COOPERATIVE & AUTOMATED TRANSPORTATION PROGRAM

TEXAS DEPARTMENT OF TRANSPORTATION

How Can TxDOT Utilize CAT Data?

CAT Brief

Strategic Initiatives and Innovation Division

November 2024

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

ADAS	Advanced Driver-Assistance System
AI	Artificial Intelligence
AV	Automated Vehicle
CAT	Cooperative and Automated Transportation
CCTV	Closed-Circuit Television
CTECC	Combined Transportation, Emergency, and Communications Center
CV	Connected Vehicle
DMS	Dynamic Message Signs
DTC	Diagnostic Trouble Code
EMS	Emergency Medical Services
EOS	Engineering Operations Support
FOX	Freight Operations Exchange
HD	High-Definition
IT	Information Technology
ITS	Intelligent Transportation Systems
ITS America	Intelligent Transportation Society of America
LOS	Level of Service
ML	Machine Learning
OTA	Over-the-Air
PIO	Public Information Officer
RSU	Roadside Unit
SME	Subject Matter Expert
TMC	Traffic Management Center
TMS	Traffic Management System
TSMO	Transportation Systems Management and Operations
TxDOT	Texas Department of Transportation
V2X	Vehicle-to-Everything
VRU	Vulnerable Road Users

1. Introduction

The Texas Department of Transportation's (TxDOT's) transportation network is the largest in the nation, with more than 80,900 miles of roadways, 271 general aviation airports, and 78 million tons of cargo moving through its seaports. For TxDOT, continuing to investigate innovative and economical methods for creating a safe and reliable transportation system for all users is critical. The integration of connected vehicles (CVs), automated vehicles (AVs), and other emerging transportation technologies into the state's multimodal transportation system offers numerous potential benefits to the traveling public. To support the efficient integration of these technologies, TxDOT launched the Cooperative and Automated Transportation (CAT) Program based on the CAT Strategic Plan and Program Plan.

The statewide CAT program supports the agency's mission of Connecting You With Texas. This program explores emerging technologies to address some of the state's greatest challenges in the areas of safety, mobility, environment, and funding, while executing strategies to accommodate disruptive changes and emerging technology trends. TxDOT seeks to proactively integrate CAT initiatives into transportation projects, from planning, design, and construction to operations and maintenance, rather than respond reactively to its proliferation in the multimodal transportation system.

A key initiative is to examine how TxDOT is leveraging CAT data to improve safety, mobility, and decision-making across the agency.

1.1 Project Background

With the rapid growth of CAT infrastructure[1] and related technologies, the volume of data generated is increasing exponentially, making its management and integration crucial. This surge of information presents both a challenge and an opportunity for transportation agencies. To harness the full potential of CAT data, a clear understanding of its various forms and applications is essential.

> **CAT data is any information integrated into, generated, or disseminated by Intelligent Transportation System (ITS) infrastructure directly or indirectly for the purpose of transportation automation, connectivity, and intelligent decision-making to improve safety, mobility, efficiency, and reliability of people and goods movement.**

This CAT Brief, "How Can TxDOT Utilize CAT Data?" aims to identify the types of data generated by CAT infrastructure, documenting current TxDOT data usage, and exploring potential use cases across divisions and districts. This analysis will equip TxDOT to leverage CAT data for improved transportation management, optimized resource allocation, and enhanced safety throughout Texas.

This CAT Brief is part of a series of initiatives supporting CAT data integration and use within TxDOT. **Figure 1** illustrates how this brief relates to other CAT data initiatives, highlighting each document's specific purposes and interconnections.

[1] CAT infrastructure refers to the physical and digital assets required to support communication, data exchange, and coordinated actions within the CAT ecosystem, directly or indirectly influencing transportation system users and operational capabilities. Source: *CAT Brief: What is CAT Infrastructure?*

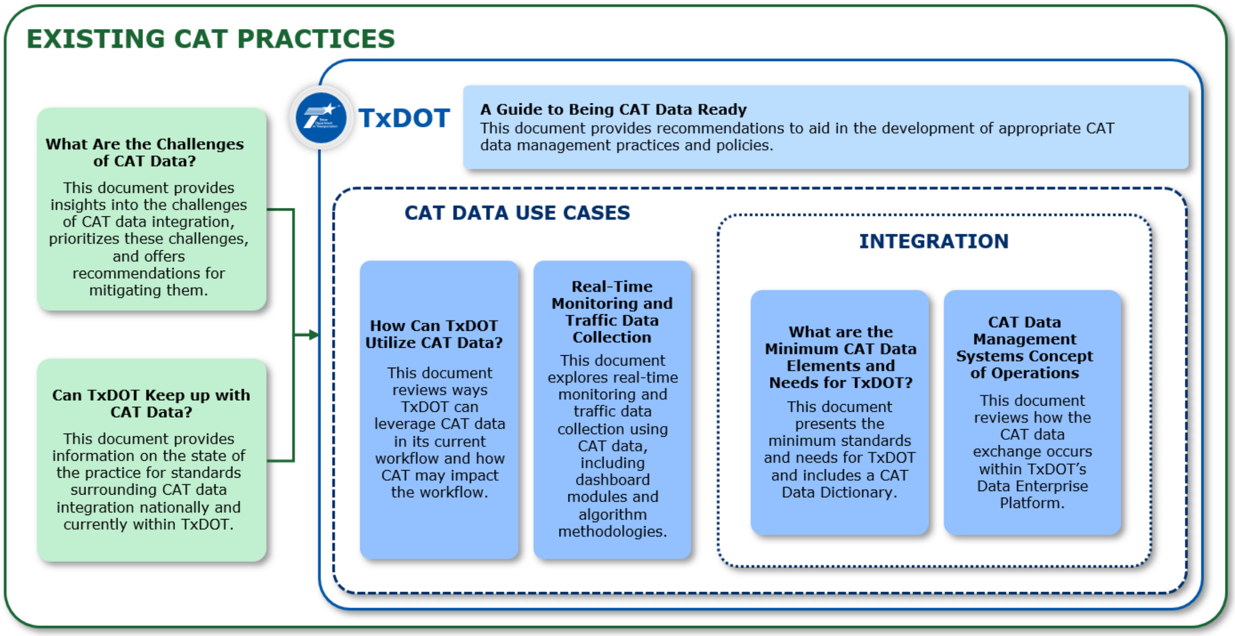

Figure 1: CAT Program Data-Related Initiatives

Figure 1 outlines a framework for TxDOT to effectively utilize and manage CAT data. It starts with establishing a foundation by assessing current practices ("Can TxDOT Keep Up with CAT Data?") and identifying challenges ("What are the Challenges of CAT Data?"). This informs the development of a guide ("A Guide to Being CAT Data Ready") for implementing CAT data use cases ("How can TxDOT Utilize CAT Data?"), such as real-time monitoring ("Real-Time Monitoring and Traffic Data Collection"). Finally, the framework addresses data integration ("What are the Minimum CAT Data Elements and Needs for TxDOT?" and "CAT Data Management Systems Concept of Operations") to ensure TxDOT is prepared to manage CAT data.

1.2 Methodology

Leveraging CAT data is crucial for enhancing TxDOT's overall operations and services. This CAT Brief examines CAT data usage across TxDOT divisions and districts, which provides insights into traffic patterns, road conditions, and vehicle behavior, enabling better decision-making and resource allocation. The findings support TxDOT's transition to data-driven operations, aligning with smart transportation systems and benefiting Texas travelers. To achieve this, the analysis focused specifically on internal TxDOT applications and involved:

- **Identifying CAT data elements:** Determining the specific types of data generated by CVs and AVs relevant to TxDOT's needs.
- **Documenting current data usage:** Assessing existing practices and identifying areas where CAT data could be further integrated into TxDOT's workflows.
- **Exploring potential use cases:** Investigating how different divisions and districts could leverage CAT data to address their unique challenges and optimize operations.

An extensive literature review was conducted to determine internal and external CAT data use cases, referenced in **Appendix A: References** and summarized in **Appendix B: State-of-the-Practice for CAT Use Cases.**

1.3 Organization of this CAT Brief

This CAT Brief is organized into the following sections:

- **Section 1: Introduction** – Provides an overview of the project background and summarizes the information presented in this document.
- **Section 2: What is CAT Data?** – Defines CAT data and explores which data elements would be useful to TxDOT.
- **Section 3: CAT Data Integration by Divisions and Districts** – Presents potential benefits to each division within TxDOT while supporting districts.
- **Section 4: TxDOT Use Cases** – Discusses potential CAT data use cases.

2. What is CAT Data?

CAT data is any information integrated into, generated, or disseminated by ITS infrastructure directly or indirectly for the purpose of transportation automation, connectivity, and intelligent decision-making to improve safety, mobility, efficiency, and reliability of people and goods movement.

Table 1 lists key data categories and elements relevant for TxDOT operations, including traffic management, incident response, multimodal support, asset monitoring, safety management, freight management, and environmental monitoring.

Many of these elements can be classified as CAT data, highlighting the potential utility of CAT data for both current and future TxDOT practices. This is not an exhaustive list, as CAT data encompass a wide range of elements beyond those presented here.

Table 1: Example of CAT Data Elements

Data Category	Data Elements	
Intersections and Roadway Mobility	Volume Signal timing Speeds/travel time Delay	Queue details Turning movement Congestion Bottleneck
Roadway Safety and Maintenance	Pavement surface/weather conditions Object detection and classification Work zones	Bridge sensor system Traffic device health Incident/event
Multimodal Transportation	Transit routes Transit trip data Pedestrian/non-motor vehicle accidents Freight movement	Bike lanes Bike lane usage Public transit usage Vulnerable Road Users (VRUs) data
Asset Management	Asset Inventory Dynamic message signs (DMS) Vehicle detection	Pavement condition Signs Traffic control
Environmental and Weather	External temperature Weather conditions (rain, snow, fog, fire) Historical weather conditions Emission levels Wind speed and direction	Air quality data Air pressure Humidity Roadbed temperature Rainfall rates

Data Category	Data Elements	
Vehicle Telemetry	Vehicle speed Fuel consumption Odometer readings Tire pressure Warning message Steering wheel angle Brake status Air bag deployment Location data	Heading and direction Sharp cornering Hard breaking Rapid acceleration Acceleration and deceleration patterns Engine temperature Battery voltage Transmission data
Safety and Driver Assistance	Data from advanced driver-assistance systems (ADAS) Collision detection and avoidance data Lane-keeping and lane-departure warnings	Adaptive cruise control data Blind-spot monitoring data Parking assist data Seat belt usage
Vehicle Diagnostics and Health	Diagnostic trouble codes (DTCs) Engine and component health information	Maintenance alerts and reminders Predictive maintenance data
Driver Behavior	Driver behavior monitoring (e.g., harsh acceleration or braking) Compliance	Distracted driving detection Wrong-way driving
Connectivity and Communication	Vehicle-to-Everything (V2X) communication	Data related to over-the-air (OTA) software updates
Usage and Vehicle History	Trip data (start time, end time, distance) Historical driving patterns	Vehicle usage statistics
Global Positioning System	Vehicle location Location of crashes	Location of areas of congestion Location of all traffic devices

3. CAT Data Use Cases in TxDOT

Data are crucial for TxDOT’s decision-making and strategic planning, especially in managing its vast and complex transportation network. Integrating CAT data across divisions and districts offers the potential to enhance TxDOT’s capabilities by providing real-time insights into traffic patterns, road conditions, and vehicle behavior.

To that end, TxDOT has collected CAT data use cases from various districts. **Table 2** below highlights the most promising use cases and their required elements. These are intended for district use, with division guidance to ensure statewide standardization. To justify any operational or policy changes, it is standard practice that divisions and districts conduct pilot studies and collaborate with research groups to fully evaluate the potential benefits of integrating CAT data. Although **Table 2** offers a representative sample of possible applications, it is not meant to be an exhaustive list of all potential use cases.

Table 2: CAT Data Use Cases in TxDOT

Use Case	Description	Potential Data Elements	Potential Benefits (Performance Measures)	Potential Infrastructure and Evolution Phase[2]	Stage in Project Life Cycle
Incident and Emergency Management					
Incident Detection and Response Optimization	Automate crash detection, response, and impact prediction for Traffic Management Center (TMC) operators.	▪ Collision detection and avoidance data ▪ Vehicle location ▪ Location of areas of congestion ▪ Air bag deployment	▪ Faster incident clearance ▪ Mobility returns to normal traffic flow/level of service (LOS) ▪ Improve roadway reliability ▪ Reduce secondary crashes ▪ Improve post-crash care	**Growth Phase** ▪ Closed-circuit television (CCTV) cameras ▪ Roadside units (RSUs) ▪ Smart intersections ▪ Digital communication network ▪ Artificial intelligence (AI)-enabled traffic management system (TMS) ▪ Data exchange platform	Operations
Predictive Flooding Detection and Response Optimization	Predict flooding, alert crews, assess impacts, and allocate resources to minimize damage.	▪ Weather conditions ▪ Historical weather conditions ▪ Road surface conditions	▪ Minimize flood costs ▪ Reduce infrastructure damage risk	**Growth Phase** ▪ Remote sensing systems ▪ Weather sensors ▪ DMS ▪ Data management platform ▪ AI-enabled prediction models ▪ Digital communication network	Operations

[2] CAT infrastructure and associated phases of evolution are defined in the [CAT Brief: What is CAT Infrastructure?]

Use Case	Description	Potential Data Elements	Potential Benefits (Performance Measures)	Potential Infrastructure and Evolution Phase[2]	Stage in Project Life Cycle
Traffic Management and Control					
Issue Warnings Through Automated DMS	Use DMS to inform drivers of environmental, weather, and traffic conditions to improve safety and preparedness for hazards.	▪ DMS locations ▪ Location of areas of congestion ▪ Weather conditions ▪ Delay ▪ Speed data ▪ Work zones details	▪ Enhance safety for drivers and road workers ▪ Decrease collisions and traffic congestion ▪ Reduce average speeds in work zones	**Existing Phase** ▪ DMS ▪ CCTV cameras ▪ Remote sensing systems ▪ Sensors ▪ Data management platform	Operations
Proactive Traffic Prediction and Congestion Management	Forecast traffic conditions using data and provide TMC operators with recommendations to prevent or alleviate congestion.	▪ Location of areas of congestion ▪ Historical driving patterns by time of day ▪ Current traffic condition ▪ Crash data ▪ Origin-destination trends ▪ Signal timing	▪ Minimize traffic delays ▪ Optimize traffic routing ▪ Improve cost-effectiveness of traffic measures ▪ Improve resiliency ▪ Reduce pollution	**Growth Phase** ▪ AI-enabled TMS ▪ Data management platform ▪ Data warehouse ▪ Intelligent transportation applications ▪ Crowdsourced data ▪ Telematics data	Operations

Use Case	Description	Potential Data Elements	Potential Benefits (Performance Measures)	Potential Infrastructure and Evolution Phase[2]	Stage in Project Life Cycle
Traffic Signal Timing Optimization for Efficient Traffic Control	Use AI/machine learning (ML) algorithms and real-time data from TMS to dynamically adjust traffic signal timings.	▪ Signal timings ▪ Vehicle speed ▪ Volume/turning movements ▪ Queue length ▪ Intersection delay ▪ Location of areas of congestion ▪ Historical driving patterns	▪ Optimize traffic signal timing ▪ Minimize traffic time ▪ Reduce manual labor needed to continually optimize traffic signals ▪ Improve resiliency ▪ Reduce pollution	**Growth Phase** ▪ Smart intersections ▪ Edge computing infrastructure ▪ AI-enabled TMS ▪ Data exchange ▪ Intelligent transportation applications	Operations
Work Zone Management	Optimize traffic flow during construction with efficient detours, equipment alerts, and work zone safety measures using CAT data.	▪ Roadway construction layouts ▪ Location of areas of congestion ▪ Historical driving patterns ▪ Signal timings ▪ Vehicle speed ▪ Volume ▪ Queue length ▪ Worker present details	▪ Traveler information for public to potentially alter route to avoid work zone, potentially reducing congestion at work zone ▪ Increase road worker safety by decreasing volume of cars near work zones ▪ Minimize work zone traffic delays and crashes	**Growth Phase** ▪ DMS ▪ Connected smart work zones ▪ CCTV cameras ▪ Variable speed limit signs ▪ Remote sensing systems ▪ Data management platforms	Construction

Use Case	Description	Potential Data Elements	Potential Benefits (Performance Measures)	Potential Infrastructure and Evolution Phase[2]	Stage in Project Life Cycle
School Bus/Public Transportation Routing Optimization	Use CAT data for smart school zones, adjusting speed limits and signals based on schedules. Coordinate between school districts, TxDOT, and city to optimize public transportation routes.	▪ DMS locations ▪ Vehicle speed ▪ Signal timings ▪ Historical driving patterns ▪ Transit routes ▪ Object detection and classification	▪ Enhance school area safety and efficiency ▪ Reduce school bus travel times ▪ Reduce congestion during morning peak hour	**Growth Phase** ▪ Smart school zones ▪ Smart intersections ▪ Digital communication network ▪ Data exchange ▪ AI-enabled TMS ▪ Mobility-as-a-service applications	Operations
Optimal Freeway and Roadway Design	Utilize traffic data from roadways/freeways of various designs and model them with expected values to determine the most optimal design to mitigate congestion and enhance safety.	▪ Location of areas of congestion ▪ Intersection/highwa y layouts ▪ Locations of crashes ▪ Air bag deployment	▪ Decrease crashes and congestion ▪ Promote data-driven design	**Growth Phase** ▪ Sensors ▪ Digital roadway data ▪ Data management platforms ▪ High-definition (HD) digital mapping ▪ AI-enabled TMS	Design
Optimizing Data Accuracy for Corridor Studies	CV speed data will be used to ensure the greatest accuracy in corridor studies.	▪ Vehicle speed, volume, and occupancy	▪ Improve corridor study accuracy	**Growth Phase** ▪ RSUs ▪ Data management platforms	Planning

Use Case	Description	Potential Data Elements	Potential Benefits (Performance Measures)	Potential Infrastructure and Evolution Phase[2]	Stage in Project Life Cycle
Enhance Spatial Map for all Relevant Data	Upgrade TxDOT maps for real-time traffic updates, including queue warnings, incident detection, and speed tracking.	▪ Locations of areas of congestion ▪ Location of crashes ▪ Vehicle speed ▪ Historical driving patterns ▪ Pavement condition ▪ Weather conditions	▪ Enhance data-driven decision-making by improving accessibility of information ▪ Increase spatial awareness for both the public and transportation agencies	**Growth Phase** ▪ HD digital mapping ▪ CCTV cameras ▪ Weather sensors ▪ Data exchange platforms	Management
Asset Monitoring and Management					
Automated Asset Detection and Management	Employ AI algorithms, TMS data, and video analytics to efficiently monitor, assess, and maintain transportation assets.	▪ Inventory data ▪ Object detection and classification	▪ Decrease manual labor needed to monitor assets ▪ Decrease costs of inventory management	**Growth Phase** ▪ AI-enabled TMS ▪ CCTV cameras ▪ Remote sensing systems ▪ Edge computing infrastructure	Maintenance and Management
Freight and Delivery Management					
Supply Chain Optimization	Integrate CAT data into supply chain systems to enhance route planning, inventory management, parking availability and scheduling; reduce delivery times; and improve maintenance forecasts.	▪ Volumes ▪ Delay ▪ Queue details ▪ Freight data ▪ Drayage operations ▪ Truck parking details and space availability	▪ Increase amount of on-time deliveries ▪ Reduce costs of delivery ▪ Minimize queues at terminals and distribution centers	**Growth Phase** ▪ Digital communication network ▪ Data exchange platform ▪ Intelligent transportation applications	Operations

Use Case	Description	Potential Data Elements	Potential Benefits (Performance Measures)	Potential Infrastructure and Evolution Phase[2]	Stage in Project Life Cycle
Environmental Monitoring and Management					
Environmental Impact Assessment	Assess the environmental impact of transportation projects, such as vehicle pollution levels, noise pollution, and air quality, to inform sustainable development strategies.	▪ Vehicle emission levels ▪ Air quality data ▪ Noise data ▪ Environmental impact reports	▪ Decrease overall carbon footprint ▪ Reduce noise levels ▪ Reduce emissions levels	**Growth Phase** ▪ Environmental sensors ▪ CVs ▪ Data management platforms ▪ AI-enabled analysis systems	Planning
Infrastructure-Based Safety Management					
Optimized Maintenance Scheduling	Predict maintenance needs for pavement, roads, bridges, and other infrastructure components, allowing for proactive scheduling of maintenance activities to minimize disruptions and ensure safety.	▪ Bridge sensor system ▪ Traffic device health ▪ Pavement conditions ▪ Delivery schedules	▪ Improve maintenance task prioritization ▪ Minimize costs from inadequate or excessive maintenance	**Growth Phase** ▪ Sensors ▪ AI-enabled predictive maintenance systems ▪ Data management platforms ▪ Connected smart work zones	Maintenance

Use Case	Description	Potential Data Elements	Potential Benefits (Performance Measures)	Potential Infrastructure and Evolution Phase[2]	Stage in Project Life Cycle
Multimodal Support and Mobility					
Smart Parking Management	Implement smart parking systems for state infrastructure, featuring real-time availability especially for freight/trucks, dynamic pricing, and efficient space allocation.	▪ Live parking counts ▪ DMS/information systems to display data ▪ Truck parking locations and availability	▪ Reduce parking search time ▪ Decrease congestion due to motorists searching for parking ▪ Improve parking availability awareness ▪ Reduce unauthorized truck parking in state right-of-way	**Growth Phase** ▪ Parking sensors ▪ DMS ▪ Intelligent transportation applications ▪ Data exchange platforms	Operations
Assessment of Priority for Transportation Projects	Use CAT data to identify areas needing budget allocation based on public transit availability, congestion levels, crash rates, and other relevant factors.	▪ Locations of all traffic devices ▪ Locations of areas of congestion ▪ Locations of crashes ▪ Pavement conditions ▪ Incident/event data ▪ Volume ▪ Speeds	▪ Enhance data-driven resource allocation ▪ Optimize budget and project impacts ▪ Increase public support	**Growth Phase** ▪ Data management platforms ▪ AI-enabled analysis systems ▪ Digital roadway data ▪ Crowdsourced data	Planning

Use Case	Description	Potential Data Elements	Potential Benefits (Performance Measures)	Potential Infrastructure and Evolution Phase[2]	Stage in Project Life Cycle
Pedestrian Cycle and Safety Analysis	Analyze CAT data to identify areas with high pedestrian and cyclist traffic, as well as locations with a high incidence of pedestrian and cyclist crashes.	▪ Bike lane locations ▪ Bike lane usage ▪ Intersection turning movements ▪ Compliance ▪ Pedestrian crossing counts	▪ Improve pedestrian and cyclist safety ▪ Increase the number of bike lanes ▪ Shorten intersection queues	**Growth Phase** ▪ Smart intersections ▪ CCTV cameras ▪ VRU notification systems ▪ AI-enabled video image processing	Planning

4. CAT Data Utilization and Integration in TxDOT

CAT data promises to transform how TxDOT approaches planning, design, operations, and maintenance across the state. This section expands upon existing data utilization and illustrates how CAT data can be leveraged to address future challenges and opportunities within TxDOT.

Table 3, compiled from a review of existing literature, subject matter expert (SME) opinions, and TxDOT's own experience with CAT data, demonstrates how TxDOT can enhance current practices or develop new approaches to utilizing and integrating CAT data at both the agency and statewide levels. TxDOT divisions should support CAT utilization and integration at the enterprise level to achieve statewide consistency and standardization.

Table 3: CAT Data Utilization and Integration in TxDOT

TxDOT Divisions	Utilization and Integration of CAT Data in TxDOT
Communications	▪ **Enhanced Communication:** CAT data enables rapid and accurate information sharing with the public, improving safety and awareness. This division may become users and disseminators of CAT data to provide insights to the public via the public information officer (PIO) community or other as appropriate. For example, major weather event (black ice, flooding, etc.) that causes a complete road closure may be detected from CAT data use cases and the communications division may accurately and quickly disseminate this information to the public. ▪ **High-Profile Event Management:** Leverage CAT data to effectively communicate critical information during major events that may impact multiple districts.
Construction	▪ **Optimized Construction Planning:** CAT data, such as probe data, can inform optimal construction scheduling and traffic control plan evaluation, minimizing disruptions during projects.
Design	▪ **Data-Driven Design:** Utilize speed, acceleration, collision, and roadway geometry data to optimize roadway designs and standards. ▪ **Performance Evaluation:** Assess roadway demand using performance data. This can be achieved by utilizing CAT data, such as volume and movement (origin-destination data), to understand demand patterns, especially in rural areas. Use these resources to collect data for evaluating the effectiveness of design measures and improvements. Leverage CAT data to establish standardized performance metrics that do not require district resources for collection and display.
Fleet Operations	▪ **Improved Fleet Maintenance:** Utilize vehicle telemetry data (e.g., diagnostic codes, engine health) to optimize maintenance schedules and proactively address potential issues. ▪ **Strategic Fleet Deployment and Emergency Response:** Deploy fleets based on real-time roadway conditions and pre-position emergency vehicles for faster response times, particularly during severe weather events.

TxDOT Divisions	Utilization and Integration of CAT Data in TxDOT
Maintenance	▪ **Enhanced Worker Safety:** Improve roadway worker safety, particularly during nighttime operations, using cloud-based work-zone alerts for approaching vehicles. ▪ **Efficient Infrastructure Management:** Monitor pavement and bridge health more efficiently using roadway condition data.
Maritime	▪ **Optimized Port Operations:** Leverage CAT data to improve trucking shipment timeliness and inform port design and maintenance strategies for increased efficiency.
Materials and Tests	▪ **Optimized Material Selection:** Utilize weather and road condition data to inform material selection, based on anticipated future conditions. ▪ **Predictive Pavement Management:** Track pavement lifecycle and predict maintenance needs, enabling proactive maintenance planning and cost optimization.
Public Transportation	▪ **Data-Driven Support for Active Transportation:** Leverage CAT data on bicycle and pedestrian patterns to inform infrastructure planning and improve safety measures.
Research and Technology Implementation	▪ **Advanced Research Capabilities:** Utilize CAT data to enable more innovative and versatile research studies. For example, once an innovative data set is available, TxDOT may leverage the research division to conduct an in-depth evaluation of the data. This evaluation can determine whether investing in and implementing the data is worthwhile. Alternatively, it can lead to developing pilot modules for predictive analytics, such as using real-time CV data from airbag deployments to detect crashes.
Strategic Initiatives and Innovation	▪ **CAT Data Integration:** Spearhead the integration of CAT data across TxDOT divisions to optimize transportation operations and drive innovation. For example, the design, deployment, and evaluation of the I-45 innovative corridor, which crosses multiple districts.
Traffic Safety	▪ **Real-Time Signal Optimization:** Improve traffic flow and reduce crashes by leveraging CAT data for real-time signal optimization and outage detection. ▪ **AI-Powered Collision Detection and Response:** Utilize AI-powered CCTV systems for rapid collision detection and near-miss analysis. ▪ **Strategic ITS Deployment and Management:** Optimize the placement and monitor the performance of ITS devices using CAT data and AI for improved traffic management. ▪ **Dynamic Messaging for Enhanced Safety:** Deploy DMS that adapt to real-time traffic conditions to provide drivers with targeted safety information, warnings, and advisories.
Transportation Planning and Programming	▪ **Data-Driven Truck Parking Management:** Optimize parking availability by analyzing commercial vehicle location data to identify areas with a high demand for parking. ▪ **Strategic Project Funding Allocation:** Inform funding decisions based on real-time insights into traffic patterns, road conditions, and safety needs.

TxDOT Divisions	Utilization and Integration of CAT Data in TxDOT
Transportation Programs	▪ **Data-Driven Project Development:** This division supports Information Technology (IT) application development and provides support for performance-based transportation project development and delivery resources through business analytics and reporting. Performance-based transportation project development within the Engineering Operations Support (EOS) section can be enhanced by utilizing comprehensive CAT data, including intersection signal data, collision data, trip data, and speed data.
Travel Information	▪ **Enhanced Travel Information Services:** Improve the accuracy and timeliness of travel information provided through platforms such as DriveTexas by integrating real-time CAT data on weather, road conditions, traffic, and incidents. ▪ **Real-Time Roadway Visualization:** Provide users with live map visualizations of roadway conditions, traffic flow, and incidents, enabling informed travel decisions and enhanced situational awareness.

The Information Technology Division is playing a crucial role in enabling secure data sharing and integration across divisions and districts at the enterprise level, ensuring data quality and accessibility for effective CAT data utilization. **Appendix C: Impacts of CAT Data to Divisions** explores the impact of CAT data and how the data should be considered within each division.

Appendix A: References

AECOM. (2020). *TxDOT Statewide TSMO Data Platform.*

Amazon Web Services. (2021). *Designing Next Generation Vehicles Communication with AWS IoT Core and MQTT: Implementation Guide OR AWS Whitepaper.* Amazon Web Services.

Bennet, S. (2023). *AI Provides Vital Assistance to TMS Companies.* Transport Topics.

Burbano, L. (2021). *What Is A Smart Parking System? Functionalities and Benefits.* Tomorrow City.

Correos, E. (2023). *Connected Cars and Data Privacy: Challenges and Solutions in a New Automotive Era.* Telecom Review.

Crow, M., Avery, P. A., & Fuller, J. (2023). *Achieving Efficiencies within ODOT with the Event Streaming Platform.*

Masello, L., Castignani, G., Sheehan, B., Murphy, F., & McDonnell, K. (2022). *On the road safety benefits of advanced driver assistance systems in different driving contexts.* Transportation Research Interdisciplinary Perspectives.

NCHRP. (2024). *Using Cooperative Automated Transportation Data for Freeway Operational Strategies.* NCHRP Research Report 1080.

Okas, J. (2023, Feb 6). *Data Management: The Challenge of Connected Cars.* https://real-wireless.com/data-management-the-challenge-of-connected-cars/

Sahar, D. (2018). *Challenges of Securing Connected Car.* https://upstream.auto/resources/upstream-chalk-talks-challenges-of-securing-connected-cars/

Smalley, S. (2023). *As car hoover up more and more driver data, is it time to regulate the industry?* The Record. https://therecord.media/connected-cars-hoover-up-data

The Intelligent Transportation Society of America. (2024). *ITS Technology Use Case Library.* Washington, D.C.

Appendix B: State-of-the-Practice for CAT Use Cases

Table 4: Use Case Literature Review

Use Cases	Description	Source
Truck Parking	To best support freight movement in Texas, the Texas Department of Transportation (TxDOT) has utilized probe data to understand macro- and micro-level truck parking demands. A dashboard was developed to determine the best truck parking available by location, duration desired, and time of day. Waco District further investigated freight generators in order to understand freight patterns and impacts.	TxDOT
Travel Time Information Automation	TxDOT has deployed solutions which utilize real-time speed data to automatically update message boards for work zone safety.	TxDOT
Improve Traffic Congestion and Roadway Safety	TxDOT and teams have deployed a traffic management technology to improve incident response time and overall roadway safety. The project calls for the implementation of Rekor's cloud-based roadway intelligence platform at the TxDOT Combined Transportation, Emergency, and Communications Center (CTECC) facilities. The platform uses AI and integrates data from multiple sources to provide more comprehensive and quicker incident identification than current methods.	TxDOT – Austin District[3]
Roadway Maintenance Need Detection and Dispatch	Roadways in need of maintenance are automatically detected. Then the location of the potential maintenance issue is monitored to determine maintenance priority. It may be monitored from vehicle cameras and inertial measurement unit data.	Achieving Efficiencies within Ohio DOT with the Event Streaming Platform[4]
Snow/Ice Treatment Determination	Snow and ice treatment levels are automatically determined if they are needed by spatial location, incoming weather, and low-friction pavement conditions. This helps to provide estimated treatment needs to snow/ice crews to support preparedness.	Achieving Efficiencies within Ohio DOT with the Event Streaming Platform[4]
Traffic/Crash Prediction and Proactive Management	Traffic/crash prediction and proactive management help provide Traffic Management Center (TMC) operators with traffic and crash management recommendations, including location and strategy, to proactively mitigate expected traffic or crashes.	Achieving Efficiencies within Ohio DOT with the Event Streaming Platform[4]

[3] Rekor. (2022). Texas Department of Transportation Standardizes on Rekor Systems' Cloud-based AI-driven Roadway Intelligence Platform.

[4] Ohio DOT. (2023). Achieving Efficiencies within ODOT with the Event Streaming Platform

Use Cases	Description	Source
Artificial Intelligence Crash Response Management	Artificial intelligence crash response management can be used to display information on live map technology that would include traffic slowdowns, active crashes, construction zones, road closures, etc. It can also display the location of public safety officers, allowing for swifter responses to the scene of an accident. Closed-circuit television (CCTV) system footage can give officers another viewpoint when responding to accidents to ensure the accidents have occurred at the reported locations. With this live map technology, authorities can click on the scene of an accident and receive all relevant information related to it, along with CCTV footage of the accident and information on current road conditions.	ITS Technology Use Case Library – Improving Bridge Travel Times With Lane Management, Richmond, California[5]
Automated Vehicles	Automated vehicles (AVs) have been implemented in various areas throughout the United States. They rapidly became more prevalent during the COVID-19 pandemic and in rural areas due to the lack of available public transportation. AVs are capable of driving people where they need to go, delivering food and groceries, and providing vital supplies while reducing the need for drivers.	ITS Technology Use Case Library – Improving Bridge Travel Times With Lane Management, Richmond, California[4]
Digital/Cloud-Based Alerting	Digital/cloud-based alerting has been proven to increase safety for roadside workers and prevent Emergency Medical Services (EMS) collisions by sending messages to nearby motorists of oncoming roadside construction, weather conditions, road closures, or emergency vehicles they are approaching. By providing this warning, drivers are more prepared for these hazards and can take preemptive measures, which have been shown to help decrease the number of accidents.	ITS Technology Use Case Library – Improving Bridge Travel Times With Lane Management, Richmond, California[4]
Automated Traffic Signal Performance Measures	Automated traffic signal performance measures can use intersection data and livestreaming to monitor the state of each intersection. These platforms are capable of alerting engineers about signal problems and outages. The city can use these data to make data-driven decisions to help improve traffic flow.	ITS Technology Use Case Library – Improving Bridge Travel Times With Lane Management, Richmond, California[4]

[5] ITS America. (2024). ITS Technology Use Case Library.

Use Cases	Description	Source
Dynamic Lanes	Dynamic lanes are large shoulders that can be opened during peak traffic conditions. These lanes can help improve incident response times and reduce congestion during peak periods and non-recurrent times such as holidays and sporting events. Variable speed controls and queue warning systems allow these lanes to be dynamically managed. These lanes can be opened and closed automatically or semi-automatically based on traffic demand with Cooperative and Automated Transportation (CAT) data.	ITS Technology Use Case Library – Improving Bridge Travel Times With Lane Management, Richmond, California[4]
Freight Operations Exchange	Freight Operations Exchange (FOX) serves as a central data management platform that reads, stores, analyzes, and reports data for the agency to use in screening trucks for inspection. By streamlining this process, weigh stations become less congested and transportation of freight vehicles becomes much more efficient.	ITS Technology Use Case Library – Improving Bridge Travel Times With Lane Management, Richmond, California[4]
Queue Warning	Queue warnings allow vehicles to receive a broadcast message from a nearby roadside unit (RSU) and give an appropriate response strategy when a substantial queue length is detected along the driver's route. This response can include lowering speed or taking an alternate route before approaching the queue. CAT data allows these queue lengths to be detected more accurately and be transmitted to the drivers quickly to help prevent issues such as increasing congestion or a potential rear-end collision.	Using Cooperative & Automated Transportation Data for Freeway Operational Strategies[6]
Ramp Metering	Ramp metering can be greatly enhanced using CAT data from nearby signalized intersections, loop detectors, connected vehicles (CVs), and cameras. This can allow the algorithm within the ramp metering system to determine the most optimal ramp metering rate. This helps reduce congestion on both the mainline and the on-ramp, avoid spillback, and increase merging safety.	Using Cooperative & Automated Transportation Data for Freeway Operational Strategies[6]
Speed Harmonization	Speed harmonization is used to send a broadcast message from a nearby RSU, letting drivers know whether they should reduce vehicle speed. This would help mitigate traffic breakdown for a given congestion-inducing event. CAT data can be used to accurately determine target speeds and reduce the time taken to calculate that speed and communicate it to drivers.	Using Cooperative & Automated Transportation Data for Freeway Operational Strategies[5]

[6] National Academies of Sciences, Engineering, and Medicine. (2024). Using Cooperative Automated Transportation Data for Freeway Operational Strategies.

Use Cases	Description	Source
Variable pricing	Variable pricing along roadways can be enhanced so that the price recommendations and the amount of time drivers can potentially save are as accurate as possible and are transmitted directly to them. This can be done using CV data in areas not covered by detectors in conjunction with traditional detector data and historical toll data to optimize the algorithm used to calculate toll prices and time estimations.	Using Cooperative & Automated Transportation Data for Freeway Operational Strategies[5]
Smart Parking Systems	Smart parking systems provide real-time parking information to drivers when they arrive at a specific location. Using sensor technology and cameras that detect vehicles, these systems employ dynamic signs to communicate the amount and locations of available parking.	What Is a Smart Parking System? Functionalities and Benefits[7]
Artificial Intelligence Based Transportation Management Systems	Artificial intelligence (AI) / machine learning (ML) processes can be trained to make informed decisions for Traffic Management Systems (TMSs) that could lead to enhanced efficiency, reduced costs, and the identification of new potential revenue streams.	Presentations at ITS America 2024, SIS61. Florida DOT and Ohio DOT Use Cases

[7] Burbano, L. (2021). What is a Smart Parking System? Functionalities and Benefits. Tomorrow City.

Appendix C: Impacts of CAT Data to Divisions

These impacts of Cooperative and Automated Transportation (CAT) data are based on general awareness of CAT data and the impacts it will have on various areas of transportation. Some divisions may already be deploying CAT data use cases in some manner and **Table 5** does not consider all potential current practices at the Texas Department of Transportation (TxDOT) and is just a sample of considerations.

Table 5: Impacts of CAT Data to Divisions

TxDOT Divisions	Impacts of CAT Data to Consider
Administration	Organizational changes to account for data governance, management, and analytics. Additionally, changes to current roles, responsibilities, and standard practices will be impacted by CAT data.
Communications	With further implementation of CAT data, the Communication Division should develop and deliver a public education and outreach plan to explain the importance of investing in digital infrastructure and how the public will benefit from using CAT data. Division personnel should be trained to better understand CAT data to enhance the resources for dissemination of information.
Construction	The Construction Division should consider requirements and the value in collecting CAT data for other user cases within construction practices. For example, tracking the additional necessary CAT data from construction vehicles such as equipment usage, fuel consumption, and safety. Utilizing connected fleets for construction and construction assets, such as smart cones and safety vest wearables can feed into work zone data exchanges and increase safety for active work zones.
Design	The Design Division should consider modifying procedures for preparing construction drawings, standards, specifications, and cost estimates, as well as further utilizing CAT data to support value engineering in optimizing designs. For example, CAT use cases may provide more granular, detailed, and recent data for infrastructure conditions, which can be used to enhance understanding of the life cycle of assets. Additionally, artificial intelligence (AI) / machine learning (ML) can be designed and used to better develop cost estimates for projects, thereby updating the current process for cost estimates.
Fleet Operations	The Fleet Operations Division should upgrade its vehicles by implementing devices or software that can track the necessary additional CAT data to make informed decisions relevant to fleet operations and optimizing supply chain management.
Human Resources	Human resources should hire and recruit, anticipating that data management and data governance roles will be needed in order to manage all this CAT data and applications.
Information Technology	The Information Technology Division should develop more tools necessary for further CAT data analysis and train employees on how these data can be used when creating tools for each division. These innovative data sets must be monitored for security concerns.
Maintenance	The Maintenance Division should consider changes to when and how it maintain roads through monitoring pavement conditions and maintenance vehicles and having remote light outage detecting capabilities.

TxDOT Divisions	Impacts of CAT Data to Consider
Materials and Tests	The Materials and Tests Division should investigate how these additional data may be used in selecting, procuring, and testing materials, systems, and technologies to optimize performance and available funding.
Professional Engineering Procurement Services	The Professional Engineering Procurement Services Division may apply additional CAT data in selecting and prioritizing projects to be included in the work program. For example, CAT data may highlight safety concerns from near-miss or compliance data compared to only utilizing crash data.
Public Transportation	The Public Transportation Division should upgrade its vehicles by implementing devices or software to track the necessary additional CAT data to improve passenger safety.
Research and Technology Implementation	The Research and Technology Implementation Division's focus should shift toward developing analytical tools that are further supported by CAT data and providing proper guidance to the other divisions in how CAT data can be used.
Strategic Initiatives and Innovation	The Strategic Programs and Innovation Division can continue to research and investigate how CAT data may be used through the discovery of industry trends and applications.
Traffic Safety	The Traffic Safety Division should consider changes to its processes to implement traffic safety measures by analyzing relevant CAT data (e.g., crash data, near-misses) and utilizing cloud alerts for the safety of workers and motorists.
Transportation Planning and Programming	The Transportation Planning and Programming Division should continue to implement CAT data in its decision-making process to optimize funding allocation for its programs. Additionally, it should work to manage the transition of the approval of data collection methodologies from old technologies to new.
Transportation Programs	Within the Transportation Program Division, the Engineering Operations Support sub-division should learn how to implement CAT data into its analytics.
Travel Information	The Travel Information Division should determine how to transmit CAT data to the public in a way that is easily digestible and leads to a clear understanding of travel alternatives to address specific needs (e.g., travel time, travel cost, mode, schedule, other user preferences). Also, this division may provide a consistent, standardized, and seamless release of data to the public (and their respective CAT technologies) across the entire state.