90 percent of adverse vehicle incidents[4].** Several CAT technologies and applications directly mitigate these human errors, often caused by fatigue, distraction, and limited situational awareness. The Insurance Institute for Highway Safety (IIHS) estimates that **automation has the potential to reduce crash fatalities by 17 percent** and crash injuries by 9 percent[5] in a scenario where all interstate miles were logged by automated vehicles. Along Texas highways, this could eliminate up to 600 fatalities per year.

In 2018, the Highway Loss Data Institute (HLDI) and IIHS also investigated the effects of safety-improvement CAV features, including lane departure warning, forward collision warning, and blind spot detection, by comparing crash reports and insurance claims for vehicles with and without these features. **The study found that vehicles with forward collision warning and automatic braking experienced 50 percent fewer rear-end collisions.** Vehicles with forward collision warning alone experienced 27 percent fewer rear-end collisions[6]. Additional findings are shown in the figure below.

Figure 1: Impacts of CAV features on crash rates and crash damage

FORWARD COLLISION WARNING
↓**27%** Front-to-rear crashes
↓**9%** Claim rates for damage to other vehicles

FORWARD COLLISION WARNING PLUS AUTOBRAKE
↓**50%** Front-to-rear crashes
↓**13%** Claim rates for damage to other vehicles

LANE DEPARTURE WARNING
↓**11%** Single-vehicle, sideswipe and head-on crashes

BLIND SPOT DETECTION
↓**14%** Lane-change crashes
↓**7%** Claim rates for damage to other vehicles

REAR AUTOMATIC BRAKING
↓**78%** Backing crashes (When combined with rear-view camera and parking sensors)
↓**12%** Claim rates for damage to the insured vehicle

In addition, according to NHTSA, the deployment of just two CV applications, **Intersection Movement Assist and Left Turn Assist, could reduce intersection crossing related crashes and fatalities by 50%[7]**. Table 1 highlights some of the CV applications and their expected benefits.

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4   National Highway Traffic Safety Administration, 2008. National Motor Vehicle Crash Causation Survey. U.S. Department of Transportation, Report DOT HS 811 059

5   Robot cars won't retire crash-test dummies anytime soon. (2016, November 10). Retrieved January 27, 2020, from https://www.iihs.org/news/detail/robot-cars-wont-retire-crash-test-dummies-anytime-soon

6   Advanced driver assistance. (2019, May). Retrieved January 27, 2020, from https://www.iihs.org/topics/advanced-driver-assistance#overview

7   Federal Motor Vehicle Safety Standards; V2V Communications. (2017, January 12). Retrieved January 27, 2020, from https://www.federalregister.gov/docu-ments/2017/01/12/2016-31059/federal-motor-vehicle-safety-standards-v2v-communications

Table 1: CV Safety Applications and Expected Benefits

CV Safety Applications	Expected Benefits
Curve Speed Warning	» Increase vehicle operator awareness of roadway conditions
Pedestrian in Signalized Crosswalk Warning	» Improve pedestrian and cyclist safety
Spot Weather Impact Warning	» Increase vehicle operator awareness of roadway conditions
Warnings about Upcoming Work Zone	» Increase vehicle operator awareness of work zone conditions
Forward Collision Warning	» Increase vehicle operator awareness of traffic conditions » Reduced likelihood of collisions

In addition to benefiting drivers and reducing vehicle-vehicle crashes, CAT technology will help improve pedestrian safety. In 2017, pedestrian fatalities totaled 615 in Texas, a 40% increase since 2008[8]. **Pedestrian detection CV applications could mitigate 65 percent of pedestrian crashes and 58 percent of pedestrian deaths in single-vehicle crashes[9].** Furthermore, there are defined CV applications aimed at improving safety for emergency vehicles, transit vehicles and riders, motorcycles, and freight.

CAT technology promises to have a profound impact on the safety of all roadway users, with automation of functions that mitigate human error and driver warnings that allow time for response and collision avoidance.

RELIABILITY

CAT technology offers several features aimed at improving travel time for both recurring and non-recurring congestion, as well as travel time reliability. In addition, in the CAV environment, the sharing of critical safety and mobility information can inform road users and traffic operators in an efficient and timely manner to improve Planned Travel Time significantly. A 2015 study found that **AVs could reduce travel time by up to 50 minutes per day** with improved traffic flow and less congestion for users[10]. According to the 2019 Urban Mobility scorecard for Texas, commuters in urban areas spent an estimated total

of 765 million hours in traffic delays in 2017[11]. The total hours of delay in some of Texas's major cities is provided in Table 2.

Table 2: Annual Hours of Delay for Auto and Truck in Major Texas Cities (2017)[12]

Urban-Area	Total Hours of Delay (Thousand)	Hours of Delay Per Commuter	Total Truck Hours of Delay (Thousand)
Austin,TX	68,187	66	2,864
Beaumont,TX	8,493	41	357
Brownsville,TX	4,629	29	194
Corpus Christi,TX	9,458	38	397
Dallas, Fort Worth, Arlington,TX	224,883	67	9,445
El Paso,TX-NM	22,711	41	954
Houston,TX	247,440	75	10,392
Laredo, TX	6,312	32	265
McAllen, TX	19,111	38	803
San Antonio,TX	69,982	51	2,939

Additionally, the Urban Mobility scorecard reported congestion experienced along significant portions of roadways in these major cities. Table 3 provides the portion of vehicle miles traveled (VMT) that are met with congestion (congested travel) as well as the percentage of total lane-miles that are congested (congested system) by major city.

Table 3: Congested Travel and Congested System Statistics in Major Texas Cities (2017)[13]

Urban-Area	Congested Travel (% Of peak VMT)	Congested System (% Of lane miles)
Austin,TX	34.2	24.0
Beaumont,TX	12.8	1.7
Brownsville,TX	8.5	7.9
Corpus Christi,TX	15.9	14.5
Dallas, Fort Worth, Arlington,TX	31.8	18.0
El Paso,TX-NM	2.2	13.1
Houston,TX	38.4	24.6
Laredo, TX	23.4	2.0
McAllen, TX	15.2	9.5
San Antonio,TX	29.0	18.3

8   Texas Motor Vehicle Traffic Crash Facts Calendar Year 2017. Texas Department of Transportation, 2019, https://ftp.dot.state.tx.us/pub/txdot-info/trf/crash_statistics/2017/01.pdf

9   Jermakian, Jessica, and David Zuby. Primary Pedestrian Crash Scenarios: Factors Relevant to the Design of Pedestrian Detection Systems. IIHS, 2011, https://www.iihs.org/api/datastoredocument/bibliography/1888

10   Bertoncello, M., & Wee, D. (2015). Ten ways autonomous driving could redefine the automotive world. Retrieved from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world#

11   Schrank, D., Eisele, B., & Lomax, T. (2019). Urban Mobility Report 2019. Retrieved from https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2019.pdf

12   Schrank, D., Eisele, B., & Lomax, T. (2019). Urban Mobility Report 2019. Retrieved from https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2019.pdf

13   Schrank, D., Eisele, B., & Lomax, T. (2019). Urban Mobility Report 2019. Retrieved from https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2019.pdf

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Research has also shown the benefits of CAV technologies in improving travel time reliability - a consistency or dependability in travel times, as measured from day to day or across different times of day. For instance, a recent research shows that mean travel time and travel time reliability can improve as significantly as 40% as CV reaches critical market penetration in work zone environment[14].

Numerous CAV applications target improving transportation operations and management, specifically to improve traffic flow stability and increase throughput by dynamically responding to slow downs that may be caused by incidents, the presence of work zones, etc. According to the United States Department of Transportation Intelligent Transportation Systems (ITS) Joint Program Office, specific CV vehicle-to-infrastructure applications have had the following effects on travel time and delay[15]:

- » **Cooperative Adaptive Cruise Control and Speed Harmonization reduced travel time on freeways by up to 42%.**

- » **Incident Scene Pre-Arrival Staging Guidance for Emergency Responders reduced travel time for emergency vehicles by up to 23%.**

- » **Signal control applications reduced multimodal travel time by up to 27%.** Freight Signal Priority and Transit Signal Priority applications provide dynamic signal priority to freight and transit vehicles, allowing them to maintain schedule adherence despite traffic flow interruptions.

Additionally, there are a suite of road weather applications that aim to mitigate incidents and traffic flow impediments that result from inclement road weather conditions with dynamic traffic management, speed limit assignment and routing support. These applications would further improve overall network dependability, while enhancing safety, under adverse conditions.

MOBILITY

CAT has the potential to improve access and mobility for numerous populations and road users, including people with reduced mobility, such as older people, disabled people, or people without driver's

licenses; transit riders; pedestrians and cyclists; and freight vehicles. A few examples of the ways CAT technologies can enhance mobility include the following:

- » Offering and improving **first and last mile connectivity** for people that do not own a car or live near transit accessible areas

- » **Reducing parking needs** (both on- and off-street) resulting in a denser mixed-use development that promotes walking and biking

- » **Improving dynamic traveler information and routing** for all transportation network users

With an estimated 3.5 million Texans over the age of 65 and 3.3 million[16] people with disabilities in Texas, CAT technologies can play an important role in improving access to jobs, education, health care services and facilities for these significant populations.

Additionally, **a number of CV mobility applications have been defined by various connected vehicle programs around the country**[17]. These applications serve numerous purposes, and populations, with some targeted at improving commercial vehicle operations, emergency vehicle prioritization, pedestrian mobility, transit operations. Examples of these applications and their anticipated benefits are provided below.

Table 4: CV Mobility Applications and Expected Benefits

CV Mobility Applications	Expected Benefits
Emergency Vehicle Preemption	» Improved travel/response time for emergency vehicles » Increased efficiency of vehicles » Reduced vehicle emissions
Pedestrian Mobility and Accessibility	» Increased pedestrian awareness of roadway conditions » Improved pedestrian ease of access » Increased accessibility
Route ID for the Visually Impaired	» Increased accessibility
Transit Connection Protection	» Improved first and last mile connections
Freight Signal Priority	» Improved travel time for freight vehicles » Increased efficiency of vehicles » Reduced vehicle emissions

14 Abdulsattar, H., Mostafizi, A., Siam, M. R. K., & Wang, H. (2019). Measuring the impacts of connected vehicles on travel time reliability in a work zone environment: an agent-based approach. Journal of Intelligent Transportation Systems, 1–16. doi: 10.1080/15472450.2019.1573351

15 Cronin, Brian. Connected Vehicle Benefits. ITS Joint Program Office, https://www.its.dot.gov/factsheets/pdf/ConnectedVehicleBenefits.pdf

16 People with Disabilities: A Texas Profile. Texas Workforce Investment Council, 2019, https://gov.texas.gov/uploads/files/organization/twic/People-With-Disabilities-2019.pdf

17 Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT). https://local.iteris.com/arc-it/html/servicepackages/servicepackages-areaspsort.html

AGILITY

TxDOT has long demonstrated a dedication to the use of technology for improvement of its roadways. This is perhaps made most clear through statewide ITS and TSMO planning efforts. The success of these programs has been confirmed with reductions in non-recurring congestion. CAT is another approach, with a cooperative suite of tools and systems, that is directly poised to expand upon the achievements of the ITS and TSMO Plans. Early investment in CAT technology will allow TxDOT to:

» **deploy emerging technologies** with relative ease;

» **take part in the advancement of CAT technologies** in partnership with the industry;

» swiftly **respond to evolving advancements in technology;** and

» **realize tangible benefits** of CAT adoption early on.

Developing a culture and workforce that is capable and informed only increases the likelihood of compounding these benefits.

VITALITY

As described in the sections above, CAT technology offers various transportation solutions that would prevent incidents and ease congestion throughout Texas's transportation system. Along with these solutions come the opportunities for significant cost savings. Based on the National Safety Council's guidance on estimating the economic cost of crashes, **the people of Texas incurred a cost of $38.4 billion from traffic crashes in 2018[18].** According to the most recent Urban Mobility scorecard for Texas, auto and truck congestion costs across major Texas cities amounted to a total of $13.7 billion and $1.4 billion, respectively, in 2017. CAT applications have the potential to significantly reduce crashes and congestion, thereby reducing these associated costs. Table 5 highlights the annual congestion cost for auto and truck in major texas cities.

Table 5: Annual Congestion Cost for Auto and Truck in Major Texas Cities (2017)[19]

Urban-Area	Total Dollars (Million)	Per Auto Commuter ($)	Annual Cost (Million)
Austin,TX	1,368	1,391	143
Beaumont,TX	171	718	18
Brownsville,TX	93	571	10
Corpus Christi,TX	191	745	20
Dallas, Fort Worth, Arlington,TX	4,511	1,272	471
El Paso,TX-NM	458	794	48
Houston,TX	4,982	1,508	522
Laredo, TX	128	593	14
McAllen, TX	383	701	40
San Antonio,TX	1,407	964	147

In addition to the cost savings afforded with fewer crashes and less congestion, CAT technology allows for platooning, which is estimated to reduce fuel consumption by 5% to 15%. Decreases in fuel consumption and congestion would yield significant cost and labor savings to the freight industry. According to the American Trucking Associations, interstate congestion costs the trucking industry over $9 billion in fuel costs and over 140 million hours of wasted worker time. Notably, labor accounts for between 30% and 75% of truck transport costs[20]. Net cost savings for freight travel, resulting from the potential efficiencies and improvements with CAT implementation, can reasonably be correlated with decreases in the costs of goods, more timely deliveries and broad economic benefits to all consumers.

In order to evaluate how the costs of CAT benefits compare to costs of CAT implementation on Texas's transportation network, studies have been performed to determine the benefit-cost ratio (BCR) associated with some of the more prevalent benefits described. A 2016 TxDOT research project looked at CAV costs and benefits with respect to congestion, crash reduction, and productivity and leisure.

18 Comparison of motor vehicle traffic deaths, vehicle miles, death rates, and economic loss 2003 - 2018. Texas Department of Transportation, 2019, http://ftp.dot.state.tx.us/pub/txdot-info/trf/crash_statistics/2018/a.pdf.

19 Schrank, D., Eisele, B., & Lomax, T. (2019). Urban Mobility Report 2019. Retrieved from https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2019.pdf

20 Banks, Steven. "Examining the Benefits, Risks of the Autonomous Truck." FreightWaves, 4 Oct. 2017, www.freightwaves.com/news/2017/10/4/examining-the-bene-fits-risks-of-the-autonomous-truck.

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Advantageous BCRs were determined for varying market penetration rates (see Table 6), suggesting that any TxDOT investment into CAT would reap significant benefits for users, especially as market penetration increases.

Table 6: Estimated BCRs for CAV Adoption in Texas[21]

| | | CAV MARKET PENETRATION | | |
		10%	50%	90%
BENEFITS	Congestion reduction ($/Veh/Year)	$318	$159	$233
	Economic crash savings ($/Veh/Year)	$454	$601	$689
	Comprehensive crash savings ($/Veh/Year)	$1,943	$2,565	$2,941
	Productivity and leisure ($/Veh/Year)	$1,357	$1,357	$1,357
	Sum of benefits ($/Veh/Year)	$3,618	$4,081	$4,530
COSTS	Price of automation and connectivity capabilities ($/Veh)	$10,000	$5,000	$3,000
Net Present Values (using comprehensive crash cost savings) ($/Veh)		$13,960	$22,024	$27,000
Benefit-Cost Ratios (BCRs) (using comprehensive crash cost savings)		2.4	5.4	10.0

Looking further into congestion savings alone, the University of Texas Center for Transportation Research also estimated potential cost savings by region (see Table 7). These estimates found that with only ten percent market penetration, the Austin region could see annual congestion cost savings of 31 million dollars. At 90% market penetration that value increases to 213 million dollars. Statewide CAT has the potential to save over 5 billion dollars at 90 percent market penetration.

Table 7: Estimated Congestion Cost Savings from CAV Use[22]

CITY	IMPACT	0%	MARKET PENETRATION 10%	50%	90%
AUSTIN	Annual Delay per Population (hr)	24.4	23.0	20.8	14.7
	Delay Reduction per Population (hr)		1.4	3.6	9.7
	Congestion Cost Savings per Population		$25	$64	$172
	Regional Congestion Cost Savings ($M)		$31	$79	$213
DALLAS/ FORT WORTH	Annual Delay per Population (hr)	24.9	23.4	212	15.0
	Delay Reduction per Population (hr)		1.5	3.7	9.9
	Congestion Cost Savings per Population		$26	$65	$175
	Regional Congestion Cost Savings ($M)		$246	$621	$1,670
HOUSTON	Annual Delay per Population (hr)	29.4	27.7	25.0	17.7
	Delay Reduction per Population (hr)		1.7	4.3	11.7
	Congestion Cost Savings per Population		$30	$77	$206
	Regional Congestion Cost Savings ($M)		$288	$727	$1,957
SAN ANTONIO	Annual Delay per Population	22.5	21.2	19.2	13.6
	Delay Reduction per Population (hr)		1.3	3.3	8.9
	Congestion Cost Savings per Population		$23	$59	$158
	Regional Congestion Cost Savings ($M)		$86	$216	$581
OTHERS	Annual Delay per Population	15.0	14.2	13.2	11.3
	Delay Reduction per Population (hr)		0.8	1.8	3.8
	Congestion Cost Savings per Population		$14	$32	$67
	Regional Congestion Cost Savings ($M)		$73	$162	$340
STATEWIDE	Congestion Costs ($M)	$13,079	$12,319	$11,185	$8,078
	Congestion Cost Savings ($M)		$760	$1,894	$5,001
	System-wide Congestion Reduction (%)		5.8%	14.5%	38.2%

21 Kockelman, K. and P. Avery Implications of Connected and Automated Vehicles on the Safety and Operations of Roadway Networks: A Final Report (2016). TxDOT Research Project 6849. Austin, Texas: UT-Austin Center for Transportation Research

22 Kockelman, K. and P. Avery Implications of Connected and Automated Vehicles on the Safety and Operations of Roadway Networks: A Final Report (2016). TxDOT Research Project 6849. Austin, Texas: UT-Austin Center for Transportation Research

No research was discovered that could assist TxDOT in predicting a return on investment for the digital and physical infrastructure necessary for CAT implementation. Potentially the more accommodating TxDOT's infrastructure is to CAT technologies, the sooner significant CAT penetration would take place. Acknowledging this simple correlation between accommodation and penetration should aid TxDOT in decision making. The sooner TxDOT is CAT-ready, the sooner TxDOT and system users will realize the benefits of CAT technologies.

OTHER GAINS

CAT technology has the potential for even further-reaching societal impacts, including improving passenger and freight mobility, air quality, and equity.

DATA AVAILABILITY

The foremost organizational benefit of implementing CAT technology will be the provision of robust transportation data. TxDOT's traffic management centers, planners and analysts will receive a significant amount of high-quality traffic operations data. This data may be used by stakeholders to improve planning, investment and decision-making. Furthermore, data may be stored and shared with other agencies and partners to substantiate further CAT improvements.

ENVIRONMENT

Improving traffic flow and reducing congestion also yields a reduction in greenhouse gas emissions[23,24]. CAT technologies like eco-driving and vehicle platooning, as well as safety applications like crash avoidance systems that reduce incidents, hold the potential to reduce the adverse energy and emissions impacts associated with traffic congestion and inefficiencies in the current transportation system. The increase of information from these technologies will lead to more eco-focused data, which can be used for decision-making that considers environmental impacts. There are numerous CV applications specifically targeted at yielding environmental benefits, such as Connected Eco-Driving, Eco-Speed Harmonization,

Low Emissions Zone Management and Gamified/Incentives-Based Multimodal Traveler Information Applications. Examples of other environmental CV applications and their expected benefits are provided in Table 8.

Table 8: CV Environmental Applications and Expected Benefits

CV Environmental Applications	Expected Benefits
Eco-Traffic Signal Timing	» Increased efficiency of vehicles through intersections » Reduced vehicle emissions
Eco-Transit Signal Priority	» Increased efficiency of vehicles through intersections » Reduced vehicle emissions
Eco-Freight Signal Priority	» Increased efficiency of freight through intersections » Reduced vehicle emissions
Eco-Lanes Management	» Increased efficiency of vehicles » Reduced vehicle emissions
Eco-Speed Harmonization	» Increased efficiency of vehicles » Reduced vehicle emissions

Additionally, AV manufacturers will likely utilize electric models, increasing the share of EVs on the market and on roads.

ISSUES AND CHALLENGES

The expansion of CAT technology, while offering numerous benefits, could create new challenges and bring about significant change that would be disruptive to TxDOT, policy makers and the industry workforce. Furthermore, CAT is met with many uncertainties based on factors that TxDOT will have little to no ability to control (e.g. national rulemaking, technology advancement and cost, etc.). Some of the high-level challenges associated with CAT are described below.

FUNDING

Among the strongest challenges facing the implementation of CAT systems is the ability to secure funding. Adequate funding will require significant support, justification, and the promise of real, measurable benefits. Limited CAT deployments and available performance measure data inhibit the ability for deployers to provide CAT benefits. An

23   Schmidt, E. (2019, May 8). Autonomous vehicles are going to be electric. Retrieved January 28, 2020, from https://www.fleetcarma.com/autonomous-vehicles-go-ing-electric/
24   Hatch, J., & Helveston, J. (1969, January 1). The Decade Ahead: Energy, Transportation, and Climate Action. Retrieved January 28, 2020, from https://www.bu.edu/ise/2018/08/27/will-autonomous-vehicles-be-electric/

CAT STRATEGIC PLAN

increase in non-personal vehicle mode use (e.g., transit, shared AVs) may also reduce revenue from a host of other personal vehicle expenditures, including driver licensing, vehicle sales tax, gas tax and vehicle registration.

LEGISLATIVE SUPPORT

Like many emerging technologies, CAT often pushes legal boundaries concerning the operation of vehicles on state highways. The adoption of CAV technology will need legislative support as well as heavy coordination across state and local agencies to collaborate and coordinate on a broad range of legislation that may contend with issues related to liability, ownership, and insurance. It may be difficult to achieve consensus on investment and regulation in areas with overlapping jurisdictions.

In the last two years, a legislative challenge was posed by the Federal Communications Commission (FCC). The FCC released a rule regarding the 5.9 GHz Band, which was the band used to communicate CV messages. The rule limited the use of the previously allocated 75 MHz that was allocated for vehicle communications and ITS applications to just 30 MHz for vehicle communications. The rule also mandated the use of Cellular V2X technology in the available bandwidth. This shift in policy is an example the still changing landscape for CAT deployments.

STAKEHOLDER SKILL SETS

The implementation of CAT technologies will require changes to transportation agencies' physical and digital infrastructures in addition to agency responsibilities for digital infrastructure support as well as data integrity, security, privacy, and analytics. The adoption of CAT technology and changes in regulation may require significant action by state and local agencies to train staff to use new applications and systems, set up new operations and maintenance processes and effectively manage process changes.

MARKET PENETRATION/PUBLIC ACCEPTANCE

Recent studies have found that most consumers have fears related to driving in or sharing the road with AVs, including overall safety, behavioral reliability, trustworthiness and privacy. Members of the automotive and transportation industries attribute these fears to confusion about highly variable systems being marketed by auto manufacturers, limited confidence in the industry and growing concerns over cybersecurity in general. In order for CAVs to proliferate the market, a highly secure CAT ecosystem should be deployed, and consumers must be educated on vehicle systems, how technologies work and their benefits and limitations. The adoption of common security protocols, standards and practices, common in other industries, can mitigate fears related to cybersecurity.

TRANSITION PROCESS

As with the introduction of most technologies, the transition process and timeline for moving from traditional vehicles to CAVs is full of uncertainties. As manufacturers and technology companies engage in research and development, the levels of automation that most significantly penetrate the vehicle market are also unknown. In any case, there will likely be a long period of time during which a mix of vehicles with varying levels of automation will coexist on the road. A shared environment between automated and human-driven vehicles has the potential to be complex, as AVs must attempt to predict and react to unpredictable human driver behavior. This shared environment also faces infrastructure challenges as CAV technologies could cause existing ITS investments to become outdated and require additional communication capabilities.

INFRASTRUCTURE READINESS

The performance and expansion of CAVs rely on physical and digital infrastructure to deliver the surface, signage and connectivity needed to support CAV technology. Infrastructure owners and operators will have increased responsibilities associated with preparing and maintaining infrastructure as well as renewal and configuration requirements for digital systems. The level of effort required for infrastructure readiness and maintenance may be difficult to plan for as the timeline for CAV penetration is uncertain.

III

PLAN DEVELOPMENT

The CAT Strategic Plan project has been initiated under the guidance of the TxDOT CAV Taskforce and CAT Project Work Group, which includes representatives from TxDOT Divisions and Districts. In addition to the CAT Strategic Plan, TxDOT has commissioned a series of other strategic initiatives to enhance its transportation solutions and prepare for emerging transportation technologies. Some of these initiatives include the Emerging Transportation Technology Plan (ETTP), Freight Network Technology and Operations Plan (FNTOP) and Connected Network Strategy. A high-level depiction of the relationship between CAT and these initiatives is shown in the figure below. CAT efforts, including the CAT Strategic Plan, will require close coordination with the ETTP and Connected Network Strategy teams to ensure consistent messaging and goals. CAT champions will also need to communicate with the ITS, Information Technology (IT) Connectivity and FNTOP teams to ensure consistency across these related initiatives.

Figure 2: TxDOT Strategic Initiatives
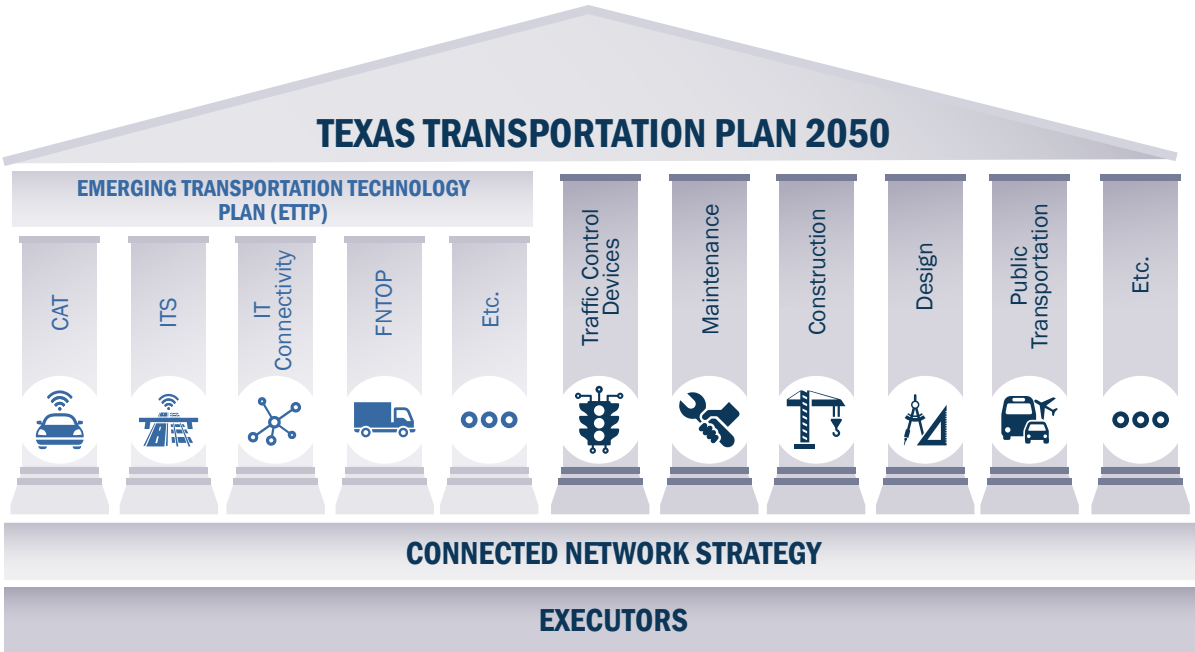
Development of the Strategic Plan began with broad information gathering, internally and externally. Meetings, interviews and workshops were held with TxDOT stakeholders to gather agency needs and desires related to CAT technology. External outreach was performed to provide industry-related developments and lessons learned on existing CAT deployments across the country. This information was used to develop the CAT State of the Practice and CAT Capability Maturity Model (CMM) reports, providing further clarity on TxDOT's technology-related maturity in the current CAT industry landscape. Upon inception of the CAT Strategic Plan, a CAT program mission, vision and set of goals were developed in collaboration with the TxDOT CAT Project Working Group to guide the development of future CAT program initiatives. Based on the results of the CMM, which highlighted categories that TxDOT seeks to advance in preparation for CAT, targeted focus areas for strategic development were determined along with a series of strategies to help TxDOT execute a desired CAT program and work towards meeting its goals.

Figure 3: CAT Strategic Plan Development
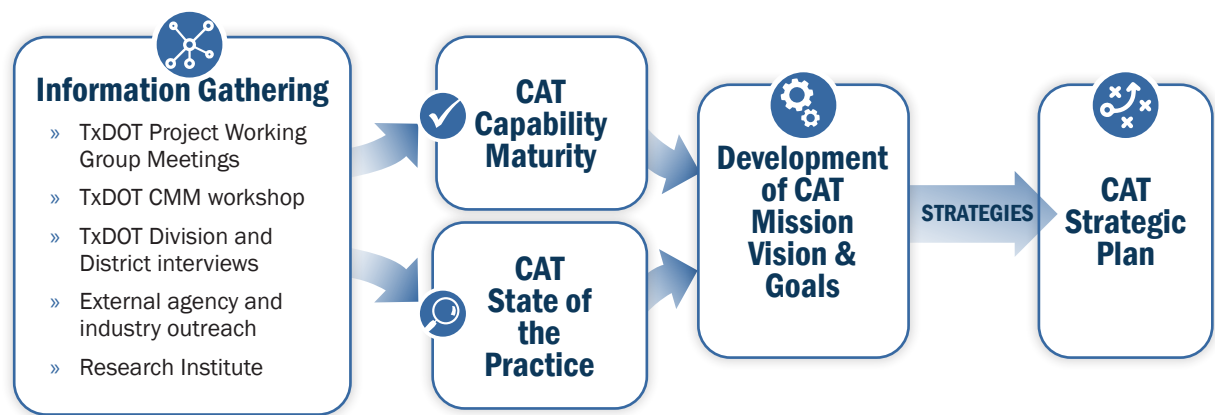
State of the Practice Summary

To gather the latest information of the state of the CAT industry, research on current activities, research efforts and regulations related to CAT technology was conducted within Texas, throughout the country, and across the world. Additionally, interviews were conducted with TxDOT divisions and Texas research organizations to identify gaps in the industry and within TxDOT. The evolution of CAT was determined to rely on three interdependent dimensions of performance: **Physical Infrastructure, Digital Infrastructure and Vehicle Technology.** While the maturity of each dimension is still largely in flux, the demonstrated potential for CAT to positively impact the way people and goods move warrants consideration and inclusion in TxDOT's planning processes.

By proactively developing the necessary physical and digital infrastructure to support CAT, TxDOT can capture opportunities early, integrate CAT into its planning and project development process and accelerate the benefits brought on by CAT technologies. The strategies provided in this plan align with TxDOT's overall mission and aim to contribute to the advancement of each CAT dimension, guiding towards solidifying TxDOT's leadership in CAT technology.

Capability Maturity Model Evaluation Summary

A CMM was developed to assess TxDOT's current maturity regarding common concepts required to perform technical and operational work with CAT. The CMM framework traditionally identifies 4 levels of maturity:

- » LEVEL 1: Exploration
- » LEVEL 2: Initiated
- » LEVEL 3: Integrated
- » LEVEL 4: Mainstreamed

The project team conducted a CMM workshop on October 8th, 2019 with representatives from TxDOT divisions, districts, cities, academic/research organizations, and consultants. The goal of this workshop was to determine TxDOT's current level of maturity in six categories that were slightly modified to accommodate CAT elements:

Business Processes

Physical Infrastructure Systems and Technology

Digital Infrastructure Systems and Technology

Performance Measurement

Organization/Staffing/Culture

Collaboration

The overall results of the workshop are provided in Figure 4. Average maturity levels across CMM categories are determined to be between 1 and 1.25, with the highest score being 4. These results suggest that TxDOT has begun to identify many of the components necessary to support a mature CAT Program but has not documented and initiated them at a large scale. Participants noted that while CAT specific programs have generally not been established, many existing TxDOT programs can be adopted and modified to support CAT initiatives.

Figure 4: TxDOT's CAT CMM Levels
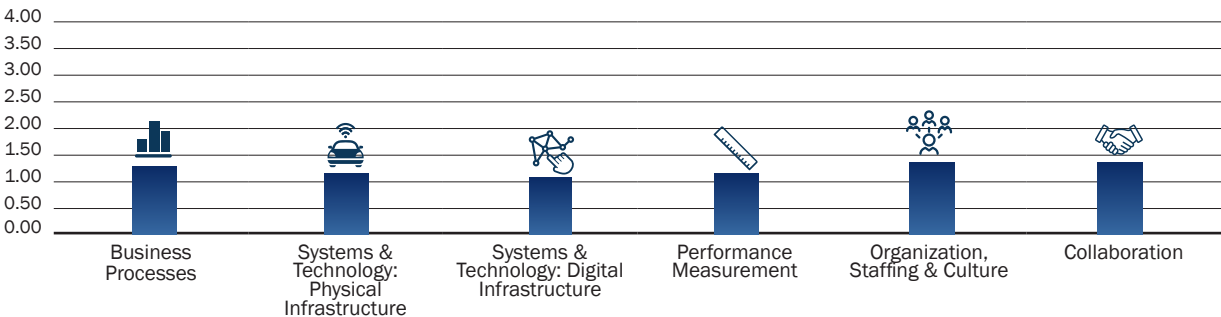
The strategies in this plan aim to further develop TxDOT's CAT program and capabilities, and are specifically aligned with CMM categories to indicate each strategy's potential for advancing its maturity. Figure 5 depicts the specific CMM categories that are addressed by each strategy (strategies provided in Section 4).

Figure 5: Strategy and CMM Alignment

Column headers:
- BUSINESS PROCESSES
- DIGITAL INFRASTRUCTURE
- PHYSICAL INFRASTRUCTURE
- PERFORMANCE MEASUREMENT
- ORGANIZATION, STAFFING & CULTURE
- COLLABORATION

POLICY

1 Institutionalize TxDOT's CAT Program
2 Coordinate Emerging Technology Planning Initiatives
3 Implement Robust Security and Privacy Policies
4 Identify Regulatory Policies that May Impact CAT Implementation
5 Develop Statewide Guidance for CAT Project Planning and Implementation
6 Update Existing Design Manuals and Standards to Accommodate CAT Deployments
7 Explore CAT Impacts on Border Crossing Policies and Procedures

FISCAL RESPONSIBILITY

8 Allocate Additional Budget for Modernizing TxDOT's Asset Management Program to Support CAT Technology Needs
9 Pursue Public-Private Partnerships for Technology Development and Deployment
10 Support the Pursuit of Federal Grant Funding for CAT Projects
11 Support and Provide Internal Funding for CAT Initiatives
12 Prepare for Changes in Revenue Streams Due to CAT Proliferation

COLLABORATION

13 Expand TxDOT's Internal and External Conferences to Feature CAT
14 Continue to Support and Expand Partnerships with Research Institutions, Academia, Industry and Peer Agencies
15 Expand Workforce Capabilities with the Provision of CAT Training
16 Perform Outreach to Promote Internal and External Acceptance of CAT Initiatives

INFRASTRUCTURE READINESS

17 Continue and Expand CAT Demonstrations / Deployments and Establish Innovation Areas
18 Prepare Traffic Management System for CAT Readiness
19 Provide Back-haul Communications for TxDOT Assets along Priority Corridors
20 Build Communications Readiness into Roadway Construction Projects
21 Support the Provision of Statewide Communications Availability
22 Strategically Allocate Space for EV Charging Infrastructure
23 Explore Design Options to Incorporate CAV Operations

SYSTEM READINESS

24 Identify and Prioritize Use Cases for CAT Data to Inform Data Management Plans and Policies
25 Update Existing Data Management Strategies to Address the Unique Challenges of CAT and Capitalize on CAT Data Opportunities
26 Develop Common Data Standards and Influence their Widespread Adoption
27 Expand Upon Efforts to Create an Information Portal for Sharing CAT Initiative Information

MULTIMODAL

28 Enhance Visibility of Vulnerable Road Users
29 Explore CAT Applications that Benefit Multimodal Travel
30 Explore Next Generation Mobility Hub Concepts

MAINTENANCE & OPERATIONS

31 Deploy CAT Projects that Address Common Operational Scenarios
32 Explore CAT-Enabled Innovative Traffic Operations and Management Strategies
33 Identify CAT Impacts and Needs for Smart Work Zones

PROCUREMENT

34 Incorporate CAT Design, Construction, Operations and Maintenance into Procurement Rules and Policies
35 Support Flexible and Agile Procurement Practices

Mission

The CAT Program mission and vision statements are built upon TxDOT's overall mission and vision and have been updated to recognize the potential success of CAT implementation efforts moving forward.

PROGRAM MISSION: The CAT Program will maximize the safe, reliable, and efficient movement of people, goods and data within Texas' multimodal transportation network.

Vision and Goals

PROGRAM VISION: The CAT Program will deliver forward-thinking transportation solutions, by implementing emerging technologies, to enhance quality of life for all Texans.

To support TxDOT's mission and vision, the following CAT Program goals were identified:

SAFETY: Support the implementation of CAT technology to improve safety for the traveling public and help achieve TxDOT's Road to Zero goal for zero roadway fatalities by 2050

RELIABILITY: Harness CAT technology to improve overall system dependability for both people and freight

MOBILITY: Emphasize CAT technologies that improve mobility and accessibility, allowing TxDOT's transportation system to reach its full potential

AGILITY: Support the ability to proactively and quickly respond to CAT technology opportunities and requirements

VITALITY: Provide economic benefit to the State of Texas and opportunities for leadership and innovation

CAT STRATEGIC PLAN

IV
STRATEGIES

Focus Areas

The CAT Strategic Plan identifies strategies that will help the agency prepare for and support the implementation of CAT technology while meeting the goals of the CAT program. These strategies are divided into 8 focus areas to reflect TxDOT's organizational and business functions:

POLICY: Legislation, standardization, institutional culture and practices

SYSTEMS READINESS: Potential for TxDOT digital and institutional systems to enable and enhance CAT

FISCAL RESPONSIBILITY: CAT implications for TxDOT funding, revenues, and budgeting

MULTIMODAL: Implications for CAT to impact travel of all manners and modes

COLLABORATION: Internal and external outreach, skill development and pursuing partnerships

MAINTENANCE & OPERATIONS: CAT implications for TxDOT's day-to-day functions of traffic management, maintenance and operations

INFRASTRUCTURE READINESS: Potential for the built environment to enable and enhance CAT

PROCUREMENT: Purchasing of goods and services necessary for CAT

How to Read this Strategic Plan

The following details are provided for each recommended strategy in this plan:

Focus Area

Focus area addressed by each strategy

Policy	Fiscal Responsibility	Collaboration	Infrastructure Readiness	Systems Readiness	Multimodal	Maintenance & Operations	Procurement

Description

Brief description of the recommended strategy

Goal Alignment

Goals addressed by each strategy

SAFETY   RELIABILITY   MOBILITY   AGILITY   VITALITY

Cost

Broad level of capital investment anticipated to carry out the strategy

$ $ $ Can be completed with low cost

$ $ $ Requires moderate capital investment

$ $ $ Requires significant capital investment and potential new funding category
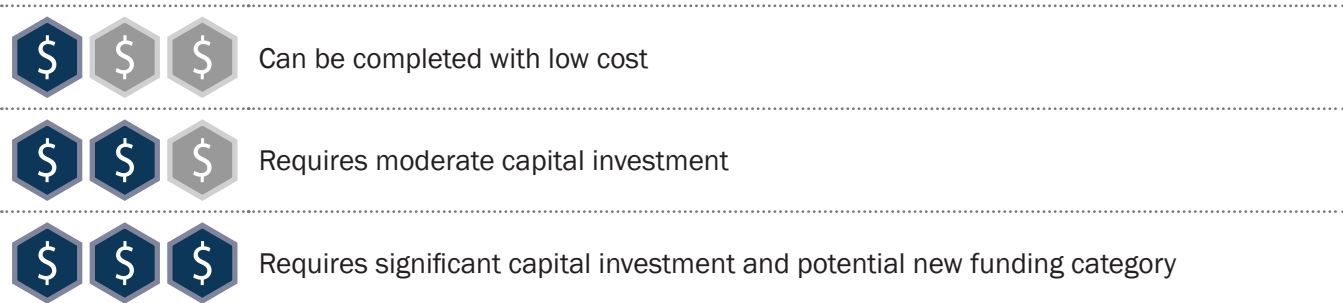
Staff Effort

Broad level of staff effort anticipated to carry out the strategy

LOW: Can be accomplished with existing staff

MEDIUM: Requires additional and dedicated staff or significant shifting of responsibilities

HIGH: Requires significant additional and dedicated staff with special training
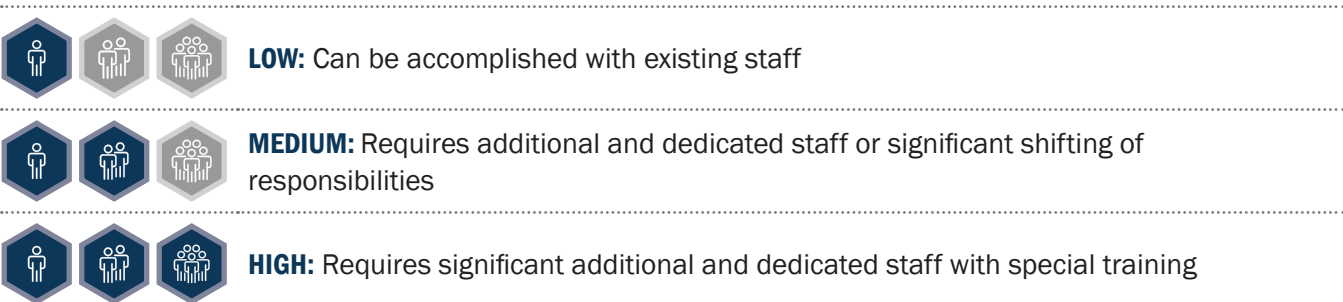
Timeline to Initiate

A recommended timeframe for initiating the strategy that aligns with TxDOT's planning processes
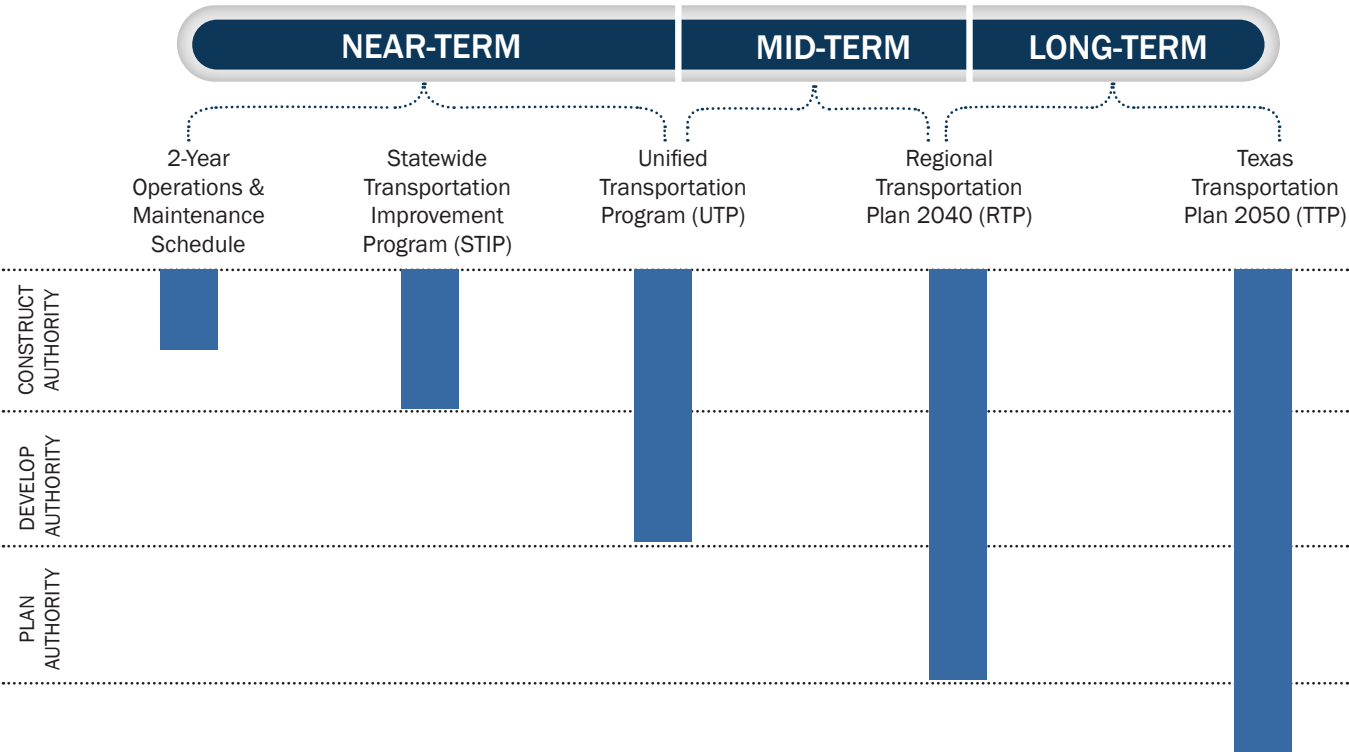
Stakeholders

INTERNAL Indicates whether TxDOT Divisions and/or Districts are affected by the strategy

EXTERNAL Indicates whether third parties, such as peer DOTs, local agencies, private industry, consultants, research institutes, etc., are affected by the strategy

FOCUS AREA:
POLICY

STRATEGY 1
Institutionalize TxDOT's CAT Program

Confirm the agency's level of commitment to leadership in emerging transportation technology and CAT with incremental steps to institutionalizing the CAT program. Steps include:

- » Designating CAT program champions across agency divisions and providing those champions with dedicated time for implementing internal and external CAT initiatives;
- » Developing a dedicated funding mechanism for transportation technology initiatives;
- » Allocating funding to support and drive CAT projects;
- » Dedicating leadership to direct and give voice to agency-wide CAT efforts; and,
- » Dedicating staff and funding for a CAT Organization that would be responsible for initiating and accelerating research, policy and standards updates, managing collaboration, pilot projects, branding, marketing, etc.

These steps towards institutionalizing the CAT program will ensure sustainable support and leadership of CAT initiatives that allows TxDOT to effectively manage efforts and maximize their potential benefits. Furthermore, they support TxDOT's legacy as a national leader committed to innovation and maximizing the value of emerging technologies.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   **AGILITY**   **VITALITY**

COST

STAFF EFFORT

STAKEHOLDERS

INTERNAL ☑   **EXTERNAL** ☑

TIMELINE

IMMEDIATE

NEAR-TERM   MID-TERM   LONG-TERM

STRATEGY 2
Coordinate Emerging Technology Planning Initiatives

Create a technical working group, made up of project managers and consultants handling various agency transportation technology efforts, to align TxDOT's multiple innovation-based plans and ensure consistent institutional messaging and objectives related to emerging transportation technologies.

Establishing a working group with direct lines of communication across these planning efforts will support the ability to harmonize goals and avoid conflicting messaging across related plans throughout their development.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   **AGILITY**   **VITALITY**

COST

STAFF EFFORT

STAKEHOLDERS

INTERNAL ☑   **EXTERNAL** ☑

TIMELINE

IMMEDIATE

NEAR-TERM   MID-TERM   LONG-TERM

STRATEGY 3
Implement Robust Security and Privacy Policies

Develop and implement robust security and privacy policies to plan for networking challenges and cybersecurity risks associated with CAT technology, ensure consumer privacy and cybersecurity and support a trusted network. Within these policies, consider management of security credentials, advanced threat detection and prevention, vulnerability management, security logging and monitoring, and incident response plan capabilities to protect public safety and privacy. Clearly communicate security and privacy policies to all affected stakeholders upfront to avoid misunderstanding and doubt, especially with respect to data privacy.

Robust security and privacy policies will prepare TxDOT for potential threats posed by groups or individuals who may maliciously exploit CAT applications. Communication of these policies will help to address internal and external data privacy concerns and garner trust in the measures being taken to protect the public and TxDOT, which could otherwise create obstacles for the deployment of CAT.

GOAL ALIGNMENT

SAFETY RELIABILITY MOBILITY AGILITY VITALITY

COST

$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓   **EXTERNAL** ✓

TIMELINE

IMMEDIATE

NEAR-TERM   MID-TERM   LONG-TERM

STRATEGY 4
Identify Regulatory Policies that May Impact CAT Implementation

Develop a legal brief, that may be updated routinely, to identify regulatory standards and barriers that may affect the implementation of CAT and CAV operation on Texas highways with a review of relevant laws and codes and an assessment of their impact on CAT.

Like many emerging technologies, CAT often pushes legal boundaries concerning the operation of vehicles on state highways. This strategy will allow TxDOT to maintain awareness of up-to-date regulations and federal rulemaking that could support or inhibit the acceleration of CAT.

GOAL ALIGNMENT

SAFETY RELIABILITY MOBILITY AGILITY VITALITY

COST

$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓   **EXTERNAL** ✓

TIMELINE

NEAR-TERM   MID-TERM   LONG-TERM

FOCUS AREA:
POLICY

STRATEGY 5
Develop Statewide Guidance for CAT Project Planning and Implementation

Develop high-level guidance on how to define, plan for and implement statewide CAT projects that reference relevant CAT Design Standards and policies. This guidance may also point CAT project champions to project documentation from previous CAT initiatives, to build upon comparable work when suitable.

This strategy will ensure that CAT project champions are equipped with the tools to:

» Adhere to TxDOT's project development and planning processes;
» Propose sources of sustainable project funding;
» Include projects in the appropriate statewide planning documents (e.g., UTP, STIP, LRTP, TTP 2050, etc.); and,
» Achieve planning and implementation consistency across CAT projects that span rural and urban districts with varying scales.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   AGILITY   VITALITY

COST

STAFF EFFORT

STAKEHOLDERS

INTERNAL   ✓   EXTERNAL   ✓

TIMELINE

NEAR-TERM   MID-TERM   LONG-TERM

STRATEGY 6
Update Existing Design Manuals and Standards to Accommodate CAT Deployments

Assess necessary updates to design and installation standards to accommodate the expansion of CAT in coordination with OEMs and automated driving system developers. Infrastructure standards to be considered include the following:

» Installation standards that may inhibit the placement of roadside equipment, often required for CAT applications, on existing infrastructure, such as traffic signal poles;
» Standard roadside equipment that may require replacement to accommodate CAT components, such as traffic cabinets that may be too small to house roadside units needed to support CAV applications;
» Design and maintenance standards for infrastructure that CAVs may rely on, such as pavement markings and signage;
» Design and maintenance standards for physical infrastructure that may be burdened by the proliferation of CAT, including bridges and pavement that may face stress impacts due to increased, concentrated loading from CAV travel and platooning;
» Traffic design standards related to lane configuration, including merge, diverge and weaving segments, that may be impacted by CAT applications, such as CAV platooning;
» Work zone standards that may be enhanced with the adoption of CAT technology applications;
» Design standards and guidelines that may be impacted by freight technology and automation.

Some of the specific manuals to be evaluated and updated include the Texas MUTCD, Freeway Signing Guide, Highway Safety Improvement Program Manual, Pavement Manual, Procedures for Establishing Speed Zones, ROW Property Management Manual, ROW Utilities Manual, Traffic Data and Analysis Manual, Traffic Safety Program Manual, Traffic Signals Manual, Transportation Multimodal Systems Manual, and Transportation Planning Manuals.

Aligning TxDOT standards with requirements for CAT implementation ensures that Texas roadways can support and streamline future CAT projects, and maximizes the safe adoption of CAT.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   AGILITY   VITALITY

COST

STAFF EFFORT

STAKEHOLDERS

INTERNAL   ✓   EXTERNAL   ✓

TIMELINE

NEAR-TERM   MID-TERM   LONG-TERM

CAT STRATEGIC PLAN

FOCUS AREA:
POLICY

STRATEGY 7
Explore CAT Impacts on Border Crossing Policies and Procedures

Perform a study to identify border crossing policies and procedures that may be affected by the implementation of CAT technology (e.g., driverless AVs crossing the border).

Studying these implications will allow TxDOT to prepare for and begin to address policy changes that would support the deployment of CAT technology at the border crossings with Mexico and borders with New Mexico, Oklahoma, Arkansas, and Louisiana.

GOAL ALIGNMENT

SAFETY · RELIABILITY · MOBILITY · AGILITY · VITALITY

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ☑   EXTERNAL ☑

TIMELINE

NEAR-TERM · **MID-TERM** · LONG-TERM

FOCUS AREA:
FISCAL RESPONSIBILITY

STRATEGY 8
Allocate Additional Budget for Modernizing TxDOT's Asset Management Program to Support CAT Technology Needs

Allocate additional budget for modernizing TxDOT's asset management program in support of future technology needs. Commit to performing timely upgrades/replacements to ensure that assets support modern security settings (including regular patching), integrate with other CAT technology, support remote management and, most importantly, do not reach their end-of-life. Expand TxDOT's asset management system to feature system and device visibility and allow for remote health monitoring, configuration management and lifecycle tracking.

Currently many TxDOT devices and systems exceed their end-of-life or are outdated, which could pose risks to system operations and may impede the agency's ability to implement CAT technology and equipment. Active and robust asset management will allow the agency to avoid investment in obsolete assets, proactively invest in assets that support CAT initiatives and maximize the value of its investments.

GOAL ALIGNMENT

SAFETY · RELIABILITY · MOBILITY · AGILITY · VITALITY

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ☑   EXTERNAL ☑

TIMELINE

NEAR-TERM · MID-TERM · LONG-TERM

FOCUS AREA:
FISCAL RESPONSIBILITY

STRATEGY 9
Pursue Public-Private Partnerships for Technology Development and Deployment

Continue to routinely assess and pursue opportunities for partnerships with private industries, including fiber communication providers, broadband companies, vehicle manufacturers, transportation network companies and CAT-centered vendors, that leverage public infrastructure to share revenue and resources for CAT projects.

Pursuing potential partnerships early-on allows TxDOT to optimize the potential benefits of CAT technologies, accelerate their deployment and bear influence on their development.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   **AGILITY**   **VITALITY**

COST

$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓   **EXTERNAL** ✓

TIMELINE

NEAR-TERM   MID-TERM   LONG-TERM

STRATEGY 10
Support the Pursuit of Federal Grant Funding for CAT Projects

Continue to pursue federal grant funding opportunities and support other agencies (e.g., cities, MPOs, Texas Innovation Alliance, etc.) in seeking grant funding as well. There are a wide range of grant opportunities specific to the adoption, integration and acceleration of transportation technology that could increase funding for CAT deployments across Texas. Additionally, there are grants focused on general goals, such as safety, sustainability and resilience, that can be accomplished using CAT technology.

In addition to the provision of funding, obtaining grants offers TxDOT the opportunity to inform rulemaking and foster collaboration among local government, state government and private partners.

GOAL ALIGNMENT
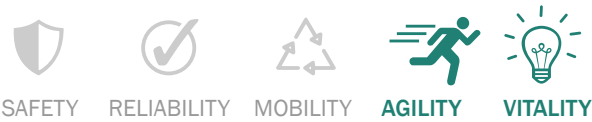
SAFETY   RELIABILITY   MOBILITY   **AGILITY**   **VITALITY**

COST

$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓   **EXTERNAL** ✓

TIMELINE

NEAR-TERM   MID-TERM   LONG-TERM

FOCUS AREA:
FISCAL RESPONSIBILITY

STRATEGY 11
Support and Provide Internal Funding for CAT Initiatives

Provide a source of internal TxDOT funding for CAT efforts. Develop and continually update a robust business case that justifies dedicated funding for CAT, including cost-benefit information from ongoing TxDOT transportation technology projects. A portion of funding that is dedicated to meeting the agency's safety goals for achieving its Road to Zero mission may be allocated for CAT projects that aim to meet those goals.

Dedicated CAT funding would confirm the agency's commitment to and support for the advancement of transportation technology.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   **AGILITY**   **VITALITY**

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ☑   **EXTERNAL** ☐

TIMELINE

NEAR-TERM   **MID-TERM**   LONG-TERM
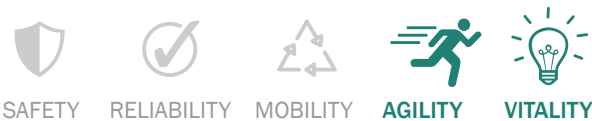
STRATEGY 12
Prepare for Changes in Revenue Streams Due to CAT Proliferation

Routinely assess current TxDOT revenue streams that may be inhibited by CAT. For instance, AVs may drive EV adoption, which would cause a reduction in gas consumption and its associated gas tax revenue. Study options to generate new sources of revenue with modernized collection means. The proliferation of CAT could cause reductions in private vehicle ownership, fuel consumption and traffic violations that would interrupt existing streams of TxDOT revenue. This strategy would allow the agency to capitalize on new revenue generation opportunities and financially plan for shifting revenue streams.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   **AGILITY**   **VITALITY**

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ☑   **EXTERNAL** ☐

TIMELINE

NEAR-TERM   **MID-TERM**   LONG-TERM

STRATEGY 13
Expand TxDOT's Internal and External Conferences to Feature CAT

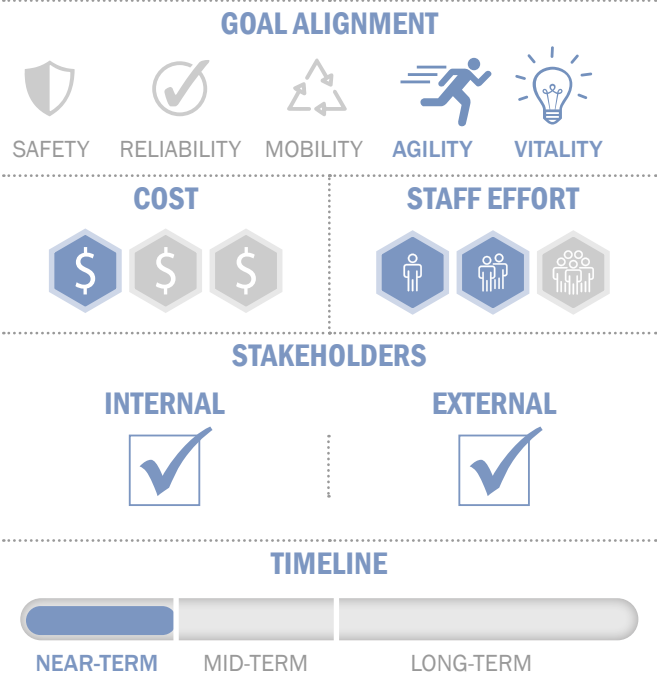Continue hosting TxDOT's annual Mobility Summit conference, which features CAT industry and vendor participation, showcases emerging technologies and facilitates relationship-building between the agency and potential industry partners. Expand TxDOT's internal conferences to educate staff about the agency's CAT initiatives.

Promoting CAT at TxDOT's existing conferences allows the agency to foster workforce interest, support and expertise in the latest emerging technologies, maintaining its position as a leader in this area.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   **AGILITY**   **VITALITY**

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓   **EXTERNAL** ✓

TIMELINE

NEAR-TERM   MID-TERM   LONG-TERM

STRATEGY 14
Continue to Support and Expand Partnerships with Research Institutions, Academia, Industry and Peer Agencies

Increase efforts to collaborate with research institutions, academia and peer agencies on CAT projects, technology pilots and sharing of expertise and resources. Continue partnerships with research institutions to test CAT technologies on TxDOT highways and explore sources of funding available to these institutions that differ from traditional transportation agency funding opportunities. Strengthen existing relationships with peer transportation agencies to share lessons learned and expertise and potentially coordinate resources for joint ventures. Develop partnerships with academic institutions, including technical schools, universities and colleges, to promote innovation and incorporate aspects of CAT technology into their curricula.

These relationships support TxDOT's ability to maintain a pulse on the latest advancement and news in CAT technology by creating an ecosystem that actively shares resources and knowledge. Furthermore, it offers the opportunity for TxDOT to cultivate interest and talent among future members of the workforce.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   **AGILITY**   **VITALITY**

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓   **EXTERNAL** ✓

TIMELINE

NEAR-TERM   MID-TERM   LONG-TERM

STRATEGY 15
Expand Workforce Capabilities with the Provision of CAT Training

Foster workforce development and the expansion of job skills related to CAT technology. Provide on-the-job training for CAT project implementation. Training may include work with RSUs, fleet vehicle OBUs, IT and data management systems, etc. Identify subject matter experts (SMEs) that receive specialized training, participate in industry forums, and assist with training other staff. SMEs can also promote CAT across the agency, given their in-depth knowledge of new systems. As CAT projects become more prevalent across the agency, define CAT job titles, skill requirements and allocate appropriate compensation for those positions.

Growth of a well-trained, experienced workforce will support TxDOT's efforts in accelerating the deployment of CAT initiatives and establishing itself as a leader in this realm. Additionally, the provision of workforce development opportunities will allow TxDOT to attract and retain expertise.

GOAL ALIGNMENT

SAFETY RELIABILITY MOBILITY **AGILITY** **VITALITY**

COST $ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓ **EXTERNAL** ✓

TIMELINE

NEAR-TERM **MID-TERM** LONG-TERM

STRATEGY 16
Perform Outreach to Promote Internal and External Acceptance of CAT Initiatives

Perform CAT outreach to inform internal staff and the public about ongoing and planned CAT initiatives and the expected benefits/risks of CAT technologies. Outreach activities include preparing communication materials (e.g., flyers and presentations), posting CAT communication materials and project updates to TxDOT's website, routine engagement with internal and public CAT meetings, and publicizing CAT liaison(s) to field stakeholder questions, comments and concerns. In addition, communicate TxDOT system changes/upgrades related to CAT to internal stakeholders. Provide information on why system changes are required, workflow impacts and improvements, training opportunities, routinely posted schedules for system changes and system resources (e.g., primers, user manuals).

These activities will solicit understanding of CAT technologies, facilitate acceptance and support, and ensure that all stakeholders and constituents are actively engaged in CAT preparedness and adoption efforts.

GOAL ALIGNMENT

SAFETY RELIABILITY MOBILITY **AGILITY** **VITALITY**

COST $ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓ **EXTERNAL** ✓

TIMELINE

NEAR-TERM **MID-TERM** LONG-TERM

FOCUS AREA:
INFRASTRUCTURE READINESS

STRATEGY 17
Continue and Expand CAT Demonstrations / Deployments and Establish Innovation Areas

Continue efforts to work with the private sector on the implementation of CAT applications e.g., truck platooning (along freight corridors) to gain experience with CAT deployments and provide opportunities for testing, partnerships and proving CAT benefits. Support open communication with the industry to gain the latest insights on CAT opportunities and accompanying infrastructure needs. Establish innovation areas where CAT demonstrations and/or deployments may be promoted at varying scales and locations, including at intersections, along corridors and active use paths and in airspace.

Pilot projects and demonstrations allow agencies to test new technologies while managing and minimizing risk.

GOAL ALIGNMENT
SAFETY   RELIABILITY   MOBILITY   AGILITY   VITALITY

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS
INTERNAL ✓   EXTERNAL ✓

TIMELINE
NEAR-TERM   **MID-TERM**   LONG-TERM

STRATEGY 18
Prepare Traffic Management System for CAT Readiness

Connect TxDOT's traffic signals to prepare signals for CAT technology, optimize signal performance and enable the provision of performance data. Continue efforts and investment across TxDOT divisions and districts to close the current connectivity gaps (only 10% of existing signals are connected). Additionally, ensure that new and planned traffic signals are equipped with signal phasing and timing (SPaT) broadcast capabilities that support numerous safety and mobility CAV applications.

Expanding TxDOT's traffic signals with connectivity and SPaT broadcast capabilities will allow the agency to make recognizable improvements to traffic flow and support its ability to adopt CAT applications that offer significant safety and mobility benefits.

GOAL ALIGNMENT
SAFETY   RELIABILITY   MOBILITY   AGILITY   VITALITY

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS
INTERNAL ✓   EXTERNAL ✓

TIMELINE
NEAR-TERM   MID-TERM   LONG-TERM

FOCUS AREA:
INFRASTRUCTURE READINESS

STRATEGY 19
Provide Backhaul Communications for TxDOT Assets Along Priority Corridors

Identify priority TxDOT corridors that may be target testbeds for CAT deployments (e.g., locations equipped with ITS devices that have safety or mobility needs which may be addressed by CAV applications). Provide backhaul communications for TxDOT's ITS devices and signals along these corridors and in accordance with TxDOT's Connected Network Strategy to support the functionality of CAT applications that require connectivity to its core network, which include numerous existing environmental, road weather, mobility, and agency data CV applications.

Connecting TxDOT's assets along priority corridors will well-position the agency to easily adopt many available CAT applications and serve as a testbed for continued CAT development, expanding opportunities to realize and share the benefits of these emerging technologies.

GOAL ALIGNMENT
SAFETY • RELIABILITY • MOBILITY • AGILITY • VITALITY

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS
INTERNAL ✓   EXTERNAL ✓

TIMELINE
NEAR-TERM • MID-TERM • LONG-TERM

STRATEGY 20
Build Communications Readiness into Roadway Construction Projects

Include conduit and access points for communications infrastructure in planned roadway construction projects to support future fiber installation with ease and minimal additional construction. Install fiber communications in accordance with TxDOT's statewide fiber network plan.

Incorporating simple, low-cost means of communications readiness into construction projects allows TxDOT to maximize installation efficiency and streamline future CAT deployments that necessitate core network connectivity.

GOAL ALIGNMENT
SAFETY • RELIABILITY • MOBILITY • **AGILITY** • **VITALITY**

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS
INTERNAL ✓   EXTERNAL ☐

TIMELINE
NEAR-TERM • **MID-TERM** • LONG-TERM

STRATEGY 21
Support the Provision of Statewide Communications Availability

Develop a statewide communications plan to identify locations that do not currently have access to usable communications coverage. Study public-private partnership options to address communication gaps, particularly in rural areas, which will also likely not be afforded 5G availability by the private sector.

Supporting private sector in providing communications coverage across the State of Texas demonstrates TxDOT's commitment to offering reliable, vehicle connectivity and maximizing public safety.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   AGILITY   VITALITY

COST

$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓   EXTERNAL ✓

TIMELINE

NEAR-TERM   **MID-TERM**   LONG-TERM

STRATEGY 22
Strategically Allocate Space for EV Charging Infrastructure

Assess opportunities to strategically allocate space for EV charging infrastructure at mobility hubs and near businesses that could support EV acceleration and offer partnership opportunities related to charging station branding and advertising.

Well planned EV charging stations have the potential to increase EV penetration and maximize social and economic benefits to communities across Texas. Charging infrastructure plans should align with the federally designated alternative fuel corridors.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   AGILITY   VITALITY

COST

$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓   EXTERNAL ✓

TIMELINE

NEAR-TERM   **MID-TERM**   LONG-TERM

FOCUS AREA: INFRASTRUCTURE READINESS

STRATEGY 23
Explore Design Options to Incorporate CAV Operations

Explore various design options for highway infrastructure to meet the challenge of having mixed fleet of CV and AV at different levels of driving automation. Study the pros and cons of having mix-flow operations and dedicated CAV operations at different maturity levels.

Studying various design options, for instance, mixed lane vs. dedicated CAV lane, will allow TxDOT to pro-actively plan for their potential implementation, which could optimize the benefits of CAT technology, encourage technology adoption and maximize safety for all road users.

GOAL ALIGNMENT
SAFETY · RELIABILITY · MOBILITY · AGILITY · VITALITY

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS
INTERNAL ✓ **EXTERNAL** ✓

TIMELINE
NEAR-TERM · **MID-TERM** · LONG-TERM
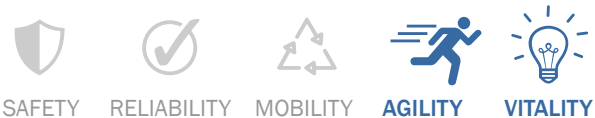

FOCUS AREA: SYSTEM READINESS

STRATEGY 24
Identify and Prioritize Use Cases for CAT Data to Inform Data Management Plans and Policies

Coordinate across divisions to identify, vet and prioritize use cases for CAT data. Specify what roadside data needs to be collected, how the data will be used by various TxDOT divisions (e.g., how could basic safety messages be used for operations applications, asset management, etc.), and third-party data uses, if any.

Collaborating early-on to identify CAT data use cases and user needs supports agile project management practices, which will promote the development and execution of high-quality data management plans.

GOAL ALIGNMENT
SAFETY · RELIABILITY · MOBILITY · **AGILITY** · **VITALITY**

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS
INTERNAL ✓ **EXTERNAL** ☐

TIMELINE
IMMEDIATE
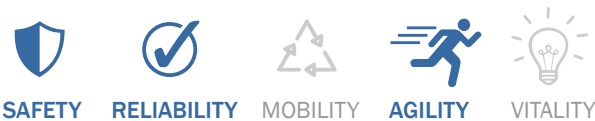NEAR-TERM · MID-TERM · LONG-TERM

STRATEGY 25
Update Existing Data Management Strategies to Address the Unique Challenges of CAT and Capitalize on CAT Data Opportunities

Develop a data management framework for V2I data that supports TxDOT's CAT data use cases. Considerations for the framework should include the following:

» Infrastructure needs to support significant real-time, operational data processing needs
» Data volume estimates and strategies to address data volume reduction, cloud data storage, deduplication and edge processing, and communication needs, which will be impacted by the influx of CAT data
» Data storage policies, processes for the anonymization of traffic data, analytic data gathering needs, and data portal needs/users
» Software standards and protocol, including Lonestar software, necessary to exchange CAT data with traditional ITS (e.g., dynamic message signs) and cooperative systems (e.g., in-vehicle messaging)
» Data sharing policies to accommodate the exchange of CAT data and digital infrastructure information with third parties, industry, research institutions, other transportation organizations and transportation network companies
» Common data standards and protocol for messages types utilized by CAT applications (e.g., traveler information messages, work zone messages, etc.)

Investing time and resources into the development of TxDOT's data management framework will allow the agency to optimize existing and future operations and processes reliant on data, disseminate CAT and digital infrastructure and data, maximize the value of TxDOT's data and leverage data to achieve the agency's goals and objectives.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   AGILITY   VITALITY

COST

STAFF EFFORT

STAKEHOLDERS

INTERNAL   **EXTERNAL**

TIMELINE

NEAR-TERM   MID-TERM   LONG-TERM

STRATEGY 26
Develop Common Data Standards and Influence their Widespread Adoption

Promote the use of open data and common, or widely adopted, data standards internally and among TxDOT contractors to facilitate the exchange of data across various levels of government, private sector industries and vendors, which will be critical to sharing massive amounts of real-time CAT data. Emphasize the importance of common, non-proprietary data standards in system procurements.

Utilizing common data standards will well-position TxDOT to collaborate with public and private sectors on future CAT data innovations. Leading statewide efforts to adopt these standards will also expand TxDOT's influence on national standards development.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   AGILITY   VITALITY

COST

STAFF EFFORT

STAKEHOLDERS

INTERNAL   **EXTERNAL**

TIMELINE

NEAR-TERM   MID-TERM   LONG-TERM

FOCUS AREA: INFRASTRUCTURE READINESS

STRATEGY 27
Expand Upon Efforts to Create an Information Portal for Sharing CAT Initiative Information

Continue efforts to create a user-friendly, internal portal that lets staff easily share and access information on all statewide CAT efforts, including internal project documentation that may assist future project owners in deploying CAT technologies/ projects.

The portal will provide a mechanism for TxDOT staff to share information related to project planning as well as project outcomes and lessons learned, which will streamline project efforts across similar initiatives and maximize investments across the state.

GOAL ALIGNMENT
SAFETY   RELIABILITY   MOBILITY   **AGILITY**   VITALITY

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS
INTERNAL ☑   EXTERNAL ☑

TIMELINE
NEAR-TERM   MID-TERM   LONG-TERM

FOCUS AREA: MULTIMODAL

STRATEGY 28
Enhance Visibility of Vulnerable Road Users in CAT Project Areas

Include measures to enhance the visibility and detectability of vulnerable road users, including, pedestrians, cyclists, scooter users and people with disabilities, in CAT design documents.

Increasing the visibility of pedestrians and cyclists will enhance the functionality of CAT applications that detect and respond to other road users, thereby promoting overall safety.

GOAL ALIGNMENT
SAFETY   **RELIABILITY**   **MOBILITY**   AGILITY   VITALITY

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS
INTERNAL ☑   EXTERNAL ☑

TIMELINE
NEAR-TERM   MID-TERM   LONG-TERM

FOCUS AREA: MULTIMODAL

STRATEGY 29
Explore CAT Applications that Benefit Multimodal Travel

Research CAT applications and technologies that benefit various modes of travel, including:

» Smartphone and e-bike/scooter CV applications for pedestrians and cyclists;
» CV mobility applications that improve safety and mobility for transit vehicles and riders;
» Rail technologies that enable device connectivity, provide real-time operations data and support forecasting analysis;
» Truck platooning applications, automated truck delivery systems and automated rail/unmanned aircraft system/ship technologies for freight, aviation and maritime travel; and
» Unmanned aircraft system technologies for ambulatory services and incident response that may impact aviation and maritime travel.

Consider partnership opportunities to study and pilot these technologies, which would strengthen TxDOT's multimodal network.

Research and potential implementation of CAT technologies with multimodal application allows TxDOT to plan for impacts to varying modes of travel and maximize benefits to all road users.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   AGILITY   VITALITY

COST

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓

EXTERNAL ✓

TIMELINE

NEAR-TERM   **MID-TERM**   LONG-TERM

STRATEGY 30
Explore Next Generation Mobility Hub Concepts

Study future mobility hub concepts that incorporate CAT infrastructure, such as EV charging facilities and AV parking and pick-up/drop-off services. Assess TxDOT's need for next generation mobility hubs and identify candidate locations along TxDOT highways. Consider AV parking requirements, EV infrastructure needs and curb management when studying candidate locations.

Mobility hubs can play a vital role in connecting people with destinations by providing benefits such as multimodal connection, congestion relief, first/last mile connection and community services. Next generation mobility hubs that include additional modes and uses have the potential to provide even more benefits to Texans.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   AGILITY   VITALITY

COST

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓

EXTERNAL ✓

TIMELINE

NEAR-TERM   MID-TERM   **LONG-TERM**

CAT STRATEGIC PLAN

FOCUS AREA:
MAINTENANCE AND OPERATIONS

STRATEGY 31
Deploy CAT Projects that Address Common Operational Scenarios

Prioritize and deploy near-term CAT pilots and project opportunities that address TxDOT's key operational needs and objectives. Determine location-specific needs and objectives for each District (e.g., evacuations may be an operational scenario for specific districts). An example objective would be to improve operations and management for extreme weather scenarios, which may be addressed with weather probe data gathering and CV safety and weather applications.

The deployment of CAT projects that can improve TxDOT's typical operations will allow the agency to realize CAT benefits that impact TxDOT's day-to-day functions, proving the value of CAT to internal and external stakeholders.

GOAL ALIGNMENT

SAFETY	RELIABILITY	MOBILITY	AGILITY	VITALITY

COST / STAFF EFFORT

STAKEHOLDERS

INTERNAL ☑   **EXTERNAL** ☐

TIMELINE

NEAR-TERM   MID-TERM   LONG-TERM
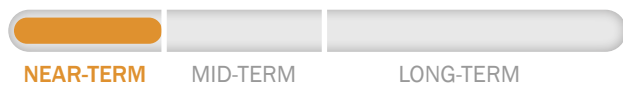
STRATEGY 32
Explore CAT-Enabled Innovative Traffic Operations and Management Strategies

Identify CAT systems and applications that may improve TSMO, TIM and TMC strategies and operations. Plan and prepare for the integration of CAT into these existing operations by performing a systems engineering analysis to identify affected users, system impacts, changes to operating procedures, etc.

TSMO, TIM and TMC strategies and practices primarily seek to maximize safety for TxDOT's road users, while the foremost potential benefit of CAT is the improvement of safety. Mainstreaming CAT into these practices offers the potential to aligns their needs and goals with the most pertinent solutions.

GOAL ALIGNMENT

SAFETY	RELIABILITY	MOBILITY	AGILITY	VITALITY

COST / STAFF EFFORT

STAKEHOLDERS

INTERNAL ☑   **EXTERNAL** ☐

TIMELINE

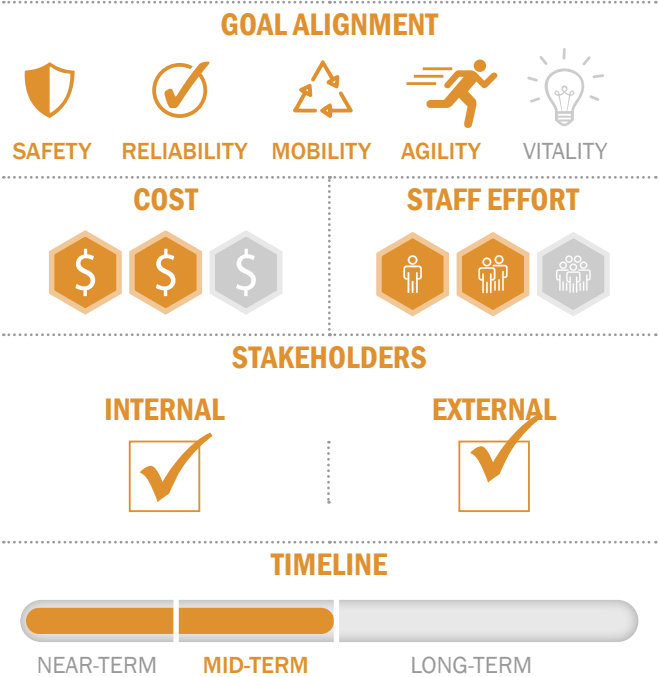**NEAR-TERM**   MID-TERM   LONG-TERM

FOCUS AREA: MAINTENANCE AND OPERATIONS

STRATEGY 33

Identify CAT Impacts and Needs for Smart Work Zones

Assess the impacts CAT may have on current Smart Work Zone (SWZ) operations. Bring together CAT and SWZ experts to identify gaps and potential enhancements to SWZ procedures, guidance and standards based on the availability of relevant CAT applications and technologies. Consider USDOT's Work Zone Data Exchange standards, which provide guidelines pertinent to CAT and SWZs.

Preliminary planning for the implementation CAT into SWZs will maintain the success and innovation of this established TxDOT program.

GOAL ALIGNMENT

SAFETY • RELIABILITY • MOBILITY • AGILITY • VITALITY

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓ • EXTERNAL ✓

TIMELINE

NEAR-TERM • **MID-TERM** • LONG-TERM

FOCUS AREA: PROCUREMENT

STRATEGY 34

Incorporate CAT Design, Construction, Operations and Maintenance into Procurement Rules and Policies

Routinely update existing boilerplate procurement and contract documents, including PS&E documents, construction documents, schedules, and consultant contract attachment C language, to incorporate CAT language and requirements, such as the inclusion of privacy requirements. Routinely place CAT equipment and services on TxDOT's Material Producer and Vendor Lists. Field test devices that are added to these lists for functionality and interoperability so that they are proven in advance of actual project deployments.

Regular updates to TxDOT's procurement and purchasing mechanisms ensures that the agency is ready to acquire goods and services needed to support the evolving CAT landscape.

GOAL ALIGNMENT

SAFETY • RELIABILITY • MOBILITY • **AGILITY** • VITALITY

COST
$ $ $

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓ • EXTERNAL ✓

TIMELINE

NEAR-TERM • MID-TERM • LONG-TERM

FOCUS AREA: PROCUREMENT

STRATEGY 35
Support Flexible and Agile Procurement Practices

Assess and implement changes to rigid procurement terms and conditions that would support more flexible, timely and effective technology procurement.

Changes to procurement standards would provide TxDOT with the flexibility and agility necessary to better align with the rate of emerging transportation technology innovation.

GOAL ALIGNMENT

SAFETY   RELIABILITY   MOBILITY   **AGILITY**   VITALITY

COST

STAFF EFFORT

STAKEHOLDERS

INTERNAL ✓

EXTERNAL ✓

TIMELINE

NEAR-TERM   MID-TERM   LONG-TERM

V
NEXT STEPS

Gain Momentum

This Strategic Plan identifies numerous strategic initiatives that TxDOT should undertake to maximize the benefits of CAT across Texas. The following strategies will promote TxDOT's ability to gain momentum towards the mission and goals of the CAT program.

The following strategies are recommended to be implemented immediately:

STRATEGY 1: Institutionalize TxDOT's CAT Program

STRATEGY 2: Coordinate Emerging Technology Planning Initiatives

Strategy 1 seeks to guide TxDOT forward in integrating CAT as a transportation solution with incremental steps to institutionalizing the CAT program. These steps will ensure sustainable support and leadership of CAT initiatives that allows TxDOT to effectively manage efforts and maximize their potential benefits. Furthermore, they support TxDOT's legacy as a national leader committed to innovation and maximizing the value of emerging

technologies. Strategy 2 is recommended to maximize collaboration, harmonize initiatives and eliminate redundancies across planning efforts. Additionally, TxDOT should take on the immediate action of communicating this Strategic Plan and its CAT efforts with internal stakeholders across divisions to facilitate understanding and support across TxDOT.

Program Plan

The next major milestone to advance CAT efforts at TxDOT will be the development of a Program Plan. While the Strategic Plan focuses on high-level, forward-looking priorities, the Program Plan will serve as a work plan with specific operational initiatives recommended to achieve the goals of the CAT program. Having both a Strategic Plan and Program Plan will align CAT efforts across all TxDOT divisions. The Program Plan will explore:

Action Item Roadmap

» Identify tactics or actions to achieve each strategy.

CAT Project Prioritization Methodology

» Determine evaluation criteria for proposed CAT projects aligning with the goals of the CAT Program, deliver high value CAT projects and maximize benefits for the cost expended.

» Develop user-friendly methodology to prioritize CAT projects, based on those criteria, to maximize available funding. Criteria will allow the agency to complete an "apples to apples" comparison between technology projects.

Performance Measures

» Provide CAT Program evaluation performance measure guidance at a high level. Project-specific performance measures shall be developed by stakeholder teams for each action.

Potential Funding Sources

» Grant Opportunities: Discuss grants that include opportunities specific to the adoption, integration, or acceleration of CAT technology. Additionally, identify grants that may be focused on other goals that can be accomplished using CAT technology, e.g. safety, sustainability, or resilience objectives.

» Potential Partnerships: Develop public and private partnerships as described in this section in order to ensure a smooth and successful introduction of CAT technology.

Strategic and Program Plan Follow Ups

» Identify recommended follow up check points and their recurrence to progress towards meeting the goals set forth in the Strategic and Program Plans.

APPENDIX

LIST OF ACRONYMS

3GPP	3rd Generation Partnership Project
AV	Automated Vehicle
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
BCR	Benefit Cost Ratio
CAT	Cooperative Automated Transportation
CAV	Connected Automated Vehicle
CMM	Capability Maturity Model
CV	Connected Vehicle
CVRIA	Connected Vehicle Reference Implementation Architecture
DSRC	Dedicated Short Range Communication
ETTP	Emerging Transportation Technology Plan
EV	Electric Vehicle
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FNTOP	Freight Network Technology and Operations Plan
GPS	Global Positioning System
HLDI	Highway Loss Data Institute
IIHS	Insurance Institute for Highway Safety
IT	Information Technology
ITS	Intelligent Transportation Systems
LRTP	Long-Range Transportation Plan
MUTCD	Manual on Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administrations
NPRM	Notice of Proposed Rulemaking
OBU	On Board Unit
OEM	Original Equipment Manufacturer
ROW	Right-of-Way
RSU	Roadside Unit
RTP	Regional Transportation Plan 2040
SME	Subject Matter Expert
STIP	Statewide Transportation Improvement Program
SWZ	Smart Work Zones
TIM	Traffic Incident Management
TMC	Traffic Management Center
TSMO	Transportation Systems Management and Operations
TTP	Texas Transportation Plan 2050
TxDOT	Texas Department of Transportation
USDOT	United States Department of Transportation
UTP	Unified Transportation Program
VMT	Vehicle Miles Traveled
V2I	Vehicle to Infrastructure Communications
V2X	Vehicle to Everything/Many Communication

SUMMARY OF STRATEGIES

#	High-Level Strategy	Goal Alignment					Cost	Staff Effort	Internal Stakeholders	External Stakeholders	Timeline to Initiate
		Safety	Reliability	Mobility	Agility	Vitality					
POLICY											
1	**Institutionalize TxDOT's CAT Program** Confirm the agency's level of commitment to leadership in emerging transportation technology and CAT with incremental steps to institutionalizing the CAT program. Steps include: » Designating CAT program champions across agency divisions and providing those champions with dedicated time for implementing internal and external CAT initiatives; » Developing a dedicated funding mechanism for transportation technology initiatives; » Allocating funding to support and drive CAT projects; » Dedicating leadership to direct and give voice to agency-wide CAT efforts; and, » Dedicating staff and funding for a CAT Organization that would be responsible for initiating and acclerating research, policy and standards updates, managing collaboration, pilot projects, branding, marketing, etc. These steps towards institutionalizing the CAT program will ensure sustainable support and leadership of CAT initiatives that allows TxDOT to effectively manage efforts and maximize their potential benefits. Furthermore, they support TxDOT's legacy as a national leader committed to innovation and maximizing the value of emerging technologies.				●	●	2	2	✓	✓	Immediate (ASAP)
2	**Coordinate Emerging Technology Planning Initiatives** Create a technical working group, made up of project managers and consultants handling various agency transportation technology efforts, to align TxDOT's multiple innovation-based plans and ensure consistent institutional messaging and objectives related to emerging transportation technologies. Establishing a working group with direct lines of communication across these planning efforts will support the ability to harmonize goals and avoid conflicting messaging across related plans throughout their development.				●	●	1	2	✓	✓	Immediate (ASAP)
3	**Implement Robust Security and Privacy Policies** Develop and implement robust security and privacy policies to plan for networking challenges and cybersecurity risks associated with CAT technology, ensure consumer privacy and cybersecurity and support a trusted network. Within these policies, consider management of security credentials, advanced threat detection and prevention, vulnerability management, security logging and monitoring, and incident response plan capabilities to protect public safety and privacy. Clearly communicate security and privacy policies to all affected stakeholders upfront to avoid misunderstanding and doubt, especially with respect to data privacy. Robust security and privacy policies will prepare TxDOT for potential threats posed by groups or individuals who may maliciously exploit CAT applications. Communication of these policies will help to address internal and external data privacy concerns and garner trust in the measures being taken to protect the public and TxDOT, which could otherwise create obstacles for the deployment of CAT.	●	●		●		3	2	✓	✓	Immediate (ASAP)
4	**Identify Regulatory Policies that May Impact CAT Implementation** Develop a legal brief, that may be updated routinely, to identify regulatory standards and barriers that may affect the implementation of CAT and CAV operation on Texas highways with a review of relevant laws and codes and an assessment of their impact on CAT. Like many emerging technologies, CAT often pushes legal boundaries concerning the operation of vehicles on state highways. This strategy will allow TxDOT to maintain awareness of up-to-date regulations and federal rulemaking that could support or inhibit the acceleration of CAT.				●	●	2	1	✓	✓	Near
5	**Develop Statewide Guidance for CAT Project Planning and Implementation** Develop high-level guidance on how to define, plan for and implement statewide CAT projects that references relevant CAT Design Standards and policies. This guidance may also point CAT project champions to project documentation from previous CAT initiatives, to build upon comparable work when suitable. This strategy will ensure that CAT project champions are equipped with the tools to: » Adhere to TxDOT's project development and planning processes; » Propose sources of sustainable project funding; » Include projects in the appropriate statewide planning documents (e.g., UTP, STIP, LRTP, TTP 2050, etc.); and, » Achieve planning and implementation consistency across CAT projects that span rural and urban districts with varying scales.	●	●		●	●	2	2	✓	✓	Near

CAT STRATEGIC PLAN

#	High-Level Strategy	Goal Alignment					Cost	Staff Effort	Internal Stakeholders	External Stakeholders	Timeline to Initiate
		Safety	Reliability	Mobility	Agility	Vitality					
6	**Update Existing Design Manuals and Standards to Accommodate CAT Deployments** Assess necessary updates to design and installation standards to accommodate the expansion of CAT in coordination with OEMs and automated driving system developers. Infrastructure standard updates to be considered include the following: » Installation standards that may inhibit the placement of roadside equipment, often required for CAT applications, on existing infrastructure, such as traffic signal poles; » Standard roadside equipment that may require replacement to accommodate CAT components, such as traffic cabinets that may be too small to house roadside units needed to support CAV applications; » Design and maintenance standards for infrastructure that CAVs may rely on, such as pavement markings and signage; » Design and maintenance standards for physical infrastructure that may be burdened by the proliferation of CAT, including bridges and pavement that may face stress impacts due to increased, concentrated loading from CAV travel and platooning; » Traffic design standards related to lane configuration, including merge, diverge and weaving segments, that may be impacted by CAT applications, such as CAV platooning; » Work zone standards that may be enhanced with the adoption of CAT technology applications; » Design standards and guidelines that may be impacted by freight technology and automation. Some of the specific manuals to be evaluated and updated include the Texas MUTCD, Freeway Signing Guide, Highway Safety Improvement Program Manual, Pavement Manual, Procedures for Establishing Speed Zones, ROW Property Management Manual, ROW Utilities Manual, Traffic Data and Analysis Manual, Traffic Safety Program Manual, Traffic Signals Manual, Transportation Multimodal Systems Manual, and Transportation Planning Manuals. Aligning TxDOT standards with requirements for CAT implementation ensures that Texas roadways can support and streamline future CAT projects, and maximizes the safe adoption of CAT.	●	●		●	●	2	3	✓	✓	Near
7	**Explore CAT Impacts on Border Crossing Policies and Procedures** Perform a study to identify border crossing policies and procedures that may be affected by the implementation of CAT technology (e.g., driverless AVs crossing the border). Studying these implications will allow TxDOT to prepare for and begin to address policy changes that would support the deployment of CAT technology at the border crossings with Mexico and borders with New Mexico, Oklahoma, Arkansas, and Louisiana.	●			●	●	2	2	✓	✓	Mid
FISCAL RESPONSIBILITY											
8	**Allocate Additional Budget for Modernizing TxDOT's Asset Management Program to Support CAT Technology Needs** Allocate additional budget for modernizing TxDOT's asset management program in support of future technology needs. Commit to performing timely upgrades/replacements to ensure that assets support modern security settings (including regular patching), integrate with other CAT technology, support remote management and, most importantly, do not reach their end-of-life. Expand TxDOT's asset management system to feature system and device visibility and allow for remote health monitoring, configuration management and lifecycle tracking. Currently many TxDOT devices and systems exceed their end-of-life or are outdated, which could pose risks to system operations and may impede the agency's ability to implement CAT technology and equipment. Active and robust asset management will allow the agency to avoid investment in obsolete assets, proactively invest in assets that support CAT initiatives and maximize the value of its investments.	●	●		●		3	3	✓	✓	Near
9	**Pursue Public-Private Partnerships for Technology Development and Deployment** Continue to routinely assess and pursue opportunities for partnerships with private industries, including fiber communication providers, broadband companies, vehicle manufacturers, transportation network companies and CAT-centered vendors, that leverage public infrastructure to share revenue and resources for CAT projects. Pursuing potential partnerships early-on allows TxDOT to optimize the potential benefits of CAT technologies, accelerate there deployment and bear influence on their development.				●	●	1	2	✓	✓	Near
10	**Support the Pursuit of Federal Grant Funding for CAT Projects** Continue to pursue federal grant funding opportunities and support other agencies (e.g., cities, MPOs, Texas Innovation Alliance, etc.) in seeking grant funding as well. There are a wide range of grant opportunities specific to the adoption, integration and acceleration of transportation technology that could increase funding for CAT deployments across Texas. Additionally, there are grants focused on general goals, such as safety, sustainability and resilience, that can be accomplished using CAT technology. In addition to the provision of funding, obtaining grants offers TxDOT the opportunity to inform rulemaking and foster collaboration among local government, state government and private partners.				●	●	1	2	✓	✓	Near
11	**Support and Provide Internal Funding for CAT Initiatives** Provide a source of internal TxDOT funding for CAT efforts. Develop and continually update a robust business case that justifies dedicated funding for CAT, including cost-benefit information from ongoing TxDOT transportation technology projects. A portion of funding that is dedicated to meeting the agency's safety goals for achieving its Road to Zero mission may be allocated for CAT projects that aim to meet those goals. Dedicated CAT funding would confirm the agency's commitment to and support for the advancement of transportation technology.				●	●	**2**	2	✓		**Mid**

#	High-Level Strategy	Goal Alignment					Cost	Staff Effort	Internal Stakeholders	External Stakeholders	Timeline to Initiate
		Safety	Reliability	Mobility	Agility	Vitality					
12	**Prepare for Changes in Revenue Streams Due to CAT Proliferation** Routinely assess current TxDOT revenue streams that may be inhibited by CAT. For instance, AVs may drive EV adoption, which would cause a reduction in gas consumption and its associated gas tax revenue. Study options to generate new sources of revenue with modernized collection means. The proliferation of CAT could cause reductions in private vehicle ownership, fuel consumption and traffic violations that would interrupt existing streams of TxDOT revenue. This strategy would allow the agency to capitalize on new revenue generation opportunities and financially plan for shifting revenue streams.				●	●	1	2	✓		Mid
COLLABORATION											
13	**Expand TxDOT's Internal and External Conferences to Feature CAT** Continue hosting TxDOT's annual Mobility Summit conference, which features CAT industry and vendor participation, showcases emerging technologies and facilitates relationship-building between the agency and potential industry partners. Expand TxDOT's internal conferences to educate staff about the agency's CAT initiatives. Promoting CAT at TxDOT's existing conferences allows the agency to foster workforce interest, support and expertise in the latest emerging technologies, maintaining its position as a leader in this area.				●	●	1	2	✓	✓	Near
14	**Continue to Support and Expand Partnerships with Research Institutions, Academia, Industry and Peer Agencies** Increase efforts to collaborate with research institutions, academia and peer agencies on CAT projects, technology pilots and sharing of expertise and resources. Continue partnerships with research institutions to test CAT technologies on TxDOT highways and explore sources of funding available to these institutions that differ from traditional transportation agency funding opportunities. Strengthen existing relationships with peer transportation agencies to share lessons-learned and expertise and potentially coordinate resources for joint ventures. Develop partnerships with academic institutions, including technical schools, universities and colleges, to promote innovation and incorporate aspects of CAT technology into their curricula. These relationships support TxDOT's ability to maintain a pulse on the latest advancement and news in CAT technology by creating an ecosystem that actively shares resources and knowledge. Furthermore, it offers the opportunity for TxDOT to cultivate interest and talent among future members of the workforce.				●	●	1	2	✓	✓	Near
15	**Expand Workforce Capabilities with the Provision of CAT Training** Foster workforce development and the expansion of job skills related to CAT technology. Provide on-the-job training for CAT project implementation. Training may include work with RSUs, fleet vehicle OBUs, IT and data management systems, etc. Identify subject matter experts (SMEs) that receive specialized training, participate in industry forums, and assist with training other staff. SMEs can also promote CAT across the agency, given their in-depth knowledge of new systems. As CAT projects become more prevalent across the agency, define CAT job titles, skill requirements and allocate appropriate compensation for those positions. Growth of a well-trained, experienced workforce will support TxDOT's efforts in accelerating the deployment of CAT initiatives and establishing itself as a leader in this realm. Additionally, the provision of workforce development opportunities will allow TxDOT to attract and retain expertise.				●	●	2	2	✓	✓	Mid
16	**Perform Outreach to Promote Internal and External Acceptance of CAT Initiatives** Perform CAT outreach to inform internal staff and the public about ongoing and planned CAT initiatives and the expected benefits/risks of CAT technologies. Outreach activities include preparing communication materials (e.g., flyers and presentations), posting CAT communication materials and project updates to TxDOT's website, routine engagement with internal and public CAT meetings, and publicizing CAT liaison(s) to field stakeholder questions, comments and concerns. In addition, communicate TxDOT system changes/upgrades related to CAT to internal stakeholders. Provide information on why system changes are required, workflow impacts and improvements, training opportunities, routinely posted schedules for system changes and system resources (e.g., primers, user manuals) . These activities will solicit understanding of CAT technologies, facilitate acceptance and support, and ensure that all stakeholders and constituents are actively engaged in CAT preparedness and adoption efforts.				●	●	1	2	✓	✓	Mid

CAT STRATEGIC PLAN

#	High-Level Strategy	Goal Alignment					Cost	Staff Effort	Internal Stakeholders	External Stakeholders	Timeline to Initiate
		Safety	Reliability	Mobility	Agility	Vitality					
INFRASTRUCTURE READINESS											
17	**Continue and Expand CAT Demonstrations / Deployments and Establish Innovation Areas** Continue efforts to work with the private sector on the implementation of CAT applications e.g., truck platooning (along freight corridors) to gain experience with CAT deployments and provide opportunities for testing, partnerships and proving CAT benefits. Support open communication with the industry to gain the latest insights on CAT opportunities and accompanying infrastructure needs. Establish innovation areas where CAT demonstrations and/or deployments may be promoted at varying scales and locations, including at intersections, along corridors and active use paths and in airspace. Pilot projects and demonstrations allow agencies to test new technologies while managing and minimizing risk.	●	●	●			2	3	✓	✓	Mid
18	**Prepare Traffic Management System for CAT Readiness** Connect TxDOT's traffic signals to prepare signals for CAT technology, optimize signal performance and enable the provision of performance data. Continue efforts and investment across TxDOT divisions and districts to close the current connectivity gaps (only 10% of existing signals are connected). Additionally, ensure that new and planned traffic signals are equipped with signal phasing and timing (SPaT) broadcast capabilities that support numerous safety and mobility CAV applications. Expanding TxDOT's traffic signals with connectivity and SPaT broadcast capabilities will allow the agency to make recognizable improvements to traffic flow and support its ability to adopt CAT applications that offer significant safety and mobility benefits.	●	●	●	●	●	3	2	✓	✓	Near
19	**Provide Backhaul Communications for TxDOT Assets Along Priority Corridors** Identify priority TxDOT corridors that may be target testbeds for CAT deployments (e.g., locations equipped with ITS devices that have safety or mobility needs which may be addressed by CAV applications). Provide backhaul communications for TxDOT's ITS devices and signals along these corridors and in accordance with TxDOT's Connected Network Strategy to support the functionality of CAT applications that require connectivity to its core network, which include numerous existing environmental, road weather, mobility, and agency data CV applications. Connecting TxDOT's assets along priority corridors will well-position the agency to easily adopt many available CAT applications and serve as a testbed for continued CAT development, expanding opportunities to realize and share the benefits of these emerging technologies.	●	●	●	●		3	3	✓	✓	Near
20	**Build Communications Readiness into Roadway Construction Projects** Include conduit and access points for communications infrastructure in planned roadway construction projects to support future fiber installation with ease and minimal additional construction. Install fiber communications in accordance with TxDOT's statewide fiber network plan. Incorporating simple, low-cost means of communications readiness into construction projects allows TxDOT to maximize installation efficiency and streamline future CAT deployments that necessitate core network connectivity.				●	●	2	1	✓		Mid
21	**Support the Provision of Statewide Communications Availability** Develop a statewide communications plan to identify locations that do not currently have access to usable, communications coverage. Study public-private partnership options to address communication gaps, particularly in rural areas, which will also likely not be afforded 5G availability by the private sector. Supporting the private sector in providing communications coverage across the State of Texas demonstrates TxDOT's commitment to offering reliable, vehicle connectivity and maximizing public safety.	●	●		●		3	3	✓	✓	Mid
22	**Strategically Allocate Space for EV Charging Infrastructure** Assess opportunities to strategically allocate space for EV charging infrastructure at mobility hubs and near businesses that could support EV acceleration and offer partnership opportunities related to charging station branding and advertising. Well planned EV charging stations have the potential to increase EV penetration and maximize social and economic benefits to communities across Texas.	●	●	●	●	●	2	2	✓	✓	Mid
23	**Explore Design Options to Incorporate CAV Operations** Explore various design options for highway infrastructure to meet the challenge of having mixed fleet of CV and AV at different levels of driving automation. Study the pros and cons of having mix-flow operations and dedicated CAV operations at different maturity levels. Studying various design options, for instance, mixed lane vs. dedicated CAV lane, will allow TxDOT proactively plan for their potential implementation, which could optimize the benefits of CAT technology, encourage technology adoption and maximize safety for all road users.	●	●	●	●		2	2	✓	✓	Mid

#	High-Level Strategy	Goal Alignment					Cost	Staff Effort	Internal Stakeholders	External Stakeholders	Timeline to Initiate
		Safety	Reliability	Mobility	Agility	Vitality					
SYSTEMS READINESS											
24	**Identify and Prioritize Use Cases for CAT Data to Inform Data Management Plans and Policies** Coordinate across divisions to identify, vet and prioritize use cases for CAT data. Specify what roadside data needs to be collected, how the data will be used by various TxDOT divisions (e.g., how could basic safety messages be used for operations applications, asset management, etc.), and third-party data uses, if any. Collaborating early-on to identify CAT data use cases and user needs supports agile project management practices, which will promote the development and execution of high-quality data management plans.				●	●	1	1	✓		Immediate (ASAP)
25	**Update Existing Data Management Strategies to Address the Unique Challenges of CAT and Capitalize on CAT Data Opportunities** Develop a data management framework for V2I data that supports TxDOT's CAT data use cases. Considerations for the framework should include the following: » infrastructure needs to support significant real-time, operational data processing needs » data volume estimates and strategies to address data volume reduction, cloud data storage, deduplication and edge processing, and communication needs, which will be impacted by the influx of CAT data » data storage policies, processes for the anonymization of traffic data, analytic data gathering needs, and data portal needs/users » Software standards and protocol, including Lonestar software, necessary to exchange CAT data with traditional ITS (e.g., dynamic message signs) and cooperative systems (e.g., in-vehicle messaging) » data sharing policies to accommodate the exchange of CAT data and digital infrastructure information with third parties, industry, research institutions, other transportation organizations and transportation network companies » common data standards and protocol for messages types utilized by CAT applications (e.g., traveler information messages, work zone messages, etc.) Investing time and resources into the development of TxDOT's data management framework will allow the agency to optimize existing and future operations and processes reliant on data, disseminate CAT and digital infrastructure and data, maximize the value of TxDOT's data and leverage data to achieve the agency's goals and objectives.	●	●		●		2	3	✓	✓	Near
26	**Develop Common Data Standards and Influence their Widespread Adoption** Promote the use of open data and common, or widely adopted, data standards internally and among TxDOT contractors to facilitate the exchange of data across various levels of government, private sector industries and vendors, which will be critical to sharing massive amounts of real-time CAT data. Emphasize the importance of common, non-proprietary data standards in system procurements. Utilizing common data standards will well-position TxDOT to collaborate with public and private sectors on future CAT data innovations. Leading statewide efforts to adopt these standards will also expand TxDOT's influence on national standards development.		●		●	●	1	2	✓	✓	Near
27	**Expand Upon Efforts to Create an Information Portal for Sharing CAT Initiative Information** Continue efforts to create a user-friendly, internal portal that lets staff easily share and access information on all statewide CAT efforts, including internal project documentation that may assist future project owners in deploying CAT technologies/projects. The portal will provide a mechanism for TxDOT staff to share information related to project planning as well as project outcomes and lessons learned, which will streamline project efforts across similar initiatives and maximize investments across the state.				●	●	1	2	✓	✓	Near
MULTIMODAL											
28	**Enhance Visibility of Vulnerable Road Users in CAT Project Areas** Include measures to enhance the visibility and detectability of vulnerable road users, including, pedestrians, cyclists, scooter users and people with disabilities, in CAT design documents. Increasing the visibility of pedestrians and cyclists will enhance the functionality of CAT applications that detect and respond to other road users, thereby promoting overall safety.	●	●	●			2	2	✓	✓	Near
29	**Explore CAT Applications that Benefit Multimodal Travel** Research CAT applications and technologies that benefit various modes of travel, including: » smartphone and e-bike/scooter CV applications for pedestrians and cyclists; » CV mobility applications that improve safety and mobility for transit vehicles and riders; » Rail technologies that enable device connectivity, provide real-time operations data and support forecasting analysis; » truck platooning applications, automated truck delivery systems and automated rail/unmanned aircraft system/ship technologies for freight, aviation and maritime travel; and » unmanned aircraft system technologies for ambulatory services and incident response that may impact aviation and maritime travel. Consider partnership opportunities to study and pilot these technologies, which would strengthen TxDOT's multimodal network. Research and potential implementation of CAT technologies with multimodal application allows TxDOT to plan for impacts to varying modes of travel and maximize benefits to all road users.	●	●	●	●	●	2	2	✓	✓	Mid

CAT STRATEGIC PLAN

#	High-Level Strategy	Goal Alignment					Cost	Staff Effort	Internal Stakeholders	External Stakeholders	Timeline to Initiate
		Safety	Reliability	Mobility	Agility	Vitality					
30	**Explore Next Generation Mobility Hub Concepts** Study future mobility hub concepts that incorporate CAT infrastructure, such as EV charging facilities and AV parking and pick-up/drop-off services. Assess TxDOT's need for next generation mobility hubs and identify candidate locations along TxDOT highways. Consider AV parking requirements, EV infrastructure needs and curb management when studying candidate locations. Mobility hubs can play a vital role in connecting people with destinations by providing benefits such as multimodal connection, congestion relief, first/last mile connection and community services. Next generation mobility hubs that include additional modes and uses have the potential to provide even more benefits to Texans.			●	●	●	2	2	✓	✓	Long
	MAINTENANCE & OPERATIONS										
31	**Deploy CAT Projects that Address Common Operational Scenarios** Prioritize and deploy near-term CAT pilots and project opportunities that address TxDOT's key operational needs and objectives. Determine location-specific needs and objectives for each District (e.g., evacuations may be an operational scenario for specific districts). An example objective would be to improve operations and management for extreme weather scenarios, which may be addressed with weather probe data gathering and CV safety and weather applications. The deployment of CAT projects that can improve TxDOT's typical operations will allow the agency to realize CAT benefits that impact TxDOT's day-to-day functions, proving the value of CAT to internal and external stakeholders.	●	●	●			2	2	✓		Near
32	**Explore CAT-Enabled Innovative Traffic Operations and Management Strategies** Identify CAT systems and applications that may improve TSMO, TIM and TMC strategies and operations. Plan and prepare for the integration of CAT into these existing operations by performing a systems engineering analysis to identify affected users, system impacts, changes to operating procedures, etc. TSMO, TIM and TMC strategies and practices primarily seek to maximize safety for TxDOT's road users, while the foremost potential benefit of CAT is the improvement of safety. Mainstreaming CAT into these practices offers the potential to aligns their needs and goals with the most pertinent solutions.		●	●	●	●	1	2	✓		Near
33	**Identify CAT Impacts and Needs for Smart Work Zones** Assess the impacts CAT may have on current Smart Work Zone (SWZ) operations. Bring together CAT and SWZ experts to identify gaps and potential enhancements to SWZ procedures, guidance and standards based on the availability of relevant CAT applications and technologies. Consider USDOT's Work Zone Data Exchange standards, which provide guidelines pertinent to CAT and SWZs. Preliminary planning for the implementation CAT into SWZs will maintain the success and innovation of this established TxDOT program.	●	●	●	●		2	2	✓	✓	Mid
	PROCUREMENT										
34	**Incorporate CAT Design, Construction, Operations and Maintenance into Procurement Rules and Policies** Routinely update existing boilerplate procurement and contract documents, including PS&E documents, construction documents, schedules, and consultant contract attachment C language, to incorporate CAT language and requirements, such as the inclusion of privacy requirements. Routinely place CAT equipment and services on TxDOT's Material Producer and Vendor Lists. Field test devices that are added to these lists for functionality and interoperability so that they are proven in advance of actual project deployments. Regular updates to TxDOT's procurement and purchasing mechanisms ensures that the agency is ready to acquire goods and services needed to support the evolving CAT landscape.				●		1	2	✓	✓	Near
35	**Support Flexible and Agile Procurement Practices** Assess and implement changes to rigid procurement terms and conditions that would support more flexible, timely and effective technology procurement. Changes to procurement standards would provide TxDOT with the flexibility and agility necessary to better align with the rate of emerging transportation technology innovation.				●	●	1	2	✓	✓	Near

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