TEXAS VSL DEPLOYMENT

ATTAIN Grant Application

Volume 1 | Technical Application

Texas Department of Transportation

I. COVER SHEET & TABLE OF CONTENTS

Project Name	Texas Variable Speed Limit Deployment
Eligible Entity Applying to Receive Federal Funding	Texas Department of Transportation
Total Project Cost (from all sources)	$4,604,894.67
Advanced Transportation Technology and Innovation Program Request	$3,652,405.77
Are matching funds restricted to a specific project component? If so, which one?	No
State(s) in which the project is location?	Texas
Is this project currently programmed in the: ☐ Transportation Improvement Program ☐ Statewide Transportation Improvement Program ☐ MPO Long Range Transportation Plan ☐ State Long Range Transportation Plan	No
Technologies Proposed to Be Deployed (briefly list)	Changeable speed limit signs, mini-weather stations or sensor technologies, probe-based speed and travel time data, integration with Lonestar traffic management systems, road side units, connected vehicle data framework, performance monitoring dashboard
Will the project use connected vehicle technologies? If so, which technologies will be used – for instance, will the project use: ☒ DSRC/5.9 GHz spectrum? ☒ Cellular/ 4G/5G communications? ☐ Another connectivity technology (please specific – e.g., “Wi-Fi,” “Bluetooth,” “RFID,” etc.) If the connectivity has yet to be determined, please specific “TBD.”	Yes
Will the project use automated driving system technologies?	No
Rural Considerations: a. Is the project serving a rural area(s)? A rural area is an area with a population of less than 50,000 residents according to the 2020 Census population estimates. b. If yes, how much ATTAIN funding is being requested to be put toward serving the rural area(s)	 Yes $3,652,405.77

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II. PROJECT NARRATIVE

1. Project Summary

The Texas Department of Transportation (TxDOT) is seeking funding from the Advanced Transportation Technology and Innovation (ATTAIN) Program to implement TxDOT's first full-scale deployment of a variable speed limit (VSL) system. This deployment will include system planning and integration of VSL equipment supported by algorithms that will enhance TxDOT's connected framework. TxDOT selected one rural deployment location to demonstrate and refine TxDOT's processes and procedures for using VSL to proactively manage speeds.

Introducing Texas' Innovative Approach to VSL

VSL has traditionally been conveyed to drivers through the infrastructure on the roadway. Typical deployments of VSL require the use of warning signs to tell drivers that they are entering an area where the speed limit may vary and speed limit signs with dynamic variable speed displays to tell drivers the speed limit at the time. TxDOT proposes to innovate under the ATTAIN program by adding two new ways to alert drivers to VSL.

> *In 2023, Governor Greg Abbott signed House Bill 1885, allowing variable speed limits to be used on Texas roads in locations that have construction, inclement weather, congestion, or any other condition that affects the safe and orderly movement of traffic.*

First, roadside units (RSU)—wireless communication devices located on the side of the road—will communicate with connected vehicles. If a driver is performing driving tasks, the vehicle will alert the driver to the change in speed. If a vehicle is in an autonomous mode, the vehicle will adjust its speed accordingly.

The second novel approach to inform drivers of speed limit changes is for the infrastructure to communicate with third-party travel information applications. The following diagram illustrates the three-prong approach to communicating a VSL.

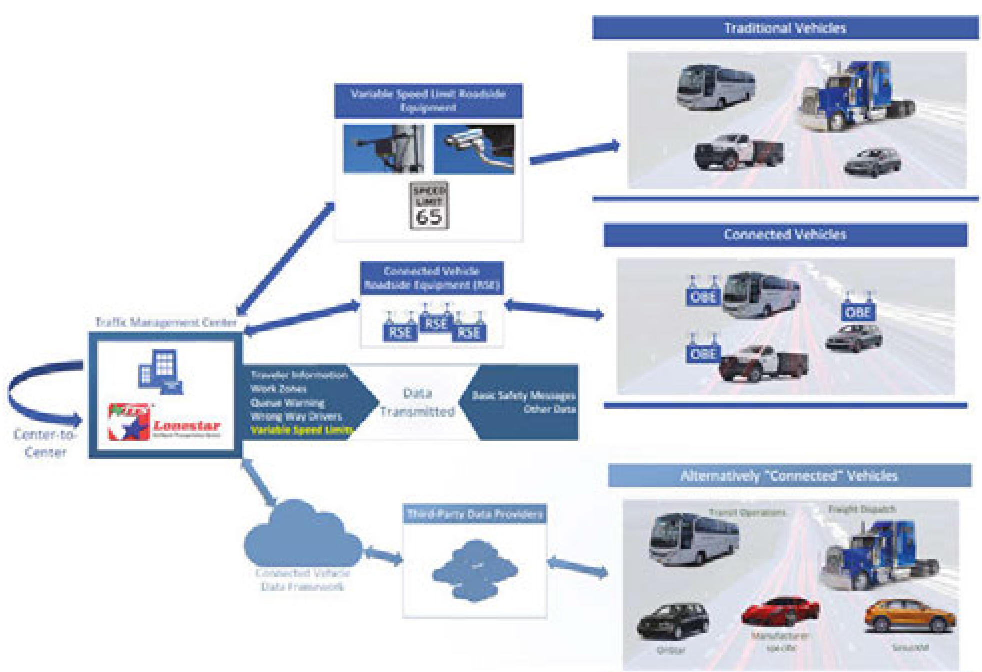


Figure 1: *VSL Integration and Dissemination Strategies (SwRI, 2024)*

This project will build on the mature intelligent transportation system (ITS) technologies already deployed in TxDOT Districts statewide. Through the Texas Connected Freight Corridor (TCFC) project, TxDOT has implemented the use of RSUs for vehicle-to-infrastructure (V2I) applications. What TxDOT proposes to do with the ATTAIN grant is configure infrastructure-to-vehicle (I2V) connectivity, and integrate with third-party travel information applications like Google Maps.

2. Geographic Location

The location for implementation of VSL in Texas was identified through a process of evaluating corridors that had existing ITS infrastructure and a history of crashes with contributing circumstances related to weather, congestion, and multi-vehicle crashes. The selected segment is Interstate 20 (I-20) in rural Eastland and Erath Counties. This location represents a variety of real-world issues experienced throughout the nation, as detailed in subsequent sections of this application. *Figure 2* shows the location of the segment.

Figure 2: *Proposed VSL deployment location*

I-20 in Rural Texas

The I-20 corridor (eastbound and westbound) in Eastland and Erath Counties is approximately 29 miles in length (58 miles total). The corridor is located entirely in a rural area, stretching from State Highway (SH) 112 in Eastland County east to SH 108 in Erath County. Between 2019 and 2023, there were 731 crashes along this segment of I-20. This corridor is significant because of the steeply graded hill which features a curve in the roadway. Additionally, the area has a history of icy roads and foggy conditions contributing to crashes.

I-20 Corridor	
Census Tracts	**Historically Disadvantaged**
48133950100	Yes
48133950200	Yes
48143950100	No
48363000200	Yes

Segment Location: I-20 from SH 112 in Eastland to SH 108 east of Thurber.
Segment Mileage: 29 miles in each direction (58 miles total)
Rural/Urban Designation: Rural
Current ITS Deployments: DMS, Fiber Optics, and Cameras
Disadvantaged Tracts: 75%

3. Issues and Challenges to be Addressed by the Proposed Technology

TxDOT's number one priority is safety. Despite the Department's efforts to build and maintain roads and educate Texans on safe driving behaviors, traffic fatalities continue to occur. For more than two decades, at least one person has died on Texas roadways every day. In calendar year 2022, 4,481 people died in Texas traffic crashes. This VSL deployment is a critical element in TxDOT's Road to Zero initiative to help end the streak of daily deaths on Texas roadways.

Real-World Issues Addressed by this Project

In February 2021, a catastrophic event unfolded on I-35W in Fort Worth, Texas. A massive 130-vehicle pileup triggered by unusually icy conditions on an elevated roadway resulted in the tragic loss of six lives. This area, typically unfamiliar with such extreme weather, was ill-prepared for the icy challenge, underscoring a critical need for improved road safety measures.

The NTSB investigation of the February 2021 pileup on I-35W recommended implementation of environmental sensor stations at strategic locations and the introduction of VSL signs to better manage traffic under diverse road conditions.

February 27, 2023 Highway Investigation Report HIR-23-01

Multivehicle Crash in Icy Conditions on Interstate 35 West

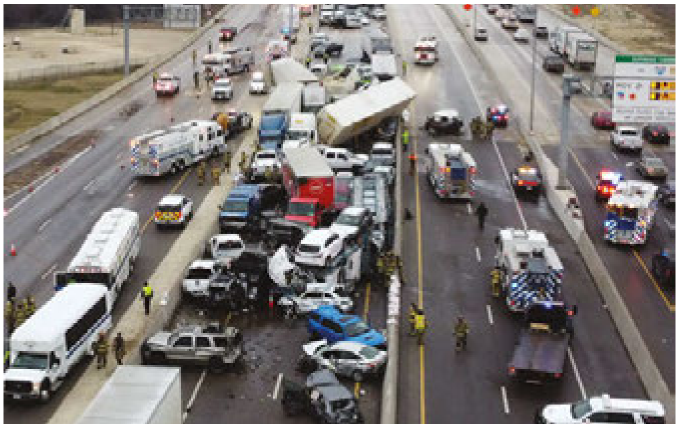
Fort Worth, Texas
February 11, 2021

Abstract: On the morning of Thursday, February 11, 2021, a multivehicle crash occurred in the southbound toll lanes of Interstate 35 West (I-35W), in Fort Worth, Tarrant County, Texas. The crash sequence began on an elevated portion of the roadway near the exit to Northside Drive and ultimately involved 130 vehicles. In the days before the crash, the area had experienced 36 consecutive hours of below-freezing temperatures. In anticipation of forecast freezing rain and sleet, North

In response to this disaster, the National Transportation Safety Board (NTSB) conducted a thorough investigation. Their findings emphasized the urgent need for Texas to enhance its road safety infrastructure, particularly in terms of responding to extreme weather conditions. The NTSB recommended the implementation of environmental sensor stations at strategic locations and the introduction of VSL signs to better manage traffic under adverse road conditions.

In June 2023, the Texas legislature passed House Bill 1885, empowering TxDOT to use VSL on its roadways. This law allows for the temporary reduction of speed limits in response to various factors such as inclement weather, congestion, or road construction, ultimately aiming to enhance the safe and orderly movement of traffic.

Through this legislative breakthrough and implementing lessons learned from previous technology deployments, TxDOT, in collaboration with the University of Texas at Austin Center for Transportation Research (CTR), Southwest Research Institute (SwRI), and Texas A&M Transportation Institute (TTI), is seeking funding from the ATTAIN program to implement Texas's first full-scale VSL system. This innovative technology comprises an integrated network of digital speed limit signs, changeable message signs, video cameras, and traffic detection sensors, all supported by sophisticated algorithms. This setup is designed to improve TxDOT's connected framework, enabling proactive adjustments of speed limits to enhance safety and mobility under varying conditions.



Source: Dallas Morning News, February 2021

For the initial deployment, TxDOT has identified a segment that will allow for the integration of VSL into existing corridor technology, with ample right of way to allow for straightforward installation and monitoring. The segment was also chosen based on a statewide analysis of crashes, congestion, and weather events. The location presents unique opportunities for the effective deployment of VSL technology and the segment is located on the Strategic Highway Network (STRAHNET), used for rapid mobilization and deployment of armed forces in the event of war or peacekeeping activity.

The I-20 corridor in Rural Texas is a 29-mile stretch west of Fort Worth with a posted speed of limit of 75 miles per hour (mph). *Figure 4* (in the Appendix) shows the crash severity and hotspots along this corridor. Of the 731 crashes between 2019 and 2023, weather was a factor in 387 of the crashes—more than half. Rain accounted for 65% of the weather related incidents and accounted for most of the fatal or serious injury crashes. According to the Insurance Institute for Highway Safety, "…when impact speed increases from 40 to 60 mph, the energy that needs to be managed increases by 125%" (IIHS, 2024). Providing an enforceable reminder to slow down in this rural corridor during inclement weather brings Texas one step closer to ending the streak of traffic deaths.

The Annual Average Daily Traffic (AADT) on this 58-mile rural segment (29-miles in each direction) of I-20 ranges from 25,832 to 25,880 with truck volume ranging from 44.4% to 47.8%. This fast growing segment of roadway is expected to have a 60% increase in traffic by the year 2042. The United States Department of Transportation (USDOT)'s Freight Analysis Framework value of freight moving along this Primary Freight Highway Network corridor segment exceeds $28 billion. The route is one of the key supply chains identified in *Texas Delivers 2050*, the 2023 TxDOT State Freight Plan. Truck delay per mile was 1,062 truck hours, resulting in a truck congestion cost of $3.4 million. *Texas Delivers 2050* notes that Texas will need to implement sufficient capacity and reliability along I-20 to transport heavy machinery and drilling inputs from supplier and distributors to support this critical supply chain. Due to the high percentage of trucks and the heavy cargo being transported, improvements in this corridor to reduce speed differential and manage unforeseen weather events will substantially increase the safety for all drivers and reliability for the freight industry.

How the Project Addresses the Goals of the ATTAIN Program

The deployment requested through this grant application addresses several goals of the ATTAIN program, as described in this section.

Advanced Data Collection

A VSL system collects information on traffic speed, lane occupancy, traffic volume, visibility, and road surface conditions in real-time to determine the appropriate speeds at which drivers should be traveling. The components are connected to a communications infrastructure which feeds the data to a traffic management center. There, management personnel are able to observe live traffic and weather conditions, in addition to any digital speed limit signs that have been deployed. Although an operator may manually make changes to the speed limit, most often an algorithm designed by an engineer will automatically adjust the posted speeds.

Crash Reduction

The use of VSL during less than ideal conditions, such as during heavy traffic and adverse weather, can improve safety by both decreasing the risks of traveling at speeds that are higher than appropriate for the conditions and by reducing speed variance among vehicles. In addition, VSL can be used to dynamically manage speed during planned and unplanned events, like daily rush hours and sporadic incidents. The algorithm responds to downstream congestion to eliminate or delay bottlenecks and mitigate the risk of crashes.

Research from the Federal Highway Administration (FHWA) underscores the potential impact of this project. VSL systems have been shown to reduce total freeway crashes by up to 34%, rear-end crashes by up to 65%, and fatal and injury crashes by up to 51% (Avelar et al., 2020). These numbers highlight the significant safety benefits that the VSL system could bring to Texas roadways.

Infrastructure Return on Investment

The location selected for deployment already has a baseline Advanced Traffic Management System (ATMS) infrastructure, which uses advanced traveler information system technologies to post travel time, incident, construction, and general weather warning messages on dynamic message signs throughout the state. The infrastructure is connected to Lonestar™, TxDOT's ATMS software, the intermediary between ITS devices and the district Transportation Management Centers. Lonestar™ has several software processes to make connected components useful for various operations. The VSL system components intended to harmonize traffic (visibility sensors, friction sensors, radar sensors, closed-circuit cameras, digital regulatory speed limit signs, variable speed limit warning signs, and fiber or cellular communication infrastructure) will ultimately augment any traffic management operation. The VSL project will maximize the return on investment of existing infrastructure by adding technologies that expand the scope of the ITS network. A diagram showing the typical section of a rural deployment is included in the appendix as *Figure 5*.

Mobility & Efficiency

For this deployment, Lonestar™ will be configured to manage the VSL system and disseminate traffic information to the ITS website, Dynamic Message Signs, navigation applications, and connected vehicles. Travelers will know traffic conditions specific to their segments in advance, allowing them time to plan their most efficient route. Transportation providers will be able to make real-time routing decisions using the live data, or archived data to plan long-term programs.

Implementation of VSL aligns with the goals of *Texas Delivers 2050* approved in 2023. The applicable goals are:

- Safety, efficiency, and performance of the freight network
- Improve the performance of the freight network to enhance contribution of transportation infrastructure to economic competitiveness, productivity, and development
- Maintain, preserve and modernize assets on the network to support movement of goods and people
- Reduce congestion and improve system efficiency and performance of the freight network
- Develop and maintain a resilient and secure multimodal system that can withstand and respond to various sources of disruption

Implementation of VSL also aligns with policy recommendations contained in *Texas Delivers 2050*.

- Partner with local agencies on strategies to address urban freight congestion and bottlenecks
- Address freight movement safety hot spots in coordination with planning partners
- Monitor and support policies that encourage technology deployment while ensuring public interests are protected
- Expand the development of advanced real-time information systems and dissemination of information
- Explore technology enhancements for freight bottleneck relief

4. Project Requirements

The following section details how the proposed project addresses the requirements contained in Section A.4 of the Notice of Funding Opportunity (NOFO), including Program Vision, Program Goals, the Administration's Priorities, and DOT Focus Areas.

Alignment with Vision of the ATTAIN Program

This project aligns with FHWA's vision for the ATTAIN program by addressing safety and mobility issues through the deployment of a VSL system. The system will be integrated into routine functions of the local highway system and existing third-party navigation application providers. The VSL deployment will provide benefits by maximizing efficiencies based on the intelligent management of assets and the sharing of information using integrated technology solutions. Lessons learned from the deployment of the VSL system in this area will advise future VSL deployments in Texas and around the country.

Alignment with Goals of the ATTAIN Program

At its core, the VSL program is designed to address safety concerns. By dynamically adjusting speed limits according to real-time road conditions, such as congestion, adverse weather, and construction zones, it will significantly reduce the number and severity of traffic crashes. This approach will bring a notable improvement in safety for drivers, passengers, and pedestrians, making Texas roads safer for everyone and supporting national freight movement for key commodities including semiconductors. *Table 1* shows the ATTAIN project goals considered in this application, which are described in this section:

Table 1: *ATTAIN Program Goals Addressed by Application*

	Program Goals	Implemented Addressed by Application (Check all that apply)
1.	Reduction in the number and severity of traffic crashes and an increase in driver, passenger, and pedestrian safety;	X
2.	Delivery of economic benefits by reducing delays, improving system performance and throughput, and providing for the efficient and reliable movement of people, goods, and services;	X
3.	Demonstration, quantification, and evaluation of the impact of these advanced technologies, strategies, and applications towards improved safety, efficiency, equity, and sustainable movement of people and goods;	X
4.	Improvement in the mobility of people and goods;	X
5.	Improvement in the durability and extension of the life of transportation infrastructure;	

	Program Goals	Implemented Addressed by Application (Check all that apply)
6.	Reduced costs and improved return on investments, including through the enhanced use of existing transportation capacity;	X
7.	Protection of the environment and delivery of environmental benefits that alleviate congestion and streamline traffic flow;	X
8.	Measurement and improvement of the operational performance of the applicable transportation networks;	X
9.	Collection, dissemination, and use of real-time transportation-related information including, but not limited to, work zone, weather, transit, and paratransit, to improve mobility, reduce congestion, and provide for more efficient and accessible, and integrated transportation, including access to safe, reliable, and affordable connections to employment, education, healthcare, freight facilities, and other services;	X
10.	Facilitating account-based payments for transportation access and services and integrating payment systems across modes;	
11.	Monitoring transportation assets to improve infrastructure management, reduce maintenance costs, prioritize investment decisions, and ensure a state of good repair;	
12.	Accelerated deployment of V2V, V2I, vehicle-to-pedestrian, and technologies associated with automated vehicle applications and other advanced technologies	X
13.	Integration of advanced technologies into transportation system management and operations;	X
14.	Reproducibility of successful systems and services for technology and knowledge transfer to other locations facing similar challenges;	X
15.	Incentivizing travelers— (I) to share trips during periods in which travel demand exceeds system capacity; or (II) to shift trips to periods in which travel demand does not exceed system capacity.	

Reduction in the number and severity of traffic crashes and an increase in driver, passenger, and pedestrian safety.

The TxDOT VSL program significantly enhances road safety by dynamically adjusting speed limits based on real-time road conditions such as congestion, weather, and construction. This data-driven approach, mandated by Texas law to be based on engineering and traffic investigations, allows for speed limits that are optimized for current conditions, thereby reducing the risk of crashes. The FHWA notes that VSLs can reduce total freeway crashes by up to 34%, rear-end crashes by up to 65%, and fatal and injury crashes by up to 51%.

The program's comprehensive planning includes detailed system design, technological integration with advanced monitoring and display equipment, and collaboration with law enforcement for effective enforcement. These elements collectively contribute to the program's goal of decreasing the number and severity of traffic crashes and increasing overall safety for roadway users.

Delivery of economic benefits by reducing delays, improving system performance and throughput, and providing for the safe, efficient, and reliable movement of people, goods, and services.

VSL contributes to a smoother and more consistent traffic flow, reducing the likelihood of crashes and their associated costs. USDOT's *Developing Crash Modification Factors for Variable Speed Limits* includes a case study in Georgia that most directly applies to the traffic conditions and deployment plan in Texas. For a maximum AADT of 242,000, an installation cost of $1.03 million per directional mile, and $165,000 budgeted per year for maintenance and law enforcement, researchers observed a benefit-to-cost ratio of 40.4 (Avelar et al., 2020). VSL promises significant economic benefits through improved traffic efficiency and safety, aligning with the broader goals of enhancing the transportation system's performance.

Demonstration, quantification, and evaluation of the impact of these advanced technologies, strategies, and applications towards improved safety, efficiency, equity, and sustainable movement of people and goods.

Further results from Georgia's case study demonstrated a reduction in crash rate for the following categories:

Total Crash Reduction 29.2%			
Daytime	27.2%	**Nighttime**	45.3%
Fatal & Injury	11%	**Rear-End**	35.2%

Source: Avelar et al., 2020

The VSL program is grounded in robust national research showing a decrease in crashes by up to 34%. Its deployment involves systematic evaluation and quantification of impacts, serving as a demonstrable model for advanced transportation technologies and strategies. By dynamically adjusting speed limits in response to real-time conditions such as congestion, adverse weather, and work zones, the program promotes safer and more efficient journeys for both commuters and the transportation of goods. It mitigates crashes, reduces delivery times, and promotes equitable access to transportation options, all while contributing to sustainability through improved traffic management and reduced emissions.

Improve the mobility of people and goods.

VSL systems allow for quicker recovery of bottlenecks as a result of crash events. This is accomplished by providing adaptable speed limits that respond to real-time road conditions, thereby facilitating smoother and more predictable travel. The VSL system, by reducing speed differentials and mitigating congestion, promotes a more consistent and efficient flow of traffic.

Reduced costs and improved return on investments, including through the enhanced use of existing transportation capacity.

VSL's systems reduce crashes and maximize capacity of the existing transportation infrastructure. System management tools like VSL reduce bottleneck issues on corridors that are near capacity. By using VSL in coordination with other system management approaches, TxDOT can reduce congestion and improve on-time performance without increased road miles.

Protection of the environment and delivery of environmental benefits that alleviate congestion and streamline traffic flow.

VSL deployments help promote smoother traffic flow and reduced traffic congestion, which can lead to lower fuel consumption and decreased greenhouse gas emissions. Improved traffic flow and reduced congestion lead to fewer idling vehicles and lower emissions, contributing to cleaner air quality and reduced noise. VSL programs also contribute to energy savings by reducing traffic-related energy consumption. This leveling of traffic flow also has a monetary benefit to drivers, as less fuel is consumed when a car is being operated at a consistent rate of speed.

Measurement and improvement of the operational performance of the applicable transportation networks.

VSL systems reduce crashes and congestion, ultimately leading to improved safety and mobility. The deployment strategy that is proposed by TxDOT considers strategies for evaluation of operational performance during the design process. Being able to evaluate metrics related to the goals of the program is important to this first full-scale deployment in Texas, as it will provide valuable insights that can be used to inform future deployments.

Collection, dissemination, and use of real-time traffic-related information including, but not limited to, work zone, weather, transit, paratransit and parking, to improve mobility, reduce congestion, and provide for more efficient and accessible, and integrated transportation services.

The VSL program effectively aligns with the goal of enhancing real-time traffic management by dynamically adjusting speed limits based on road conditions, congestion, and weather. Integrating with the Lonestar™ system, it uses live data from sensors and cameras, supported by algorithms, to optimize traffic flow and improve safety. This proactive approach not only enhances mobility and reduces congestion but also promotes efficient and integrated transportation systems. With its focus on data-driven decision-making and public information dissemination, the VSL program represents a scalable and adaptable solution for contemporary traffic challenges, balancing technology and operational efficiency.

Accelerated deployment of V2V, V2I, vehicle-to-pedestrian, and technologies associated with automated vehicles and other advanced technologies.

The VSL program aligns with the accelerated deployment of advanced technologies like V2V and V2I, and will include robust communication infrastructure and redundant traffic detection for efficient technology functionality. VSL relies on sophisticated traffic detection and communication systems for real-time speed limit adjustments. This augmentation of TxDOT's ITS network represents a significant step towards embracing infrastructure-to-vehicle and automated vehicle technologies in traffic management. An I2V interaction will be established that shares relevant traffic data with external navigation applications. The inclusion of VSL is part of a unique strategy package forming the Connected Vehicle Data Framework (CVDF). This framework is designed to allow third-party data services the ability to integrate with transportation networks to access and share notifications with their users. The idea of the CVDF originated from the *Connected Vehicle Pooled Fund Study* (CV PFS), which aimed to create standardized interfaces for third parties to facilitate I2V communication. TxDOT's participation in the CV PFS underlines their dedication to collaborating with research and USDOT's partners across the country to explore, assess, and deploy innovative solutions for transportation and mobility challenges.

Integration of advanced technologies into transportation system management and operations.

VSL deployment is a prime example of integrating advanced technologies into transportation management, utilizing dynamic message signs, environmental sensors, and data algorithms for real-time operational decisions. This integration enhances overall traffic system management and operations, leading to safer, more efficient roadways.

The use of algorithms plays a crucial role in the VSL system. The algorithms are used for automated control and decision-making in VSL operations. These algorithms can activate or deactivate VSLs based on predefined threshold conditions, notify operators for manual confirmation, and maintain a log of VSL activity. Additionally, algorithms are responsible for updating displayed speed limits on signs without constant operator intervention and incorporating data smoothing procedures. The selection and calibration of these algorithms depend on system goals and require careful tuning, especially for real-time decision-making during traffic congestion.

Reproducibility of successful systems and services for technology and knowledge transfer to other locations facing similar challenges.

Focusing efforts on segments that address safety, mobility, and the efficient movement of freight allows for implementable solutions that can be deployed in other strategically prioritized locations in Texas. The deployment of VSL described in this application prioritizes the development of plans and processes that will allow for scaling and replicability, both in Texas and nationwide. Using system integration approaches to connect VSL with the corridor management tools that are already deployed in a specific segment, such as ramp metering or managed lanes, improve the effectiveness and flexibility of the system. The partnership with TTI, CTR and SwRI will enhance the evaluation of the deployment through strong methodology and analysis. The results of the evaluation will be translated into research publications and presentations focused on improving the state of the practice for system management.

Alignment with Administration Priorities

Table 2: *FHWA Priorities Addressed by Application*

Administration's Priorities	Implemented Addressed by Application (Check all that apply)
1. Safety	X
2. Climate Change and Sustainability	X
3. Equity	X
4. Workforce Development, Job Quality, and Wealth Creation	X

This project represents a strategic investment aimed at bolstering safety. The deployment of a VSL system, a technology designed to **enhance safety** of highway motorists, would actively promote and instill safe driving behaviors, consequently reducing the risk of severe crashes.

Beyond its primary safety-related goals, the integrated VSL system offers an additional advantage in the form of **congestion reduction**. By optimizing the efficiency of the existing highway, this system holds the potential to reduce traffic congestion, a positive outcome with far-reaching implications. Not only does reduced congestion enhance the overall functionality of the roadway, but it also contributes to a decrease in pollutant emissions.

The geographical focus of this project is on improving an existing roadway situated in an area identified as a **disadvantaged community**. This dual-purpose approach not only addresses safety concerns for roadway users but also aligns with the broader objectives of promoting fairness in infrastructure development and environmental stewardship.

ConnectU2Jobs (CU2J) is a joint effort between FHWA's Highway Construction Workforce program and the TxDOT Civil Rights Division created to fill a need for a skilled highway construction workforce in Texas. Heavy highway skills will always be essential. This industry offers job security, above-average wages, and a career ladder for those willing to put in the work. CU2J includes about 24 partners, such as community organizations, education agencies, and industry employers.

Alignment with DOT Focus Areas

Table 3: *DOT Focus Areas Addressed by Application*

DOT Focus Areas	Implemented Addressed by Application (Check all that apply)
1. State of Good Repair	X
2. Integration of intelligent transportation systems with the Smart Grid and other energy distribution and charging systems	
3. Advanced public transportation systems	X
4. Freight (or Port) Community Systems	X
5. ROUTES Initiative	X
6. Complete Trip Program	X
7. Data Availability	X

The VSL deployment project identified for this grant aligns well with the USDOT's focus areas. Using both TxDOT and USDOT's focus areas as guiding points allows for a holistic and structured approach to evaluating the impact and effectiveness of the VSL program, aligning with broader transportation goals and priorities.

State of Good Repair

State of Good Repair focuses on maintaining transportation facilities and systems to optimize the investment. In the context of the VSL program, its success can be assessed through various metrics:

- **Infrastructure Damage Reduction:** One key metric is the reduction in road infrastructure damage caused by crashes. By facilitating smoother traffic flow and minimizing congestion-related crashes, VSL contributes to a decrease in the number of barrier wall, guardrail, guard cable, crash cushions, and sign posts, and light poles that are destroyed or damaged due to a crash.
- **Maintenance Cost Savings:** The deployment of VSL will occur in a location that already has connected equipment installed. CCTV installed as part of this system will provide traffic managers a consistent view of the physical infrastructure. This feature will become a tool used to identify needs without the time and cost of a field visit. Additionally, the specific data collected for each segment will allow maintenance operators to prioritize time-sensitive activities like salting for winter weather, responding to flooded areas, or avoiding work in foggy conditions. The view from the traffic management center and data available from the various roadside components—used for prevention and planning—will be immensely valuable to TxDOT's bottom line.

Freight Efficiency

Traffic oscillations, known more commonly as "stop-and-go" driving conditions in heavily congested traffic, reduce capacity, increase safety risks, delay travel, and increase fuel consumption. A form of speed harmonization, VSLs intend to slow traffic ahead of congestion in order to reduce operational recovery time. Efficiency in freight movement can be enhanced by VSL, with metrics for success including:

- **Shorter Delivery Times:** VSL can contribute to shorter delivery times for freight shipments. Improved traffic flow reduces wasted time and supports timely deliveries.
- **Supply Chain Reliability:** An essential metric is the improvement in supply chain reliability. Reduced congestion-related delays lead to more dependable supply chains and fewer disruptions to freight operations. This reliability is especially critical for the just-in-time supply chains of advanced manufacturing and warehousing and distribution.

- **Reduction in Freight-Related Costs:** The VSL program can be evaluated by its impact on reducing freight-related crashes and costs. Lower crash rates and fuel consumption due to congestion will save drivers time and money, contributing to the industry's bottom line.

Rural Opportunities to Use Transportation for Economic Success (ROUTES) Initiative

According to *Texas Mobility 2050*, rural truck-involved crashes are three times as likely to be fatal as urban truck-involved crashes. Implementing a VSL in a rural environment through this deployment will provide important information on the effectiveness of the technology in rural, high-speed conditions. VSL deployment in rural areas can be evaluated through metrics such as:

- **Improved Access:** In 2021, Texas scored a 1.17 to a target of 1.12 on the Rural Reliability Index that represents the average traffic congestion and travel times on rural Texas roadways (*https://www.txdot.gov/data*). Success can be measured by assessing improved access to transportation services for rural residents. Reduced travel times and enhanced road safety contribute to better access, particularly during uncommon weather events for the area.
- **Safety Enhancement:** Metrics will focus on safety enhancements on rural roadways. Reduced crash rates and improved overall road safety serve as measurable outcomes. Increased visibility to road conditions in rural areas will be an advantage for first responders.

Complete Trip Program

The VSL program indirectly supports the Complete Trip Program through metrics that emphasize:

- **Travel Experience Improvement:** Texas residents experienced 23.5 hours of delay in 2021 (*https://www.txdot.gov/data*). Hours of delay on Texas roadways incurs time and cost for businesses and the general population. Implementation of VSL will include improvements in the overall travel experience, such as reduced travel times, smoother trips, and fewer disruptions.

Data Availability

Data availability is crucial for informed decision-making in the VSL program, with metrics including:

- **Quantity and Quality of Data:** Success can be gauged by evaluating the quantity and quality of data collected on traffic conditions, weather, and VSL operations. Higher data availability and accuracy contribute to program effectiveness.
- **Data Utilization:** Metrics will also focus on the utilization of collected data. Effective use of data for evaluating program effectiveness, assessing costs and benefits, and informing transportation management strategies is a key indicator of success.

5. Transportation Systems and Services to be Included

As TxDOT's first permanent deployment of VSL, this project will require the development and implementation of guiding materials, including system requirements, safety plans, detailed design, and operating plans. Historically, VSL deployments have been infrastructure intensive. Traditional VSL deployments use a network of traffic speed and volume sensors, sign gantries with electronic changeable speed limit signs every 0.5 to 1.5 miles, and weather sensors to measure and assess prevailing travel conditions. Computer algorithms process data for the system and automatically determine the appropriate speed limits to be posted on the electronic signs. Two types of speed control algorithms are commonly deployed to improve safety: 1) those focused on harmonizing speed and 2) those focused on improving mobility and reducing environmental impacts. This deployment will focus on both.

Through this grant, TxDOT will implement augmenting systems and technologies that support a VSL deployment. As part of this grant, TxDOT will:

- Design, procure and install dynamic changeable speed limit signs.
- Deploy mini-weather stations or sensor technologies for detecting deteriorating road conditions due to inclement weather.
- Integrate probe-based speed and travel time data (such as from INRIX or similar sources) into control algorithms.
- Procure and deploy additional V2X technologies to support future integration of connected and automated vehicles operations.
- Integrate Lonestar™ variable speed limit module support into the connected vehicle (CV) frameworks, to include formatting VSL information into traveler information messages (TIMs) and third-party navigation applications.
- Broadcast road safety messages triggered by field RSU pipeline collecting and processing speed and weather condition information for interpretation by the algorithm.
- Implement and integrate center-to-center VSL support into the CVDF (inter-district communication), to include adding support for interfaces and queries of VSL data by region.
- Deploy a performance monitoring and management system and dashboards for use in assessing the effectiveness of the VSL under different operating conditions. This system will maintain a record of the regulatory speed limits posted and the condition and justification for the posted speed limits.

6. Deployment Plan and Lifecycle Management

This deployment will focus on one corridor which will inform the future scaling up to a larger adoption on the TxDOT system. The intent of this deployment is to implement VSL as part of an integrated corridor management system. The identified segments are equipped with ITS managed through TxDOT's Lonestar™ freeway management system, which will connect VSL with other system management strategies deployed in the location and enhances the effectiveness of previous investments. The following section will describe the tasks associated with deployment and operations.

Deployment Plan

TxDOT is a national leader in exploring and deploying technological solutions to improve roadway safety and mobility. This deployment plan is based on lessons learned from the pilot deployment in 2015 and consistent with current Texas State Statute related to VSL use. The deployment plan for VSL includes several stakeholders and follows a project management approach that has been successful in previous technology solution deployments. The deployment will consists of three tasks, and is presented fully in the Deployment Schedule section of this proposal. The three tasks are:

- **Task 1:** Planning and High-Level Design
- **Task 2:** Detailed Design, Build, and Deployment
- **Task 3:** Maintain and Operate

This strong deployment process includes technology development and integration, testing, stakeholder engagement, and public education, setting the project up for success.

Plan for Long-term VSL Operation

This initial deployment is intended to pave the way for future widescale adoption on the TxDOT system. Throughout this deployment, evaluation will be conducted by research partners TTI, CTR, and SwRI. They will establish performance measures to help TxDOT with determining deployment efficacy and appropriate locations and conditions for future adoption. With the results from this deployment, VSL will be included in a package of strategies that will make up a first-of-its-kind implementation of a connected vehicle data framework to enable third-party data services to distribute a host of infrastructure notifications to their user networks. The CVDF concept was born out of a CV PFS seeking to develop a set of common interfaces for third parties to enable I2V messaging. Involvement in the CV PFS reinforces TxDOT's commitment to work with nationwide research and DOT partners to test, evaluate and implement cutting-edge solutions to transportation and mobility problems.

Plan for VSL Maintenance

The ATTAIN grant will support the operation and maintenance (O&M) of the system during the initial stages of the project. TxDOT, working with its partners, will determine the appropriate entity with responsibility for operations and maintenance of the different elements of the deployment. These entities will work to create appropriate funding in their respective budgets to support the long-term O&M. The long-term O&M migration plan from the project funds will be completed a minimum of one year prior to the end of the award period. This allows for sufficient time to allocate the O&M funds within the appropriate fiscal year of each entity.

7. Obstacles to Deployment

TxDOT does not anticipate any regulatory, legislative, or institutional obstacles to deployment. Recently, Texas House Bill 1885 was passed in the 88th regular legislative session. Section 545.353, Texas Transportation Code, was amended to provide TxDOT regulatory latitude to decrease speed limits to address risk related to inclement weather, congestion, road construction, or any other condition that affects the safe and orderly movement of traffic. H.B. 1885 was presented by the chair of the transportation subcommittee and it was passed with little amendment. The largest obstacle to deployment of a successful VSL system will be driver compliance. Institutional support will come from state and local law enforcement which will focus on enhancing compliance through enforcement.

8. Quantifiable System Performance Improvements

The implementation of VSL stands as a pivotal strategy in advancing the TxDOT transportation infrastructure, backed by data-driven results and tangible improvements in various key areas. This approach not only addresses immediate traffic concerns but also aligns with long-term goals of managing congestion at the system level, improving access to transportation services, and ensuring financial sustainability in infrastructure management. TxDOT will evaluate system performance of this implementation based on the goals for the ATTAIN program and other measurement items, as described in this section.

System Performance Metrics

Many benefits of VSL deployment are experienced through improvements to system performance. Quantifiable system performance improvements include traffic flow metrics such as evaluating the duration of congested conditions and assessing the VSL system's ability to maintain or increase the number of vehicles passing through a segment of highway. Optimizing existing roadway capacity represents thoughtful stewardship of transportation investments. Measuring successes and failures will influence future deployments of similar technologies.

Measurement Items:
Congestion Duration — Evaluate the duration and severity of congestion during peak periods with and without VSL interventions.

Throughput — Assess the system's ability to maintain or increase the number of vehicles passing through a segment of the highway.

Adaptation to Inclement Weather Metrics

The VSL system significantly enhances the adaptability of TxDOT's transportation infrastructure to inclement weather, a critical aspect for ensuring road safety and efficiency. Key metrics such as system response time and the reduction in weather-related incidents are pivotal in this regard. The VSL system's effectiveness is measured through its ability to adapt and manage traffic flow during adverse weather conditions, which is reflected in the Incident Response Time. This metric evaluates how quickly the system can respond to changing weather conditions and implement necessary speed adjustments . The VSL system plays a vital role in reducing the frequency and severity of weather-related crashes.

Measurement Items:
System Response Time — Measure the system's effectiveness in adapting to and managing traffic during adverse weather conditions.

Reduction in Weather Related Crashes — Track changes in the frequency and severity of incidents during adverse weather with VSL interventions.

ITS System Reliability Metrics

The reliability of VSL systems within the TxDOT transportation network is critically assessed through focusing on the robustness and consistency of the ITS system's performance. One such vital metric is the reliability of communication systems, which evaluates the dependability and promptness of the communication networks responsible for modifying speed limits. This metric is essential to measuring the timeliness and accuracy of speed limit changes communicated to drivers, particularly during rapidly changing road conditions or emergencies. Another significant metric is system downtime, which involves measuring the frequency and duration of any ITS system failures or downtimes. Minimizing system downtime is crucial for maintaining continuous traffic management and safety measures. By closely monitoring these metrics, TxDOT can verify that the VSL system operates reliably, maintaining consistent communication with drivers and reducing the impact of any potential system interruptions.

Measurement Items:
Reliability of Communications Systems — Evaluate the reliability and responsiveness of the communication systems used to change the speed limit.

System Downtime — Measure the frequency and duration of system downtimes or failures.

Emergency Response Metrics

Within the TxDOT transportation infrastructure, the deployment of VSL has the potential for improving emergency response. A crucial metric in this regard is the response time for emergency vehicles. VSL systems allow authorities to dynamically adjust speed limits in response to traffic conditions. During emergencies, VSL systems can optimize traffic flow to reduce delays so emergency responders can reach their destinations more swiftly and effectively. Another key metric is incident management, which assesses the system's proficiency in managing and mitigating traffic incidents. This includes evaluating the VSL system's ability to quickly adapt traffic conditions around an incident site, such as reducing speed limits to minimize the risk of secondary crashes and manage traffic buildup effectively. Effective incident management not only enhances road safety during emergencies but also mitigates the overall impact of incidents on the transportation network.

Measurement Items:
Response Time for Emergency Vehicles — Assess the effectiveness of the VSL system in facilitating rapid response times for emergency vehicles.

Incident Management — Evaluate the system's contribution to efficient incident management and clearance.

9. Quantifiable Safety, Mobility, and Environmental Benefits

Beyond improvements to the transportation system detailed in the previous section, quantifiable safety, mobility, and environmental benefits are expected as a result of VSL deployment. TxDOT will asses this implementation based on the goals for the ATTAIN program and other measurement items, as described in this section.

Safety Benefits

TxDOT's proposed VSL infrastructure project will be evaluated to determine effectiveness at delivering safety improvements. According to the FHWA's *Developing Crash Modification Factors for Variable Speed Limits*, evidence from existing VSL implementations signals a positive impact on road safety. For instance, a VSL case study in Georgia showed reductions in total, daytime, and rear-end crashes by 29.2%, 27.2%, and 35.2% respectively. Similarly, in Wyoming, the implementation of VSL led to significant decreases in various crash categories, including total, fatal and injury, property damage only, rear-end, and fixed-object crashes. Results of the study further underline the efficacy of VSL in curtailing severe and fatal crashes by up to 29% (Avelar et al., 2020).

Measurement Items:
Crash Rate — Measure the frequency of crashes on controlled highway segments compared to periods without VSL intervention.

Severity of Crashes — Assess the severity of crashes during different speed limit conditions.

Compliance with Speed Limits — Assess the rate of driver compliance with the posted speed limit.

Moreover, Texas' pilot experience with temporary VSL under different operational scenarios, such as urban congestion and construction zones, has been promising. The *Developing Crash Modification Factors for Variable Speed Limits* study highlights Texas' deployment of VSL in diverse settings like San Antonio's urban loops, construction zones in Temple, and weather-affected areas in Eastland County. Over 400 activations during a three-month period showcased a decrease in total crashes and crash severity, with no fatal or incapacitating crashes reported. This evidence underscores VSL's role in improving roadway safety across various traffic conditions.

Mobility Benefits

The implementation of VSL systems, tailored to real-time traffic dynamics, promises enhanced mobility. Analyzing pre- and post-VSL data, particularly in terms of traffic flow, travel times, and truck travel time reliability provide quantifiable evidence of these benefits. The ability of VSL to manage speeds in response to weather conditions and construction activities not only improves traffic efficiency but also minimizes delays, thereby facilitating smoother transportation of people and goods.

Measurement Items:

Average Speed — Evaluate how well VSL system maintains desired average speeds during various traffic conditions.

Queue Length — Measure the length of queues or backups at bottleneck points and during peak periods.

Environmental Benefits

The VSL optimization of traffic flow produces two environmental benefits: reduction of fuel consumption and reduction of vehicle emissions. By analyzing data on fuel usage and emission levels before and after VSL implementation, TxDOT can gauge the environmental impact of the project. Furthermore, integrating VSL with road weather information systems aids in disseminating real-time weather updates to drivers, encouraging adjustments in driving behavior that align with air quality goals.

Measurement Items:

Fuel Efficiency — Assess the impact of the VSL system on fuel efficiency by monitoring changes in vehicle speed patterns.

Emissions Reduction — Track reductions in pollutant emissions as a result of improved traffic flow.

10. Vision, Goals, and Objectives

The VSL project aligns seamlessly with the strategic goals and vision of Texas and USDOT. This initiative is not just a step towards enhancing current traffic systems but a leap into the future of smart transportation. Central to this project is the integration of cutting-edge technology with existing infrastructure to address a range of challenges, from traffic congestion to crash reduction. The deployment of the VSL system, characterized by its adaptability and responsiveness to real-time conditions, promises a transformative impact on road safety, efficiency, and sustainability. By integrating advanced ITS to improve safety and mobility, the project is set to substantially reduce fuel consumption, lower emissions, and optimize energy usage, aligning with broader air quality and economic goals.

The project's scope includes a comprehensive deployment plan encompassing urban and rural segments, augmented by a robust set of technologies including CCTV cameras, radar systems, and regulatory VSL sign assemblies. These elements are designed to work in unison so that the transportation infrastructure operates at its optimal level. The focus on maintaining a state of good repair, combined with the implementation of advanced public transport systems and freight efficiency measures, embodies the organization's commitment to a holistic improvement of transportation services. Future deployments will build upon this foundation, enhancing the system's adaptability.

The project anticipates and addresses potential obstacles, primarily focusing on driver compliance and institutional support. By working closely with local municipalities and law enforcement, the project aims to secure the necessary support for successful deployment. The quantifiable improvements expected from the VSL project, such as reduced traffic-related crashes and congestion, and improved system efficiency are testaments to its alignment with the organization's vision. The VSL project, therefore, stands as a beacon of the organization's commitment to safety and mobility, paving the way for a future where transportation is not only more efficient and safer but also more attuned to the needs of users.

Future Deployments

The results of this deployment will allow TxDOT to refine strategies related to future deployments including considerations about technology integration, design, location, and partnerships. These future deployments will be part of integrated corridor management solutions that will optimize mobility and safety and leverage previous corridor and ITS investments.

11. Plan to Leverage Existing Technologies

This project will leverage ITS assets already deployed on the identified segment. Additionally, TxDOT and its partners will leverage the work from the Texas Connected Freight Corridors (TCFC) project, which this deployment of an integrated VSL system will build upon. TCFC utilizes a combination of technologies including cellular, dedicated short range communications, and smart infrastructure to implement a suite of V2X applications. Deployment of this VSL system would expand the CV data framework to increase real-world applications and uses on Texas roadways. Already, limited CV applications are currently supported such as work zone warnings and incident warnings (debris, crash). However, limitations to the existing applications (such as manual data entry and unidirectional flow) would be ameliorated by the proposed VSL system deployment. These technologies are expected to enable a sustainable deployment where TxDOT will be able to acquire a rich set of traffic conditions data and, in turn, provide better information to its partners.

12. Deployment Schedule

The following section provides details of this VSL deployment, including a definition of tasks, milestones and a schedule for implementation. This deployment approach has been designed based on TxDOT's experience with the implementation of technology-based projects.

Deployment Activities

The following scope describes the tasks and subtasks associated with the planning, design, installation, operations and maintenance of this deployment. The three tasks divide the project based on milestone activities with Task 1 focused on planning and conceptual design, Task 2 focused on detailed design and installation, and Task 3 focused on operations and maintenance.

Task 1: Planning and High-Level Design

1.1: Program Management

This task covers the development of a comprehensive set of plans for managing the entire Task 1 project effort and establishing regular and consistent communications between USDOT and the Texas Team (the Team). Effective project management is crucial to achieving project targets and strategic objectives. Project failures occur more often due to project management problems rather than technical issues. Effective project management consists of two phases: planning and execution. In the planning phase, the required coordination and communication between the Team and oversight committees is identified to leverage buy-in and gain TxDOT leadership commitment. In the execution phase, the focus shifts to tracking and reporting activities. Regular communication through meetings, conference calls, and webinars will help facilitate the execution of the project. The project schedule is also an important component for communicating progress on project milestones.

1.2: Deployment Concept of Operations (ConOps)

The ConOps is a key document to establish the project's overall needs and to define expectations and success of the project. The Team has considerable experience in developing ConOps and understands the importance of having a guiding document for the remainder of the project. This document will be informed and reviewed by partners associated with the deployment of the VSL project. This includes the associated TxDOT district offices, and headquarters staff from ITS, construction, traffic engineering, traffic safety, general counsel, and procurement. State and local law enforcement and traffic management organizations will also be involved in this portion of the project.

1.3: Safety Management Plan

One of the key safety issues in planning a transportation technology deployment is ensuring that information and warnings are presented to drivers in a way that is effective but not distracting. Another issue surrounding VSL deployment is work zone safety while installing roadside equipment.

The safety management plan will cover both the deployment and operational tasks of the VSL system project. The Team has considerable experience in deploying technology in transportation corridors that will inform the deployment task of the safety management plan. The Team will also apply safety management plans that are used on a day-to-day basis to plan and execute the safe deployment of ITS equipment.

1.4: Performance Measurement and Evaluation Support Plan

Performance measurement and evaluation will be reflective of the goals of both TxDOT and the USDOT, and will include specific emphasis on performance measures identified in the ATTAIN grant NOFO. This task results in a performance measurement plan, which key elements include data collection, data archiving, and data reporting. Under this task, the Team will reserve no more than 5% of total resources in the budget to participate in these activities.

1.5: Outreach Plan

For this project, the Team will capitalize on extensive ITS and stakeholder outreach experience to communicate the project's goals, objectives, and outcomes to stakeholders. In this task, a plan will be developed related to the goals, audience, type and timing of outreach associated with the deployment of this project. Project partners that are identified in previous tasks will begin participation during Task 1, while other audiences may receive outreach during Task 2 or the full deployment and operations in Task 3. Audiences for engagement during this deployment may include:

- State, county, and city transportation agencies, including traffic management centers
- FHWA Division Office
- Highway service patrol/contractors
- State and local law enforcement
- Fire departments and emergency medical services
- Transit agencies and operators
- Other incident management agencies, including public safety answering points
- Elected and appointed officials
- Media
- Trade schools, community colleges, universities, and other workforce development partners
- Traveling public

The engagement identified in this plan will be implemented through subtasks in each part of the deployment.

1.6: Deployment System Requirements

Development of system requirements is a complex process that starts with examining the ConOps document for user needs and concerns. Some of the issues involved in this process are:

- Documented user needs change over time
- Stakeholders leave and are replaced with different stakeholders who have different needs and concerns
- Needs may be too vague or not result in testable requirements

To help address these issues, the Team will stay in close communication with stakeholders during requirements development. Part of the requirements development process will be to categorize and analyze the requirements for completeness, feasibility, and priority. During this process, traceability of requirements to the needs and ConOps will be documented. Development of the System Requirement Specification will utilize the appropriate Institute of Electrical and Electronics Engineers and USDOT guidelines.

The Team is experienced in requirements development and has completed system requirements documentation for multiple customers and varied stakeholders. SwRI has been independently assessed as Capability Maturity Model Integrated Level 5, the highest rating, for systems engineering processes. The TxDOT Lonestar® software maintains multiple requirements documents which include functional interface, performance, and data requirements that are prioritized, categorized, and have traceability to the ConOps, test cases, design documentation, and source code.

1.7: Comprehensive Deployment Plan

The development of a Comprehensive Deployment Plan (CDP) for the three identified corridors can be a challenge as it involves the state, cities and counties. The CDP will document the testing and implementation steps to achieve full deployment. Some of the issues and strategies involved in this process are:

- Regional/Local Input and Data. The Team has worked extensively with local partners to help improve the safety, mobility, and environmental impact of the transportation network. The Team will leverage this experience to confirm that the partners have bought into the plan and have sufficient resources within their organizations to help implement the CDP and obtain data they need for local operation.
- New Technology Deployment. TxDOT has actively begun deploying DSRC within the proposed deployment area and is developing and testing applications that will be of use to TxDOT in the future.
- Data Sharing. The Team is knowledgeable of USDOT's Research Data Exchange and the process of submitting data.

The CDP will also include a deployment readiness summary to support the successful execution of this task. The Team commonly develops deployment plans and deployment readiness summaries for deployments of TxDOT's Lonestar® software system throughout the state. ITS deployments are vitally important to the regions they serve, so the Team develops integration and deployment plans and then a deployment readiness summary that is reviewed with the region to account for key issues and establish backup plans if the deployment experiences severe, unexpected problems.

The completion of this plan will be the final deliverable in Task 1, and will be used to transition the deployment to Task 2.

Task 2 Detailed Design, Build, and Deployment

2.1: Program Management

The Team will leverage experience to effectively manage all aspects of this program. Throughout the program, the Team will continue to track the progress of each task, communicate the progress of the tasks and the program to USDOT and the other stakeholders, analyze and track risks, and re-plan as necessary. Task 2 will use a considerable amount of the project budget and will require close monitoring of costs and schedule due to the large number of external constraints that will be encountered.

2.2: Detailed Design Development

Following a successful Task 1, the Team will continue to follow the FHWA Systems Engineering Model and develop a detailed design of the system. This design will include sufficient detail to allow the Team to build the many system components in parallel with confidence that they will integrate well during system integration. The Team expects that this design will include, but not be limited to, the following:

- Hardware design that will be integrated with current ITS elements deployed on the identified corridors.
- Hardware design for the servers and network equipment that will host the data collection, analysis and decisions support systems .
- Specifications for all hardware that will be procured.
- Software design showing the detailed subsystem design and application interfaces for all software components of the system. This design will maximize reuse of existing, proven software components wherever possible. TxDOT is very familiar with the applications that exist as part of the Open Source Application Development Portal and will analyze the applications for potential reuse within our deployment.
- Detailed Interface Control Documents that will specify the interface between each of the major software components.

The Team will submit this detailed design to USDOT for review and comment. The Team will then review the comments, address them, and submit the updated detailed design that will facilitate the development of the system.

2.3: Specify and Procure Hardware

Based on the detailed design of the system and the detailed hardware specifications, the Team will procure the hardware. The Team is experienced at applying stringent but efficient procurement processes to maintain the project schedule while ensuring optimal value for the project. The Team expects this procurement to include the following hardware components:

- Roadside Equipment
- Application Servers
- Spare Equipment

The Team has the capability and facility resources to be able to acquire, inventory, and store the equipment required to implement this program. The Team has hands-on experience with almost every one of the potential equipment vendors and therefore know what to expect.

2.4: Application Development

In parallel to the procurement of hardware, the Team will begin to develop the applications that were identified in the concept of operations, system requirements, and detailed system design. The Team will maximize the reuse of mature software wherever possible. The Team also understands that the system is going to be much more than just a research deployment and will need to be robust and reliable enough to enable continual operation throughout the remainder of this project and beyond. The Team will leverage experience implementing and deploying field-hardened ITS applications to create and integrate a software suite that will enable a successful deployment for this project. The Team uses proven coding standards and software development methodologies to facilitate this development, minimize risk during system integration, and maximize the maintainability of the system throughout its lifecycle.

This task will also include testing the hardware that was procured for this system. The Team has conducted a VSL pilot program in the past. Therefore, the Team is very familiar with the processes and test methods for equipment reliability and interoperability within the system's deployment. For application servers and other hardware systems procured, the Team will follow the normal processes for ensuring that this equipment is functional and meets the requirements specified in the procurement documents.

2.5: Application Unit Testing

Continuing to follow the FHWA System Engineering Model, the Team will install and individually test each application. This will verify that each application is functioning properly and will minimize risk during system integration. Each application will have its own test plan that will be used to verify that it is working correctly and reliably. The applications will be tested on a controlled set of roadside installations and vehicles prior to a larger scale integration.

2.6: Security Credential Management System Integration

The Team understands the need for deployments to be not only efficient and reliable, but also secure. It is understood that any security breaches encountered may undermine large scale deployment and ultimately prevent the realization of the safety, mobility, environmental, and public agency efficiency improvements that this application can help to achieve.

2.7: System Integration and Testing

Once all the applications are individually tested, the Team will deploy them on all vehicles, roadside equipment, and application servers and begin full system integration testing. The Team will update the system integration test plan that was outlined in the detailed design and will implement this test plan to confirm that the deployment is fully operational. The Team understands the importance of this technology and the benefits that it can realize and will deploy the system in a staged approach that will facilitate a controlled deployment. The Team will leverage experience in deploying ITS systems and will fully test the system prior to operating it. The Team will update all the system documentation with as-built information to assist with maintainability going forward.

2.8: Deployment Outreach Plan

The Team will develop a Deployment Outreach Plan which focuses on generating appropriate messages and materials for target audiences. Examples of materials include: one-pagers, website content, frequently asked questions documents, fact sheets, slide decks, talking points, and press releases. Anticipated levels of outreach include a quarterly stakeholder meeting to coordinate and prepare project stakeholders for next steps in the project. Additionally, the Team will participate in and travel, as needed, to select conferences and trade shows each year. Finally, the Team will develop a Lessons Learned Logbook (LLL) to capture best practices from the project and disseminate the information through select webinars.

2.9: Training

The Team will facilitate up to three training sessions and develop training guides for the following stakeholder groups:

- **Equipment Installation** – Trains TxDOT and subcontractors on how to appropriately install and maintain the VSL system equipment.
- **Traffic Management Center (TMC) Operators** – Coach the TMC operators on how to access, use, and troubleshoot the VSL module that is integrated into the Lonestar interface.
- **Road Users** – Informs freight fleet partners and a focus group of the traveling public on how to effectively use the VSL system. Feedback will be incorporated and used to refine the VSL user experience.

Training sessions may include both virtual and in-person elements. At least one training session will be an in-person demonstration of the VSL system.

2.10: Workforce Development Playbook

The Team will create a Workforce Development Playbook with ITS curricula and training modules that may be integrated into trade schools, community colleges, and universities to cultivate a transportation workforce of the future. The Playbook will focus on three domains: 1) ITS Equipment, 2) Automotive Technology, and 3) Data & Cybersecurity. Additionally, the Workforce Development Playbook will outline the establishment of an internship program to be led by TxDOT Special Crews Section. The internship will provide an opportunity for up to two individuals to gain new skills and on-the-job training related to the installation of ITS systems.

The Workforce Development Playbook will outline the establishment of an internship program to be led by TxDOT Special Crews Section .

2.11: Baseline Data Collection

The Team will collect baseline data along the corridor in order to establish a foundation for the performance measurement and evaluation task. In particular, the Team will collect baseline data pertaining to each corridor's safety, mobility, and environmental aspects. Additionally, sample data and user surveys from fleet partners will be collected to serve as a focus group and provide qualitative feedback regarding the user experience of the VSL system.

2.12: Plans, Specifications, and Estimates

In preparation for the construction bidding process, the team will develop a full set of project plans, standard plans, specifications, the Engineer's Estimate, and required federal and state contract provisions. The PS&E package will be reviewed internally prior to being submitted to FHWA for review and approval.

2.13: Installation

The Team will work with TxDOT forces on installation of the equipment consistent with the PS&E plans. Installation will be consistent with FHWA guidance.

Task 3: Maintain and Operate

3.1: Program Management

This task will continue the program management effort from the previous tasks and will continue to effectively manage risks, communications, budget, scope, schedule, and resources. During this maintenance and operations portion of the project, the Team will work to keep the system fully operational to maximize the investment and the benefits to all stakeholders.

3.2: System Operation and Maintenance

Following a successful Task 2 in which the Team built, fully deployed, and tested the system, the Team will now transition the focus to keeping the system operational. As TxDOT's Traffic Safety Division is leading this deployment, the expectation is for a smooth transition utilizing experience in deploying and operating well-integrated and fully functional ITS applications throughout the state for over 30 years.

3.3: Data Collection and Analysis

The Team understands the importance of this deployment in improving safety and efficiency of the roadway network, but also to provide valuable data and lessons learned for future deployments of the technology. In this task, the Team will execute the plan to collect and analyze the data that will be used to support the performance measure reporting and the independent evaluation.

3.4: Performance Measure Reporting

During this task, the Team will perform a System Impact Evaluation and will report quarterly on the assessment of the robustness, effectiveness, usability, and acceptance of the VSL applications as deployed. The Team will evaluate metrics pertaining to safety, mobility, and environmental impacts. The goal is to continually assess the deployment's progress towards the established goals and therefore understand the need to continually measure and report on how well the project is performing. The Team will summarize and display key performance indicators on a project dashboard so project stakeholders may easily monitor progress.

3.5: Coordination with Independent Evaluator

The Team will leverage its experience in working with the USDOT provided Independent Evaluators in previous programs to this deployment to help assess the progress toward our established goals. This will help USDOT assess the cost-effectiveness of the deployment and will help inform future deployments conducted nationwide. The Team will work with the Independent Evaluator and provide the necessary documentation, data, and access to the system deployment and operations experts to assist the USDOT in conducting this evaluation.

3.6: Stakeholder Outreach

The Team will update the Deployment Outreach Plan and appropriate project materials. Anticipated levels of outreach include a quarterly stakeholder meeting to coordinate maintenance and operations activities. Additionally, the Team will participate in and travel to select conferences and trade shows each year as needed. Finally, the Team will update the Lessons Learned Logbook (LLL) and publish a Transition Plan to ensure sustainability of the project beyond the performance period.

3.7: Workforce Development

The Team will update the Workforce Development Playbook with ITS curricula and training modules. Additionally, the Workforce Development Playbook will capture lessons learned and best practices from the TxDOT Special Crews internship program.

Project Schedule

This project, from deployment through the operations and evaluation stage, is scheduled to last 48 months. This schedule was defined based on previous deployments and understanding of procurement timelines for ITS products.

Task	Schedule		
1. Planning and High-Level Design	12 Months		
2. Detailed Design, Build, and Test		24 Months	
3. Operate, Maintain, and Evaluate			12 Months

Project Deliverables

The following deliverables will be developed as part of this project. Within the tasks, most of the documents will be developed concurrently and will inform each other. Full details about the deliverables can be found in the Deployment Activities section.

Task 1:

- Project Management Plan
- Deployment Concept of Operations Document
- Safety Management Plan
- Performance Measurement and Support Plan
- Outreach Plan
- Deployment System Requirements Document
- Comprehensive Deployment Plan

Task 2:

- Detailed Design – System
- Specifications and Procurement Materials
- Application Unit Testing Plan
- Application Unit Testing Report
- System Testing Plan
- System Testing Report
- Deployment Outreach Plan
- Lessons Learned Logbook
- Training Guides
- Workforce Development Playbook
- PS&E Plans

Task 3:

- Performance Reporting
- Independent Evaluation Materials
- Deployment Outreach Plan (Updates)
- Lessons Learned Logbook (Updates)
- Transition Plan
- Workforce Development Playbook (Updates)

13. Required FMCSA/FMCSR or Other Exemptions

The TxDOT procurement process and practice requires all project awards to be compliant with local, state, and federal statutes and regulations. No FMCSA, FMCSR, or other regulatory exemptions are anticipated to be needed in deployment of this VSL system.

14. Compliance with Buy America Act

The equipment required for the VSL system deployment is available domestically and will be procured using a fair process in accordance with TxDOT policy and practice. The TxDOT procurement process requires all project awards be compliant with local, state, and federal requirements including the Buy America Act.

15. ITS Program or Innovative Technology Initiatives

The goal of TxDOT's ITS program is a transparent investment into state-of-the-art technology integrable across all transportation modes with the cooperation of stakeholders that benefits the public.

TxDOT is developing a CVDF to exchange data from connected vehicles, Intelligent Transportation Systems, and Lonestar™ infrastructure with vehicles' original equipment manufacturers , navigation app providers, and other industry stakeholders. The infrastructure needed for a VSL system provides the groundwork for expansion to interoperability on Texas highways. Fiber optic and satellite communications, ITS, radar, and road condition sensors are all components of a connected framework.

Preceding full vehicle and infrastructure automation, a VSL system at this stage is a gradual indication to travelers of the technology making its way, a show of its usefulness, and reassurance that TxDOT is working to bring greater efficiency and safety to their commute.

III. MANAGEMENT STRUCTURE

Organization Description

TxDOT has identified a strong team, made up of TxDOT staff and partners from three Texas research institutions, to implement the Texas VSL Deployment ATTAIN Grant. The following sections will describe the management structure and the approach to grant administration and the technical deployment.

Lead Applicant - TxDOT

TxDOT will serve as the primary grant applicant for the project and will be charged with project delivery. TxDOT meets the eligibility criteria defined in the NOFO as a unit of state government. In the fiscal year ending August 31, 2022, TxDOT received $4.32 billion in federal aid, making up 31% of its annual operating budget. As the recipient of this federal aid, TxDOT maintained compliance with federal aid requirements and worked in partnership with USDOT and its operating agencies.

TxDOT has a professional workforce of over 12,000 people, including engineers, administrators, financial experts, and many others who work together to realize the TxDOT mission: *Connecting you with Texas*.

TxDOT has substantial experience implementing ITS solutions on their system. ITS deployments are based on statewide and regional planning activities and are connected through a statewide central management system called Lonestar™. On the project level, a strong systems engineering process is implemented as part of all ITS deployment activities so that the design and integration is consistent with the needs of the project location. This process also includes configuring the Lonestar™ system to be compatible with the latest technology solutions.

Proposed Management Structure

Project Implementation

The lead agency for this project will be TxDOT with support from the Texas A&M Transportation Institute (TTI), the University of Texas at Austin Center for Transportation Research (CTR), and Southwest Research Institute (SwRI). As a group, the Team has experience collaborating on transportation initiatives. For the deployment of this VSL system, the following definitions apply:

- **Team Member** – the core team responsible for delivering Tasks 1, 2, and 3 of the ATTAIN project.
- **Stakeholders** – public and private sector entities with an interest in the deployment of VSL technology in Texas.
- **Partner** – a special class of stakeholder that will directly take part in the deployment and operation of the VSL project. The deployment plan for this project has been developed to serve as the guide for the implementation steps of the project. The three tasks divide the project based on milestone activities with Task 1 focused on planning and conceptual design, Task 2 focused on detailed design and installation, and Task 3 focused on operations and maintenance.
- **Grant Management** – As the designated recipient for most federal-aid transportation funding in Texas, TxDOT has a process in place for successful grant management through the lifecycle of the grant. After notification of award, TxDOT will work with the identified USDOT operating agency to sign a grant project agreement, which stipulates the specific requirements for implementation and scope of the project. During the project, TxDOT will work with the identified grant monitor to provide progress reports and reimbursement requests. When the project is completed, TxDOT will work with the grant monitor to close out the project by providing all required deliverables and will maintain records in accordance with federal requirements.

Partnering Plan

TxDOT has a strong history of engaging with partners and the public during the development and implementation of transportation investments. The deployment plan has a focused subtask related to engagement planning. During the engagement planning subtask, potential stakeholders will be mapped and their role in the deployment will be defined based on the International Association of Public Participation's spectrum of public participation.

There are many important partners that will be included in the deployment process, including local and state law enforcement, metropolitan planning organizations, and navigation providers.

The engagement plan will also detail the communication and education strategy to the traveling public, and will partner with local media outlets to provide information about the deployment.

Subrecipients and Their Roles

This project will continue a long relationship between TxDOT and Texas research institutions in evaluating the effectiveness of specific investments. For this project, TxDOT will have three subrecipients, CTR, SwRI and TTI, that will lend their support to the development of the deployment and evaluation of the outcomes.

Specifically, SwRI will assist with tasks associated with system development and application development of the deployment plan. CTR will assist with stakeholder outreach, workforce development, and performance measurement and evaluation. TTI will assist with tasks associated with concept development and application development.

There is a long history of stability and depth in the ITS and transportation operations groups for TxDOT and the identified subrecipients. The key personnel have considerable combined experience and have worked together on several projects over the past decade. Additional qualified team members are able to seamlessly respond to any changes in personnel to keep the project on track, on time, and within budget. The Team will establish a second tier of key personnel (i.e. deputy leads) that will be involved in the day-to-day operation of the project and knowledgeable to serve in place of the leads, due to vacation, leave, or attrition.

Organizational Chart

TxDOT has assembled a complementary core team of partners with experience in general systems engineering as well as in designing, testing, and implementing system management tools. TxDOT will serve as the prime contractor for the Team, led by Mr. Michael Chacon and Dr. Tomas Lindheimer as the overall Program Sponsor and Project Manager, respectively. Dr. Lindheimer will be the primary point of contact for the contracting officer and the contracting officer's representative. *Figure 3* shows the organizational chart for this project.

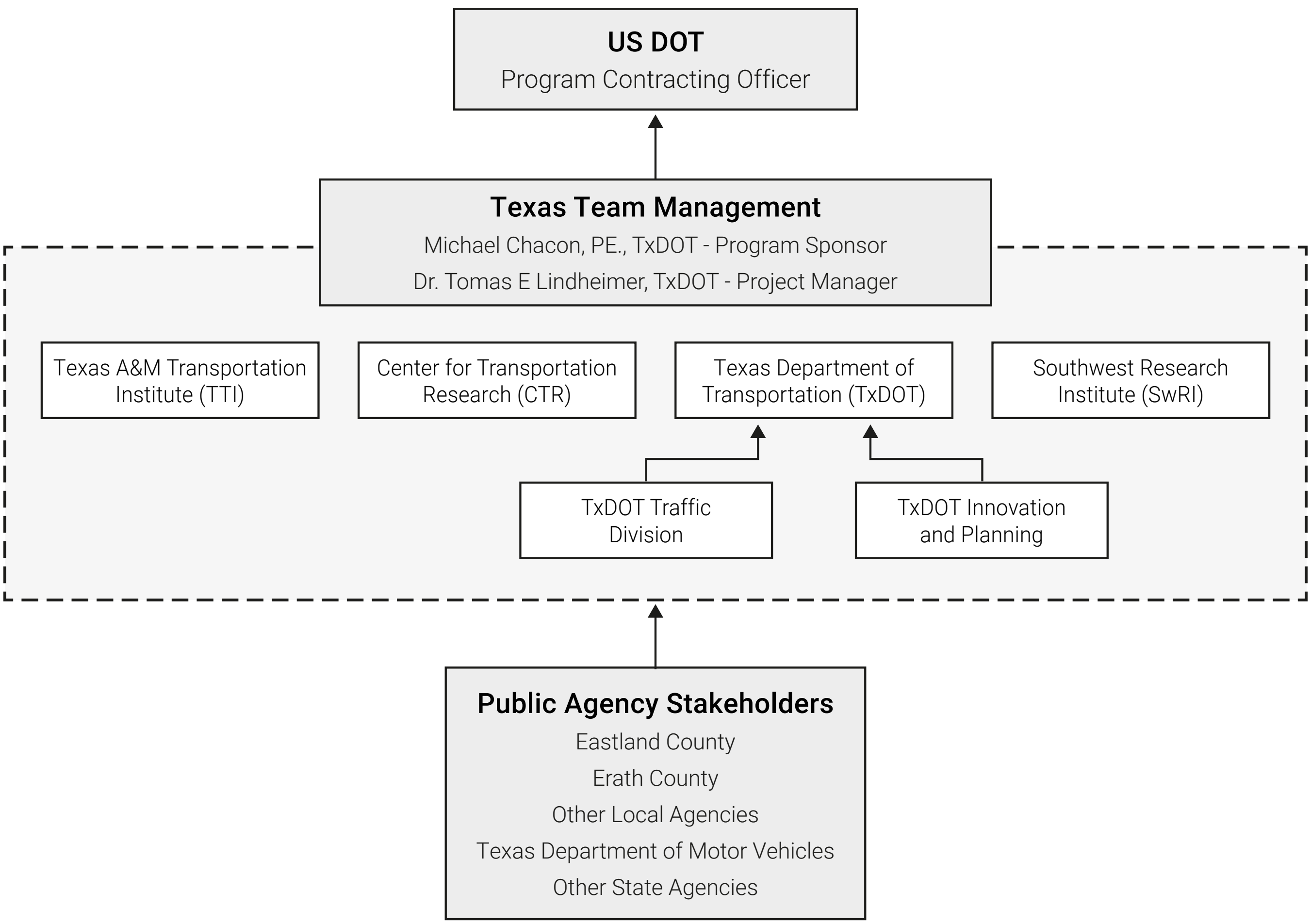


Figure 3: *ATTAIN grant organizational chart*

IV. STAFFING DESCRIPTION

The Team has designated key personnel for the following roles for this project. Each of these individuals has extensive experience with their agency and the ITS industry.

Project Manager (PM) — Dr. Tomas E. Lindheimer, TxDOT

Dr. Lindheimer worked for the Texas A&M Transportation Institute and the City of College Station before joining TxDOT in December of 2022. His dissertation involved traffic safety by observing and synthesizing red light running behavior along heavy-volume arterials and evaluating low-cost countermeasures. In addition, he has worked on projects regarding managed lane operations, pedestrian crosswalk safety, access management, public transportation, highway work zone safety, and retroreflectivity of traffic signs. His research interests incorporate many areas of transportation engineering, including traffic safety, freight movement and safety, public transportation planning, asset management, traffic operations, traffic control, connected and automated vehicles, pedestrian safety, access management, geometric design, and multimodal sustainability. As PM, Dr. Lindheimer will oversee all day-to-day technical activities of the Team.

Program Sponsor — Michael Chacon, P.E., TxDOT

Michael Chacon oversees all aspects of TxDOT's Traffic Safety Division, including the Traffic Management System, traffic policy and standards, speed zoning, crash records, crash data analysis, and the Texas Traffic Safety Program.

He began his TxDOT career in 1994 in the Traffic Operations Division, working in the field with several districts. In 1998, he joined the South Travis area office of the Austin district working on design and safety project development. In 2002, he returned to Traffic Operations as a lead worker. He was named the Policy and Standards branch manager in 2006, where he was responsible for the Texas Manual on Uniform Traffic Control Devices, traffic engineering standard sheets, and other traffic engineering policies and procedures.

In July 2015, Chacon was named the director of the Traffic Engineering Section, where he oversaw engineering operations, policy and standards, and safety engineering. He was named Traffic Operations Division director on Oct. 1, 2016. The name of the Traffic Operations Division was changed to the Traffic Safety Division, effective September 1, 2018.

Chacon graduated from the University of Texas at Austin with a bachelor of science in civil engineering in 1993. He received his license as a professional engineer in 2000 and has served with TxDOT for 28 years.

Concept and Application Development — Dr. Kevin Balke, TTI

Dr. Balke has more than 38 years of experience in the field of transportation. Specific areas of expertise include Intelligent Transportation Systems (ITS), Freeway Operations and Management, Traffic Signal Systems and Control, Weather Responsive Traffic Management, Traveler Information Systems, Incident Management, and Work Zones. Working with the Battelle Institute, Dr. Balke is one of the primary developers of FHWA's current signal phasing and timing system deployed at the Saxton Transportation Operations Laboratory at the Turner Fairbank Highway Research Center. Dr. Balke also led several projects to develop concept of operations for connected vehicle deployments for transit signal priority at signalized intersections, construction and work zones, and wrong-way detection.

System and Application Development — Dr. Eric Thorn, SwRI

Dr. Thorn is manager of the Robotic Autonomy section at Southwest Research Institute (SwRI), where he oversees research programs related to connected vehicles (CVs), automated vehicles (AVs), off-road automated ground vehicles, and unmanned aerial systems (UAS). Efforts under his supervision include large deployments of vehicle-to-everything (V2X) technology, development of algorithms and techniques to enable UAS to explore unknown environments, development and refinement of off-road autonomy capabilities, and development of frameworks and approaches to assessing the safety of AVs, among others. He also has over 18 years of experience designing, implementing, and validating advanced robotic systems. His areas of expertise include world modeling, decision-making, motion planning and control, as well as live robotic field testing. Dr. Thorn is currently leading SwRI's efforts on the Texas Connected Freight Corridors program, which seeks to improve safety and mobility of freight movement throughout Texas by deploying V2X equipment and applications. He is coordinating tasks to evaluate and procure V2X equipment and security credential management system solutions, develop updates within TxDOT's Lonestar™ ATMS to support new V2X applications, develop a new connected vehicle data framework CVDF interface that will provide safety and mobility data directly to third-party service providers, and support outreach and training for public and private partners. He is also leading projects for the National Highway Traffic Safety Administration to develop an approach to assess the performance of automated driving system (ADS) perception systems and to document and summarize artificial intelligence and machine learning techniques employed in ADS.

Stakeholder Outreach/Workforce Development – Dr. Kristie Chin, UT-CTR

Dr. Kristie Chin is the Director of Civic Innovation for the University of Texas at Austin's Center for Transportation Research (CTR). She specializes in public-private stakeholder engagement for connected and automated vehicles, strategic planning for emerging technologies, and transportation workforce development. Dr. Chin is currently leading CTR's stakeholder engagement efforts on the Texas Connected Freight Corridors program, where she is coordinating with nine TxDOT districts, the TxDOT Special Crews section, the TxDOT Fleet division, the third-party data platform Drivewyze, and six freight partners. Dr. Chin is also Principal Investigator to several transportation projects, including an interagency contract to assess the gaps and develop new training solutions for TxDOT's data workforce. She is leading the development of a safety score using data fusion to identify high-risk roadway conditions; and has conducted an evaluation of Waze and 9-1-1 data to improve incident management. Dr. Chin also lectures on transportation policy development in the University of Texas at Austin's Lyndon B. Johnson School of Public Affairs.

Point of Contact

The primary point of contact for TxDOT will be:

Dr. Tomas Lindheimer
Transportation Engineer
Telephone: (512) 413-9218
Email: *tomas.lindheimer@txdot.gov*
Address: Texas Department of Transportation
6230 E Stassney Lane
Austin, Texas 78744

APPENDIX

Resumes

Tomás E. Lindheimer, Ph.D., P.E.

(801) 230-2315
tomas.lindheimer@txdot.gov

EDUCATION

Ph.D. Degree University of Kansas, Lawrence, KS Fall 2014

- Civil and Environmental Engineering
- **Dissertation:** *Long-term effects of confirmation lights on red-light running behavior.*

M.S. Degree Utah State University, Logan, UT Fall 2010

- Civil and Environmental Engineering
- **Thesis:** *Safety Evaluation of Utah Work Zone Practices.*

B.S. Degree Utah State University, Logan, UT Spring 2009

- Civil and Environmental Engineering

PROFESSIONAL LICENSES

Professional Engineer (Texas) #136566 December 2019

RELATED WORK EXPERIENCE

Transportation Engineer V for TxDOT *January 2024 – Present*

- Provide vision, guidance, and an environment for a knowledgeable, motivated team that is committed to achieving the goals of the department.
- Provide direction, guidance, recommendations, assistance, and expertise on TMS, data initiatives, and emerging transportation technologies.
- Review and provide comments on proposed legislation and direct implementation of legislation affecting traffic management.
- Thoroughly research assignments and activities and provide concise work products that are per current Department policies and guidelines.
- Review and provide comments on proposed legislation and direct implementation of legislation affecting traffic management.
- Assist with special projects and initiatives.

Transportation Engineer IV for TxDOT December 2022 –December 2023

- Assist in mentoring interns and engineering assistants.
- Manage projects and consultant contracts. Projects that were managed include the Texas Connected Freight Corridor (TCFC), wrong-way driving district surveys, Variable Speed Limit implementation, upgrading DMS 11170, among others.
- Provide technical assistance for the development of rural ITS/traffic management corridors.
- Certify ITS project bidders
- Oversees the development and support of transportation operations systems.
- Assists in utilization of available funds to improve and install traffic control devices.
- Evaluates the performance of new transportation products.
- Interprets manuals and required guidelines for traffic operations.
- Negotiates fees and budgets, develops, and negotiates scopes of work, negotiates contract work schedules, and negotiates other contract agreements.
- Performs engineering oversight for FHWA, State, NTTA and Third Party funded construction projects.

Traffic Engineer I for City of College Station January 2020 –November 2022

- Lead and manage the parking removal program for the City of College Station
- Manage the City of College Station Transportation Management Center
- Mentor EIT and educate other city staff on traffic operation.
- Lead and manage traffic studies.
- Lead Aggie post-game traffic management. This includes leading coordination and conducting meetings between CSPD, Texas A&M, City of College Station staff, and TxDOT.
- Lead public meetings.
- Use signal performance measures
- Study traffic incidents using the Traffic Control Center
- Assist City Traffic Engineer, and Traffic Operations
- Monitor traffic during Texas A&M football games at Kyle Stadium

Graduate Engineer for City of College Station February 2018 – January 2020

- Conduct sight-triangle evaluations
- Perform plan reviews for various departments
- Answer citizen complaints
- Conduct on-street parking evaluations

Associate Transportation Researcher for TTI August 2014 – February 2018

- Assist in research projects
- Data collection
- Analyze traffic data
- Write reports, tech-memos, and research papers
- Present findings and research at national conferences

Intern for Lawrence Transit Authority October 2012 – August 2014

- Analyze ridership data and system performance
- Inventory existing bus stop signs, create and maintain asset database
- Help supervise installation of new bus stop signs and amenities
- Conduct Origin/Destination study by surveying riders of KU, Lawrence Transit, and K-10 connector bus service

Intern for KU on Wheels August 2011 – August 2014

- Analyze data and system performance for the transit department at the University of Kansas
- Make recommendations for new routes for KU transit system
- Program luminator message boards on buses

Graduate Research Assistant, University of Kansas August 2011 – August 2014

- Evaluate low-cost red-light running countermeasures
- Manage study on red-light running in Overland Park, KS, Waterloo, IA and Altoona IA

AWARDS

- 2014 Lohenz Student Award for outstanding minority students in engineering, **KU**
- 2014 Ruben Zadigan Graduate School of Engineering Scholarship recipient, **KU**
- 2013 Bert & Dorothy Steves Memorial Scholarship recipient, **KU**
- 2012 Placed in Student Poster Competition at the Midwestern ITE Conference, **KU**
- 2010 Student of the Year for the Utah State University Transportation Center, **USU**

SKILLS

Language	Fluent in Spanish, English, Bulgarian
Civil	Excel, Synchro, CUBE, Microsoft Word, Vissim, R-statistical package, AutoCAD, ArcGIS

Kevin Balke, Ph.D., PE, PMP

Senior Research Engineer

YEARS OF QUALIFYING EXPERIENCE: 38

Education

- Ph.D., Civil Engineering, Texas A&M University, 1998.
- M.S., Civil Engineering, Texas A&M University, 1987.
- B.S., Civil Engineering, Texas A&M University, 1984.

Background and Qualifications

Dr. Balke has more than 38 years of overall experience in the field of transportation. Specific areas of expertise include Intelligent Transportation Systems (ITS), Freeway Operations and Management, Traffic Signal Systems and Control, Weather Responsive Traffic Management, Traveler Information Systems, Incident Management, and Work Zones. He has led several prominent national evaluations for the Federal Highway Administration, including the Connected Vehicle Pilot Deployment Independent Evaluation, the Urban Partner/Congestion Mitigation Demonstration projects, and the TravTek Demonstration project. Dr. Balke is also a leader in the development, testing, and demonstration of prototype connected vehicle applications for Traffic Optimization for Signalized Corridors (TOSCo), Intelligent Network Flow Optimization (INFLO), and others.

In addition to developing a research portfolio in connected vehicle applications, Dr. Balke has continued to conduct research related to traffic system operations and management. He recently completed the development of a new *Traffic Signal Program Handbook* for the FHWA. He is also the author of FHWA's *Traffic Signal Management Capability Maturity Model Framework*. He has also performed researched on weather responsive traffic signal operations, incident management, capability maturity modeling for traffic system management, regional traffic signal operations programs, active traffic management, work zone management, and more.

Dr. Balke is a long-time instructor and course developer for National Highway Institute on traffic signal design and operations, and freeway operations. He has also developed training courses related to Intelligent Transportation Systems design, weather responsive traffic management, incident management, and traffic signal design and operations for several public and private entities.

Recent Work Experience

Dates	Position(s)	Organization
2016-Present	Senior Research Engineer	Texas A&M Transportation Institute
1990 - 2016	Research Engineer	Texas A&M Transportation Institute
1999 - 2012	Center Director / Program Manager	Texas A&M Transportation Institute
1986 – 1990	Engineer II	City of Austin, Transportation & Public Work Dept.
1984 – 1985	Research Assistant	Texas Transportation Institute

Accomplishments and Professional Affiliations

- Registered Professional Engineer in Texas No. 66529
- Certified Program Management Professional
- Institute of Transportation Engineers,
- Transportation Research Board, Traffic Signal Systems

Subject Matter Expertise

Traffic Signal Control Traveler Information Systems	Connected Vehicle Systems Weather Traffic Managements	Traffic Management Systems and Operations

ERIC THORN, Ph.D.
Manager
Intelligent Systems Division

Ph.D., Mechanical Engineering, University of Florida, 2009
M.S., Mechanical Engineering, University of Florida, 2007
B.S., Mechanical Engineering, *Cum Laude*, University of Florida, 2004
B.S., Aerospace Engineering, *Cum Laude*, University of Florida, 2004

Dr. Thorn is the Manager of the Robotic Autonomy Section at Southwest Research Institute (SwRI), where he oversees research programs related to connected vehicles (CVs), automated vehicles (AVs), off-road automated ground vehicles, and unmanned aerial systems (UAS). Efforts under his supervision include large deployments of vehicle-to-everything (V2X) technology, development of algorithms and techniques to enable UAS to explore unknown environments, development and refinement of off-road autonomy capabilities, and development of frameworks and approaches to assessing the safety of AVs, among others. He also has over eighteen years of experience designing, implementing, and validating advanced robotic systems. His areas of expertise include world modeling, decision making, motion planning and control, as well as live robotic field testing.

Dr. Thorn is currently leading SwRI's efforts on the Texas Department of Transportation (TxDOT) Texas Connected Freight Corridors (TCFC) program, which seeks to improve safety and mobility of freight movement throughout Texas by deploying V2X equipment and applications. He is coordinating tasks to evaluate and procure V2X equipment and security credential management system (SCMS) solutions, develop updates within TxDOT's Lonestar advanced traffic management system (ATMS) to support new V2X applications, develop a new connected vehicle data framework (CVDF) interface that will provide safety and mobility data directly to third-party service providers, and support outreach and training for public and private partners. He is also leading projects for the National Highway Traffic Safety Administration (NHTSA) to develop an approach to assessing the performance of automated driving system (ADS) perception systems and to document and to summarize artificial intelligence and machine learning techniques employed in ADS.

Dr. Thorn served as co-principal investigator on a series of internal research projects that developed enabling technologies to allow UAS to autonomously explore and map unknown environments. He also led a project for NHTSA to develop a framework for generating test scenarios for ADS. This involved surveying prototype ADS under development, along with their operational design domains (ODDs) and object and event detection and response (OEDR) capabilities. He also supported NHTSA in identifying Federal Motor Vehicle Safety Standards (FMVSS) updates to accommodate ADS and develop strategies for executing FMVSS tests for ADS-equipped vehicles.

Dr. Thorn has managed and led the integration of autonomy hardware and software into two client-furnished Class VIII commercial trucks, demonstrating auto-pilot and platooning capabilities for commercial vehicles. He also led development of navigation algorithms for a prototype automated crash attenuation vehicle for enhancing work-zone safety. He was involved in design and development for the Office of Naval Research (ONR) Small Unit Mobility Enhancement (SUMET) program, previously acting as technical lead for navigation. He was one of the leading contributors to the SwRI Mobile Autonomous Robotics Technology Initiative (MARTI) internal research project, which developed a fully autonomous sport utility vehicle.

During graduate school, Dr. Thorn participated in the 2007 Defense Advanced Research Projects Agency (DARPA) Urban Challenge as a member of the University of Florida's Team GatorNation, acting as technical lead for navigation and control. He has co-authored multiple technical papers related to autonomous ground vehicle development, testing of ADS, and guidance on adoption of ADS and CV technology, and has made technical presentations on ADS and CV technology and testing both domestically and internationally.

PROFESSIONAL CHRONOLOGY: Southwest Research Institute: 2010- [research engineer, 2010-13; senior research engineer, 2013-16; acting manager, 2015-16; manager, 2016-present].

April 2023

SOUTHWEST RESEARCH INSTITUTE®

Kristie Chin, PhD, CTR

Director of Civic Engagement

Dr. Kristie Chin serves as the Director of Civic Innovation for the University of Texas at Austin's Center for Transportation Research. She leads an interdisciplinary team, supervises graduate students, and manages a multimillion-dollar portfolio of emerging technology projects for the Texas Department of Transportation (TxDOT) and other Texas transportation agencies. Dr. Chin specializes in smart cities systems optimization, including data analysis, strategic planning for emerging technologies, and public-private stakeholder engagement for connected and automated vehicles. She also lecturers on Transportation Policy Development in the UT Austin LBJ School of Public Affairs.

PROJECT EXPERIENCE

Texas Innovation Alliance | Project Sponsor: TxDOT | 2017 - Present

Dr. Chin co-founded the Texas Innovation Alliance, a peer-to-peer network of over 40 transportation agencies who develop and scale best practices for connected and automated vehicles, freight and logistics, electrification, and other topics. The Texas Innovation Alliance meets bi-weekly and facilitates quarterly community of practice meetings that would support the dissemination of lessons learned for this grant.

Texas Connected Freight Corridors (TCFC) | Project Sponsor: FHWA and TxDOT | 2018 – Present

Dr. Chin serves as the Principal Investigator for the Texas Connected Freight Corridor's stakeholder engagement activities. The TCFC project is Texas's largest deployment of connected vehicle technology and includes the deployment of roadside units along the Texas Triangle, installation of on-board units on TxDOT and freight partner fleet vehicles, and the development of five connected vehicle applications. She is responsible for developing and maintaining partnerships with nine TxDOT districts, TxDOT Special Crews Section, Drivewyze, and six freight partners. Furthermore, she supports the fleet partner training, using a train-the-trainer model, on topics including connected vehicle technology fundamentals and installation of on-board units. Finally, she led the development of data sharing agreements in coordination with TxDOT to support the baseline data collection and performance evaluation tasks.

EDUCATION

PhD and MS in Transportation Engineering, University of Texas at Austin, 2017 and 2015

M.Arch in Architecture, University of Notre Dame, 2014

ScB and AB in Civil Engineering and Architectural Studies, Brown University, 2014

YEARS OF EXPERIENCE

9 Years

YEARS WITH CTR

7 Years

SYNERGISTIC ACTIVITIES

Co-chair, Workforce Development Subcommittee, Governor's Connected and Automated Vehicle Task Force

Expand Connected Vehicle Data Framework (CVDF) Data Sources to Increase Applications and Use on Texas Roadways | Project Sponsor: TxDOT | 2022 – Present

Dr. Chin is the Principal Investigator for this research project that is leveraging the CVDF, originally developed for the Texas Connected Freight Corridors project, to expand Texas's CV ecosystem. Conducted in partnership with Southwest Research Institute, this project is testing and deploying road weather warning as well as developing data standards for several other CV applications, including first responder alerts and pedestrian in crosswalk.

NOTABLE PUBLICATIONS & PRESENTATIONS

- Munira, S., **K. Chin**, M. Moore, & N. Juri., N. (2024). "Investigating the Benefits, Challenges, and Potential Applications of Waze for Real-Time Traffic Management in Public Safety Answering Points," Center for Transportation Research, TRB Annual Meeting (January 2024).
- **Chin, K.,** A. McAuley, A. Gold, "Texas Connected Freight Corridors: Deployment Outreach Plan," Center for Transportation Research, The University of Texas at Austin (April 2021).
- Gold, A., **K. Chin,** M. Hinderaker, S. Munira, M. Sample, "Texas Technology Task Force White Papers: Innovation Corridors; Data and Artificial Intelligence; Hydrogen in Transportation," Center for Transportation Research, The University of Texas at Austin (July 2023).
- **Chin, K.,** J. Wang, X. Zhou, M. Sample, H. Ross, A. Gold, "Automated Vehicle Recommendations for Texas: A Study of Highway and Urban Operational Design Domains," Center for Transportation Research, The University of Texas at Austin (April 2023).
- **Chin, K.,** M. Avera, A. Gold, N. Ruiz-Juri, "Model Development: A Cluster Analysis Using Wejo Probe Vehicle Data," Center for Transportation Research, The University of Texas at Austin, Research Report 0-7033-1 (January 2021).

Exhibits

Table 4: ATTAIN Technologies Addressed by Application

	Technologies	Implemented Addressed by Application (Check all that apply)
1.	Advanced traveler information systems	X
2.	Advanced transportation management technologies	X
3.	Advanced transportation technologies to improve emergency evacuation and response by Federal, State, and local authorities	
4.	Infrastructure maintenance, monitoring, and condition assessment	X
5.	Advanced public transportation systems	
6.	Transportation system performance data collection, analysis, and dissemination systems	X
7.	Advanced safety systems, including V2V and V2Icommunications, technologies associated with automated vehicles, and other collision avoidance technologies, including systems using cellular technology	X
8.	Integration of intelligent transportation systems with the Smart Grid and other energy distribution and charging systems	
9.	Integrated corridor management systems	
10.	Advanced parking reservation or variable pricing system or system to assist trucks in locating available truck parking	
11.	Electronic pricing, toll collection, and payment systems	
12.	Technology that enhances high occupancy vehicle toll lanes, cordon pricing, or congestion pricing	
13.	Integration of transportation service payment systems	
14.	Advanced mobility and access technologies, such as dynamic ridesharing and information systems to support human services for elderly and disabled individuals	
15.	Retrofitting DSRC technology deployed as part of an existing pilot program to C–V2X technology, subject to the condition that the retrofitted technology operates only	
16.	Advanced transportation technologies, in accordance with the research areas described in section 6503 of Title 49	

Table 5: ATTAIN Program Goals Addressed by Application

	Program Goals	Implemented Addressed by Application (Check all that apply)
1.	Reduction in the number and severity of traffic crashes and an increase in driver, passenger, and pedestrian safety;	X
2.	Delivery of economic benefits by reducing delays, improving system performance and throughput, and providing for the efficient and reliable movement of people, goods, and services;	X
3.	Demonstration, quantification, and evaluation of the impact of these advanced technologies, strategies, and applications towards improved safety, efficiency, equity, and sustainable movement of people and goods;	X
4.	Improvement in the mobility of people and goods;	X
5.	Improvement in the durability and extension of the life of transportation infrastructure;	
6.	Reduced costs and improved return on investments, including through the enhanced use of existing transportation capacity;	
7.	Protection of the environment and delivery of environmental benefits that alleviate congestion and streamline traffic flow;	X
8.	Measurement and improvement of the operational performance of the applicable transportation networks;	X
9.	Collection, dissemination, and use of real-time transportation-related information including, but not limited to, work zone, weather, transit, and paratransit, to improve mobility, reduce congestion, and provide for more efficient and accessible, and integrated transportation, including access to safe, reliable, and affordable connections to employment, education, healthcare, freight facilities, and other services;	X
10.	Facilitating account-based payments for transportation access and services and integrating payment systems across modes;	
11.	Monitoring transportation assets to improve infrastructure management, reduce maintenance costs, prioritize investment decisions, and ensure a state of good repair;	X
12.	Accelerated deployment of V2V, V2I, vehicle-to-pedestrian, and technologies associated with automated vehicle applications and other advanced technologies	X
13.	Integration of advanced technologies into transportation system management and operations;	X
14.	Reproducibility of successful systems and services for technology and knowledge transfer to other locations facing similar challenges;	X
15.	Incentivizing travelers— (I) to share trips during periods in which travel demand exceeds system capacity; or (II) to shift trips to periods in which travel demand does not exceed system capacity.	

Table 6: *FHWA Priorities Addressed by Application*

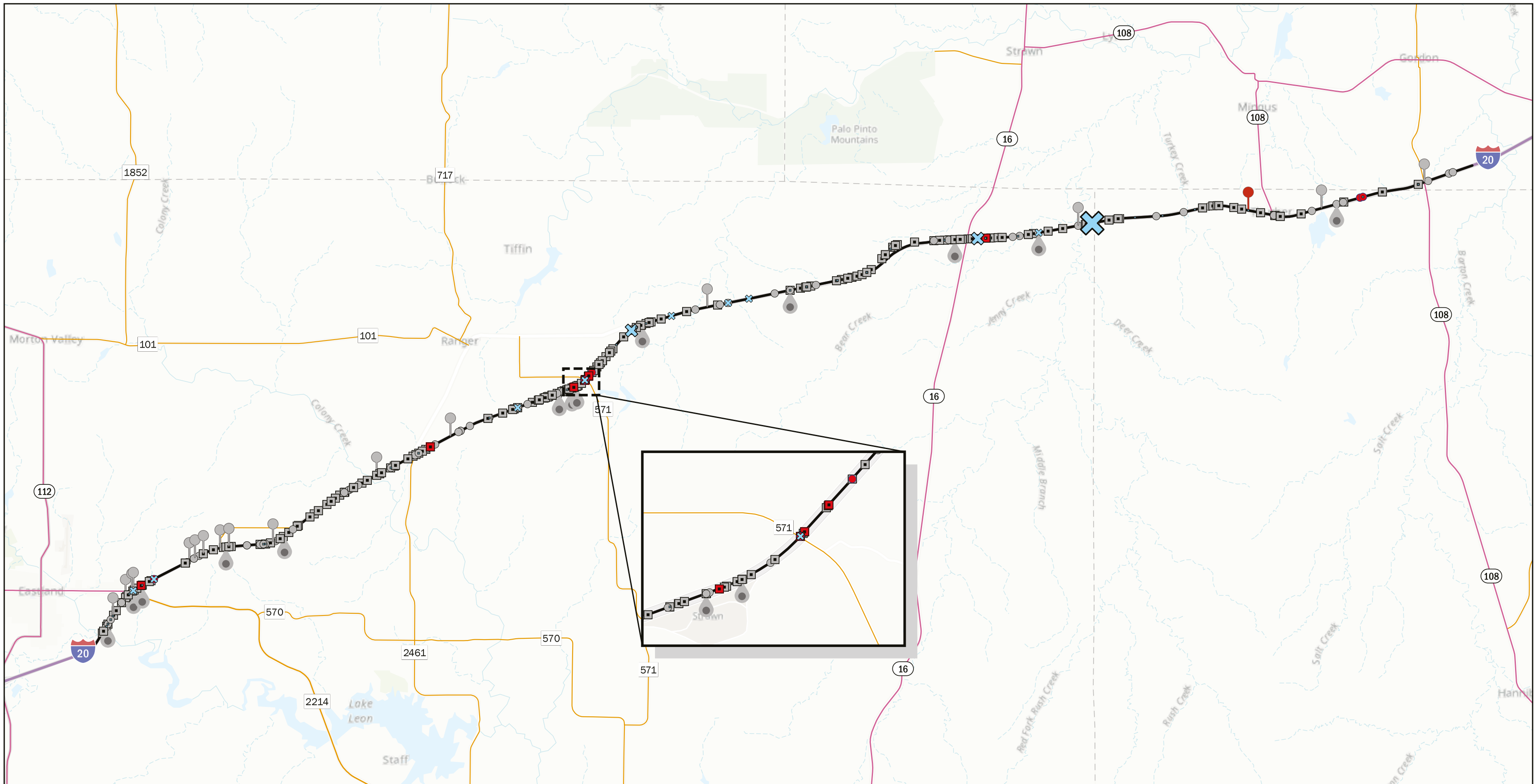
	Administration's Priorities	Implemented Addressed by Application (Check all that apply)
1.	Safety	X
2.	Climate Change and Sustainability	X
3.	Equity	X
4.	Workforce Development, Job Quality, and Wealth Creation	

Table 7: *U.S. DOT Focus Areas Addressed by Application*

	DOT Focus Areas	Implemented Addressed by Application (Check all that apply)
1.	State of Good Repair	X
2.	Integration of intelligent transportation systems with the Smart Grid and other energy distribution and charging systems	
3.	Advanced public transportation systems	X
4.	Freight (or Port) Community Systems	X
5.	ROUTES Initiative	X
6.	Complete Trip Program	X
7.	Data Availability	X

Table 8: *List of Acronyms*

Abbreviation	Definition
AADT	Annual Average Daily Traffic
ADS	Automated Driving System
ATMS	Advanced Traffic Management System
ATTAIN	Advanced Transportation Technology and Innovation
AV	Automated Vehicle
CDP	Comprehensive Deployment Plan
CF PFS	Connected Vehicle Pooled Fund Study
ConOps	Concept of Operations
CTR	University of Texas—Austin Center for Transportation Research
CU2J	ConnectU2Jobs
CV	Connected Vehicle
CVDF	Connected Vehicle Data Framework
FAF	Freight Analysis Framework
FHWA	Federal Highway Administration
I-20	Interstate 20
I2V	Infrastructure-to-Vehicle
IIHS	Insurance Institute for Highway Safety
ITS	Intelligent Transportation System
LLL	Lessons Learned Logbook
mph	Miles per Hour
MPO	Metropolitan Planning Organization
NOFO	Notice of Funding Opportunity
NTSB	National Transportation Safety Board
O&M	Operation and Maintenance
ROUTES	Rural Opportunities to Use Transportation for Economic Success
RSU	Roadside Unit
SH	State Highway
STRAHNET	Strategic Highway Network
SwRI	Southwest Research Institute
TCFC	Texas Connected Freight Corridor
TIM	Traveler Information Message
TMC	Traffic Management Center
TTI	Texas A&M Transportation Institute
TxDOT	Texas Department of Transportation
UAS	Unmanned Aerial System
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2X	Vehicle-to-Everything
VSL	Variable Speed Limit



Weather Condition All Severities
- CLOUDY (101)
- RAIN (253)
- SLEET/HAIL (19)
- SNOW (14)

Weather Related Fatal or Serious Injury
- CLOUDY (7)
- RAIN (8)
- SLEET/HAIL (1)

Multi-Vehicle Crashes
Number of Units Involved
- <=4 (32)
- <=6 (9)
- <=10 (2)
- >10 (1)

N W E S

0 1 Miles

Date: January 2024

* Study Segment Length: 28.6 Miles with 731 Total Crashes
Source: Crash Data obtained from TxDOT CRIS Query between January 2019 and December 2023.

Crash Analysis by Weather Conditions and Number of Vehicles Involved

IH 20 Segment from East of Eastland to South of Gordon From SH 112 to SH 108 (South)

TRANSCEND engineers + planners

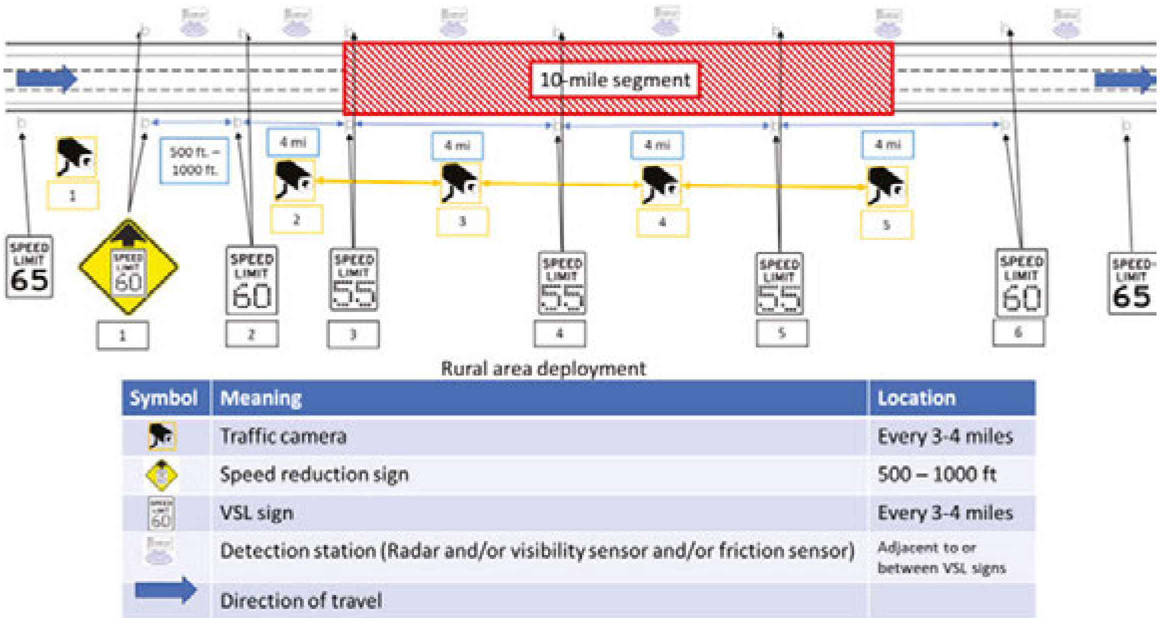


Figure 5: *Typical application of VSL for a 10-mile segment in a rural area.*

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