

# Texas Connected Freight Corridors

## A Sustainable Connected Vehicle Deployment

Opportunity No: 693JJ317NF0001

*A proposal to the*

U.S. Department of Transportation  
Federal Highway Administration

*Submitted by*

Texas Department of Transportation

*In Partnership with*

Texas A&M Transportation Institute  
Southwest Research Institute  
The University of Texas at Austin

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## Volume 1 – Technical Application

|   |   |  |  |
|---|---|--|--|
| <b>Project Name</b>   |   | <b>The Texas Connected Freight Corridors Project</b>   |  |
| <b>Eligible Entity Apply to Receive Federal Funding</b>                                 |   | <i>Texas Department of Transportation</i>  |  |
| <b>Total Project Cost (from all sources)</b>  |   | \$15,645,450   |  |
| <b>ATCMTD Request</b>   |   | \$7,774,000  |  |
| <b>Are matching funds restricted to a specific project component? If so, which one?</b> |   | No   |  |
| <b>State(s) in which the project is located</b>   |   | Texas  |  |
| <b>Is the project currently programmed in the:</b>                                      |   |  |  |
| <b>Transportation Improvement Program (TIP)?</b>  | <b>Statewide Transportation Improvement Program (STIP)?</b> | <b>MPO Long Range Transportation Plan?</b>   | <b>State Long Range Transportation Plan?</b> |
| <i>Pending</i>  | <i>Pending</i>  | No   | <i>Pending</i>                               |
| <b>Technologies Proposed to be Deployed</b>   |   | Advanced traveler information systems, advanced transportation management technologies, infrastructure condition monitoring technologies, connected vehicle V2I and V2V technologies, freight parking system technologies, truck platooning technology, border crossing technologies |  |

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## PROJECT NARATIVE

### Introduction

The Texas Connected Freight Corridors project will be Texas' largest deployment of connected vehicle (CV) technology aimed at making a significant reduction in the number and severity of crashes, reducing congestion on major interstates that serve the nation, and reducing fuel consumption of freight trucks. The Texas Connected Freight Corridors project will apply advanced safety and congestion management technologies to improve traveler information, asset condition assessment, and system performance. A U.S. Department of Transportation (US DOT) Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) award would launch this initiative in Texas to be a national model deployment for addressing freight mobility and safety needs and create the foundation for a full-scale, sustainable connected and automated vehicle deployment for the state.

### Vision, Goals, and Objectives

The Texas vision is to create a sustainable CV environment that covers the 865-mile Texas Triangle of I-35 (including extension to Laredo), I-45, and I-10 linking Austin, Dallas-Fort Worth, Houston, and San Antonio to support vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) safety and mobility applications being developed by public agencies and the CV industry.

TxDOT and its partners believe on-going success and support will be achieved by accomplishing the following goals:

- Promoting economic efficiency and safety of commercial vehicles and freight carriers which will also provide a direct safety and mobility benefit to passenger cars and other users.
- Creating Day One benefits through use of aftermarket devices and integration with existing on-board technologies.
- Minimizing infrastructure costs to state and local agencies through effective deployment of CV roadside units (RSU) and use of telecommunications technology.

In addition, Texas recognizes that connected automated vehicle technologies, including truck platooning, are also emerging. Automated vehicles, whether single function automation (Level 1) or multi-function automation (Level 2 and beyond), will benefit from connectivity to the infrastructure. Building out the connected infrastructure along the primary Interstate system will also facilitate the ultimate deployment of automated vehicles in Texas as well.

### Project Description

To achieve this vision, the Texas Team proposes the Texas Connected Freight Corridors Project to deploy the foundational elements on key parts of the Texas Triangle to begin a sustainable deployment. The lead entity contracting with the USDOT will be the Texas Department of Transportation (TxDOT). TxDOT and its partners have prioritized 12 CV applications (11 V2I and 1 V2V applications) that will meet the goals and objectives of greater safety and reduced congestions. Those applications are: advanced traveler information, eco-dynamic routing, queue warning, work zone warning, wrong way driving detection and warning, road weather warning, low bridge height warning, truck signal priority, pedestrian/animal warning, truck parking availability, border wait time notifications, and emergency electronic brake light warning. Targeting the freight community first achieves two goals: 1) a technology-ready sector that can easily integrate data from connected vehicle applications, and 2) immediate improvement in safety and mobility for the trucks operating on the Texas interstates. The Texas Connected Freight Corridors project will deploy CV

technologies in over 1,000 trucks and agency fleet vehicles that will be able to transmit data and receive warnings from these applications.

### Proposed Technology Description

The Texas Connected Freight Corridors Project will build on the mature intelligent transportation system (ITS) technologies already deployed in the TxDOT Districts across the state. TxDOT has a statewide advanced traffic management system (ATMS) software platform deployed in each District. That ATMS product uses advanced traveler information system (ATIS) technologies to post travel time, incident, construction, and weather warning messages on dynamic message signs throughout the state. The ATMS product also shares data with various private sector information providers to provide additional advanced traveler information. The Texas Connected Freight Corridors project will deploy infrastructure condition monitoring technologies on TxDOT fleet vehicles to support maintenance activities. The project will also deploy connected vehicle (V2I and V2V) technologies to support safety and mobility applications (i.e., end-of-queue, work zones, road weather, and wrong-way driving warnings) along these interstate corridors. In addition, the project will deploy freight specific technologies. Both freight parking system technologies and border crossing technologies will be deployed to provide freight operators and truck drivers with better information on parking availability and border crossing wait times. The data from CV V2I and V2V applications will also be shared with truck platooning technologies to improve the safety and efficiency of these planned deployments.

Telecommunication technology will be also deployed to support the CV applications. The I-35 corridor has the most urban regions along its corridor. Thus, the Texas Team is proposing an emphasis on DSRC communication in this corridor. The I-45 and I-10 corridors are more rural in nature and offer more cost effective deployment using other communication such as cellular (4G, and 4G LTE). This approach will also allow the public agencies to compare the benefits, performance, and infrastructure cost for different CV deployment scenarios. These design decisions will be addressed in detailed design phase of Task 2.

## DESCRIPTION OF REAL WORLD ISSUES

Texas is the second largest state with a population approaching 27 million people, with nearly three-quarters of the population living within the *Texas Triangle* bordered by I-35, I-45 and I-10 and linking Austin, Dallas, Fort Worth, Houston, and San Antonio. As shown in Figure 1, the population projections in 2040 are estimated to exceed 45 million people, most centered along the urban areas that anchor the Texas Triangle. The Texas Triangle (one of eleven mega regions) also contains three of the 10 largest urban areas in the United States, seven of the top 25 national freight congestion bottleneck

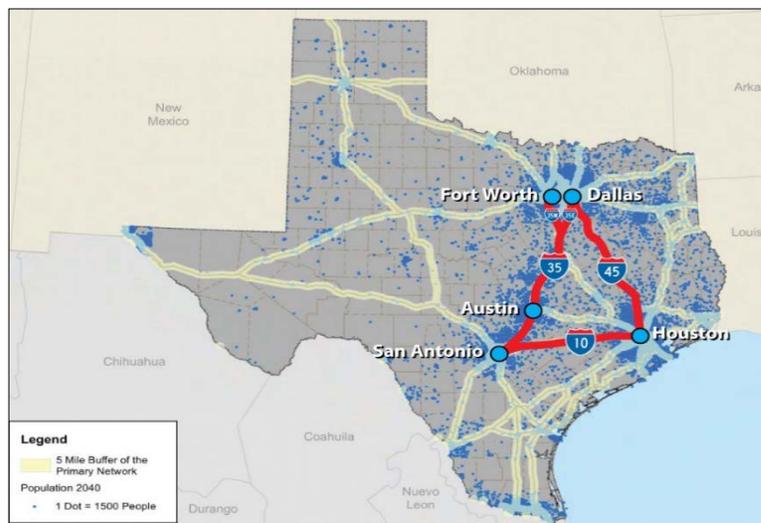


Figure 1. Population Growth for Texas Triangle – 2040.

locations, and 11 of the top 20 most congested roadway sections in Texas.

In addition to the explosive population growth, freight tonnage is projected to double from 2010 to 2040 with trucks moving over 59% of this tonnage in 2010 and 66% in 2040. In 2014, there were over 587,000 daily truck trips on Texas roadways; this is projected to double to over 1 million daily truck trips in 2040. These land ports are accessed via the key corridors within the Texas Triangle. For instance, I-35, also known as the North American Free Trade Agreement (NAFTA) corridor, is the key artery for Mexico, U.S., and Canada trade. The Texas Triangle is also home to the Port of Houston, ranked first in foreign waterborne tonnage and second in the nation in total tonnage.

## **Challenges in Texas**

Texas' economic growth and population increase have created several challenges to maintaining a safe and efficient transportation system. This section discusses the mobility, safety, freight, and border crossing challenges in Texas.

### Mobility Challenges

The most congested metropolitan highways in Texas are becoming even more crowded, resulting in lost time and wasted fuel topping \$9 billion per year — that equates to approximately \$1,150 for the average commuter in large- and medium-sized Texas metropolitan areas (<http://mobility.tamu.edu/ums/>). Six of the 25 fastest congestion growth metropolitan regions with more than 500,000 population are in Texas — Dallas-Fort Worth, Houston, San Antonio and Austin plus the border cities of El Paso and McAllen. These congested regions, and the corridors that serve them, also cause problems in the movement of goods and services through the metro areas to the rest of Texas and to markets outside of the state.

Over the past 40 years, Texas' population has more than doubled, and the number of cars and trucks on the roadways has almost tripled. The reality is Texas' population is growing at a rate that is far greater than the capacity of the existing infrastructure, continuing to make congestion relief a top priority. Better operation of the current infrastructure and implementation of technology such as connected and automated vehicles is one strategy that will assist in keeping up with the mobility and safety demands of Texas.

### Safety Challenges

Although fatalities and incapacitating injuries had been on a decline since 1996, the state has seen an increase in recent years. The general consensus among those involved in transportation safety is that further reductions are not only desirable, but feasible. Texas must continue to seek safety improvements by deploying a diverse set of countermeasures that address both engineering and behavioral issues. Technological improvements in automobile and roadway engineering, traffic management, enforcement methods, medical treatment, and educational processes suggest we have not reached the limits of our capabilities to reduce crashes and injuries.

Crashes involving commercial motor vehicles (CMVs) are also a concern. Over the past five years, the fatal crashes involving CMVs statewide has grown from 349 to 459 crashes, as shown in Table 1. Examination of the “Texas Triangle” (including the I-35 leg to Laredo) found approximately 15% of the crashes involve CMV across the same years 2010-2014.

Improving pedestrian safety is a top priority as well as reducing vehicle crashes. The FHWA has identified 30 U.S. cities as Pedestrian Focus Cities due to their high number of pedestrian fatalities. All five Pedestrian Focus Cities in Texas (Austin, Dallas, Fort Worth, Houston and San Antonio) are located within the “Texas Triangle.” There were 234 fatalities involving a pedestrian from 2010-2014 on the I-35 (including extension to Laredo), I-45 and I-10 corridors within the “Texas Triangle.”

**Table 1. Statewide Reportable Motor Vehicle Crashes and Fatalities Involving Commercial Motor Vehicle Trucks/Vans.**

| Crash Year | Fatal Crashes | Fatalities | Total Crashes |
|------------|---------------|------------|---------------|
| 2010       | 349           | 403        | 19,706        |
| 2011       | 348           | 383        | 19,726        |
| 2012       | 420           | 481        | 21,829        |
| 2013       | 417           | 489        | 24,477        |
| 2014       | 459           | 529        | 27,670        |
| Total      | 1,993         | 2,285      | 111,408       |

Safety risks associated with roadway construction and maintenance activities are a significant national and state concern. For many years, Texas has led the nation in the number of lives lost in work zones, most recently reporting a total of 104 work zone fatalities in 2013. In 2013, 40 percent of Texas work zone fatalities occurred on Interstates and freeways, even though such facilities comprise less than 2 percent of all route miles in the state. These facilities also carry the vast majority of vehicular travel within the state, which means that they require a disproportionate share of work zone activity to maintain service and functional efficiencies. And with Texas' substantial increase in highway funding from the recent legislative session, there is greater potential for work zone crashes.

#### Freight Challenges

Goods movement is crucial to the Texas and national economies. The ability of the state to maintain its position as a leader in trade and manufacturing depends on the strength of its freight mobility. An efficient and safe freight transportation system connects Texas' rural and urban areas, economic activity, production and consumption centers, and provides access to markets and jobs, as well as the delivery of raw materials and shipment of finished goods.

In 2014, more than 2.6 billion tons of freight moved in Texas, and it is anticipated to increase to nearly 3.8 billion tons by 2040, which is a 46% growth between 2014 and 2040 with trucks moving two-thirds of this tonnage. In 2013, Texas had over \$1 billion in congestion cost to the trucking industry, ranking only behind California. Dallas ranked 4<sup>th</sup> with over \$406 million and Houston ranked 6<sup>th</sup> with over \$373 million in congestion cost to the trucking industry. I-35 through Austin is the most congested roadway segment in Texas based on trucking delays with over 116,000 hours of delay in 2013. The primary routes carrying freight are shown in Figure 2.

Commercial and freight transportation vehicles are an important component of the state's highway traffic, and this component is projected to grow in the coming decades as the state's population grows. Therefore, the state's multimodal freight network must keep up with increasing demands from businesses, manufacturers and residents. The movement of freight within, through, from, and into Texas will continue to expand, thanks to a robust economy, population growth, increased trade and growing energy production.

Truck traffic also impacts the environment in the state. A finding within the Transportation Research Board's (TRB) National Cooperative Freight Research Program (NCFRP) Report 23, *Synthesis of Freight Research in Urban Transportation Planning*, is that urban freight contributes disproportionately to externalities. "Commercial vehicles contribute a significant share of nitrogen

oxide, particulate matter, and carbon dioxide emission in cities and contribute disproportionately to congestion, noise, and fatalities.”<sup>1</sup>

Border Crossing Challenges

Texas shares a common border with Mexico with over 1200 miles and 29 total crossings and 13 commercial crossings. The importance of trucks is demonstrated by the fact that 73 percent of goods manufactured in Texas and 85 percent of trade between Texas and Mexico is handled by trucks.<sup>2</sup> Average daily heavy truck volume at the border is expected to increase from approximately 18,000 in 2013 to over 51,000 by 2040 – a 178 percent increase. Total truck volumes at the border are projected to increase from 6.7 million in 2013 to 18.6 million per year by 2040. The most heavily utilized truck corridor Texas into Mexico is I-35 through Laredo World Trade Bridge with over 1.4 million trucks crossing in 2013.

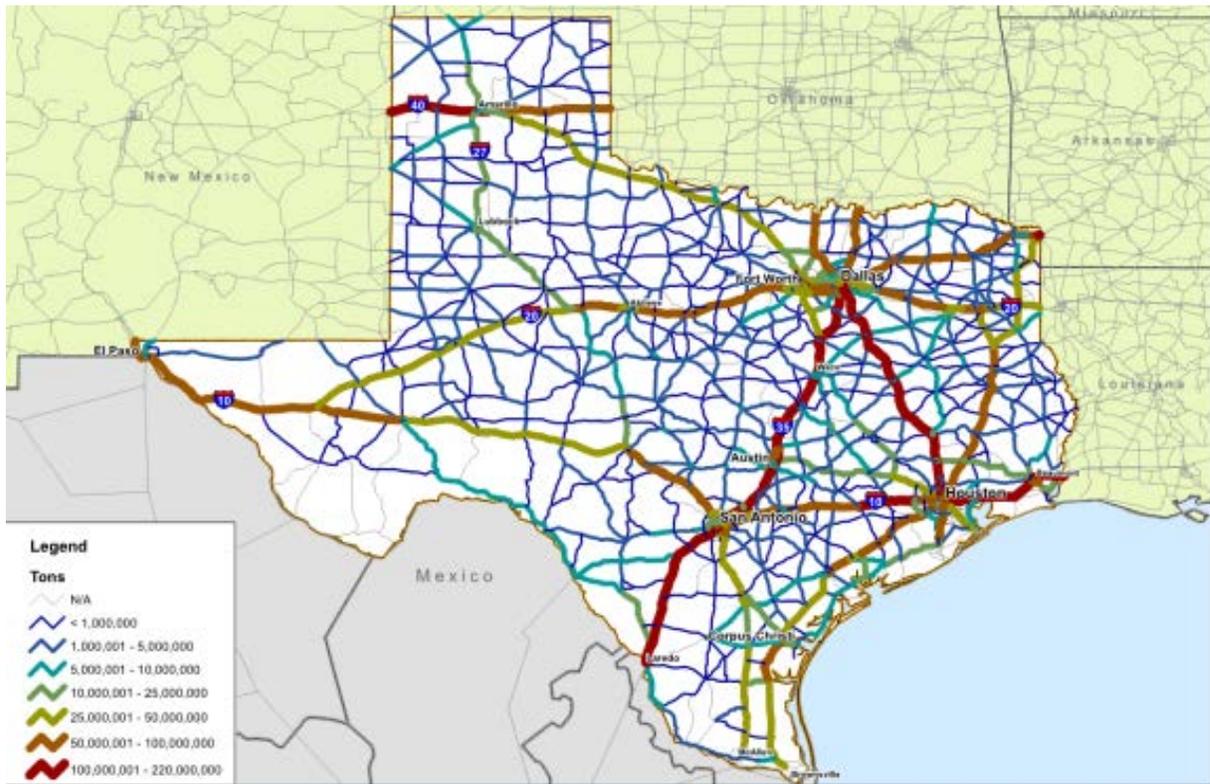


Figure 2. Projected Total Freight Tonnage, 2040.

<sup>1</sup> Giuliano, Genevieve, et. al. *NCFRP Report 23 Synthesis of Freight Research in Urban Transportation Planning*. METTRANS Transportation Center, University of Southern California. Los Angeles, CA, 2013. Online. Available: [http://onlinepubs.trb.org/onlinepubs/ncfrp/ncfrp\\_rpt\\_023.pdf](http://onlinepubs.trb.org/onlinepubs/ncfrp/ncfrp_rpt_023.pdf). Date accessed: March 13, 2015.

<sup>2</sup> Texas Department of Transportation. Texas Freight Advisory Committee. *Texas Trucking*. Online. Available: <http://ftp.dot.state.tx.us/pub/txdot-info/freight/trucking-fact-sheet.pdf>. Date accessed: June 11, 2017.

## DESCRIPTION OF GEOGRAPHIC AREA AND TRANSPORTATION SYSTEM

In the next 40 years, more Texans will be living and working within the Texas Triangle<sup>3</sup>. Because of this concentration, the Texas Connected Freight Corridors Project will start with instrumenting these primary corridors connecting the largest urban areas to create the next generation of transportation for moving people and goods. A map of the Texas Triangle, the corridors of interest, and proposed CV applications are shown on the Site Map in Figure 3.

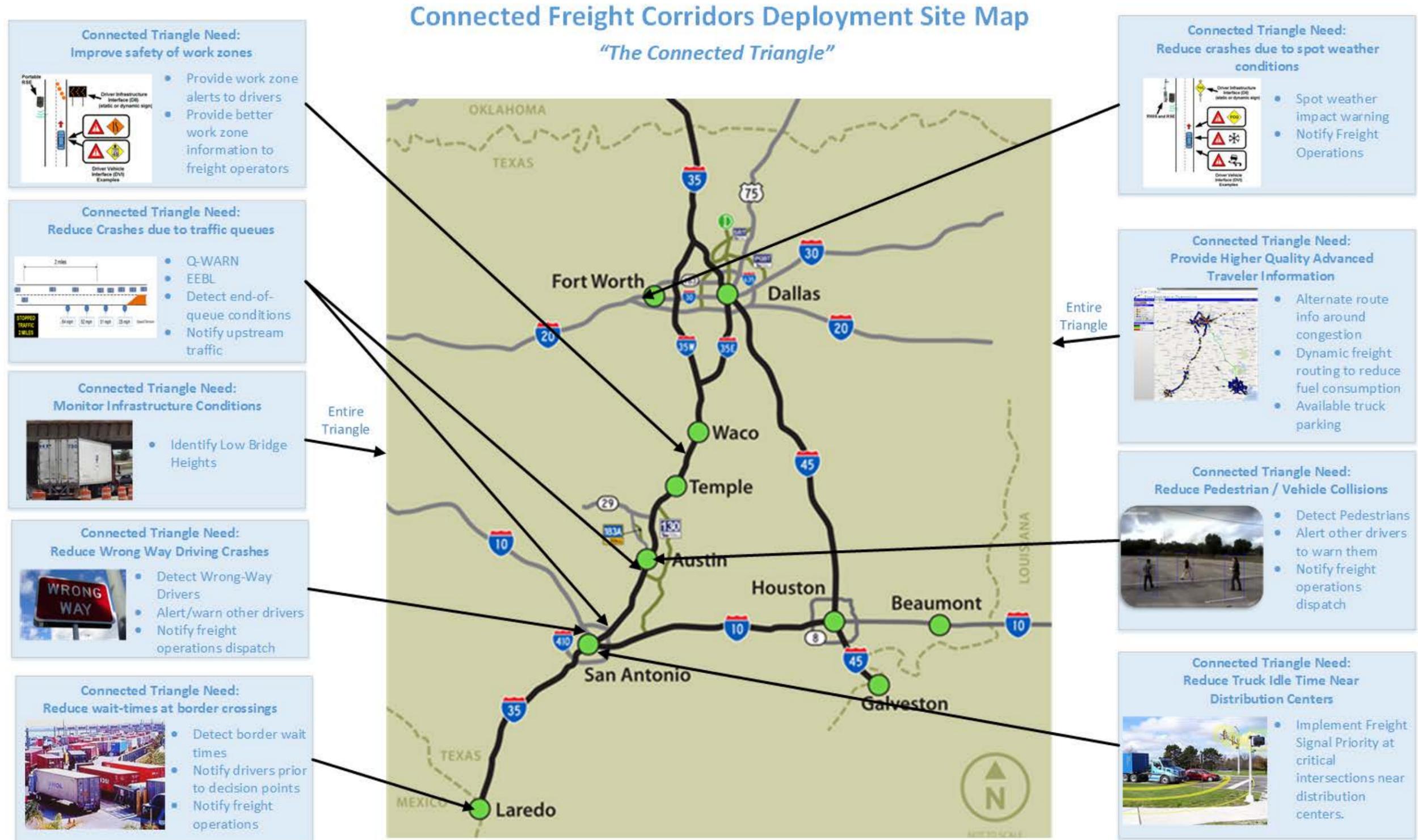
The three primary corridors that bound the geographic area are:

- I-35 is a major NAFTA trade corridor serving Mexico, the United States and Canada. In addition to connecting Austin, Dallas, Fort Worth, and San Antonio, I-35 also serves Laredo, the largest port of entry on the U.S./Mexico border. I-35 is one of the most important freight corridors in the U.S. and provides access to North American Free Trade Agreement (NAFTA) related transborder freight through Laredo.
- I-45 serves the metropolitan areas of Houston-Galveston and Dallas-Fort Worth. I-45 serves the Ports of Galveston and Texas City and, indirectly, the Port of Houston. It also serves the International Inland Ports in the Dallas area. I-45 is the main Interstate connection between Houston and Dallas. I-45 is a major coastal hurricane evacuation route.
- I-10 is the southernmost transcontinental highway and national freight corridor. In Texas I-10 is the major freight corridor connecting the port of Houston and the Eagle Ford Shale energy development region.

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<sup>3</sup> University of Texas, Navigating the Texas Triangle. (<http://www.utexas.edu/what-starts-here/finding-solutions/navigating-texas-triangle#sthash.zbaQ8lT7.dpuf>). Access March 15, 2015.

Figure 3. Site Map.



### Description of Transportation Systems, Services, and Applications

Texas is interested in a bundle of mobility and safety applications that will help freight operators and commercial vehicle drivers on the busiest and most congested corridors in Texas and the nation. The applications and core systems proposed to be developed and implemented are shown in Table 2. Some of the applications in Table 2 are under development and will be mature by the beginning of Task 2 of the scope of work, which will assist in reducing the costs associated with this deployment. Other applications will be developed as part of Task 2 in the scope of work. Table 2 also details the needs addressed by each application and potential performance measures. Through the course of Task 1, this list will be re-examined and refined to meet the prioritized needs of the project team partners and stakeholders.

**Table 2. Proposed CV Applications, Needs, and Maturity.**

| # | ATCMTD Focus Area                             | Applications  | Potential Locations                | Transportation Needs                                   | Level of Application Maturity by Task 2                 |
|---|---|---|------------------------------------|--|---|
| 1 | Multi-modal ICM                               | Advanced Traveler Information System (ATIS)   | I-35, I-45, I-10 Corridors         | Information dissemination, improved freight efficiency | Mature (will use Lonestar® and ITS infrastructure)      |
|   |   | Eco-Dynamic Routing   | I-35, I-45, I-10 Corridors         | Advisory information                                   | New   |
|   |   | Work Zone Warning   | I-35 (Austin, Temple)              | Information dissemination                              | Mature (I-35 – TxDOT/TTI)                               |
| 2 | CV for Pedestrian / Bike Safety               | Ped/Animal Warning  | I-35, Austin                       | Incident information                                   | New   |
|   |   | SPaT for Ped/Bike Safety  | Riverside Dr, Austin               | Ped / Bike Safety                                      | Mature (TTI)  |
| 3 | Unified Fare Collection/Payment System        | Truck Parking Availability System   | I-35, Rest Areas                   | Information dissemination                              | New   |
| 4 | Freight community System                      | Border Wait Times   | Laredo                             | Advisory information                                   | Mature (border crossing wait times exist)               |
| 5 | Technologies to support Connected Communities | Truck Signal Priority   | San Antonio                        | Improve mobility near distribution centers             | Mature (SPaT – TTI)                                     |
| 6 | Infrastructure Condition Assessment           | Low Bridge Height Warning, automated crash attenuator for mobile maintenance operations | I-35 DSRC<br>I-45/I-10<br>Cellular | Agency efficiency, Advisory information                | Partial (TxDOT/TTI/ SwRI developing monitoring systems) |

| # | ATCMTD Focus Area  | Applications   | Potential Locations                | Transportation Needs | Level of Application Maturity by Task 2 |
|---|--------------------|--|------------------------------------|----------------------|---|
| 7 | Rural Technologies | Wrong Way Driving (WWD)                                    | San Antonio                        | Incident information | Mature (TxDOT/TTI/SwRI)                 |
|   |                    | Emergency Electronic Brake Lights (EEBL - V2V application) | Austin / San Antonio               | Incident information | Mature (Safety Pilot - SwRI)            |
|   |                    | Queue Warning  | I-35 DSRC<br>I-45/I-10<br>Cellular | Incident information | Mature (INFLO project - TTI)            |
|   |                    | Road Weather Warning                                       | I-35 Corridor                      | Weather information  | New                                     |

**Alignment with USDOT ATCMTD Focus Areas**

The Texas Connected Freight Corridors project has close alignment with most of the ATCMTD focus areas and US DOT priorities. The deployment of CV technologies will improve safety, reduce congestion, and reduce environmental impacts. A description of how the project will address these focus areas and priorities is highlighted in Table 3.

**Table 3. Texas Connected Freight Corridors Support of USDOT Priorities.**

| Priority  | Texas Connected Freight Corridors Project  |
|---|--|
| Multimodal Integrated Corridor Management (ICM)                                   | <p>The project will link three different ICM implementations across 200 miles of I-35 corridor. TxDOT has deployed two ICM projects along I-35 in Waco and Temple, Texas. Corridor traffic conditions are monitored on I-35 and alternate loop routes around the urban areas. Business rules monitor when the alternate route offers improved mobility. Real-time information is shared with truck and passenger drivers to offer alternate route information.</p> <p>In addition, Austin, Texas received a USDOT ICM planning grant. Austin is developing an ICM project around the I-35 corridor. ICM operating strategies can be delivered to freight vehicles leveraging the data from ICM to expand to freight deliveries destined for Austin or points beyond.</p> |
| Connected Vehicle Technologies at Intersections and Pedestrian Crossing Locations | <p>Pedestrian fatalities on I-35 are significant and result from pedestrian trying to cross I-35 between downtown Austin and lower income communities east of I-35 and from vehicle breakdowns where drivers leave their vehicles to get assistance (potentially due to older vehicles from lower income demographics). The project will apply pedestrian crossing technology to detect and warn of pedestrians.</p> <p>Many arterial corridors cross I-35 that carry significant pedestrian and bicycle traffic. The project will use the Riverside Drive corridor in Austin as a model deployment of CV technologies for improved pedestrian and bicycle safety at signalized intersections.</p>   |

| Priority   | Texas Connected Freight Corridors Project  |
|--|--|
| Unified Fare Collection and Payment System                       | Lack of information about available truck parking impacts truck driver’s hours of service and freight efficiency. When spaces are not available, some truck drivers are forced to park on interstate ramps and shoulders, creating further safety concerns. The project will examine how the CV technology can be used to support truck parking availability systems with possible reservations for truck drivers.   |
| Freight Community System   | International border crossings can affect freight efficiency. Better information for freight operators and truck drivers will help freight planning and operations. This project will examine use of CV technologies to expand border crossing weight time information to freight operators.   |
| Technologies to Support Connected Communities                    | HEB is a flagship partner on the project with a freight hub in northeast San Antonio. Trucks with San Antonio destinations will be able to move from the I-35 corridor to the San Antonio arterial street corridors and continue with CV applications for their “last mile” of delivery. The project will use a traffic signal priority application for CV-equipped freight vehicles. Signal, Phase, and Timing (SPaT) data can be used with freight vehicles to more efficiently move trucks through these corridors, reducing the heavy-vehicle impacts to the community.  |
| Infrastructure Maintenance, Monitoring, and Condition Assessment | The project will instrument agency fleet vehicles with sensors to gather infrastructure conditions. Some conditions, such as low bridge heights, can be translated to truck driver warnings. Other infrastructure conditions (i.e., pavement, signs, and markings) can be monitored as part of the agency’s overall maintenance program for more cost effective maintenance treatments.  |
| Rural Technologies   | <p>Significant sections of I-35, I-45, and I-10 cross rural areas of Texas. Motorists and truck drivers can encounter unexpected congestion as a result of incidents, roadway construction, or weather. The project will deploy CV technologies to provide end-of-queue warnings for traffic congestion from incidents, inclement weather, and work zones. An emergency electronic brake light warning system will be deployed to propagate these warnings to instrumented trucks in the corridor. Safe deceleration of trucks near these events will have an overall safety impact to all motorist in the traffic stream. In addition to these state funded capabilities, the Crash Avoidance Metrics Partnership (CAMP) is currently working with USDOT on a reference passenger vehicle to receive work zone data for display in their vehicle.</p> <p>Furthermore, these rural areas are planned deployments of truck platooning. The CV applications can share the same data with truck platooning systems to allow safety adjustment of following distances near these events.</p> |

**Alignment with USDOT Goals**

The Texas Connected Freight Corridors Project also supports the USDOT ATCMTD goals. Table 4 highlights the alignment of the project with those goals.

**Table 4. Texas Connected Freight Corridors Support of ATCMTD Goals.**

| ATCMTD Goals  | Texas Connected Freight Corridors Project  |
|---|--|
| Reduced costs and improved ROI  | The Project focuses on reducing costs to public agencies and operating costs for private freight companies. The CV applications have the potential to reduce or eliminate current traffic condition and asset data collection; and thus, reduce the cost of existing operations or improve existing agency services.   |
| Delivery of environmental benefits that alleviate congestion and streamline traffic flow  | The Project will implement CV mobility and safety applications with a goal to reduce the frequency of crashes involving trucks as well as to provide optimal routing information to trucks to avoid congestion caused by crashes. The crash reduction and travel information will reduce truck fuel consumption and emissions, resulting in environmental benefits.  |
| Measurement and improvement of the operational performance of the applicable transportation networks  | The deployment of CV technology in over 1,000+ trucks will result in probe vehicle data that will be used by TxDOT and the local agencies to improve traffic management along these corridors.   |
| Reduction in the number and severity of traffic crashes and an increase in driver, passenger, and pedestrian safety   | The Project will reduce the number of crashes involving trucks by providing V2I applications (e.g., queue warning) and V2V applications (e.g., emergency electronic brake light warnings). Heavy vehicle crashes tend to be more severe and involve multiple vehicles due to the size/weight of the trucks. The Project also will target reducing pedestrian fatalities on I-35 and crossing arterials with pedestrian detection technology and improved signal operation.   |
| Collection, dissemination, and use of real-time transportation related information to improve mobility, reduce congestion, and provide for more efficient and accessible transportation, including access to safe, reliable, and affordable connections to employment, education, health care, freight facilities, and other services | The Project will use CV technology to generate and disseminate real-time data for mobility and safety with an emphasis on the freight industry. By improving the safety and efficiency of national freight movement on these interstate corridors, Texas expects to strengthen the economic development and job potential in the freight industry and those serviced by the freight industry. Improved freight operation on highways and streets will reduce the impacts and increase reliability of transportation in these communities |
| Monitoring transportation assets to improve infrastructure management, reduce maintenance costs, prioritize investment decisions, and ensure a state of good repair   | The Project will use CV data from freight vehicles and from public agency fleets to generate data to support operation, management, and maintenance of infrastructure assets. The data will allow for timely and proper maintenance treatments to maintain transportation infrastructure.  |

| ATCMTD Goals  | Texas Connected Freight Corridors Project   |
|---|---|
| <p>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</p>                        | <p>The Project will deploy CV mobility and safety applications with initial emphasis on the freight industry. By improving the safety and efficiency of national freight movement on these interstate corridors, Texas expects to improve throughput, travel time, and reliability of these corridors for all travelers. These improvements should have the additional benefit of economic development and job potential in the freight industry and freight customers.</p>   |
| <p>Accelerated deployment of vehicle-to-vehicle, vehicle-to-infrastructure, and automated vehicle applications, and autonomous vehicles and other advanced technologies</p>                                       | <p>The Project will accelerate the CV V2V and V2I applications on the highest-priority, highest-volume interstate corridors in Texas. In addition, the Project will examine use of V2I applications for truck platooning and automation development. Peloton Technology is supporting this project as they move forward with one of their national truck platooning pilots on I-45 between Dallas and Houston. In addition, TxDOT has a current Level 2 truck platooning research project looking at V2I applications to optimize the platooning operation.</p> |
| <p>Integration of advanced technologies into transportation system management and operations</p>  | <p>The Project builds on the traditional ITS deployed in these interstate corridors by TxDOT and their partners. The project will both incorporate the CV data into TxDOT’s existing ATMS software and examine how CV data can be used to improve transportation system management and operations along these corridors.</p>  |
| <p>Demonstration, quantification, and evaluation of the impact of these advanced technologies, strategies, and applications towards improved safety, efficiency, and sustainable movement of people and goods</p> | <p>The Project fully supports this goal by developing a sustainable CV deployment to demonstrate how CV technologies will improve safety and efficiency on these corridors. Deployment of these CV applications will improve movement of goods by the freight industry, which should further improve mobility for all travelers.</p>  |
| <p>Reproducibility of successful systems and services for technology and knowledge transfer to other locations facing similar challenges</p>  | <p>The Project will serve as the largest model deployment of CV in Texas. The Texas Team is committed to conducting outreach, technology transfer, and transfer of lessons learned to other national stakeholders.</p>  |

## DEPLOYMENT PLAN AND PROGRAM DESCRIPTION

This section describes how the Texas Team will manage the elements of the program, including partners and stakeholders, performance measurement, benefit evaluation, regional and national technology investments, and long-term operation and maintenance.

### **Description of Long-Term O&M**

The ATCMTD grant will support the operation and maintenance of the system largely during the operation period of the project. TxDOT, working with its partners, will determine the appropriate entity with responsibility for O&M of the different elements of the project. These entities will work to create appropriate funding in their respective O&M 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 project operational period. This will ensure that there is sufficient time to acquire the O&M funds within the appropriate fiscal year of each entity. The new FAST Act includes funding categories for V2I equipment under the HSIP, CMAQ, NHPP, and STBG programs. In addition, TxDOT has made the deployment of CV a priority and is now including deployment of RSUs as part of construction on freeways.

### **Description of System Performance Measures**

Performance measurement is a primary component of many operational programs and a focus of numerous agencies and traffic management centers. The objectives of a successful performance measurement program should be: 1) set goals and standards, 2) detect and correct problems, 3) manage, describe, and improve processes, and 4) document accomplishments. A successful performance measurement system for CV technologies would use a few select measures that are easy to understand for both decision-makers and operators and are meaningful to the intended audience. Measures reflecting the potential benefits of CV deployments should be logical, repeatable, allow economic data collection, timely reporting, and be sensitive enough to the data to show changes and trends. Critical components of any measure, in addition to the definition, are the calculation methodology and the targets. Challenges with assessing the performance of CVs can arise. For example, when multiple applications are deployed simultaneously, the impacts of a single strategy can be confounded. Thus, agencies need clear guidance on appropriate performance measures and how best to use them to assess results.

Performance monitoring offers agencies the following benefits: 1) provides transparency to the public and accountability of public officials; 2) allows agencies to understand where problems are located and what is needed to fix these problems; 3) permits agencies to better manage limited resources to maximize performance potential; and 4) allows agencies to determine how well past investments worked and whether they are making a difference in addressing identified problems. The applications for the Texas Connected Freight Corridors Project are shown in Description of Transportation Systems, Services, and Applications.

Texas is interested in a bundle of mobility and safety applications that will help freight operators and commercial vehicle drivers on the busiest and most congested corridors in Texas and the nation.

The applications and core systems proposed to be developed and implemented are shown in

Table 5. Some of the applications in

Table 5 are under development and will be mature by the beginning of Task 2, which assists in reducing the costs associated with this deployment. Other applications will be developed as part of Task 2. The table also details the needs addressed by each application and potential performance measures. Through the course of Task 1, this list will be re-examined and refined to meet the prioritized needs of the project team partners and stakeholders.

Table 5. Proposed CV Applications, Needs, and Performance Measures.

| #  | Applications   | Needs  | Performance Measure   |
|----|--|--|---|
| 1  | Advanced Traveler Information System (ATIS) including in vehicle information | Information dissemination, improved freight efficiency | Improve truck safety<br>Improve public safety<br>Improve travel time reliability<br>Improve agency efficiency |
| 2  | Eco-Dynamic Routing  | Advisory information                                   | Improve travel time reliability<br>Reduce environmental impact  |
| 3  | Work Zone Warning  | Information dissemination                              | Improve truck safety<br>Improve public safety<br>Improve travel time reliability                              |
| 4  | Ped/Animal Warning   | Incident information                                   | Improve public safety<br>Improve truck safety<br>Improve travel time reliability                              |
| 5  | Truck Parking Availability/Reservation System                                | Information dissemination,                             | Improved freight efficiency<br>Improved parking utilization   |
| 6  | Border Wait Times  | Advisory information                                   | Improve travel time reliability<br>Reduce environmental impact  |
| 7  | Truck Signal Priority  | Improve mobility near distribution centers             | Improve travel time reliability<br>Reduce environmental impact  |
| 8  | Low Bridge Height Warning  | Agency efficiency, Advisory information                | Improve truck safety<br>Improve public safety<br>Protect TxDOT infrastructure                                 |
| 9  | Emergency Electronic Brake Lights (EEBL - V2V application)                   | Incident information                                   | Improve truck safety<br>Improve public safety<br>Reduce environmental impact                                  |
| 10 | Queue Warning  | Incident information                                   | Improve truck safety<br>Improve public safety   |
| 11 | Road Weather Warning   | Weather information                                    | Improve truck safety<br>Improve public safety<br>Improve travel time reliability                              |
| 12 | Wrong Way Driving (WWD)  | Incident information                                   | Improve truck safety<br>Improve public safety<br>Improve agency efficiency                                    |

### Description of Benefits

With the challenges facing Texas, there are several benefits that can be achieved by deploying these advanced management and technologies:

- For improved safety on the Interstate system, warnings are needed to inform drivers and freight operators of slowed or stopped traffic due to recurring or non-recurring congestion (i.e., work zones, incidents, weather events, or special events) or to warn of hazards near the roadway such as animals, pedestrians, wrong-way drivers, or low bridge heights.

- For improved mobility, drivers and operators need better traveler information about real-time alternatives to avoid congestion and delays. Reduced delays will reduce the environmental impact of travel by decreasing gas consumption and emissions.
- For improved safety and mobility during inclement weather, better weather and road condition information is needed for drivers.
- For freight operations, there is a need to better operate the infrastructure near border crossings and freight distribution centers to reduce delays to commercial vehicles.

### **Partnering Plan**

As stated previously, the Texas Team has begun assembly of key public and private stakeholders (that may evolve into partners) to guide the Texas Connected Freight Corridors Project through all three tasks.

#### Public Agency Stakeholders

Each of the public agency stakeholders has submitted support letters indicating their commitment to the ATCMTD program. Elements of the Texas Connected Freight Corridors Project will be deployed in the public agency jurisdictions and will require collaboration with TxDOT. These collaborations build on the past involvement most of these partners have had with TxDOT on USDOT grants and proposals such as the USDOT ITS Model Deployment in San Antonio, USDOT Smart Cities Challenge in Austin, and the US 75 ICM Program in north Texas.

The stakeholders will form the Concept of Operations Review Panel to help guide the concept development of a CV environment *that will grow and be sustained* by stakeholders across the state.

#### Freight Companies

The participating freight companies have also submitted letters of commitment to the ATCMTD project. These companies will be critical in forming the commercial vehicle fleet using CV applications operating on the Texas Triangle interstate highways. HEB is a regional grocer with significant freight operations in Texas utilizing the Texas Triangle. All of the other freight companies have operations in Texas that use the Texas Triangle.

### **Plan to Leverage Regional Technology Investments**

TxDOT and its partners have been conducting several connected and automated vehicle projects that will serve as a foundation to the Texas Connected Freight Corridors Project. The following summarizes these leading projects.

#### TxDOT CV Testing in San Antonio

To begin developing and testing CV applications that could provide safety, mobility, and environmental benefits in Texas, TxDOT initiated a project with SwRI to deploy DSRC roadside equipment along a 12-mile stretch of I-410 in San Antonio. This test bed is connected with SwRI's CV affiliated test bed, which allows testing of applications in a controlled environment (SwRI's test track) along with real-world freeway conditions along I-410.



This initial project focused on two particular applications of interest to TxDOT: in-vehicle signing and overheight vehicle detection/warning. As part of the in-vehicle signing application, the team inventoried all static road signs along the 12-mile stretch of I-410 where 3 DSRC roadside units were installed. These devices are listed on USDOT's QPL for RSE (version 3.0) and TxDOT worked with USDOT to obtain authorization from the National Telecommunications and Information Administration (NTIA) to deploy 5.9 GHz DSRC and now has authorization to operate statewide until 2024.

SwRI staff led the site selection and assisted with installation of the units. Over 300 signs were collected, encoded using SAE J2735, and deployed onto the roadside units. Two in-vehicle demonstration units were developed, capable of receiving the encoded signs and displaying them to the driver through a standard Android tablet. These OBEs leveraged software from the OSADP (Open Source Application Development Portal) as the basis on which to quickly develop the prototype applications. The overheight detection system was developed using commercial off-the-shelf (COTS) overheight sensors, integrated with a process on the roadside units to identify the specific vehicle that was detected as being overheight, and would send directed messages to that vehicle over DSRC, providing information to the driver.



### [I-35 Connected Work Zone](#)

The I-35 Connected Work Zone project is a cooperative research agreement between the USDOT and TxDOT. The overarching thrust of the research is to implement the USDOT Connected Vehicle Architecture on top of an advanced and mature operational system that exists in the Waco District of TxDOT. The implementation of the CV architecture will provide a substantial field test of the USDOT tools and serve as a national beta test of the architecture. The first task of the project will focus on expanding the Freight Advanced Traveler Information System (FRATIS) with regional commercial shipping companies driving the I-35 corridor. Using the major freight hubs in Temple, Texas, near the southern point of the I-35 corridor construction area, regional commercial vehicles often make one or more trips per day between Temple and Dallas-Fort Worth. The objective of this first task is the integration of high quality data from the I-35 Advanced Traveler Information Systems into an existing route optimization software platform to enhance/optimize pre-trip and en-route planning for the regional carriers. The next task of the connected work zone project will be to expand this type of traveler information and corridor routing to passenger vehicles. TxDOT has begun development of a connected vehicle module to enable these and other capabilities. The Crash Avoidance Metrics Partnership (CAMP) is currently working with USDOT on a reference passenger vehicle to receive work zone data for display in their reference vehicle.

### [Commercial Vehicle Truck Platooning](#)

TxDOT has initiated a research project with TTI to develop a two-truck, level 2 automation platooning prototype. This project aims to equip two prototype vehicles and conduct foundational studies in collaboration with major industry partners. As indicated by many industry experts, truck platooning is possibly one of the first automated vehicle applications that will be introduced to the market. Additionally, this technology is one of the few CV applications, from both V2V and V2I perspectives that can offer day one benefits. While the V2V aspect of truck platooning is better understood, the V2I has been much less investigated.

### **Plan to Leverage USDOT ITS or Technology Initiatives**

The Texas Team is committed to working with the other ATCMTD and previously awarded CV pilots to share knowledge and reduce deployment costs.

It is the intent of the operating agencies and private sector companies to provide services and goods in a national marketplace that is responsive to customer needs and resources and enables their effective delivery in a competitive ecosystem. An outcome of the US DOT ATCMTD projects is to seed that marketplace through:

- Providing transferable lessons learned for other deployers across the nation; creating a foundation for expanded and enhanced deployments; sharing data broadly with the community to inform other deployers of CV applications; sharing systems engineering documentation and source code with the US DOT and the community; and
- Participating in workshops, conferences, trade shows, and webinars.

The Texas Team believes that the **project goals can be enhanced by actively collaborating with other organizations** that are participating in CV Pilot Deployments and ATCMTD. The Texas Team has seen firsthand how these multi-state collaborations can benefit these national deployers with experience in the ITS model deployment in San Antonio and the ICM projects in Dallas, Houston, and San Antonio. The Texas Team is fully committed to engage in regular coordination, collaboration, and knowledge sharing during all three tasks of the USDOT ATCMTD program through regularly scheduled substantive meetings, in-person site visits, and conference calls. Substantive meetings would be conducted either in-person or through teleconferencing, at least 3–4 times per year, and conference calls and webinars would occur more regularly.

### **Description of Regulatory, Legislative, or Institutional Obstacles to Deployment**

TxDOT does not anticipate any regulatory, legislative, or institutional obstacles to deployment. The Texas Team has institutional support from its partners for the project. TxDOT has worked with the USDOT to obtain NTIA authorization to operate 5.9 GHz DSRC within the state until 2024.

Recently, the legislative support has increased with the passage of new laws. The Texas legislature ended its 85<sup>th</sup> regular session Monday May 29, 2017. The session resulted in several bills being passed by the Texas House and Texas Senate that support the research, development and deployment of Connected and Automated Vehicle Technologies. The legislation signed or pending signature of the Governor includes:

- Texas House Bill 1791-
  - Provides for vehicles equipped with a connected braking system which are following a vehicle equipped with the same system to be assisted by the system in maintaining a minimum clear distance. The bill has been signed by the governor and took effect immediately.
- Texas Senate Bill 2205-
  - Provides that an automated motor vehicle may operate in Texas with the automated driving system engaged, regardless of whether a human operator is physically present in the vehicle if the Automated Vehicle is:
    - capable of operating in compliance with applicable traffic and motor vehicle laws of this state
    - equipped with a recording device installed by the manufacturer of the automated motor vehicle or automated driving system
    - equipped with an automated driving system in compliance with applicable federal law and federal motor vehicle safety standards;
    - registered and titled in accordance with the laws of the State
    - Covered by motor vehicle liability coverage equal to the amount of coverage that is required under the laws of this state

- Has been forwarded for Governor’s signature and will take effect September 1, 2017
- Texas Senate Bill 1004-
  - Provides for the installation of private cellular provider network nodes (small cells) on public right-of-way
    - Small cells are critical infrastructure and important to industry efforts to meeting growing data demand now, assist in the buildout of 5G networks and prepare for the upcoming technology devices including connected and automated vehicle technologies
    - Network providers' access to the public right-of-way and the ability to attach network nodes to poles and structures in the public right-of-way allow network providers to densify their networks and provide next-generation services;
    - TxDOT will work with the industry to develop policies and practices for small cell installation
  - Has been forwarded for Governor’s signature and will take effect September 1, 2017

## STAFFING AND ORGANIZATION PLAN

This section presents the staffing and organization plan for the Texas Connected Freight Corridors ATCMTD project.

### Description of Lead Entity

The lead agency for this project will be the Texas Department of Transportation.

#### Primary Point of Contact

The primary point of contact for TxDOT will be:

Dr. Jianming Ma, P.E.

Transportation Engineer

Telephone: (512) 506-5106

Email: Jianming.Ma@txdot.gov

Address:

Texas Department of Transportation

9500 N. Lake Creek Parkway

Austin, Texas 78717

### Team Partners

The Texas Department of Transportation (TxDOT) has engaged the Texas A&M Transportation Institute (TTI), Southwest Research Institute (SwRI), and the University of Texas at Austin (UT) as team members in the development and planned implementation of this proposal, the *Texas Team*. The Texas Team has already engaged both public sector agencies and private sector freight companies as partners and stakeholders in considering the needs outlined in this proposal. For the Texas Connected Freight Corridors project, we are using the following definitions:

- Team Member – the core team responsible for delivering Tasks 1, 2, and 3 of the ATCMTD project.
- Stakeholders – public and private sector entities with an interest in the deployment of advanced technology in Texas.
- Partner – a special class of stakeholder that will directly take part in the deployment and operation of the Texas Connected Freight Corridors project, either through operating freight or fleet vehicles or operating CV infrastructure.

The Texas Team intends to identify additional partners and stakeholders and engage them throughout the implementation of each task of the deployment project. Management of partners and stakeholders needs and concerns will be an ongoing process. The staffing plan in Part II identifies the team, partner, and stakeholder structure in more detail.

### **Description of the Organization of Staffing**

TxDOT has assembled a complementary core team of partners with experience in general systems engineering as well as in designing, testing, and implementing connected and automated vehicles. TxDOT will serve as the prime contractor for the team, led by Mr. Michael Chacon and Dr. Jianming Ma as the overall Program Sponsor and Project Manager, respectively. Dr. Ma will be the primary point of contact for the contracting officer and the contracting officer's representative. The management team of Mr. Brian Fariello and Dr. Ma will report to an advisory panel made up of the key staff from each of the Team Members.

As shown in Figure 4, TxDOT leads the Texas Team members of TTI, SwRI and UT. In addition, TxDOT has three public outreach firms under contract that will serve as a small business outreach specialist(s). The Texas Team also has begun the assembly of two primary stakeholder groups made up of freight companies and public agencies.

The Texas Team will have a project executive advisory panel to assist in the technical and administrative direction of the project. The Project Executive Advisory Panel consists of the following five individuals:

- Mr. Marc Williams, Deputy Executive Director, TxDOT
- Mr. Darran Anderson, Chief Strategy and Innovation Officer, TxDOT
- Dr. Steve Dellenback, Vice President, SwRI
- Dr. Ed Seymour, Associate Agency Director, TTI
- Dr. Michael Walton, Professor, UT

Each of these individuals has extensive experience with their agency and the ITS industry. Mr. Williams, Dr. Dellenback, and Dr. Seymour each serve as their agency's representative to ITS America's executive leadership and are involved in national research, development, deployment, and operation. Dr. Walton is an internationally known expert on ITS and freight transport.

### Key Personnel

The Texas Team has designated the following key personnel and their roles on the Texas Connected Freight Corridors project:

- Project Management (PM) – Mr. Brian Fariello and Dr. Jianming Ma, TxDOT
- Planning and Freight Industry Strategy – Ms. Caroline Mays, TxDOT
- Concept Development/Application Development – Dr. Christopher Poe, Mr. Mike Lukuc, and Dr. Kevin Balke, TTI
- System Development/Application Development – Mr. Mike Brown, Ms. Lynne Randolph, and Mr. Purser Sturgeon II, SwRI

There is a long history of stability and depth in the ITS and transportation operations groups of all the agencies involved. The key personnel have considerable combined experience and have worked together on several projects over the past decade. If there needs to be a change in any of the key personnel, there are qualified team members able to step in and keep the project on track technically, on-time, and within budget. The Texas 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, whether due to vacation, leave, or departure from their agencies/firms.

Within TxDOT, there is broad support for the Texas Connected Freight Corridors Project. In addition to Mr. Williams and Mr. Anderson from the executive leadership serving on the advisory panel, several divisions and districts will support the project. Staff from the Traffic Operations Division will support traffic operations, traffic engineering, and ITS functions. Staff from the freight planning group within the Traffic Planning and Programming Division will support freight applications and freight stakeholder coordination. The TxDOT Districts along the Texas Triangle corridors will support infrastructure deployment.

The Texas Team also includes a number of Project Management Professionals (PMP) who have technology project management experience and CV domain knowledge. TxDOT, TTI, SwRI, and UT are involved in the CV arena and have both ongoing and completed project work in the field. The SwRI personnel are part of a CMMI® Level 5 organization and are familiar with and practiced in the PMBOK project management approach, including the development of concept of operations and other systems/software documentation.

### Staffing Description

The resumes for the key staff from the Texas Team members are presented as an appendix at the end of the proposal. Figure 4 shows the organization of the Texas Team.

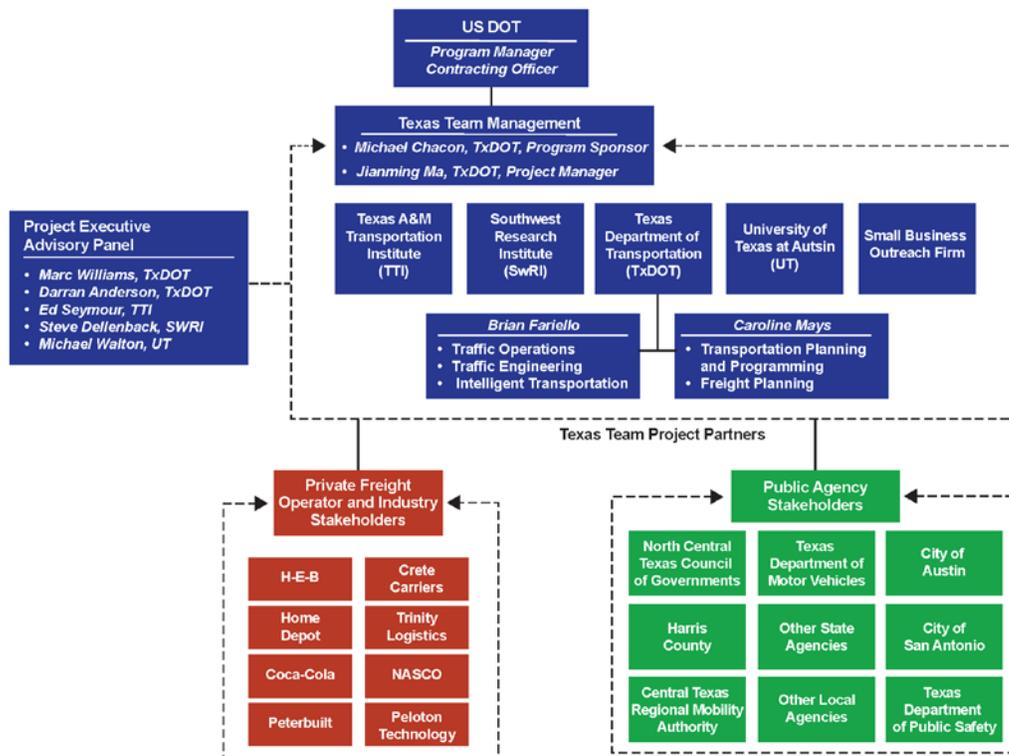


Figure 4. Texas Team Structure.

### STATEMENT OF WORK

The statement of work summarizes the three tasks for this overall project.

## **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. Effective project management is crucial to achieve 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 project 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 and the continued communication between the project technical team and the oversight committee. 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 to ensure the project remains on schedule.

**1.2: Deployment Concept of Operations (ConOps)** – The ConOps is a key document to establish the project’s overall needs and to define expectation and success of the project. The Texas Team has considerable experience in developing ConOps and understands the importance of having a guiding document for the remainder of the project.

During the development of a concept of operations, one of the most important considerations is ensuring that stakeholder needs and concerns are addressed. The stakeholders for this project will include both private and public sector partners, the USDOT COR, and the project team partners. Each entity has different interests and needs and even within one of the groupings, the concerns will vary. To help address any issues, the ConOps Stakeholder Review Panel will be established, which consists of members of each of the groupings of stakeholders. Representatives from all sectors will be responsible for final decision making on the content of the ConOps. To ensure all stakeholders’ concerns are heard, a variety of data collection methods will be used including surveys, meetings, webinars, teleconferences, and brainstorming sessions.

**1.3: Security Management Operating Concept** – Our team understands that one of the key issues surrounding the development of a Privacy and Security Management Operating Concept is the collection of any information that may be personally identifiable. This will be critical for our preliminary deployment concept as it is freight-centric and will likely involve the collection and analysis of data from each trip origin to the planned destination for purposes of fleet optimization and freight network optimization. Issues related to security that are also applicable for our deployment include but are not limited to the following:

- Physical security of an ITS network over a large geographical deployment.
- Physical security for each of the trucks providing and consuming data.
- Communications security from the Connected Vehicle Situation Data Warehouse to each fleet operator’s dispatch center.
- Communications security for V2V and V2I interactions.
- The next generation prototype national-level Security Credential Management System (SCMS) is currently being implemented and many components of SCMS will be emerging over time.

To help address the concern around the potential collection of Personally Identifiable Information (PII), our team will work closely with our freight partners and all stakeholders to carefully identify any PII-related data that may need to be collected to support key performance measures and develop a strategy to opt-in to that particular application.

**1.4: 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 CV deployment is work zone safety while installing roadside equipment.

The safety management plan will cover both the deployment and operation tasks of the Texas Connected Freight Corridors Project. The Texas Team has considerable experience in deploying technology in transportation corridors that will inform the deployment task of the safety management plan. We will also apply our safety management plans that are used on a day-to-day basis to plan and execute safe deployment of ITS equipment. Our team will work closely with our freight stakeholders to review potential CV applications and identify the information and warnings that will serve their operational needs while paying careful attention to driver distraction issues. The team will solicit feedback on how best to balance the amount and content of the information with drivers' need to stay focused on safe operation of the vehicle. The FHWA Driver Distraction Guidelines will provide input into the selection of methods for conveying information to drivers.

**1.5: Performance Measurement and Evaluation Support Plan** - Performance measurement and evaluation must reflect the local needs of the partners/stakeholders as well as the evaluation goals of the Texas Team and the USDOT. The Texas Team has begun identifying some of the performance measures for the Texas Connected Freight Corridors CV applications (Table 3). In addition, there are performance measures important to specific stakeholders. For example, the freight stakeholders have identified changes in miles driven and miles per gallon as key performance measures for freight improvement from CV technologies. This task results in a performance measurement plan, which key elements include the data collection, data archiving, and data reporting. Under this task, the Texas Team will also support the USDOT's evaluation efforts through reviewing and commenting on national evaluation criteria and linking the Texas performance measures and evaluation criteria to the national criteria. The Texas Team will reserve resources in the budget to participate in these activities.

**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 project 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 (SyRS) will utilize the appropriate IEEE and USDOT guidelines. Prior to submittal, the draft requirements document will be sent to stakeholders for review for any additional comments or concerns. In addition, the Stakeholder Review Panel will keep the team informed of any changes to stakeholders.

The project team is experienced in requirements development and has completed system requirements documentation for multiple customers and varied stakeholders. Stakeholders for requirements documents have included both public and private entities. SwRI has been independently assessed as Capability Maturity Model Integrated (CMMI®) 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: Application Development Plan** – The Texas Team is proposing several V2V and V2I applications that will form a program of complementary applications to improve safety, mobility, environmental impacts, and agency efficiency. The applications are targeted for freight use, but will be developed for expansion to light-duty vehicles. The freight stakeholders offer professional drivers with well-equipped vehicles that will help ensure deployment success. The freight stakeholders are very interested in the driver interaction with these applications. This task will include a special human machine interface assessment. The simulation-based evaluation determines whether or not the commercial vehicle CV application interface supports driving performance without unduly increasing distraction and mental workload. This will be conducted using TTI’s portable driving environment simulator which can be configured to allow a commercial vehicle operator to “drive” along a simulated roadway similar to I-35 while interacting with the CV technology. The driving environment simulator offers a safe environment in which to evaluate in-vehicle technologies that should not be yet be evaluated in on-road environments due to possible risk and allows the research team to collect data at a convenient driver location. We anticipate evaluating at least 30 commercial drivers in response to CV warnings and information in both typical (e.g., low stress) and non-typical (e.g., high stress) scenarios. Results will indicate whether the CV technology 1) supports driver and system designer goals (e.g., driver performance) while not encouraging distraction and high workload and 2) should be considered for on-road testing.

**1.8: Human Use Approval** – TTI will lead the human use approval process for the proposal. TTI and Texas A&M University (TAMU) have a formal Institutional Review Board (IRB) process. As mandated by the federal government, all research projects involving human subjects conducted by TAMU, must be approved by the University’s IRB. TTI will follow these procedures.

For this project, the Texas Team also proposes to create an external Data and Safety Monitoring panel. This is a frequent approach on clinical studies. The panel will receive periodic (quarterly or semi-annually) reports of any incident, malfunction, or complaint from the subject group. An evaluation will be made as to whether it poses an undue risk and a determination as to whether the data collection should continue or not. This process gives the Texas Team a chance to assess risk per person and risk as a percentage of total subjects. Borrowing these techniques from clinical practice will give the Texas Team and the USDOT the oversight from best practices for human subject data collection. Copies of the submitted final protocol and approvals will be provided to USDOT.

**1.9: Participant Training and Stakeholder Education Plan** – The Texas Team will leverage our broad experience communicating ITS technology and freight issues to a variety of audiences to develop a suite of training materials to educate participants and stakeholders. Because the Texas Connected Freight Corridors Project is focused on freight and commercial vehicles, the participants are largely trained drivers with the partnering freight companies. Additionally, the Texas project will instrument TxDOT fleet vehicles that operate in the Districts and on roadways along the Texas Triangle. These participants are TxDOT staff that will be trained by the Texas Team on the use of equipment and applications.

The Texas Team will develop the materials necessary to train the fleet operators and drivers, including, but not limited to: system overview, application capabilities and limitations, Driver-Vehicle Interface (DVI) overview, system monitoring (if required), data collection procedures, what to do in case of a cyber-attack, and what to do in the event of a system failure or a crash.

The Texas Team will consider innovative training and educational approaches tailored to complement our recruitment strategy. For example, with a fleet-centric approach, traditional one-on-one, in-vehicle training is impractical due to interference with business operations. Instead, we will consider alternative options, such as driving simulator, web-based tools, smart phone/tablet applications, and other educational materials.

**1.10: Outreach Plan** – For this project, The Texas Team will capitalize on extensive ITS and freight stakeholder outreach experience to communicate the project’s goals, objectives, and outcomes to stakeholders. A diverse group of public and private sector stakeholders can help ensure a successful deployment and should include policy-makers and staff from the transportation agency(ies) divisions that might be responsible for deploying, operating, and maintaining a CV project or system. Depending on the scale of a project deployment, potential agency stakeholders may include, but not be limited to:

- State, county, and city transportation agencies
- Metropolitan Planning Organizations (MPOs)
- Regional mobility authorities (RMAs)
- 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
- Elected and appointed officials
- Media
- Traveling public

The Texas Team will reach out to these stakeholders using a variety of mechanisms with which we have broad expertise in developing for communicating with the transportation community.

**1.11: Comprehensive Deployment Plan** – The development of a Comprehensive Deployment Plan (CDP) for a large geographical deployment can be a challenge as it involves the state, MPOs, 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 Texas Team has worked extensively with our local partners to help improve the safety, mobility, and environmental impact of our transportation network. We will leverage this experience to ensure that our 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. We have actively begun deploying DSRC within the proposed deployment area and developing and testing applications that will be of use to TxDOT in the future.
- Data Sharing with CV Community. The Texas Team is knowledgeable of Research Data Exchange (RDE), OSADP and the process of submitting data to RDE and applications to OSADP. We are registered users of both and have used data from RDE for use in our own research projects. We will leverage our experience in submitting applications to OSADP (CV Retrofit Kits) to identify software that can be contributed to OSADP.

The CDP will also include a deployment readiness summary to ensure the successful execution of this task. We commonly develop deployment plans and deployment readiness summaries for deployments of our Lonestar® software system throughout the state. A region cannot be without ITS capability for any significant period of time, so we develop integration and deployment plans and then a deployment readiness summary that is reviewed with the region to ensure that all key issues are accounted for and backup plans are in place if the deployment experiences severe unexpected problems.

## **Task 2: Detailed Design, Build, and Test**

**2.1: Program Management** – Our team will leverage our experience at applying the PMBOK and CMMI Level 5 processes to effectively manage all aspects of this program. Throughout the program, the Texas Team will continue to track the progress of each task, communicate the progress of the tasks and the program as a whole 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, our 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. We expect that this design will include, but not be limited to, the following:

- Hardware design at each roadside installation location and for each vehicle type.
- Hardware design for the servers and network equipment that will host the data collection, analysis and decisions support systems that will be integrated with the TxDOT Lonestar system.
- 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. We are very familiar with the applications that exist as part of the Open Source Application Development Portal (OSADP) 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 Texas Team will submit this detailed design to USDOT for review and comment. We 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 Texas Team will procure the hardware. We are experienced at applying stringent but efficient procurement processes to maintain project schedule while ensuring optimal value for the project. We expect this procurement to include the following hardware components:

- Roadside Equipment
- On-Board Equipment
- Signal System Upgrades
- Pedestrian Detection Systems
- Application Servers
- Spare Equipment

Our Team has an incredible amount of physical resources to be able to acquire, inventory, and store the equipment required to implement this program. We have 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, our team will begin to develop the applications that were identified in the concept of operations, system requirements, and detailed system design. We will maximize the reuse of mature software wherever possible. Our 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. We will leverage our experience implementing and deploying field hardened ITS applications to create and integrate a software suite that will enable a successful deployment for this project. We use 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. Our team has helped establish the certification program for Connected Vehicle systems and therefore we are very familiar with the processes and test methods to ensure that the equipment will be reliable and interoperable within our system deployment. We will utilize this certification program to test the connected vehicle hardware that is procured. For application servers and other hardware systems procured, we will follow our 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, our 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** – Our team understands the need to ensure that our deployment is not only efficient and reliable, but also secure. We understand that this will be one of the initial deployments of this technology in the country and that any security breaches encountered may undermine a larger scale deployment nationwide and ultimately prevent the realization of the safety, mobility, environmental, and public agency efficiency improvements that these applications can help to achieve. Our team is experienced with the previous implementation of the Security Credential Management System and is closely tracking the development of the Proof-of-Concept version that is currently under development. We will leverage this experience and knowledge to integrate our deployment closely with the newly developed SCMS and other security techniques. We will also work closely with the current CV Pilot Deployments to model our SCMS integration after theirs and take advantage of their experience and lessons learned.

**2.7: System Integration and Testing** – Once all of the applications are individually tested, our team will deploy the applications on all vehicles, roadside equipment and application servers and begin full system integration testing. We will update the system integration test plan that was outlined in the detailed design and will implement this test plan to ensure that the deployment is fully operational. Our 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. We will leverage our experience in deploying ITS systems and will fully test the system prior to operating it. The Texas Team will update all of the system documentation with as-built information to ensure maintainability going forward.

**2.8: Training** – Once the system is fully operational, our team will train the system and vehicle operators and maintenance staff to be able to effectively use and maintain the system. In some cases, we will be training the trainers. We understand that this training is crucial to ensuring a successful deployment.

**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 Texas 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 Texas team built, fully deployed, and tested the system, we will now transition our focus to keeping the system operational. As TxDOT’s Traffic Operations Division is leading this deployment, we expect this transition to be smooth as our team will utilize our experience in deploying and operating ITS throughout the state for over 25 years to ensure this deployment is well integrated and fully functional.

**3.3: Data Collection and Analysis** - Our team understands the importance of this deployment in providing benefits to our stakeholders and improving safety and efficiency of our roadway network, but also to provide valuable data and lessons learned to a much larger deployment of the technology. In this task, our team will execute our 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 Texas team will perform our System Impact Evaluation and will report quarterly on our assessment of the robustness, effectiveness, usability, and acceptance of the CV applications and technologies as deployed. We want to continually assess our deployment’s progress towards our established goals and therefore understand the need to continually measure and report on how well we are doing.

**3.5: Coordination with Independent Evaluator** - Our team will leverage our 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. We will work with the Independent Evaluator and provide the necessary documentation, data, and access to our system deployment and operations experts to assist the USDOT in conducting this evaluation.

**Project Schedule**

| Task                                 | Texas Connected Freight Corridors Schedule |    |           |    |    |    |           |    |    |    |         |    |    |    |         |           |    |    |  |
|--------------------------------------|--|----|-----------|----|----|----|-----------|----|----|----|---------|----|----|----|---------|-----------|----|----|--|
|                                      | CY 2017                                    |    | CY 2018   |    |    |    | CY 2019   |    |    |    | CY 2020 |    |    |    | CY 2021 |           |    |    |  |
|                                      | Q3   | Q4 | Q1        | Q2 | Q3 | Q4 | Q1        | Q2 | Q3 | Q4 | Q1      | Q2 | Q3 | Q4 | Q1      | Q2        | Q3 | Q4 |  |
| 1 - Planning and High Level Design   |  |    | 12 months |    |    |    |           |    |    |    |         |    |    |    |         |           |    |    |  |
| 2 - Detailed Design, Build, and Test |  |    |           |    |    |    | 24 months |    |    |    |         |    |    |    |         |           |    |    |  |
| 3 - Operate, Maintain, and Evaluate  |  |    |           |    |    |    |           |    |    |    |         |    |    |    |         | 12 months |    |    |  |

**Deliverables**

**Table 6. Deliverables to USDOT.**

| <b>Deliverable</b>                        | <b>Approximate Due Date</b>             |
|---|---|
| Kick-off Meeting                          | Within 4 weeks of award                 |
| Project Management Plan                   | Within 4 weeks of award                 |
| Progress Reports                          | Monthly                                 |
| Concept of Operations                     | Within 4 months of award                |
| Safety Management Plan                    | Within 6 months of award                |
| System Requirements Document              | Within 6 months of award                |
| Application Development Plan              | Within 8 months of award                |
| Detailed Design Plan                      | Within 10 months of award               |
| Participant Training Plan                 | Within 12 months of award               |
| Outreach Plan                             | Within 12 months of award               |
| Comprehensive Deployment Plan             | Within 12 months of award               |
| Deployment Readiness Summary              | Within 12 months of award               |
| Project Report to Secretary (Section 508) | Annually beginning one year after award |

## **APPENDIX A - TRANSMITTAL LETTER**

## **APPENDIX B - RESUMES**