1 Project Overview

The Texas Department of Transportation (TxDOT) is pleased to submit this FY2022 Strengthening Mobility and Revolutionizing Transportation (SMART) grant application for $1.7 million to develop an implementation plan for deploying Connected Vehicle (CV) infrastructure in the TxDOT Houston District. The Houston District has already tested older CV technology at 15 intersections and identified 128 additional intersections for the deployment of modern CV equipment, which it is currently installing in a phased rollout. However, the funding for a systematic evaluation of this new technology's performance and the development of a broader tactical plan for district-wide implementation is still lacking. This proposed project would fill that gap.

The evaluation of these intersections (including proposed upgraded equipment at the aforementioned 15 intersections) will inform the development of a **Connected Transportation Tactical Plan** (the Plan). The Plan will articulate the regional strategy for deploying and using CV technology to address critical mobility and safety needs, allowing for such applications as Transit Signal Priority, emergency responder signal pre-emption, and enhanced hurricane evacuation route mobility. TxDOT is the lead applicant for this **Stage 1 application** in partnership with the Texas A&M Transportation Institute (TTI) and Houston TranStar, the region's transportation and emergency management consortium involving the City of Houston, Harris County, Metropolitan Transit Authority of Harris County (Houston METRO), and TxDOT. As described more fully in Section 5.1, this project would:

- **Develop an Implementation Strategy** to scale up CV deployments in the Houston District. This grant will fund the replacement of obsolete Dedicated Short-Range Communications (DSRC) equipment at 15 intersections with Cellular Vehicle-to-Everything (C-V2X) compatible units. The new units will standardize all field deployments in the district, where TxDOT is in the process of installing C-V2X units at 128 additional intersections.
- **Develop a Concept of Operations (ConOps)** for a connected transportation ecosystem of CV applications operating seamlessly across the Houston District. The process will be driven by input from TxDOT's TranStar partners, district counties and cities, and TxDOT emergency responders involved with incident clearance and emergency management.
- **Conduct a Pilot Project** at the 143 CV-equipped signals to assess the functionality of connected intersections using C-V2X technologies. TTI will assist in evaluating the technical deployment and integration of C-V2X infrastructure and the impacts of CV application and services on safety, mobility, and emergency response.
- **Finalize the Connected Transportation Tactical Plan** using the lessons learned from the pilot, paving the way for Stage 2 implementation throughout the Houston District. The lessons learned from the pilot project will inform the implementation strategy on the technical and institutional requirements needed to scale the deployment of CV infrastructure to reach the approximately 1,050 TxDOT intersections in the Houston District.

This proposal is a direct response to the rapidly evolving nature of connected infrastructure technology and builds on years of TxDOT experience from numerous smart mobility projects. For the FHWA-sponsored Traffic Optimization for Signalized Corridors (TOSCo) project, TxDOT and TTI conducted a field demonstration in Houston using the DSRC-equipped intersections to communicate with and optimize signal operations for vehicle platoons operating in adaptive cruise control mode (SAE Level 1). The Houston District has also deployed safety warning detection systems to notify the public of wrong-way drivers and to provide advanced warning to oversized vehicles approaching low-clearance bridges.

In another effort, Houston TranStar and TTI worked together with the Harris County Flood District to integrate rainfall sensors from various agencies so that information on flooded roadways can be disseminated through TranStar; this collaborative project received the National Operations Center of Excellence (NOCoE) 2020 award for best Transportation Systems Management and Operations (TSMO) project. Table 1 identifies use cases under the CV ecosystem that TxDOT and its partners will demonstrate in the pilot project. The CV-equipped intersections will support data connectivity with vehicle on-board units (OBUs). Users with apps on cellular devices will also be supported, which accommodates bicycles, pedestrians, and transit riders.

Table 1 Connected Transportation Ecosystem Services

Connected Transportation Ecosystem Services	Pilot Ready?	Cellular or OBU Support
Signal Phase and Timing (SPaT) to Driver	Yes	Both
Pedestrian Warning	Yes	Both
Emergency Signal Preemption	Yes	Both
Work Zone Application	Yes	Both
Virtual Dynamic Message Sign (DMS)	In Progress	Both
Texas Connected Freight Corridors Application	In Progress	OBU
ConnectSmart App	Yes	Cellular
TOSCo Application	Yes	OBU
SPaT Data to Traffic Management Center (TMC)	In Progress	Cellular
GPS-based Detection	In Progress	Both
School Zone Warning	Yes	Both

Source: TxDOT Houston District.

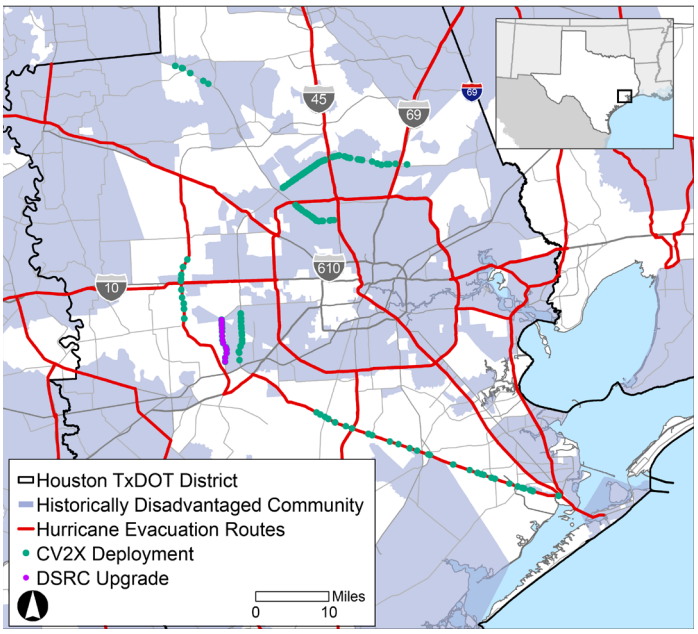
TxDOT's Intelligent Transportation System (ITS) deployments and initial CV testbeds have provided substantial technical expertise for the proposed project leaders in Section 5.3. Their work in smart infrastructure has advanced to a point that a coordinated tactical plan is needed to make further progress in a deliberate, effective manner. It was for this reason that the development of a tactical plan was identified as a need in the Houston District TSMO Program Plan. This SMART grant would fulfill this unfunded need.

As described in Section 4.3, this project will confer numerous benefits that address real-world problems. For example, the wide-scale deployment of smart infrastructure would help traffic flow out of the Houston metro area during hurricanes by not only holding greens for traffic signals on evacuation routes, but also by communicating with CVs on the best routes to take.

Just this single application of the technology has the potential to save lives in the face of extreme weather events.

2 Project Location

Stage 1 will develop a Connected Transportation Tactical Plan for the entire TxDOT Houston District, which is comprised of **Brazoria**, **Fort Bend**, **Galveston**, **Harris**, **Montgomery** and **Waller** Counties and is considered a large urban area. Located in southeast Texas near the Gulf Coast, the geographic area of the Houston District covers over 5,800 square miles and has 31,790 centerline miles of roadways, including 1,100 miles of hurricane evacuation routes. The Connected Transportation Tactical Plan proposes to implement CV technology to address mobility and safety needs for a region that contains significant populations living in Historically Disadvantaged Communities (HDCs). As identified using the HDC Status Tool, there are 344 census tracts within the Houston District that are classified as Transportation Disadvantaged. Most (110 of 143, or 77%) of the pilot project intersections are located in HDC tracts.



For more detailed mapping, please see the Project Website

3 Community Impact

The Connected Transportation Tactical Plan will consider community impacts to ensure that the benefits of CV deployments accrue to HDCs in the following ways: **increasing safety** for transit, biking, and walking, which are modes important to households that cannot afford a private automobile; **improving transit performance** by utilizing C-V2X to improve signal priority services for transit; and **improving hurricane evacuation and emergency response** for low-income areas that face higher risk of impacts from extreme weather events. A description of the performance measurement approach is in Section 5.1.

4 Technical Merit Overview

4.1 Problem Understanding

Emergency preparedness is an important focus of the Houston District and its regional partners. Located near the Gulf Coast, the region is impacted by the increasing frequency and intensity of extreme weather events. The last major hurricane was in August 2017, when widespread flooding from **Hurricane Harvey claimed more than 80 lives and caused $125 billion in damages** – among the costliest natural disasters in American history. Maintaining mobility during an evacuation is challenging with Houston's large population, which can quickly overwhelm evacuation routes and the roadways that feed them. For residents seeking information during Harvey, Houston TranStar was a valuable resource; its website served over

3 million unique users in August 2017 compared to just over 810,000 in the month prior. Even in the absence of a hurricane, extended periods of rainfall can still cause widespread flooding, creating hazardous conditions for the traveling public and underscoring the need for emergency preparedness tools.

With a population of over 7 million, **the Houston metro area is among the most congested in the country**. According to TTI's ranking of the 100 most congested roadways in the state, the region had 34 of the 100 most congested highway segments in 2021. Houston also has 8 of the 12 locations in Texas that are on the list of the nation's top 100 truck bottlenecks. The confluence of heavy congestion and freight activity contributes to a **high number of crashes**. Between 2020 and 2021, total crashes (148,170) and total serious injuries plus fatalities (4,864) increased by 17% and 25%, respectively, according to TxDOT crash statistics. Among fatalities and the seriously injured, nearly 1 out of 5 involved a bicycle or pedestrian. **The total number of fatalities (798) in 2021 was the highest of any of the 25 TxDOT Districts** and represents an increase of 16% over the previous year.

As described in the next section, the deployment of C-V2X units at intersections district-wide will help to address these safety and mobility problems.

4.2 Proposed Solution

The Connected Transportation Tactical Plan represents an appropriate solution for providing a coordinated approach to deploy CV infrastructure in the Houston region. The Plan development will be guided by the following principles in line with the objectives of the SMART grant program:

Use of Proven Technologies: All roadside and onboard equipment considered for implementation in the Plan will use standard communications protocols and will support C-V2X protocols. CV messages – BSM (basic safety messages), PSM (personal safety messages), SPaT, MAP (Map information), and TIMs (Traveler Information Messages) – will be communicated in the SAE J2735 standard message set. Information end-to-end will be encrypted and personally identifiable information (PII) will not be collected, nor would project partners have access to PII for users of third-party apps.

Scalability: One of the challenges with deploying CV technologies is ensuring that the different types of vendor equipment and software can work seamlessly in a large and complex multi-jurisdictional environment. These efforts, in coordination with the development of the Houston region's TSMO strategic plan, informed the need for the Connected Transportation Tactical Plan. To expand CV deployments and coverage across the region, the Plan will identify an approach to systematically deploy new infrastructure to fill in gaps, integrate CV functionality and services into the Houston TranStar environment, and migrate any remaining DSRC units to C-V2X. The Plan will also address how CV infrastructure in the City of Sugarland and other local jurisdictions can be integrated under a regional CV umbrella and integrated with Houston TranStar.

Verifiable Improvements: As described in Section 5.1, TTI will be conducting the evaluation of the expected safety and mobility benefits from the pilot project. Robust performance measures will be defined to evaluate before-and-after conditions for the technologies demonstrated in the pilot project. TxDOT will also verify the functionality of the

pilot project equipment's functionality (e.g., API integrations with other jurisdictions' communications protocols) in accordance with system and user requirements.

Context Sensitivity: The pilot project will test and evaluate CV applications at intersections and along corridors within the context of user needs and the operating environment through the use of performance and safety indicators such as congestion; the frequency, severity, and types of crashes; the types of multimodal users; proximity to transit stops, schools, and other community level generators; and connectivity with hurricane evacuation systems. Evaluation of community impacts will consider the ability of the technology to serve the mobility needs of HDCs, focusing on safety and improved access to employment and educational opportunities.

4.3 Expected Benefits

Emergency preparedness, safety improvements, and congestion reduction are some of the benefits expected with implementation of CV infrastructure and the use of C-V2X services. The overarching goal is to reduce crashes and fatalities while improving mobility in one of the largest urban regions in the country. The anticipated benefits are aligned with the following priorities for the SMART grants program:

- Increasing **safety and reliability** for multimodal transportation users through enhanced information at intersections, where many crashes occur;
- Increasing the **resiliency** of the transportation system in the face of hurricane evacuations and other extreme weather events;
- Promoting **access to opportunities** through investments in technologies that could enhance mobility and safety for HDCs and increase transportation options to reach employment and educational opportunities;
- Supporting **environmental** initiatives by supporting transit mobility and enhancing transit reliability through the use of transit signal priority;
- Continuing strong **partnerships** between the Houston District and its partners that have played a pivotal role in the success of the regional ITS program and TranStar; and
- The **integration** of CV deployments in an interoperable manner consistent with federal ITS policy and requirements.

These benefits will be measured and validated as described in Section 5.1.

5 Project Readiness

5.1 Workplan Feasibility

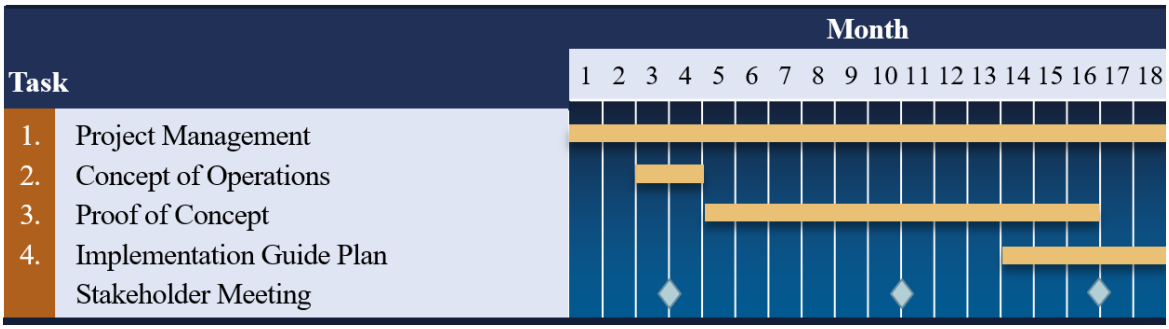
The project has a realistic timeline, workplan, and a group of highly qualified staff to ensure successful delivery. All partners involved in the Plan have a proven track record of working together to deliver innovative transportation technology solutions in the Houston area.

TxDOT and its partners will implement this Stage 1 project over the course of 18 months (Figure 1). The scope includes four major tasks to be completed by the project team:

- **Task 1** is for ongoing project management throughout the project, such as developing the Project Management Plan.

- **Task 2** will review existing conditions and initiate a stakeholder engagement plan to develop a Concept of Operations for a district-wide CV ecosystem. The ConOps will evaluate CV use cases, including a review of existing conditions, user needs, resource requirements, and operational roles and responsibilities. TranStar will serve as the convening body for regional stakeholder meetings.
- **Task 3** will deliver a proof-of-concept pilot project (evaluating 143 intersections proposed for C-V2X technology) to prepare for full-scale deployment. The pilot project is designed to help measure and validate the Stage 2 project's expected benefits and community impacts. The evaluation phase (conducted by TTI) will include a thorough analysis of performance improvements and cost savings.
- **Task 4** will use the key findings from previous tasks to develop the final Connected Transportation Tactical Plan, including a road map, partner commitments, and phased schedule and budget for the technology roll out across TxDOT's Houston District. In Stage 2 the same project team will deploy the C-V2X units at all intersections across the District (over 1,000) using lessons learned in Stage 1.

Figure 1: Project Timeline



The installation and deployment of the pilot project **may require extension of an existing license**. Depending on how quickly the project can get started, the Experimental License from the FCC may need to be extended in September 2024. No personal information will be collected from individuals as a part of this project.

To measure the performance in Stage 1 of the project, TTI, on behalf of TxDOT, will analyze the pilot project to determine: 1) Safety impacts, which will be measured by a reduction in certain types of preventable crashes; 2) Interoperability between systems in different jurisdictions to ensure a seamless travel experience for the public; and 3) Emission reductions. These measures will ultimately be used to measure success of the Stage 2 roll out.

As indicated in the NOFO, TxDOT will develop an Evaluation and Data Management Plan to identify measures of effectiveness to quantify and report the safety and mobility benefits of CV applications for the region as a whole and the specific benefits and impacts to HDCs. The number of engagements with travel apps and websites will also be evaluated based on user location to capture interactions with non-motorized users in HDCs.

This project promotes workforce development. It provides an opportunity to further build internal expertise at TxDOT and for private sector innovation. There are many ways to use connected vehicle technology, each requiring special training. This technology conveys information about traffic control devices and must be deployed by trained professionals to

ensure it is operating safely. The Implementation Plan (Task 4) will include workforce development activities for TxDOT to work with vendors, staff, and technical colleges to develop training for this emerging technology. This project also provides an opportunity for private sector actors to develop applications that can interact with the technology. This could lead to new jobs, inventions, and companies.

5.2 Community Engagement and Partnerships

This project will follow all community engagement protocols in the TxDOT Public Involvement Toolkit and Language Assistance plans. Additionally, the project team will conduct a focus group with TxDOT's Emergency Management Services (EMS) and will request feedback from ConnectSmart application users. The demonstration project also includes intersections located in HDCs which will allow the team to understand how this technology may impact disadvantaged communities.

One goal of this Plan is to create technology that **improves safety and access for persons with disabilities and limited English proficiency**. By enabling vehicles to speak with one another, this technology could provide better emergency evacuation information in all languages and protect vulnerable road users. Outreach to these populations may be conducted throughout the course of the project in accordance with TxDOT public engagement protocols.

TxDOT will leverage existing sustainable partnerships across sectors and governmental jurisdictions to collaborate on this plan; these partnerships will continue into Stage 2 of this project and beyond. TranStar, a consortium of City of Houston, Harris County, Houston METRO, and TxDOT, will act as a convening body for intergovernmental coordination. TTI is a long-standing partner for TxDOT and will play a critical role in the evaluation of this project's effectiveness. As described in Section 1, this collaboration between partners has won national recognition and sustains the Houston District as a national leader in smart infrastructure deployment.

This coalition between academia, nonprofits, and technical experts will be essential to help streamline the pilot program development and deployment, develop workforce training around this technology, ensure that historically disadvantaged communities benefit from this technology, and validate the transferability of standard, open-source systems so that vehicles across different manufacturers can all talk to each other.

5.3 Leadership and Qualifications

The TxDOT Project Manager is Ugonna Ughanze, PE, Director of Transportation Operations for the Houston District. He has over 30 years of experience in the transportation sector and a strong history of partnering with TranStar and TTI to deliver innovative transportation technology projects. Supporting Mr. Ughanze are Task Leads Steve Chiu, Engineering Specialist at TxDOT, and Valerie Taylor, PE, Transportation Engineer Supervisor at Houston TranStar. Mr. Chiu has an extensive background in implementing and overseeing pilot projects in the Houston District and will lead Tasks 2 and 3 with support from Darrel Borchardt, PE of TTI who will design the performance measure tracking for the demonstration project. Ms. Taylor has extensive experience partnering with key stakeholders to deploy district-wide transportation technology ecosystems and will lead Task 4. These project leaders will continue to oversee the project beyond Stage 1. See Appendix I for resumes.

Appendix I: Resumes

Ugonna Ughanze, PE
Director of Transportation Operations (DTO), TxDOT

Ugonna Ughanze oversees the Transportation Operations function for highways and facilities in TxDOT's Houston District. Reporting directly to the District Engineer, he manages a group of 135 professional, technical, and administrative employees and oversee district-wide construction contract work concerning transportation operations. Mr. Ughanze works with other governmental officials and private entities and interfaces with all district core functional groups. Other duties include:

- Acts as a consultant to help solve the Houston District's transportation problems.
- Coordinates, cooperates, and works as a team leader with other governmental agencies in emergency and traffic management consortium (TranStar).
- Ensures that plans, strategies, and objectives support TxDOT goals for the benefit of the traveling public.
- Ensures that TxDOT operations are compliant with the Federal Highway Administration (FHWA) federal requirements.
- Is responsible for his section's interaction involving planning, design, construction, maintenance, and operations activities in and outside the agency (permits).

He has over 30 years of experience deploying new transportation technology, working with federal and state laws, policies, procedures, standards, and guidelines to ensure successful and safe deployment.

Steve Chiu
Engineering Specialist, TxDOT

Steve Chiu has over 20 years of experience working on the technical development, design, and deployment of innovative transportation technology for TxDOT. He has extensive technology knowledge related to C-V2X equipment and has partnered with TranStar and TTI on numerous successful deployments. He has worked with the Houston TranStar Computerized Transportation System Design for 12 years. Prior to this, he spent 11 years in the Houston District Traffic Signal Maintenance and Construction groups (TxDOT). He has worked on various construction projects to relocate and install ITS equipment, network design, and has deployed and integrated various CAV technologies within TxDOT and in partnership with Houston TranStar.

His skills include site inspection and evaluation to determine conduit, CCTV, Dynamic Message Sign (DMS) and ensuring construction design is done in accordance with the guidelines from the TxDOT design manual and utility coordination.

Valerie Taylor, PE
Transportation Engineer Supervisor, Houston TranStar

Valerie Taylor oversees all functions of Transportation Management Systems in TxDOT's Houston District encompassing CTMS design, ITS special projects, freeway operations and

ITS maintenance to include the supervision of 40 professional, technical, and administrative staff. Duties also include:

- Management of all data, video, and fiber sharing agreements with regional public and private partners.
- Responsible for planning and maintaining all budgets related to overhead for staff, projects, and ongoing maintenance.
- Oversight of the design, installation, and maintenance of all traffic management systems equipment.
- Management of freeway operations at Houston TranStar to include daily operations, incidents, and emergencies in close coordination with the Consortium partners.

Ms. Taylor has worked on several award-winning transportation technology projects including:

1. Houston District Flood Warning Expansion, ITS Texas Award 2021
2. Ferry real-time travel time and positioning, ITS Texas Award 2019
3. Regional Flood Warning System, ITS Texas Award 2018
4. IH10 Overheight Vehicle Detection, ITS Texas Award 2017

Darrel W. Borchardt, PE
Senior Research Engineer, Transportation Operations Group, Texas A&M Transportation Institute (TTI)

Darrell W. Borchardt has 40 years of experience in traffic and transportation engineering. He is routinely contacted by TxDOT staff for input into analyses of various types of traffic problems throughout the region. He served as principal investigator of a TxDOT RMC project which developed and deployed a warning system for high-speed trucks on freeway-to-freeway connectors. Mr. Borchardt has been involved in hurricane evacuation planning for the Houston-Galveston region since 2004 and has attended local, state, and national evacuation conferences. Mr. Borchardt has also led efforts on projects completed by TTI for the U.S. Army Corps of Engineers for an extensive hurricane evacuation study for two separate regions of South Texas which included evacuation zone development, vulnerability, and transportation analysis. Mr. Borchardt has also completed traffic operations review and data analysis for the Houston region to assess the impacts of Hurricane Rita (2015), Hurricane Ike (2008), and tropical storm Harvey (2017) flooding events to assess impacts and long-term road closures on regional mobility.

He has a B.S. and M. Eng in Civil Engineering from Texas A&M University and is a registered professional engineer in Texas.

Appendix II: Budget Narrative

The total funding request for this project is $1,692,940 as described in this budget narrative.

Personnel - $400,000

This project will be managed by **Ugonna Ughanze, PE**, who will spend 10% of his time on this project. He will be coordinating between USDOT and TxDOT, overseeing the delivery of the tasks as described in the Project Narrative, and ensuring compliance with relevant federal guidelines. He will lead Task 1 (Project Management). In that role, he will undertake regular monitoring of the schedule and budget as well as the development of the Project Management Plan.

Tasks 2 (Develop Concept of Operations for Houston District) and Task 3 (Develop and Deliver Proof of Concept) will be led by **Steve Chiu**, who will spend 40% of his time on this project. For Task 2, he will manage the existing conditions assessment of the Houston District and coordinate stakeholder engagement among the many institutional and organizational stakeholders with an interest in smart infrastructure roll-out. The Concept of Operations that Mr. Chiu will produce for this task will provide the vision for the technology deployment on which the Pilot Project is founded.

For Task 3, Mr. Chiu will field test the new C-V2X equipment as well as the intersections upgraded from DSRC to C-V2X. He will oversee the technical work to install the equipment and manage the integrations with other infrastructure elements (e.g., signal systems). He will manage the evaluation undertaken by TTI of the pilot project outcomes.

Task 4 (Develop Implementation Plan) will be led by **Valerie Taylor, PE**, who will spend 20% of her time on this project. This task will pave the way to Stage 2, which will see deployment of C-V2X units at all TxDOT intersections in the Houston District (over 1,000). This will include activities like key partner coordination and gathering of commitments, developing a phased schedule and budget for Stage 2, and recommendations on adjustments to the technical approach based on the outcome of the Pilot Project.

Additionally, there will be three junior TxDOT staff working on this project. It is anticipated that each of these staff members will spend 100% of their time on the project.

Fringe Benefits - $75,600

Fringe benefits are calculated at 18.9% of TxDOT direct personnel costs.

Travel - $8,700

Two trips to Washington, DC are assumed for this project, as per the NOFO. Two TxDOT employees anticipate traveling to Washington, DC for each trip.

Equipment - $225,000

Project costs include the upgrade of 15 DSRC units to C-V2X. The unit cost is estimated at $15,000 per unit, or $225,000 total.

Supplies - $2,000

This funding will go toward miscellaneous IT purchases such as computers or tablets (depending on the final determination of greatest need), and other office supplies.

Contractual - $954,440

TxDOT plans to use contractual labor for three elements of this project:

- The **Pilot Project Evaluation**, undertaken by TTI, will be $175,000 – a little less than 20% of the overall budget. The TTI Project Manager, Darrell Borchardt, will spend 15% of his time on this project. He will work with a team of researchers and analysts from TTI to refine the performance metrics, collect actual performance data, and compare the impact of the Pilot Project in a before-and-after study. He will be supported by research and technical staff.
- A consulting team (under contract to TxDOT) will lead **API development** for integration of the new units with existing systems across the various jurisdictions managing the intersections. $100,000 is set aside for this element.
- A consulting team (under contract to TxDOT) will be providing **planning support** on this project. The consultant(s) will support the development of the Tactical Plan identified in Task 4, such as summarizing existing conditions, documenting technical specifications for C-V2X unit deployment, facilitating stakeholder engagement, and using observed performance data to inform the ultimate vision and action plan for the Stage 2 deployment. $679,440 is set aside for this element.

Other - $10,000

This category includes costs such as printing, local travel, and the potential FCC license renewal in September 2024 depending on the timing of the grant award.

Indirect Cost - $17,200

The approved indirect rate for TxDOT is 4.73% of direct labor.

Appendix III: Letters of Commitment

Letters of Commitment are provided by the following partners:

- TranStar
- Texas A&M Transportation Institute