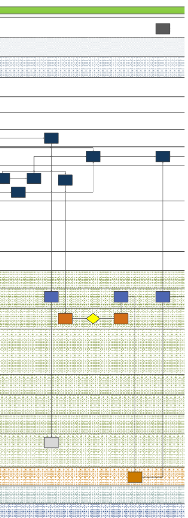
TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS (TSMO)



SAN ANGELO DISTRICT ITS MASTER PLAN

September 2021

Document Control

Version	Date	Description of Change	Author
1.0	5/18/2021	Draft plan submitted to TxDOT SJT	Arcadis
1.1	9/29/2021	Final plan submitted to TxDOT SJT	Arcadis

Disclaimer: This ITS Master Plan represents recommended improvements. ITS will be deployed as funding is secured, project prioritization may change without notice.

Table of Contents

List of Tables

List of Figures

List of Appendices

Acronyms and Abbreviations

AADT	Average Annual Daily Traffic
Arcadis	Arcadis U.S., Inc.
ATMS	Advanced Traffic Management System
COG	Council of Governments
DOT	Department of Transportation
FHWA	Federal Highway Administration
GIS	Geographic Information System
HSIP	Highway Safety Improvement Program
I-##	Interstate ##
LOTTR	Level of Travel Time Reliability
MPO	Metropolitan Planning Organization
NPMRDS	National Performance Management Research Data Set
RTZ	Road to Zero
SE	Systems Engineering
SH-##	Texas State Highway ##
SJT	San Angelo District
TMC	Traffic Management Center
TTI	Texas A&M Transportation Institute
TxDOT	Texas Department of Transportation
US-##	U.S. Highway ##
ITS	Intelligent Transportation Systems
IT	Information Technology
TSMO	Transportation Systems Management and Operations
CCTV	Closed Circuit TV
DMS	Dynamic Message Signs
ARC-IT 9.0	Architecture Reference for Operative and Intellengent Transportation
MDSS	Maintenance Decision Support Systems
AID	Automated Incident Detection
SEMP	Systems Engineering Management Plan
OT	Operations Technology
Map 21	Moving Ahead for Progress in the 21st Century
ConOps	Concept of Operations
TRZs	Transportation Reinvestment Zones
PS&E	Plans, Specifications, and Estimate
NHTSA	National Highway Traffic Safety Administration

TMA	Metropolitan Mobility and Rehabilitation
TIP	Transportation Improvement Program
RTIP	Rural Transportation Improvement Program
STIP	Statewide Transportation Improvement Program
UTP	Unified Transportation Program
TAC	Texas Administrative Code

EXECUTIVE SUMMARY

The TxDOT San Angelo District (SJT) Intelligent Transportation Systems (ITS) Master Plan outlines the District's ITS Vision and actionable steps necessary to achieve this vision, which is to provide a safe and reliable transportation experience through a collaborative regional transportation management system. In addition, the ITS Master Plan outlines the following ITS goals to provide a roadmap for the District's future ITS deployments:

- Mobility and Reliability: Leverage ITS to enhance the mobility, reliability, and efficiency of the transportation system.
- Safety: Employ ITS technology to improve the safety of the transportation system.
- Multimodal Connectivity: Support efficient movement of goods and services across all modes.
- Asset Management: Build upon and regularly update asset inventories.
- Interagency Collaboration and Public Communication: Promote interagency collaboration and effectively disseminate information to the end users.

The purpose of the ITS Master Plan is to provide a comprehensive assessment of district's current ITS inventory, planned ITS projects, ITS needs, and ITS strategies for the next 5 years. Based on the analysis of current capabilities and identified transportation needs, a number of key ITS strategies were developed to achieve the district's ITS vision, mission, and goals:

1. Flood Warning / Low Water Crossings
2. Roadway Lighting Monitoring
3. Automated Incident Detection
4. Over Height Detection System
5. Update Regional ITS Architecture

Furthermore, a list of applicable ITS projects proposed to be deployed during the next five years is shown below:

1. Flood Warning / Low Water Crossings
2. Over Height Detection System
3. Update Regional ITS Architecture

1 INTRODUCTION

This Intelligent Transportation Systems (ITS) Master Plan has been developed as part of the Texas Department of Transportation (TxDOT) San Angelo District (TxDOT-SJT) Transportation Systems Management and Operations (TSMO) Program Plan Development Project. The main purpose of the ITS Master Plan is to guide TxDOT-SJT's deployment of ITS over the next five years, and is organized around the following chapters:

- **Chapter 1, Introduction:** A discussion of the ITS Master Plan's background, purpose, and development methodology.
- **Chapter 2, ITS Vision, Mission, Goals and Objectives:** A statement of TxDOT-SJT's ITS Vision, Mission, Goals and Objectives intended to formalize and advance ITS initiatives in the District.
- **Chapter 3, Existing Conditions:** An assessment of the existing conditions of the District's roadway network, traffic safety, and traffic operations.
- **Chapter 4, ITS Inventory:** An assessment of the District's existing ITS. This includes communications infrastructure, closed circuit television (CCTV) cameras, dynamic message signs (DMSs), traffic signals, and other specialized systems and software.
- **Chapter 5, Existing and Planned ITS Projects:** An assessment of specific ITS-related needs to be addressed by TxDOT's ITS strategies.
- **Chapter 6, Needs Assessment**: An assessment of specific ITS-related needs to be addressed by the Master Plan.
- **Chapter 7, Existing and Proposed ITS Strategies:** A set of projects and strategies which address the identified needs.
- **Chapter 8, Project Development Methodology:** A high-level implementation plan for the proposed ITS strategies.
- **Chapter 9, Proposed ITS Deployments:** Project sheets for the proposed ITS deployments.

1.1 Background

In order to maximize mobility using the available transportation funding, TxDOT developed a Statewide TSMO Strategic Plan in August 2017. TSMO is a holistic approach to better manage the congestion due to increasing demand for travel on local roadways by integrating planning and design with operations and maintenance. It provides a framework for maximizing efficiency of both the project development process and the function of existing infrastructure by promoting collaboration both internally and between agencies. As part of the Statewide TSMO Strategic Plan, districts are to develop a TSMO Program Plan and, if one does not exist yet, an ITS Master Plan. The ITS Master Plan identifies and assesses the existing ITS, identifies current ITS applications to mitigate transportation problems, and develops a five-year ITS deployment plan.

The San Angelo District plans, designs, builds, operates, and maintains the State transportation system in the following fifteen counties: Coke, Concho, Crockett, Edwards, Glasscock, Irion, Kimble, Menard, Reagan, Real, Runnels, Schleicher, Sterling, Sutton and Tom Green. As of September 2020, and per TxDOT's 'District Profile', the District has a population of 166,248, covers an area of 19,061 square miles, and includes 7,413 lane miles of the State's transportation system. In addition, it is composed of about 219 TxDOT employees and had construction/maintenance expenditures of $111 million in 2020; its $28 million maintenance budget is divided among the fifteen counties in the district. An overview of the SJT District's location in relation to the rest of TxDOT's Districts is shown in **Figure 1**.

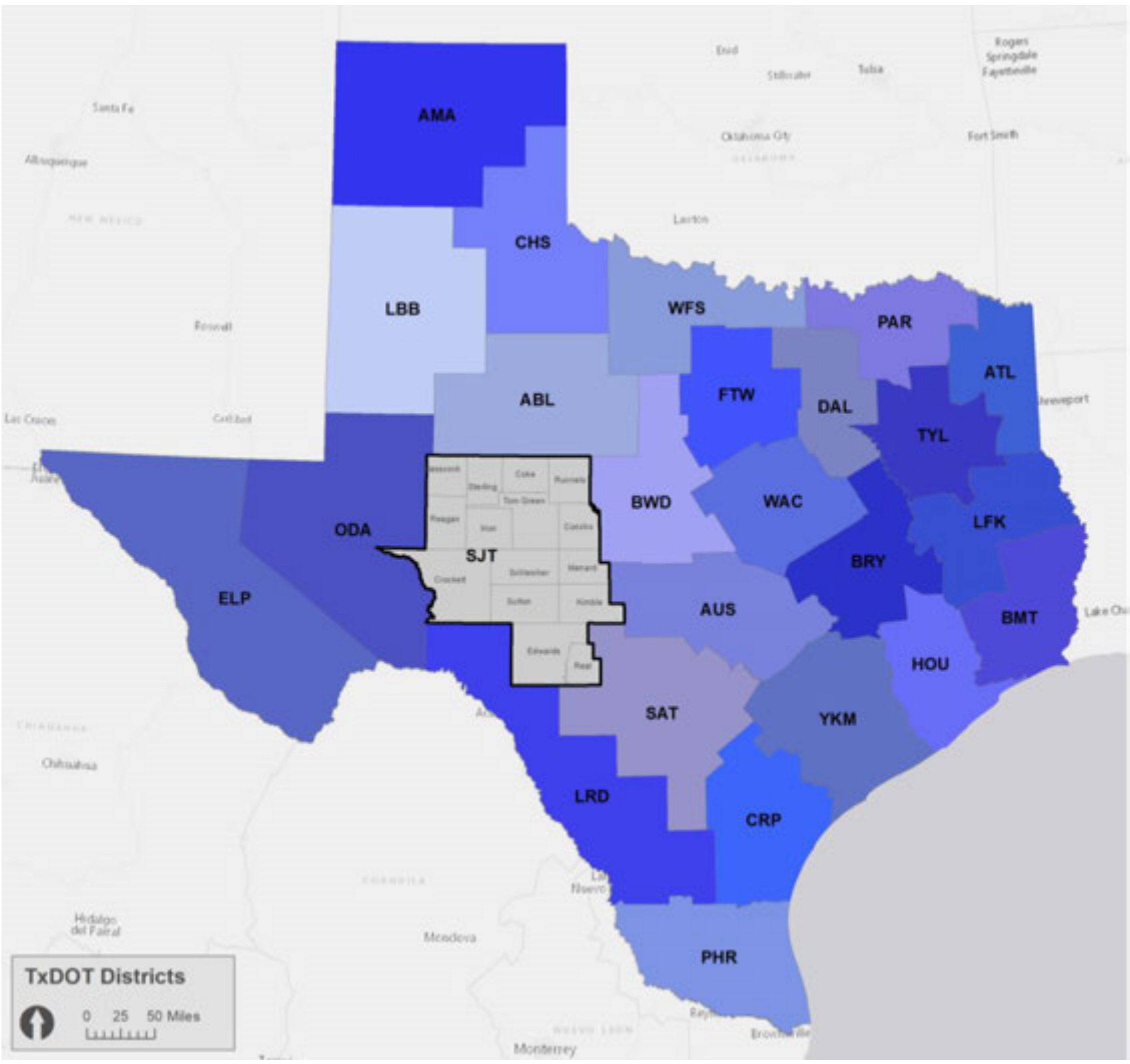


Figure 1: TxDOT District Map

As shown in **Figure 2**, the main roadways in the District are Interstate 10, US-67, US-83, US–87, US-190, US-277, US-290, US-377, SH-87, SH-110, SH-163, and SH-306.

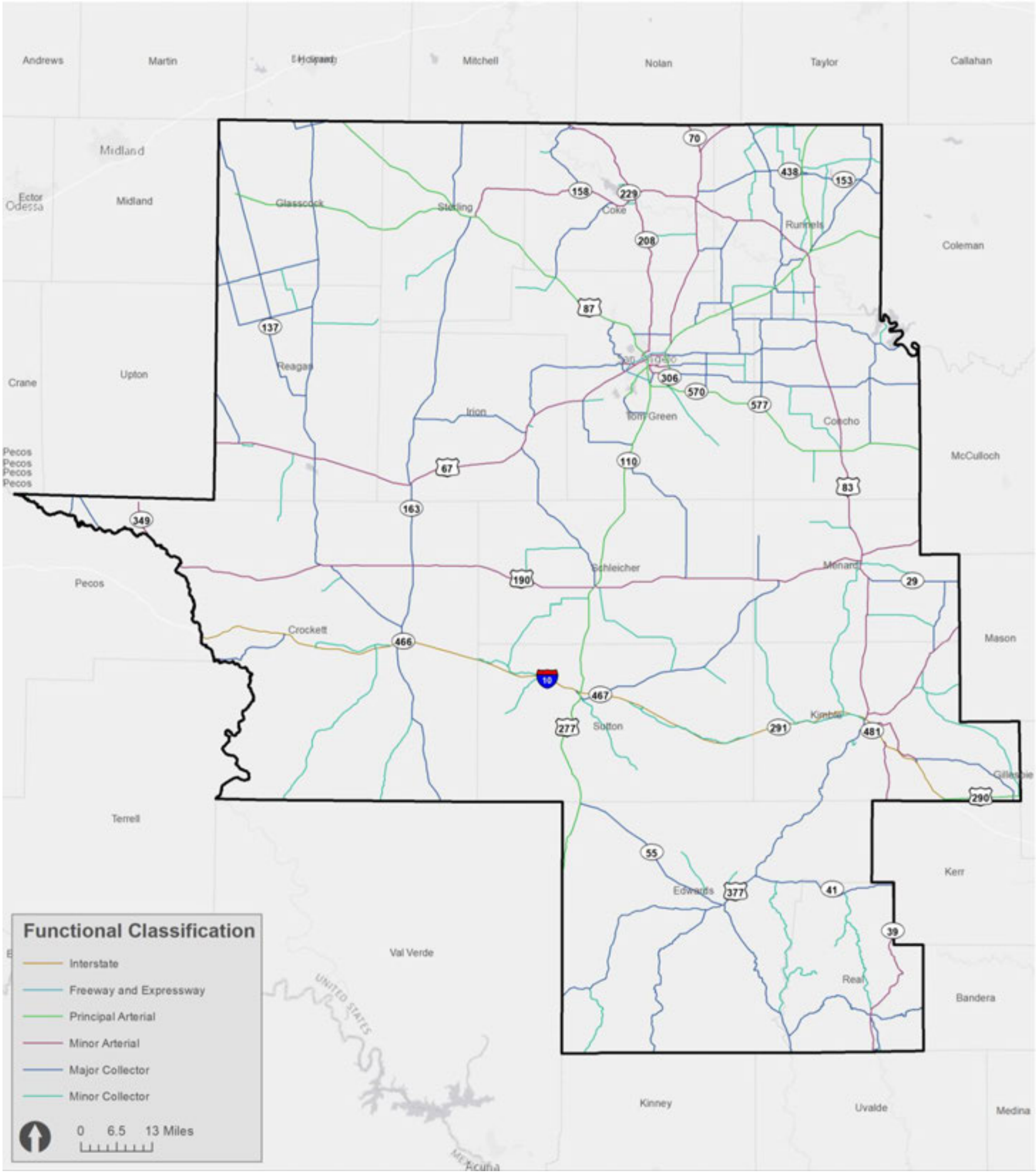


Figure 2: Roadway Functional Classification

The District's Four-year (FY 2020 – FY 2023) Safety Plan, published in March of 2020, lays out safety projects prepared for the State's Road to Zero (RTZ) initiative and Highway Safety Improvement Program (HSIP). However, the projects which are captured within the Safety Plan are not limited to these funding categories; the Safety Plan is an umbrella that encompasses project planning across all funding categories for the District. The safety projects and initiatives identified in the 2020 Safety Plan include:

- Intersection Improvements
- Roadway Lane Departure Countermeasures
- Rumble Strip Improvements
- Child Passenger Safety Seat Outreach Program
- Maintenance Inspection Day and Night Rides
- In-house District Safety Review Team

Finally, in terms of major corridors, Segment 2 of the Ports-to-Plains Corridor runs through the District along US-277 and US-87. The Ports-to-Plains Corridor is a significant corridor that connects and integrates Texas' key economic engines, international trade, energy production and agriculture. The corridor functions as the only north/south corridor facilitating the movement of people and goods in South and West Texas. The Segment 2 Committee Report, published on June 30th, 2020, presents the impacts of this corridor on the District. The main recommendations from the report are to complete TxDOT's and San Angelo MPO's planned and programmed projects and to develop a detailed planning process to upgrade the Ports-to-Plains Corridor to an interstate facility.

Regional ITS Architectures, established as "a regional framework for ensuring institutional agreement and technical integration for the implementation of ITS projects or groups of projects", are usually developed and maintained by state Departments of Transportation (DOTs), by Metropolitan Planning Organizations (MPOs) or by Council of Governments (COGs) for a region, district, or state. The concept of a regional ITS architecture was first defined in Title 23, Part 940.11 of the Code of Federal Regulations on Intelligent Transportation System Architecture and Standards with the goal of supporting:

- **Long Range Transportation Planning.** A regional ITS architecture can be used to support metropolitan and statewide long-range transportation planning. It provides a means by which peer agencies can jointly define their vision for ITS development based on regional goals and objectives. Using the regional ITS architecture, a region can plan for technology application and integration to support more effective planning for operations.
- **Programming/Budgeting:** A regional ITS architecture can be used to support the programming/budgeting of projects in metropolitan and statewide regions. It provides a high-level description of ITS projects, which can serve as an input the definition and prioritization that occurs during programming/budgeting.
- **Project Development:** By starting with the regional ITS architecture, the steps taken by each project will be on the path to fulfilling the broader objectives set forth in the long-range transportation plan. A well-

maintained regional architecture provides context for ITS projects and the initial input for the Systems Engineering (SE) for a project. Project-relevant information from can be used to support not only the development of a project architecture, but also the SE documentation such as Concept of Operations and System Architecture Document.

The San Angelo District developed a regional ITS Architecture in 2004 which included an inventory of ITS and needs for the region, a concept of operations for the region, and ITS project recommendations for the San Angelo District. The recommended high priority projects identified in the Architecture included CCTV camera deployment, traffic signal control for surface streets, traffic information dissemination, emergency vehicle routing, road weather data collection, and transit vehicle tracking, among others.

1.2 Purpose and Methodology

The purpose of this ITS Master Plan is to document the existing ITS in the SJT District and to provide a five-year plan that will guide the District's future ITS deployments. The Master Plan can be used to inform long range transportation planning, to assist in programming and budgeting, and to develop ITS projects.

ITS play an important role in the transportation network since they can improve safety and mobility by integrating advanced information technology (IT), i.e., technologies that focus on managing data, and operations technology (OT), i.e., technologies that focus on measuring and controlling the physical world, into the transportation infrastructure and vehicles. The National ITS Reference Architecture, also known as the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT 9.0), is used to develop this Master Plan. The National ITS Architecture provides a common framework for planning, defining, and integrating ITS. It includes a set of interconnected components that are organized into four views that focus on four different perspectives, enterprise, functional, physical, and communications, as shown in **Figure 3**.

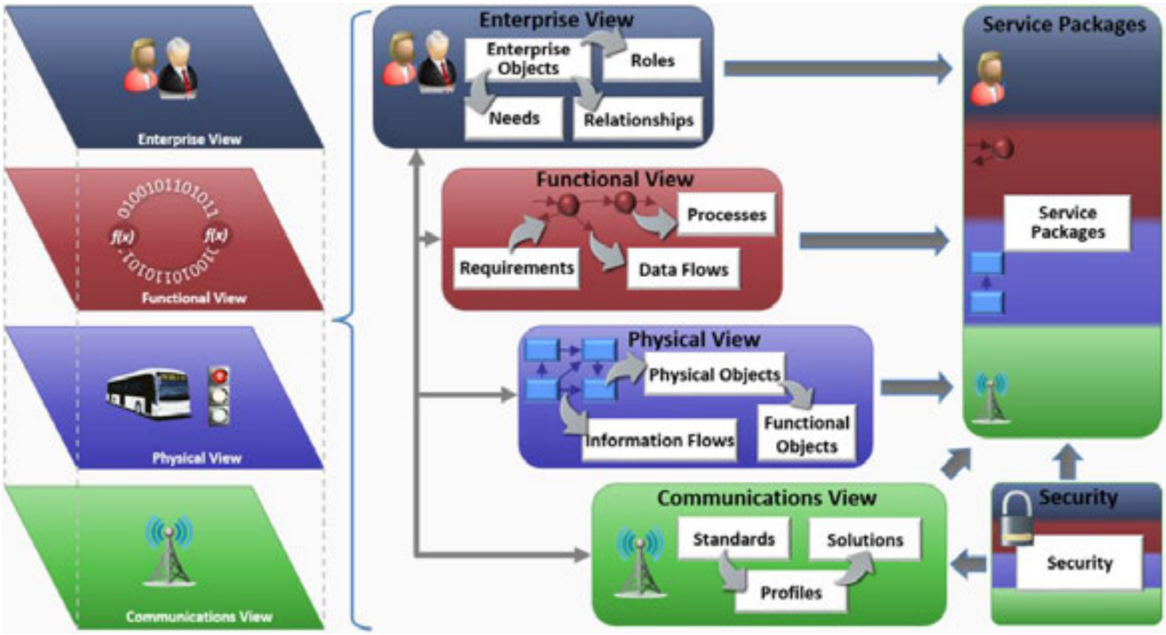


Figure 3: ARC-IT Framework

Service Packages (shown on the top right corner of **Figure 3**) represent typical services provided by a transportation system, for example, Traffic Signal Control or Traffic Information Dissemination, and are perhaps the most important parts of the architecture. Service packages are mainly used for quickly producing strategies and lists of requirements which address general ITS-related needs. Because of this, even though a full architecture is not developed as part of this Master Plan, service packages from ARC-IT are used to assist in steps 2, 3, 4, and 5 of the methodology shown in **Figure 5**. It is also useful to look at the physical view of ARC-IT. **Figure 4** shows the physical objects which are part of ARC-IT: Support systems, vehicles, field equipment, management centers, and personal devices. Each of these objects makes use of different IT/OT as shown in the figure.

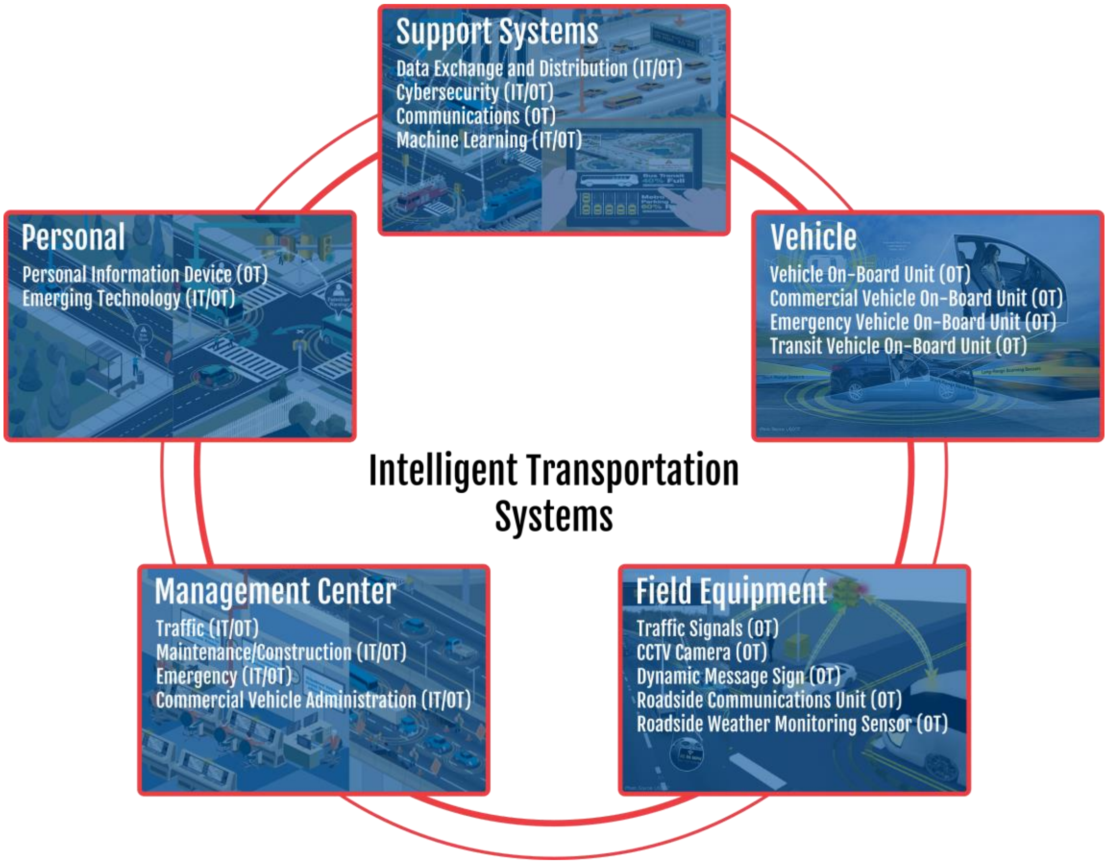


Figure 4: Intelligent Transportation Systems

Finally, this ITS Master Plan was developed using the methodology shown in **Figure 5** and described in detail below:

- **Data Collection:** Collected safety and mobility data, project planning information, and an inventory of roadway devices to determine the District's current ITS. Conducted meetings and interviews with District staff to determine the accuracy of the collected data.
- **Exisitng Conditions and ITS Inventory:** Analyzed the District's 4-year Safety Plan and the exisitng ITS inventory to determine the current capabilities. This analysis was used as an input for the ITS Planning Mini Workshop.
- **ITS Planning Mini Workshop:** Held a mini-workshop with the District's staff to determine ITS needs and clarify any gaps in data collection. In some cases, data collection verification required going back to steps 1 and 2 for review. The outcome of the workshop was a set of preliminary ITS strategies.
- **ITS Master Plan:** In steps 4 and 5, the ITS Master Plan document was developed. A draft plan was submitted to the District, reviewed, and a final document was assembled.

- **Correspondence with stakeholders via email and telephone:** Although not explicilty shown in **Figure 5**, correspondence with stakeholders took place at every step to clarify issues and discuss specific topics in greater detail.

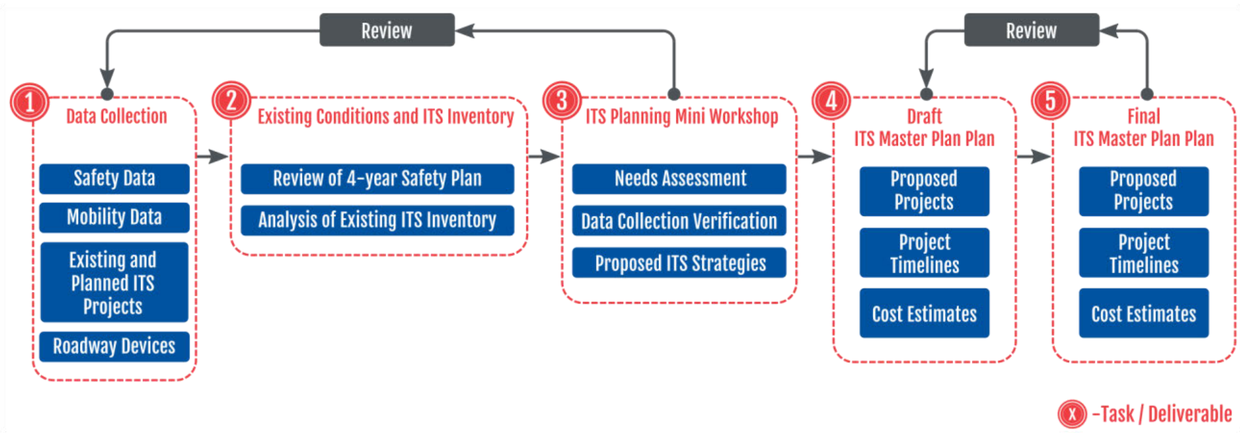


Figure 5: ITS Master Plan Methodology

2 ITS VISION, MISSION, GOALS, AND OBJECTIVES

This chapter details the methodology and outcome of the development of the ITS Vision, Mission, Goals, and Objectives. To develop the vision, mission, goals, and objectives, TxDOT's values and vision were reviewed with the ITS Master Plan's stakeholders to ensure that the Master Plan aligned with TxDOT's strategic objectives. After one-on-one discussions with the stakeholders, a draft vision, mission, goals and objectives was produced. After further refinement with the stakeholders, a final statement was obtained as shown later in this chapter.

2.1 Stakeholder Roles and Responsibilities

The District of San Angelo's roadway network spans across fifteen different counties. Hence, multiple agencies, municipalities, and departments were involved in planning, developing, operating, and managing the ITS infrastructure. **Table 1** provides the list of stakeholders and key staff members that were identified for this ITS Master Plan.

Table 1: Stakeholder List

No.	Agency	Point of Contact	Contact Information
1	TxDOT SJT District	William McLane	William.McLane@txdot.gov
2	TxDOT SAT District	John Gianotti	John.Gianotti@txdot.gov
3	TxDOT TRF Division	Barbara Russell	Barbara.Russell@txdot.gov

4	City of San Angelo	Robert Karch	robert.karch@cosatx.us
5	San Angelo Metropolitan Planning Organization (SAMPO)	Pete Madrid	pete.madrid@cosatx.us

2.2 Existing Agreements

The TxDOT San Angelo District currently has one interagency agreement in place with the SAT District as shown in **Table 2**. The agreement describes the responsibilities and procedures between the SJT and SAT Districts for control of the SJT DMSs via the Lonestar Advanced Traffic Management System (ATMS) software. Since the TRF-TM Section supports all Districts for ITS consistency throughout the state, this agreement has been developed by the TRF-TM Section and the SAT and SJT ITS Sections. The agreement may be found in Appendix A and contains detailed SJT and SAT ITS operator responsibilities for each event type.

Table 2: Existing Agreements

No.	Agency	Agreement Type	Execution Date
1	SAT District	Maintenance	2018

2.3 Vision and Mission Statements, Goals, and Objectives

Texas has a vast interconnected system of roads, rails, airports, ports, and transit that touches every resident, visitor, business, and industry in the state. The SJT District aims to create an ITS Vision that embodies TxDOT's overall strategies to advance its transportation system using ITS for the next five years. TxDOT's Vision is to be "A forward-thinking leader delivering mobility, enabling economic opportunity, and enhancing quality of life for all Texans", and its Mission is "Connecting you with Texas". In addition, its values are: *people*, *accountability, trust,* and *honesty.* With these Departmental principles in place, this ITS Master Plan sets forth an ITS Vision, Goals, and Objectives to formalize and advance SJT District's ITS initiatives.

To develop an ITS vision statement, the District's staff were provided with a preliminary vision statement. The preliminary statement was modified by the District staff and a final statement was developed. The **Vision Statement** echoes the Department's overall Vision, articulates a clear and inspirational long-term desired change, and is shown below:

To provide a safe and reliable transportation experience through a collaborative regional transportation management system.

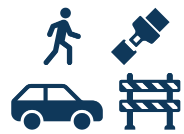
The **Mission Statement**, which is a clear and concise statement communicating what the SJT District's ITS strategies will do, is presented below:

Provide all commuters a safe, efficient, and reliable transportation experience through innovation and collaboration.

Goals statements provide direction for planning, evaluating plans, and guiding projects and actions These short statements are desired outcomes which ideally would be accomplished within the next five years and are presented below:

Mobility and Reliability: Leverage ITS to enhance the mobility, reliability, and efficiency of the transportation system.

TxDOT SJT will proactively use incident, weather, work zone, and signal timing management systems to enhance mobility and reliability.



Safety: Employ ITS technology to improve the safety of the transportation system.

TxDOT SJT will employ ITS to contribute to the achievement of the goals laid out in the District's 4-year Safety Plan.

Multimodal Connectivity: Support efficient movement of goods and services across all modes.

TxDOT SJT will use the ITS Master Plan to support project development for projects which employ ITS across different modes.

Asset Management: Build upon and regularly update asset inventories.

TxDOT SJT will employ maintenance decision support systems (MDSS) for managing device maintenance and replacement.

Interagency Collaboration and Public Communication: Promote interagency collaboration and effectively disseminate information to the end users.

TxDOT SJT will use the ITS Master Plan to support planning and programming across agencies. TxDOT SJT will employ ITS to effectively reach end users.

Associated with each goal there are objectives; an objective is a specific and measurable action that can be taken to advance a goal. Furthermore, associated with each objective there are performance measures; performance measures are how objective achievement is measured. The goals, objectives, and performance measures of this ITS Master Plan are shown in Table 3.

Table 3: ITS Master Plan Goals, Objectives, and Performance Measures

Goal	Objectives	Performance Measures
Mobility and Reliability	Improve traffic operations during inclement weather events	Improve accessibility to real time ITS data
		Improve accessibility to historic ITS data
Safety	Reduce incident frequency and severity	Reduce fatal and serious injury crashes
		Reduce incidents involving over height vehicles
		Reduce incidents involving flooding
Multimodal Connectivity	Improve regional transit through ITS data sharing	Provide real time ITS data to RTA
		Explore data sharing agreements with RTA
Asset Management	Increase asset uptime	Improve overall ITS connectivity
		Improve CCTV system uptime
		Improve DMS system uptime
		Improve roadway lighting monitoring capabilities
	Improve asset inventory accuracy	Develop routine asset inventory review procedures
		Develop routine asset inventory reporting procedures

Goal	Objectives	Performance Measures
Interagency Collaboration and Public Communication	Improve traveler information dissemination	Improve quality of ITS information on DriveTexas and TxDOT ITS websites
		Evaluate and deploy more effective traveler information dissemination technologies

3 EXISTING CONDITIONS

3.1 Safety

The District's Four-year (FY 2020 – FY 2023) Safety Plan, published in March of 2020, summarized crash data from 2015 to 2018. Based on these data, it proposed safety projects prepared for the State's Road to Zero (RTZ) initiative and Highway Safety Improvement Program (HSIP). The safety projects and initiatives identified in the 2020 Safety Plan include:

- Intersection Improvements
- Roadway Lane Departure Countermeasures
- Rumble Strip Improvements
- Child Passenger Safety Seat Outreach Program
- Maintenance Inspection Day and Night Rides
- In-house District Safety Review Team

For this ITS Master Plan, TxDOT's C.R.I.S. was used to obtain crash records from 2017 to 2019. A summary of the crash records is shown in **Table 4** and a crash heatmap for the District is shown in **Figure 6**. The trend from 2017 to 2019 has remained nearly flat and most crashes are located near interchanges on SH-87 and SH-306 in San Angelo.

Table 4: SJT District Crashes (2017 - 2019)

Year	Fatal Crashes (K)	Suspected Serious Injury Crashes (A)
2017	34	136
2018	40	112
2019	38	103
Total	112	351

Note: Letters in parentheses after crash type correspond to the 'KABCO' injury scale.

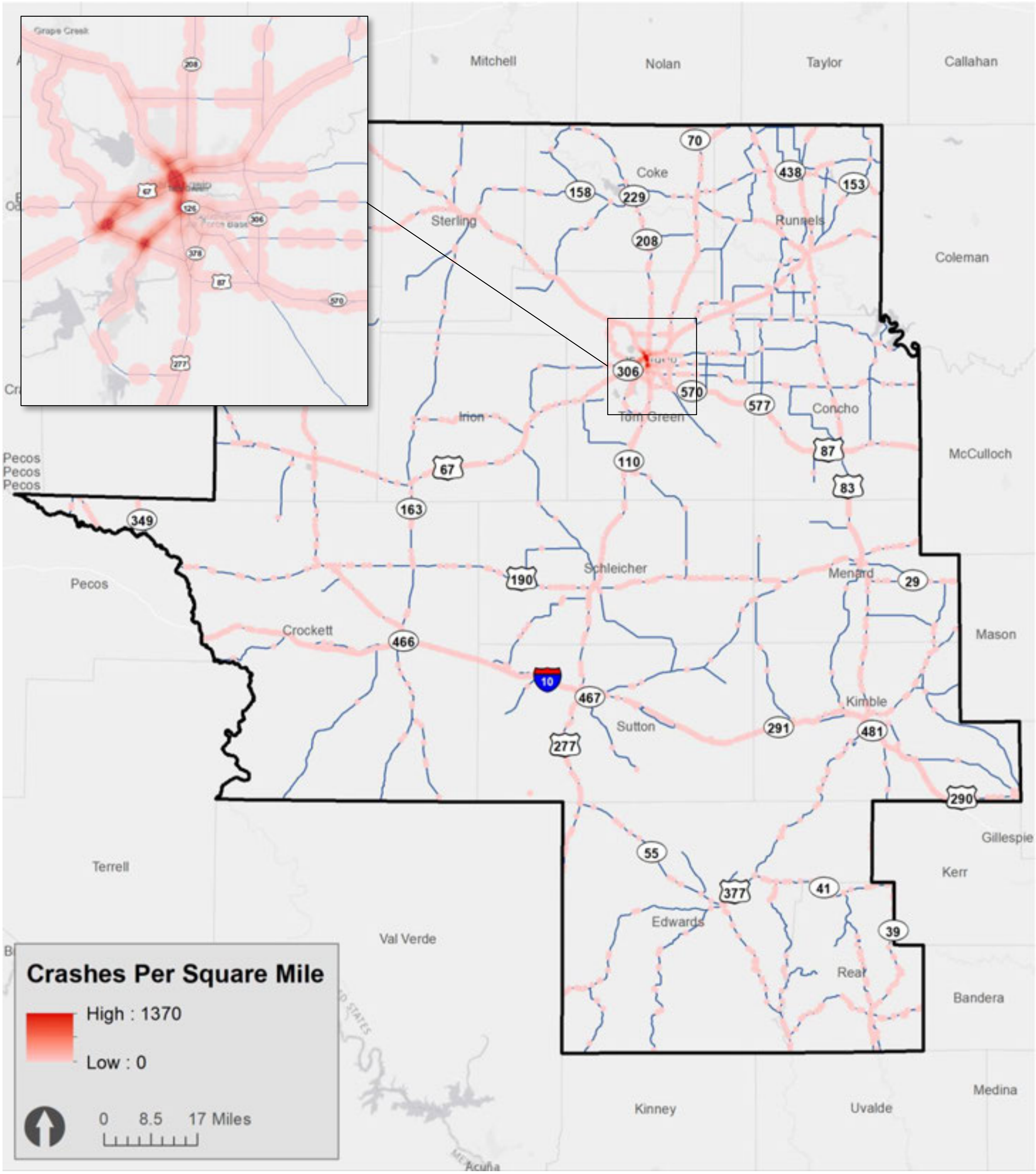


Figure 6: Crash Heatmap

3.2 Congestion

Congestion is a traffic condition characterized by slower speeds, longer travel times, and the occurrence of vehicle queues. It can be recurrent (repeating often) or non-recurrent. Recurrent congestion includes delays that are predictable in frequency and extent (e.g., rush-hour traffic); while non-recurrent congestion is due to unexpected delays from temporary drops in road capacity (e.g., blocked lane due to a crash or work zone) or sudden surges in demand (e.g., planned special events). Travel time is the time taken by a vehicle to traverse a route between two points of interest (e.g., the origin and destination). Travel time reliability is a measure of the consistency or dependability in the travel time of a trip, or time to traverse a road segment, as experienced in different hours of the day and days of the week. Although lack of travel time reliability is different from congestion, they are closely related. High levels of congestion increase the likelihood of unreliability, in addition, unreliability is directly related to non-recurrent congestion.

Although there are several ways to measure travel time reliability, 'level of travel time reliability' (LOTTR), proposed in the Moving Ahead for Progress in the 21st Century (MAP-21) performance measures, is currently recommended by the Federal Highway Administration (FHWA). Level of travel time reliability is defined as the ratio of the 80th percentile travel time to the normal travel time (i.e., the 50th percentile occurring throughout a full calendar year). It can be easily obtained using data from FHWA's National Performance Management Research Data Set (NPMRDS). An LOTTR of less than 1.5 for a segment of roadway indicates a segment that is not reliable. **Figure 7** shows a plot of LOTTR for State Highways in the San Angelo MPO boundary. As it can be seen in the figure, most of the road network is reliable, except for a few short road segments on US-87 and on Knickerbocker Rd. in San Angelo and the westbound off-ramp of US-67 at US-87. As mentioned earlier, although LOTTR is not a direct measure of congestion, **Figure 7** suggests that congestion is not a significant issue in the District. Furthermore, interviews with District staff confirm that congestion is not a significant issue.

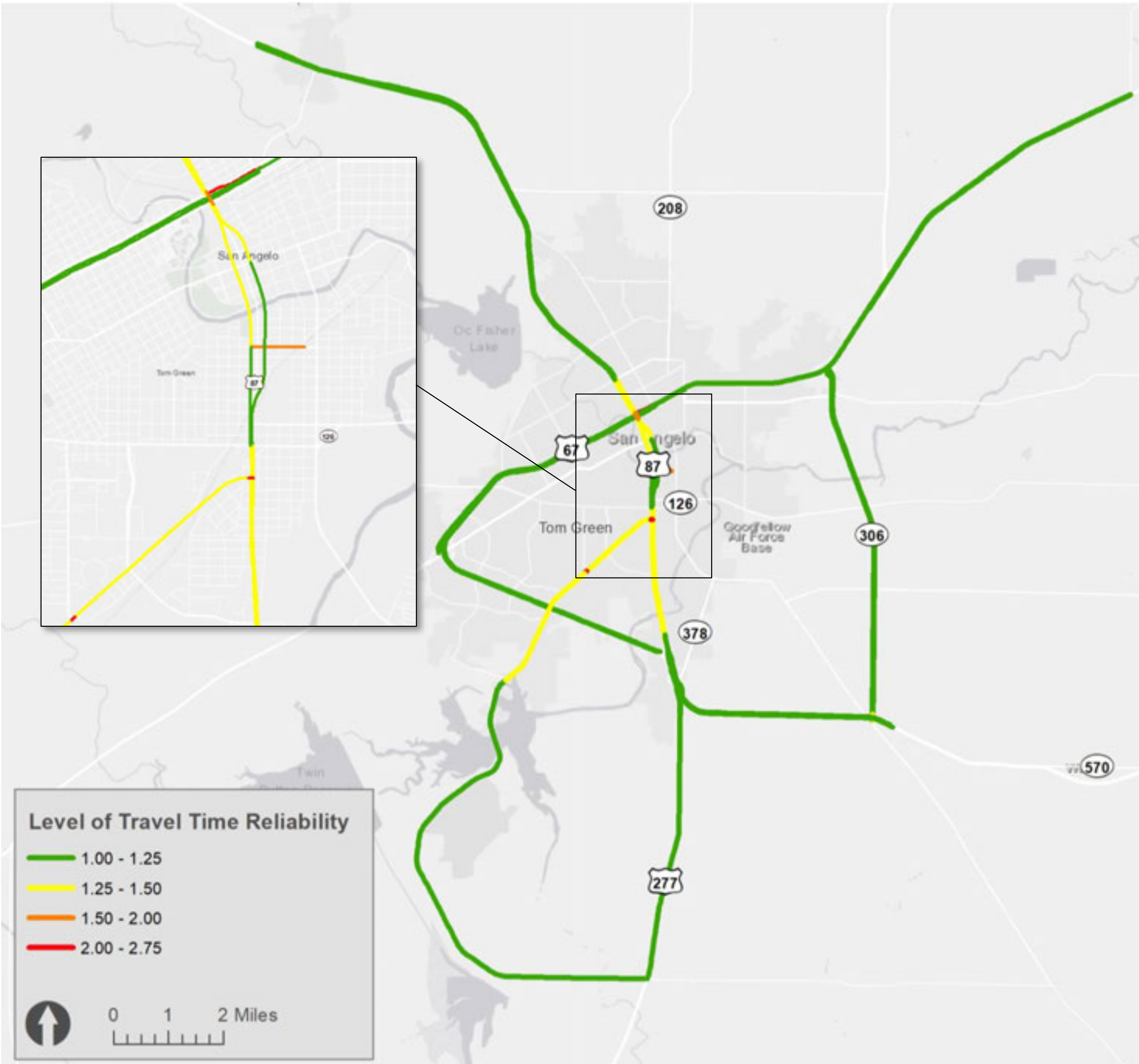


Figure 7: LOTTR for the San Angelo Metropolitan Planning Area

4 ITS INVENTORY

The San Angelo District currently operates and maintains the following ITS devices: CCTV cameras, DMSs, traffic signal vehicle detectors, an over height vehicle detection system, a mini traffic management center (TMC), and school zone flashers.

4.1 CCTV Cameras and Dynamic Message Signs

The District has CCTV cameras (Cohu Rise 4269) and DMSs deployed on I-10 at eight locations (although location 8 falls withing SAT District's boundary) as shown in **Figure 8**. The DMSs are used to post traveler information messages, including:

- Incident warning for unplanned event that may impede traffic, including responder actions to correct it
- Emergency warning for unplanned event that has or may affect public safety
- Alert for missing Person

In addition, they are operated by the SAT District and maintained by the SJT District through a joint agreement. The DMSs are equipped with cellular modems allowing them to remotely communicate with SAT District's Lonestar System.

San Angelo District DMS on I-10

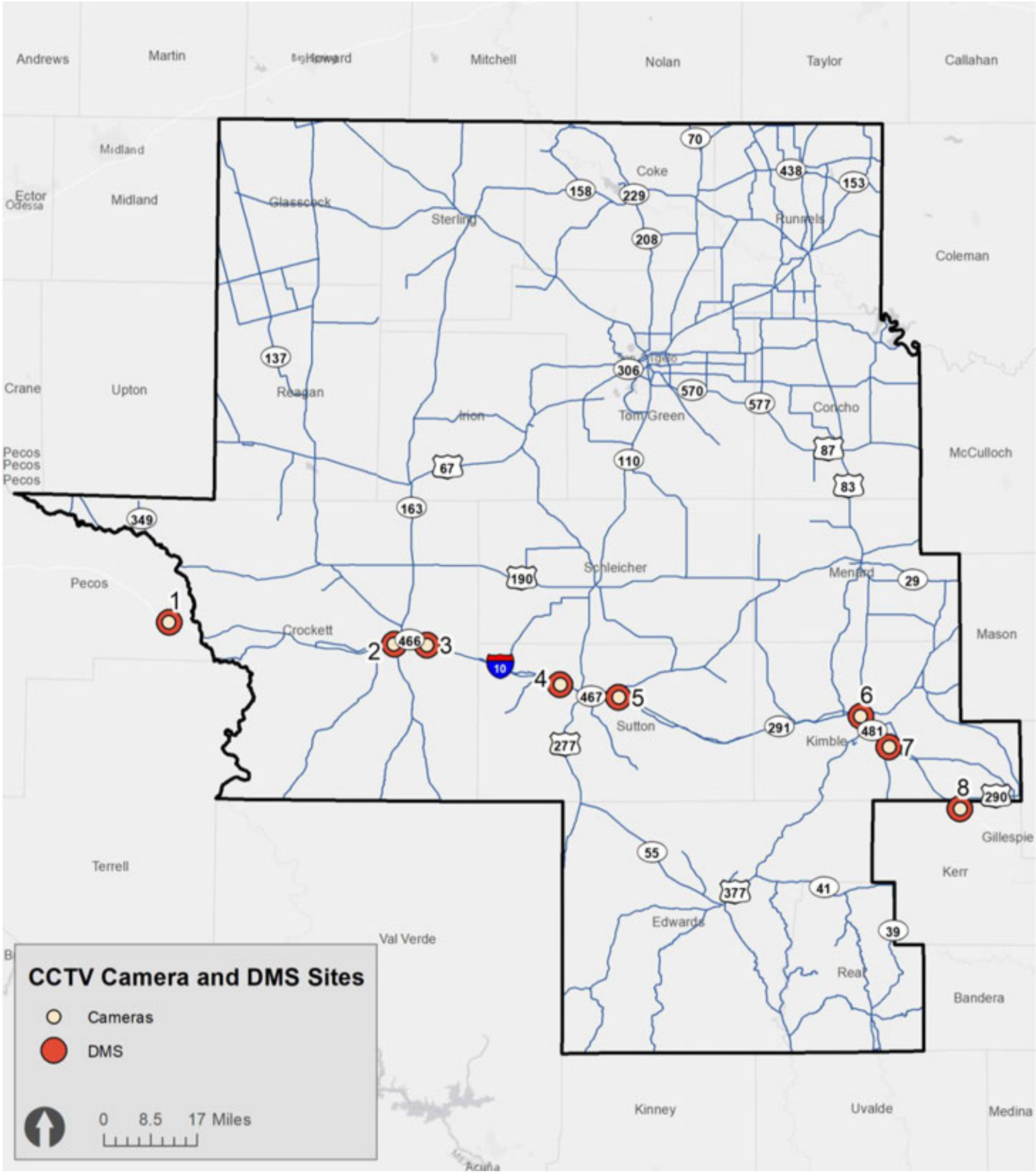


Figure 8: CCTV and DMS locations

4.2 Traffic Signal Vehicle Detectors

The SJT District has 35 signals with vehicle detection technology as shown in **Figure 9**. Video detection technology is used at every signal and it is either an Iteris (Next or WDR model) or Gridsmart camera. Most of the signal detection devices are in the San Angelo area on SH-306 and US-67. These are Iteris WDR and Next cameras. The rest of the devices are distributed within the District as shown in **Table 5**.

Table 5: Traffic Signal Vehicle Detector Locations

Location	Number of Detectors	Location	Number of Detectors
San Angelo	12	Junction	2
Sonora	4	Big Lake	2
Ozona	3	Winters	2
Ballinger	3	Other locations	7

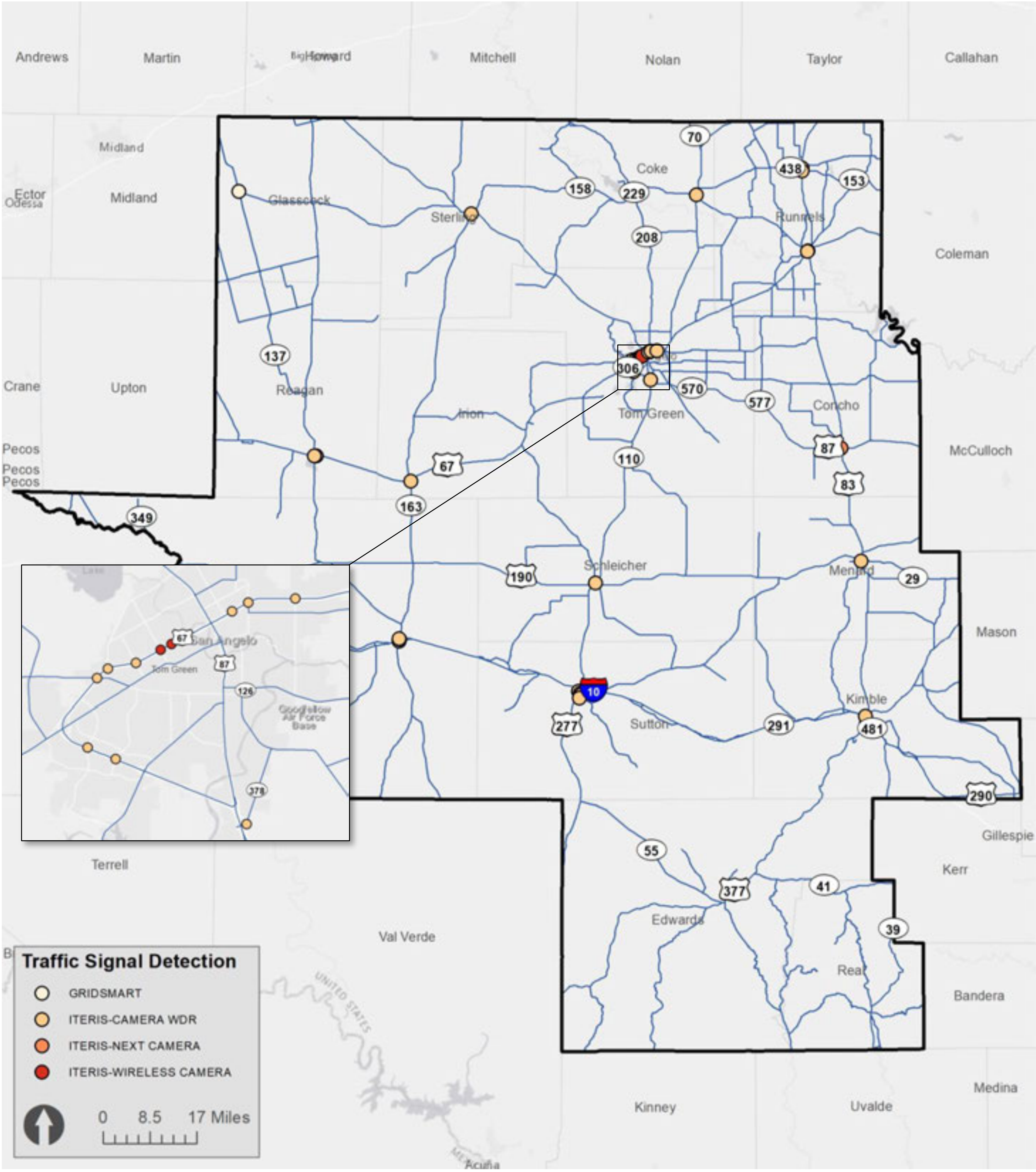


Figure 9: Traffic Signal Detection

4.3 Over Height Vehicle Detection

The SH-306 West and Knickerbocker overpass has a height of 14 ft 9 in, while in the opposite direction, on SH-306 East, it has a height of 16 ft 8 in. Due to the smaller clearance on SH-306 West, the District deployed an upgraded over height detection system on SH-306 West in June 2019. The system consists of:

- A Double Eye Z-Pattern Visible Red/Infrared Detection Sensor located around 3,150 ft upstream from the overpass as shown below.

- A Directional Alarm Bell located around 3,050 ft upstream from the overpass to alert motorists approaching the overpass as shown below.

- A 99” x 48” Blank Out Sign displaying “OVERHEIGHT LOAD DETECTED – EXIT NOW” located around 2,800 ft upstream from the overpass as shown below.

- A cell modem to enable remote notifications via email or text message.

4.4 Mini Traffic Management Center

The District has a mini TMC to monitor signals, school zone flashers, and DMSs. It is equipped with a computer with view access to the Lonestar ATMS (the District is currently engaging the Division to obtain write access) and four large screens arranged as a video wall. Currently there is no full-time staff assigned to the TMC, TxDOT traffic engineers will use the TMC on an as-needed basis. A picture of the mini-TMC is shown in **Figure 10**.

Figure 10: SJT Mini-TMC

4.5 School Zone Flashers

The SJT District has 66 school zone flashers (also known as ‘school clocks’) as shown in **Figure 11**. The schedules are updated at the start of each school year. The District’s Traffic Signal Crew installed remote access to all 72 school zone flashers via RTC cell modems in December 2019. **Table 6** shows the distribution of the flashers within the District.

Table 6: School Zone Flasher Locations

Location	Number of School Flashers
San Angelo Area	6
Garden City	4
Winters	4
Ballinger	4
Eden	4

Location	Number of School Flashers
Big Lake	4
Ozona	4
Sonora	4
Junction	4
Other locations	28

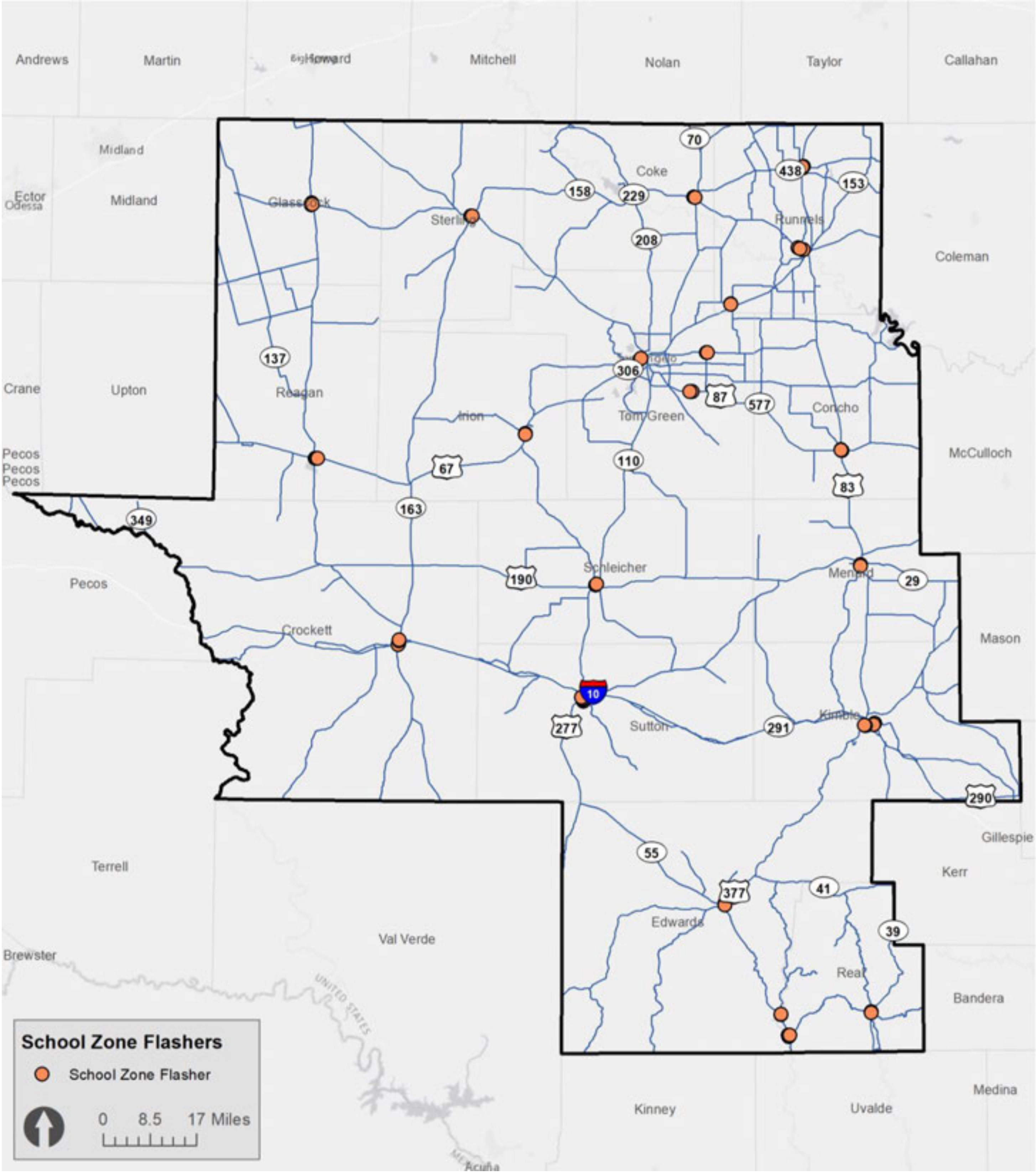


Figure 11: School Zone Flashers

5 EXISTING AND PLANNED ITS PROJECTS

While there are several existing and planned roadway construction/rehabilitation projects in the District, the only existing or planned ITS projects are listed below. Over the past few years there have been a few planned ITS projects, but they were removed from consideration due to budget constraints.

5.1 Network Monitoring & Management for Infrastructure Assets

This TRF Division sponsored project consists of providing the Districts with access to the Orion maintenance dashboards, to Skyline's network infrastructure management tools, and integration with TxDOTNOW, TxDOT's field service management software. The goal of the project is for SJT to have access to automated monitoring, alerting, and ticketing to perform:

- Automated discovery and manual onboarding of Traffic Network infrastructure devices
- Automated alerts, and creation and distribution of tickets to TxDOT resources, based on rules, triggers, and thresholds.
- Reboot or configuration changes that can be automated as a result of specific alerts or triggers.
- Daily QC to ensure that monitoring and ticketing are functioning properly.

In addition, the following automated reporting capabilities will be made available to the District:

- Highly visible asset uptime reporting to improve the reliability of the ITS infrastructure.
- Support for changes to dashboards and automated reports that allow for evaluation by TxDOT of the incident and problem tickets for future operational improvements.

The implementation of this project started in November 2020.

5.2 Transportation Data and Analytics

This TRF Division sponsored project consists of providing the Districts with access to INRIX/RITIS and StreetLight transportation data and analytics tools. INRIX/RITIS tools are grouped into two groups, probe data analytics and trip analytics, with each group containing, among others, the specialized tools shown in Table 7.

Table 7: INRIX/RITIS Traffic Data Analytics

Tool Group	Name of Tool	Description	Best used for	
			Operations	Planning
Probe Data Analytics (https://pda.ritis.org/)	Region Explorer	Explore the relationships between bottlenecks and traffic events and their impacts on traffic conditions in real-time or points in the past.	✓	✓
	Congestion Scan	Analyze conditions on one or more stretches of road. A traffic events layer allows visualizing any relationships between congestion and incidents, work zones or other adverse situations.	✓	✓
	MAP-21	A dashboard to monitor states', MPOs', and Urbanized Areas' performances against FHWA's Moving Ahead for Progress in the 21st Century (MAP-21) ruling.		✓
	Bottleneck Ranking	Identify problem locations to prioritize proposed projects. Ranking is performed using a dozen different factors including queue length, number of occurrences, impact, and accumulated delay.		✓
Trip Analytics (https://trips.ritis.org/)	OD Matrix	Generate zone-to-zone trip tables based on trip start- and end-points. Zones can be county, sub-county, or TAZ. Data can be filtered by date range, time-of-day, day-of-week, and by vehicle class.		✓
	Segment Analysis	Map origins and destinations for a selected road segment. Data can be filtered for vehicle classes and time ranges.		✓
	Route Analysis	Examine travel patterns between zones of Origin and Destination by compiling database trips that satisfy time and space filters.		✓

StreetLight Data shares many features with Trip Analytics, but it offers some extra tools. Among these, it includes annual average daily traffic (AADT) counts, origin/destination with demographic data, and trip purpose data. TxDOT is currently conducting internal outreach with the Districts so that they can start using these tools for both planning and operations applications.

5.3 DMS Communications Upgrades

The DMSs along I-10 have traditionally used T1 communications links to connect to the SAT TMC. The T1 line has been unreliable on many occasions, so towards the end of 2020, SJT started to replace the T1 line with cellular modems. This project is expected to improve the reliability of the DMSs by improving the quality of the communications links.

6 NEEDS ASSESSMENT

The mobility, safety, and departmental needs of SJT are addressed in this section. The Needs Assessment was developed based on the information gathered from the ITS Vision, Mission, and Goals; Existing Conditions Analysis; comments received from regular bi-weekly meetings with TxDOT staff; and ITS Master Plan Mini Workshop held in October 2020, and the assessment of information provided by the Steering Committee. The Mini Workshop consisted of a 2-hour long meeting with the District's Staff in which Geographic Information Organization (GIS) maps were used to identify needs in the following areas:

- DMS coverage and management
- ITS Maintenance
- Over Height Detection System
- Traffic Signal System
- Traffic Management Operations
- Road Weather

Documenting these needs is an integral step that must be taken before proposing ITS solutions that may address these needs in the short term. Furthermore, addressing these needs will achieve the goals laid out at the beginning of this Master Plan. The identified needs, as well as the goals that will be achieved if the need is addressed, are shown in **Table 8**. Ensuring traceability between needs and goals is important to ensure that the vision and mission are aligned with the ITS master plan.

Table 8: Identified Needs

Need	Description	Addressing the Need will Achieve this Goal
Secure reliable funding for ITS projects	There are a minimal number of planned ITS projects in the district. Originally there were more ITS projects planned but they were removed due to budget constraints.	Mobility and Reliability, Safety, Multimodal Connectivity, Asset Management, Interagency Collaboration and Public Communication
Low water crossing flood detection system	There are many low water crossings throughout the district. The district needs these systems to be automated so that local maintenance sections can be automatically notified of malfunctions. There is also a need to engage/disengage the flashing beacons automatically.	Safety
Obtain full access to Lonestar	Currently the district only has 'view access' to the Lonestar system. The District needs full access to Lonestar so that they can manage the DMSs on I-10 by themselves.	Asset Management
Get training on Lonestar to manage DMSs	SJT staff needs to be trained on how to use Lonestar to manage the District's DMSs to improve DMS asset uptime.	Asset Management
Get training on INRIX/StreetLight data and analytics	SJT staff needs to be trained on how to use INRIX/StreetLight data and analytics to improve the District's Traffic Management Operations.	Mobility and Reliability, Interagency Collaboration and Public Communication

Need	Description	Addressing the Need will Achieve this Goal
	The over height system on TX-306 at Knickerbocker overpass sends out email notifications when triggered but is not used for operations, only for monthly reporting. There is a need to obtain real-time notifications to improve the response time when the system is triggered.	Safety, Interagency Collaboration and Public Communication
Deploy more over height detection systems	There is a need to install additional over height detection systems at four locations.	Safety
Automatic roadway lighting monitoring	TxDOT would like to explore if there is any existing technology which could automatically detect if a luminaire is out. Currently the district's maintenance team drives on special routes once a month to monitor the luminaires and it would be helpful to identify possible tools that can automate monitoring remotely.	Asset Management

7 IDENTIFIED ITS STRATEGIES

7.1 Flood Warning / Low Water Crossings

Per Texas A&M Transportation Institute (TTI), Texas leads the nation in flood-related deaths, with the majority of deaths caused by motorists driving through moving water. In addition, flash flooding is the leading cause of weather-related deaths in Texas. It is important to note that 18-24 inches of moving water can sweep away truck, while 6 inches can sweep a small car. Since it is impractical to raise/remove all low water crossings in the District, there is a need for low-cost and effective traveler information systems to warn drivers of these risks.

Goals

- Improve safety near low water crossings by warning motorists before they approach hazardous road flooding conditions.
- Send timely and effective notifications to SJT Operations, SJT Area Engineers, and emergency management personnel of the flooded roadway conditions.

Available Solutions

Currently, there are several commercially available Flood Warning Systems. Although they vary in terms of optional features, they are all designed to achieve two primary goals: to warn motorists they are approaching hazardous road flooding conditions by activating warning beacons, and to notify TMC staff of the flooded roadway condition so action can be taken. The roadside equipment of a typical system is composed of a water level and velocity sensor connected to an ITS cabinet (also called a flood gauge), and warning equipment upstream of the crossing. The ITS cabinet houses electronic components such as communications equipment, a measurement processing unit, flashing beacon actuators, and a solar controller and batteries. The warning equipment is typically a solar powered flashing beacon activated by the water sensor through wireless communications. **Figure 12** shows a typical setup for a flood warning system.

In addition to the roadside equipment, flood warning systems also include software to remotely monitor and control the roadside equipment. For example, Bexar County and the San Antonio District use the Contrail software to manage their network of low water crossing monitoring systems. Currently, the San Antonio District has a data feed directly into LoneStar from which they can monitor and control the roadside equipment.

Finally, the monitoring software is also able to share data with external traveler information websites, such as www.bexarflood.org (Bexar County, City of San Antonio, and San Antonio River Authority) and www.atxfloods.com (City of Austin).

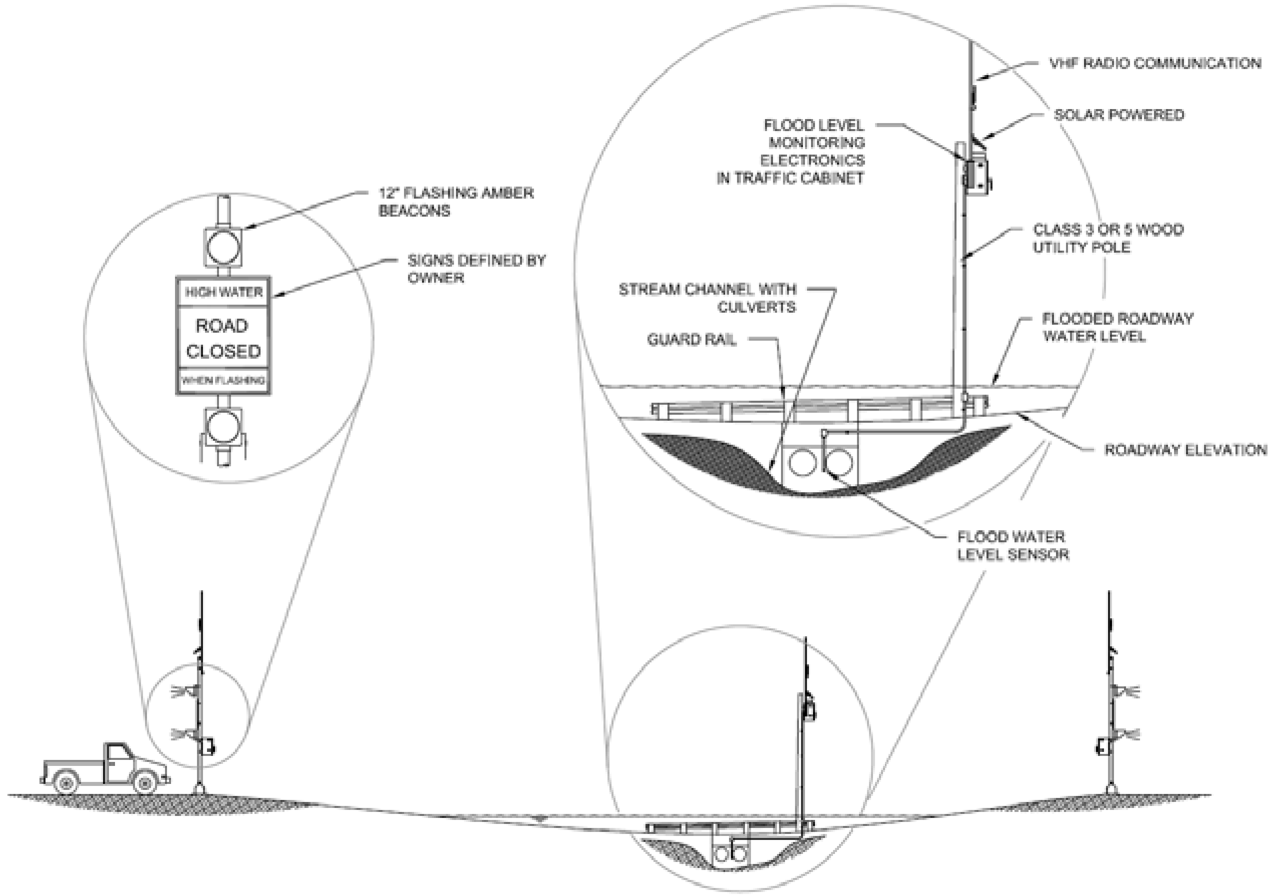


Figure 12: Flood Warning System Schematic (source: High Sierra Electronics)

Planning-Level Cost

Table 9 shows the planning-level cost estimate for a One Rain/High Sierra flood warning system composed of 12 units. The estimate only includes roadside units and monitoring and control software. The cost of a traveler information website varies depending on the scale of the flood warning deployment.

Table 9: Flood Warning Project Cost

			Yearly Cost					Total Cost
Item	Unit Cost	Units	Year 1	Year 2	Year 3	Year 4	Year 5	
OneRain Roadside Site	$10,000	12	$120,000					$120,000
Installation	$2,000	12	$24,000					$24,000
Software	$20,000	1	$20,000					$20,000
Yearly Software License	$12,000		$12,000	$12,000	$12,000	$12,000	$12,000	$60,000
							Project Cost	$224,000

Consistency with the Regional Architecture

The following ARC-IT Service Package is associated with this solution:

WX03 - Spot Weather Impact Warning: This service package will alert drivers to unsafe conditions or road closure at specific points on the downstream roadway as a result of flood conditions. The service packages are designed to use standalone weather systems to warn drivers about inclement weather conditions that may impact travel conditions. Real time weather information is collected from fixed environmental sensor stations and processed to determine the nature of the warning to be delivered to drivers via roadway signage or any other traveler information system such as public websites.

Recommendations

Given the prevalence of low water crossings in the District and the availability of mature commercial solutions, it is recommended that the District deploy flood warning systems at key locations as shown in **Figure 13**. These key locations were determined by the District's Area Engineers and represent locations that routinely experience flooded roadway conditions.

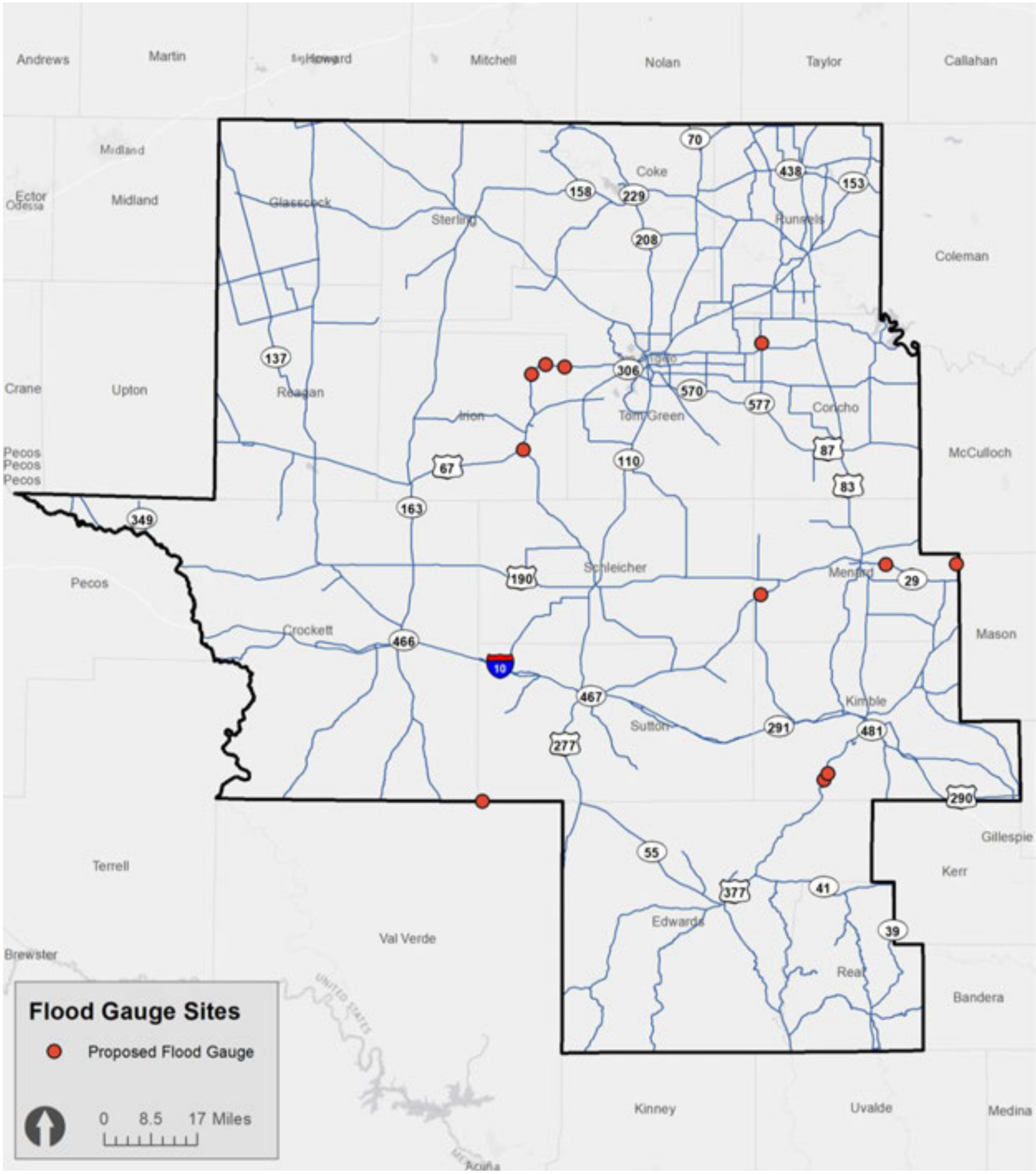


Figure 13: Proposed Flood Gauge Sites Deployment

7.2 Roadway Lighting Monitoring

As of July 2020, the SJT District had around 1,403 roadway lighting luminaires, with most of them (about 800) located on US-67 around the City of San Angelo as shown in **Figure 14**. Currently the maintenance teams of the District's Area Offices drive on special routes once a month to monitor the conditions of the luminaires. The District is interested in exploring technologies which could enable them to remotely manage the luminaries, such as detecting if a luminaire is out, determining the location of malfunctioning luminaries, monitoring how much power is being consumed, etc.

Goals

- Improve roadway lighting monitoring and control capabilities.
- Improve luminaire asset management.
- Reduce frequency of night rides which focus on roadway lighting inspection.

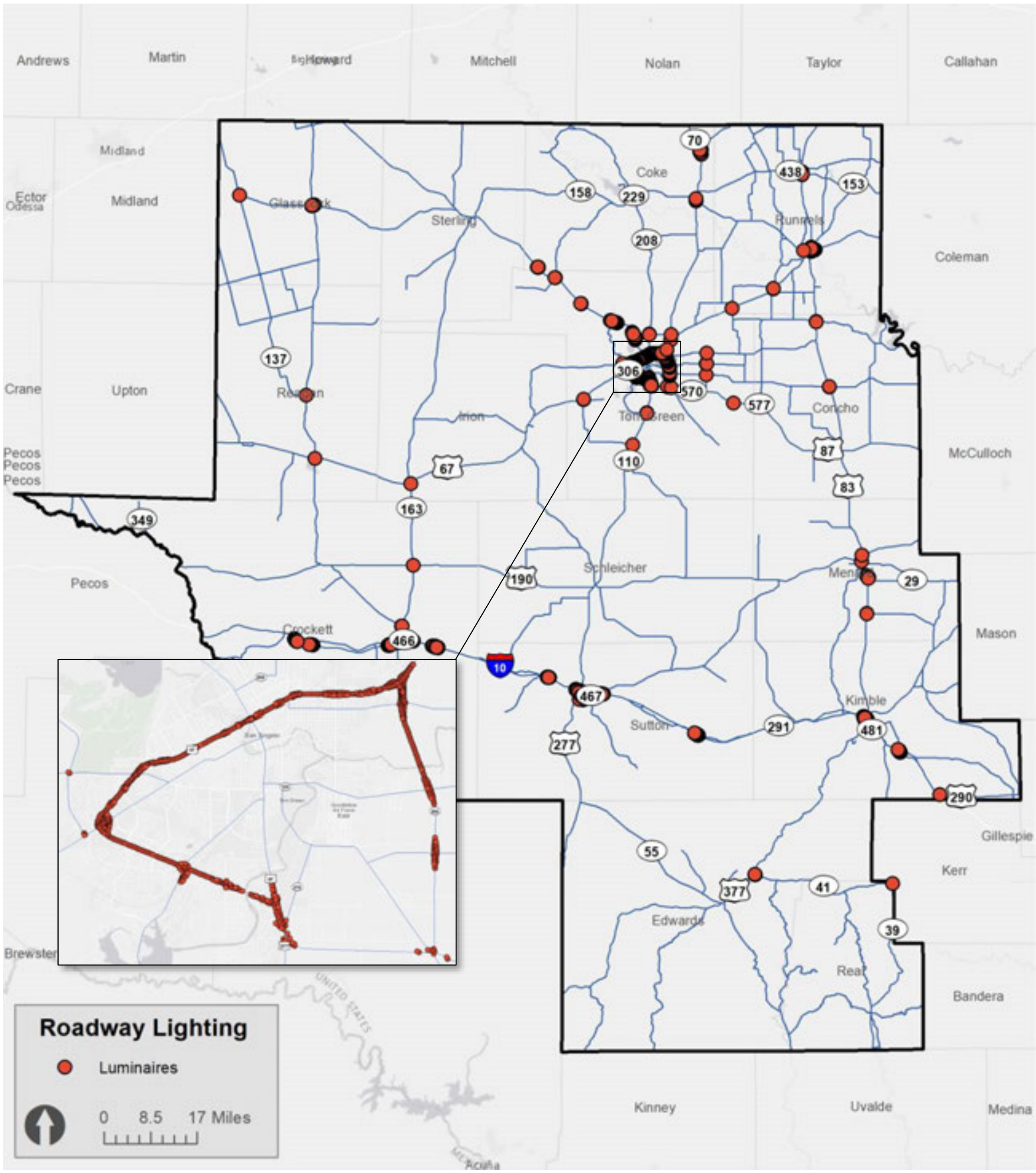


Figure 14: Roadway Lighting in the SJT District

Available Solutions

Currently, there are several commercially available roadway lighting monitoring systems. Although they vary in terms of optional features, they are all designed to achieve the primary goal of improving roadway lighting asset management. The roadside equipment of a typical system is composed of a control node placed on top of an existing luminaire as shown in **Figure 15**.

The control node houses a microcontroller to monitor and control the luminaire, a GPS unit to provide location information, and a cellular modem to provide remote management capabilities. In addition to the control node, roadway lighting monitoring systems also include software to remotely monitor and control the luminaires. Usually, the software is cloud hosted and browser-based, therefore it does not require for it to be locally installed. The software typically allows the user to:

- Visualize the location of luminaires on a map.
- Monitor the status of luminaires and setup alerts to automatically inform the user of any fault.
- Control and program lighting levels for each node.
- Meter energy usage and produce reports summarizing the information.

Table 10 shows the major features of a roadway lighting monitoring system. Up until a few years ago the communications used for these systems would have been a major differentiator. WiFi and cellular communications coexisted and due to cost constraints, some agencies would select WiFi mesh communications over cellular. Since then, the cost of cellular services has dropped significantly and nowadays most major vendors recommend the cellular option.

Table 10: Major Features of a Roadway Lighting Monitoring System

Brand/Model	Communications	Socket	Dimming Controls
Philips-Signify/CityTouch	Cellular	NEMA/Zhaga	Digital (DALI) or analog (0-10V)
Ubicquia/Ubicell	Cellular	NEMA	Digital (DALI, DALI2) or analog (0-10V)
GE Current/LightGrid	Cellular	NEMA	Digital (DALI) or analog (0-10V)

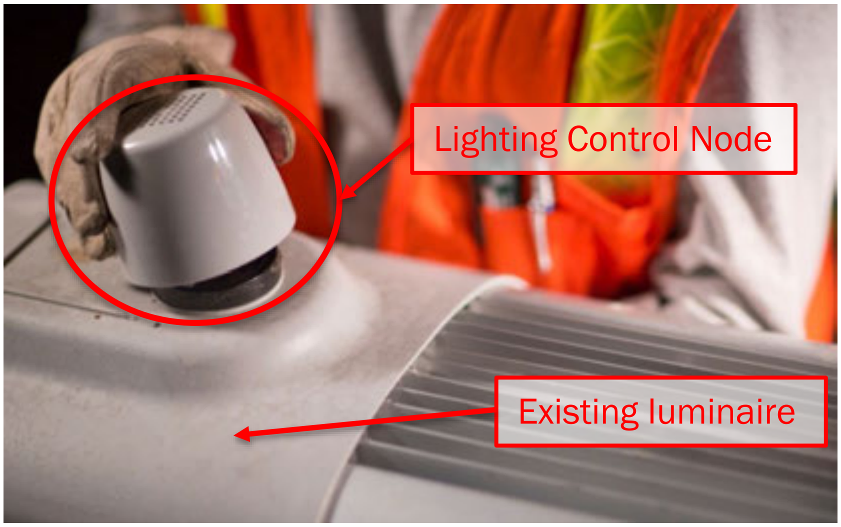


Figure 15: Typical Lighting Control Node (source: Philips-Signify)

Planning-Level Cost

Table 11 shows the planning-level cost estimate for roadway lighting control nodes. The estimate includes both the control node and the software used to manage the node. Depending on the number of nodes procured, the vendor may offer a lower cost per node but this is determined on a case-by-case basis.

Table 11: Roadway Lighting Monitoring System Cost Estimate

Brand/Model	Cost per node	Notes
Philips-Signify / CityTouch	$200 (10-year plan)	Includes cellular connectivity, data storage, software, system and firmware updates (performed over the air), product warranty.
Ubicquia / Ubicell	• $150 (5-year plan) • $180 (10-year plan)	Includes software, training, and software upgrades.
GE Current / LightGrid	$300 - $400	Includes software.

Consistency with the Regional Architecture

The following ARC-IT Service Package is associated with this solution:

MC05 - Roadway Maintenance and Construction: This service package supports numerous services for scheduled and unscheduled maintenance and construction on a roadway system or right-of-way. Maintenance services include routine maintenance activities and repair and maintenance of both ITS and non-ITS equipment on the roadway (e.g., signs, traffic controllers, traffic detectors, dynamic message signs, traffic signals, CCTV, luminaires, etc.).

Recommendations

Given the burden monthly night rides place on the District's staff and the availability of mature commercial solutions, it is recommended that the District deploy lighting monitoring nodes at key locations. These key locations may include luminaire sites located the furthest away from area offices. In this manner, the benefits of remote management will be fully achieved. In addition, a list of recommended specifications may be found in Appendix A.

7.3 Automated Incident Detection

The District currently has a mini-TMC at the headquarters office. Currently there is no full-time staff assigned to the TMC, TxDOT traffic engineers use the TMC on an as-needed basis. Due to this, there is interest in exploring automated traffic monitoring technologies, especially focused on automated incident detection (AID), using video from CCTV cameras.

Goals

- Improve the traffic monitoring capabilities of the mini-TMC.

Available Solutions

Currently there are several available commercial software products, such as TrafficVision, Axis/Citilog, and FLIR. All products share the following features, with some vendors emphasizing one feature over another:

- Capability to ingest video directly from the camera's encoder or ATMS.
- Client user interface running on a dedicated server, virtual machine, container, or the Cloud.
- Capability to set customized incident alerts for:
    - Stopped vehicle
    - Congestion
    - Pedestrian on the road
    - Wrong-way vehicle
    - Object/debris on the road
    - Low visibility
- Capability to collect the following traffic data:

- Vehicle counting
- Vehicle classification
- Average speed
- Occupancy

Planning-Level Cost

Table 12 shows the planning-level cost estimate for video-based AID software. Depending on the number of video streams being processed, the vendor may adjust the pricing.

Table 12: Video-based AID Cost Estimate

Brand	Cost per year	Notes
TrafficVision	$500 per camera stream	Minimal effort required to integrate with Lonestar.
Citilog	$300 - $600	Includes dedicated software.

Consistency with the Regional Architecture

The following ARC-IT Service Package is associated with this solution:

TM01 - Infrastructure-Based Traffic Surveillance: This service package includes traffic detectors, other surveillance equipment, the supporting field equipment, and Center to Field communications to transmit the collected data back to the Traffic Management Center. The data generated by this service package enables traffic managers to monitor traffic and road conditions, identify and verify incidents, detect faults in indicator operations, and collect census data for traffic strategy development and long-range planning.

Recommendations

It is recommended that the District explore video-based AID to improve the traffic monitoring capabilities of the mini-TMC.

7.4 Over Height Detection System

According to TxDOT and TTI, the average cost to a repair a structure after an over height vehicle related incident is around $200,000 to $300,000. An over height detection system provides the traveling public or commercial vehicle drivers with an early warning that a vehicle load may exceed height restrictions (14 feet as specified by TxDOT) with respect to a structure in the vehicle's path of travel. The District has several locations near San Angelo that have experienced incidents involving over height vehicles and this has warranted an interest in expanding the coverage of over height detection systems.

Goals

- Expand over height detection coverage around the City of San Angelo.
- Reduce the number of incidents involving over height vehicles.

Available Solutions

Currently there are several available commercial products, such as Trigg, TAPCO, and SWARCO. All systems provide the following features:

- Dual beam infrared detection sensors.
- Warning devices such as blank out sign, flashing beacon, or directional bell integrated with detection sensors.

A typical over height detection system layout is shown in **Figure 16**.

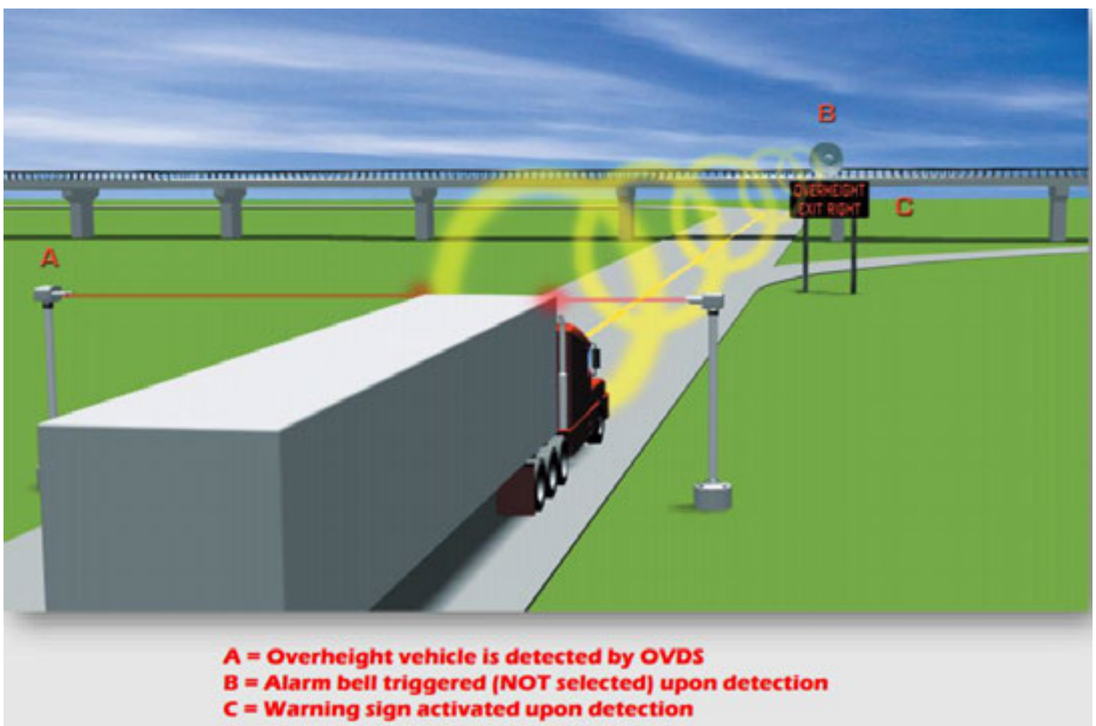


Figure 16: Typical Over Height Detection System (Source: TxDOT/TTI)

Planning-Level Cost

Table 13 shows the planning-level cost for a typical over height detection system.

Table 13: Over Height Detection System Cost Estimate

Component	Estimated Cost	Notes
Detection sensors	$13,000	Infrared sensor placed upstream of structure used to detect over height loads
Blank Out Sign (99” X 48”)	$9,000	Dynamic message sign to provide warning message to drivers
Flashing Beacon	$2,000	Optional flashing beacon to alert drivers
Directional Bell	$2,000	Optional alarm bell to alert drivers

Consistency with the Regional Architecture

The following ARC-IT Service Package is associated with this solution:

VS11 - Oversize Vehicle Warning: This service package uses external measurements taken by the roadside infrastructure, and transmitted to a warning system (sign, flashing beacons, or directional bell), to support determination of whether an alert/warning is necessary. Specifically, the infrastructure data equipment detects and measures the approaching vehicle's height. If deemed necessary, the driver is alerted to the impending low height clearance bridge prior to a decision point, enabling the vehicle to reroute and avoid a collision.

Recommendations

Given the prevalence of over height vehicle incidents near interchanges in the City of San Angelo, and the positive experience the District has had with its existing over height detection system, it is recommended that the District deploy over height detection systems at key locations as shown in **Figure 17**. These key locations were determined by the District’s staff and represent locations that have experienced incidents involving over height vehicles.

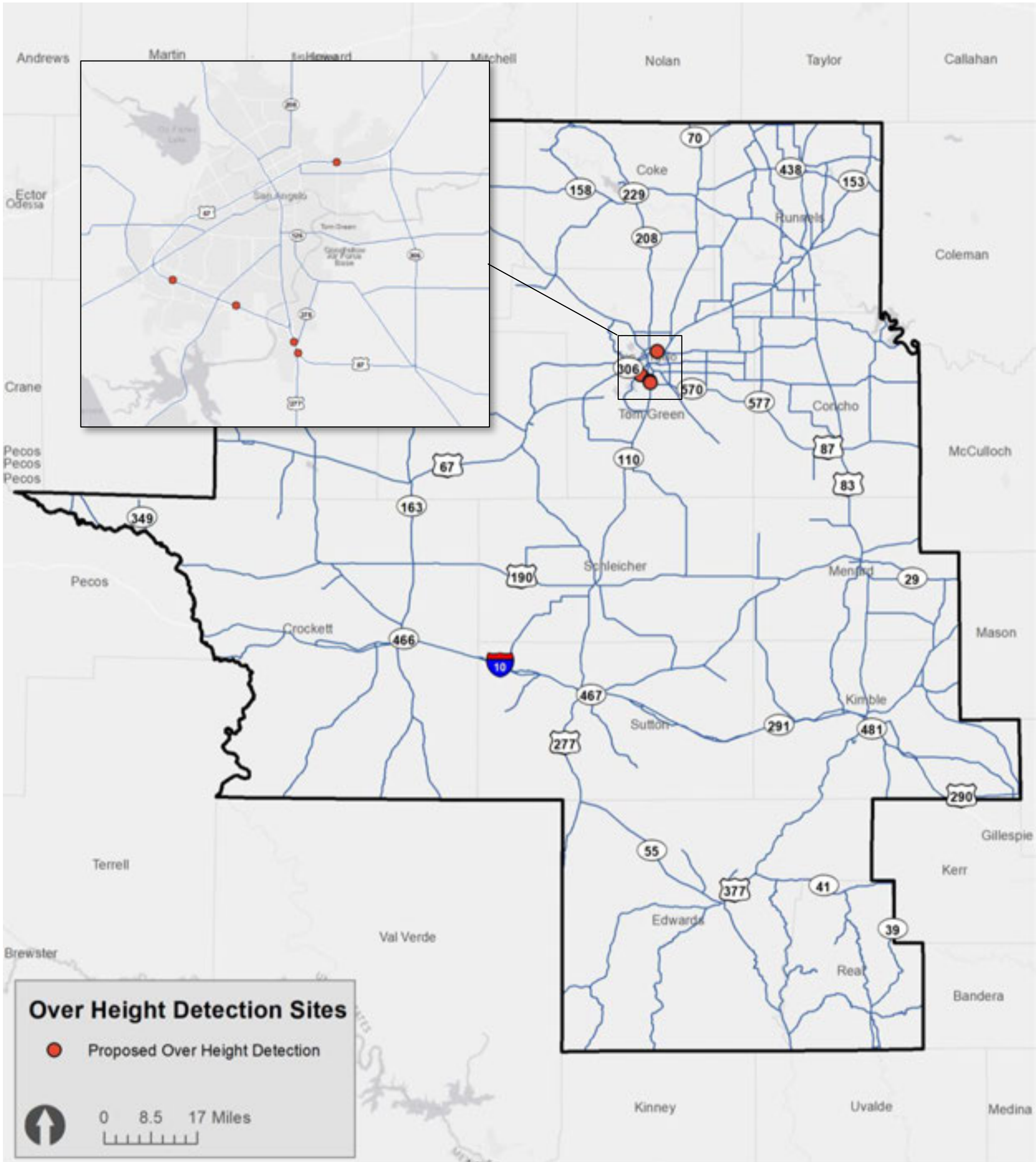


Figure 17: Proposed Over Height Detection Sites

7.5 Update Regional ITS Architecture

The San Angelo District developed a regional ITS Architecture in 2004 which included an inventory of ITS and needs for the region, a concept of operations for the region, and ITS project recommendations for the San Angelo District. The recommended high priority projects identified in the Architecture included CCTV camera deployment, traffic signal control for surface streets, traffic information dissemination, emergency vehicle routing, road weather data collection, and transit vehicle tracking, among others. It would be beneficial for the District to update the Architecture given the significant technological changes that have occurred since 2004 as well as to update the roles of the District and partner agencies regarding ITS.

Goals

- Update the ITS Regional Architecture to be compliant with ARC-IT 9.0
- Use the updated ITS Regional Architecture to help support TSMO strategies.

Planning-Level Cost

The planning-level cost for an ITS Architecture update is about $100,000 and would take 9-12 months. This includes:

- Defining the scope and determining stakeholders and champions.
- Defining the inventory, determining needs and services, developing an operational concept, and defining functional requirements.
- Identifying information interconnects and flows.
- If applicable, developing a list of agency agreements.

Recommendations

It is recommended that the District update its regional ITS Architecture. Doing so will ensure that proposed ITS projects are consistent throughout the region and an overall set of design standards are established over time. In addition, demonstrating consistency between proposed ITS projects and the updated regional architecture is a pre-requisite for the District to request federal funding for ITS projects as explained in Title 23, Part 940.11 of the Code of Federal Regulations.

8 PROJECT DEVELOPMENT METHODOLOGY

In this section, guidelines to develop the ITS strategies in **Section 7 Identified ITS Strategies** into projects are provided. The guidelines are organized around planning, inventory maintenance, and the SE process as presented in the following sub-sections. It is important to note the San Antonio District's 2017 Five-year ITS Master Implementation Plan was used as a reference for this section.

8.1 Planning

The ITS projects/strategies identified in **Section 7 Identified ITS Strategies** can be deployed as standalone projects or bundled with planned roadway projects since adding ITS to planned roadway projects can potentially reduce costs, in terms of time and funding. The following planning considerations are critical for an ITS project:

- **Pre-requisites:** Ensure that all pre-requisites for a proposed project are satisfied. These may be personnel, software, hardware, or organizational requirements. For example, a low water crossing detection project may require that staff with the appropriate training and background are available to operate and maintain the proposed system, that communications links exist between the roadway devices and the TMC, and that operational procedures are in-place at the TMC.
- **Existing/Ongoing Projects:** Evaluate whether a proposed ITS project can be added to an existing/ongoing non-ITS project. By adding ITS components to an existing project, overhead costs may be reduced due to cost sharing between the projects. In addition to cost reduction, adding ITS components to existing projects may accelerate deployment compared to stand-alone ITS projects.
- **Planned Projects:** Ensure that proposed ITS strategies complement the goals of planned projects. This will guarantee that the operational efficiency of the planned project is maximized.
- **Funding:** Ensure the proposed ITS project will be fully funded. This includes capital, operations, and maintenance costs. Successful funding of the proposed project throughout its life cycle will ensure continuous system operation to achieve short and long-term goals.
- **Institutional Agreements:** If a proposed ITS project will span across several TxDOT sections or require collaboration with external agencies, ensure that any required institutional agreements which outline roles and responsibilities are in place. It usually takes a significant amount of time to develop these agreements and for stakeholders to reach consensus.
- **Consistency with ITS Service Packages:** Ensure that the ITS deployment is associated with a specific Service Package of ARC-IT 9.0. Feasibility studies may be required to ensure that Service Package deployments are justified.
- **Consistency with ITS Regional Architecture:** Ensure that the proposed ITS project is consistent with the San Angelo Regional ITS Architecture, this will guarantee that the proposed project is better positioned for success in the regional context. In addition, demonstrating consistency between proposed ITS projects and the regional architecture is a pre-requisite for a regional agency to request federal funding for ITS projects as explained in Title 23, Part 940.11 of the Code of Federal Regulations.

8.2 Inventory Maintenance

As part of this ITS Master Plan, an ITS GIS database was developed to inventory existing ITS field equipment and digitize proposed ITS projects. The GIS database can be used to develop conceptual plans or as a starting point for an ITS asset management system. However, to ensure that the database is most useful, the database should be maintained and updated with the latest information prior to using it for project development as shown in **Figure 18**. The key components for keeping the ITS inventory up to date are:

- Identify dedicated GIS staff who will serve as the GIS database administrator.
- Develop an 'As-Builts' form that can be shared with contractors and the database administrator.
- Use the workflow shown in **Figure 18** to update the inventory.

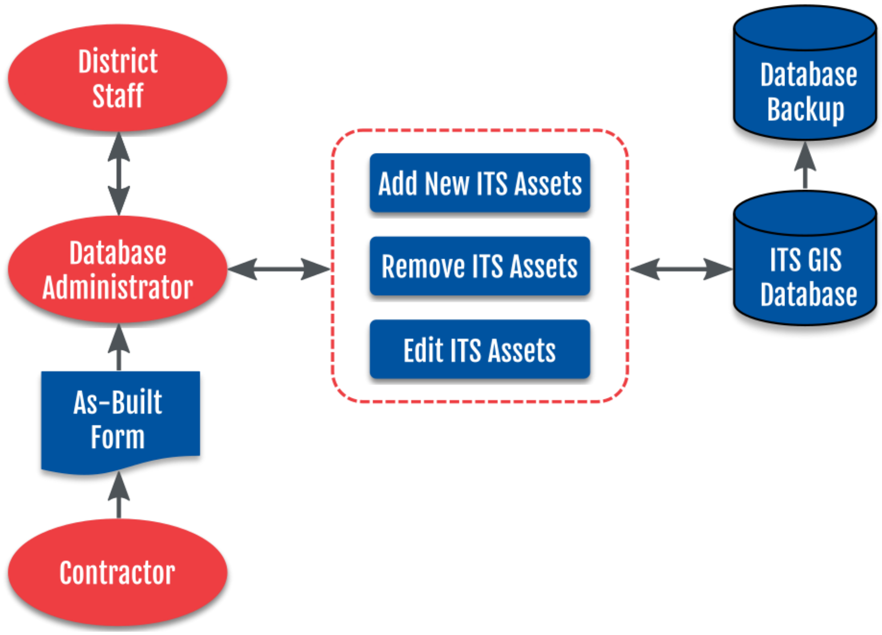


Figure 18: ITS GIS Database Inventory Maintenance

The following sub-sections present guidelines on how to maintain the database and update it to ensure it accurately reflects SJT's ITS inventory.

Coordinate System and Feature Classes

All ITS assets are to be captured in a Geodatabase using the GCS_WGS_1984 geographic coordinate system. All existing assets are stored in a single point feature class. Optic fiber networks and other linear features should be stored in a polyline feature class.

New ITS Assets

All new asset data should be captured in the same format as existing asset data, using the same field names and types. This will streamline the compilation of datasets that were developed separately (in separate Geodatabases and/or by different project team members) to generate the final GIS deliverable per TxDOT guidelines.

Removal of ITS Assets

If ITS assets are to be removed and there is no need to document the history, they can be deleted from the existing database once removal is completed. If ITS assets are to be removed and there is a desire to keep a record of their locations, these assets should be copied into a separate feature class with the keyword 'Historic' in the title. The assets should then be deleted from the existing and proposed feature classes after removal is complete. Keeping a separate feature class will prevent removed assets from erroneously being incorporated into future needs analysis.

Edits to Existing Assets

If the current asset location or any other associated data is incorrect, edit the existing spatial and tabular attributes.

Physical Relocation of Existing Assets

If an ITS project proposes to relocate an existing asset to a different location, create a copy of the existing asset, place it in the new location, and mark its status as 'planned'. Make sure to maintain all attribute data (including unique ID or serial number) and only update the status and location. Once the asset has been relocated, the original record can be deleted or moved into the 'Historic' feature class.

Database Backup

The Geodatabase administrator should make regular backups or time-stamped copies of the master files on a regular basis to avoid data loss or corruption.

8.3 Systems Engineering Process

It is recommended that SJT follow the SE process when developing ITS projects. SE is a structured development process used for planning, designing, implementing, managing, operating, and retiring a system as shown in **Figure 19**. The SE approach, outlined in the Federal Highway Administration's Systems Engineering for ITS document, emphasizes defining customer needs and required functionality early in the project development cycle (in the decomposition and definition phase), before moving on to designing, building, and deploying the system. The purpose is to plan for the entire life cycle of a project up front so that the risk to the project's budget, scope, and schedule is minimized. In addition, following the SE process is a requirement for obtaining potential federal funding.

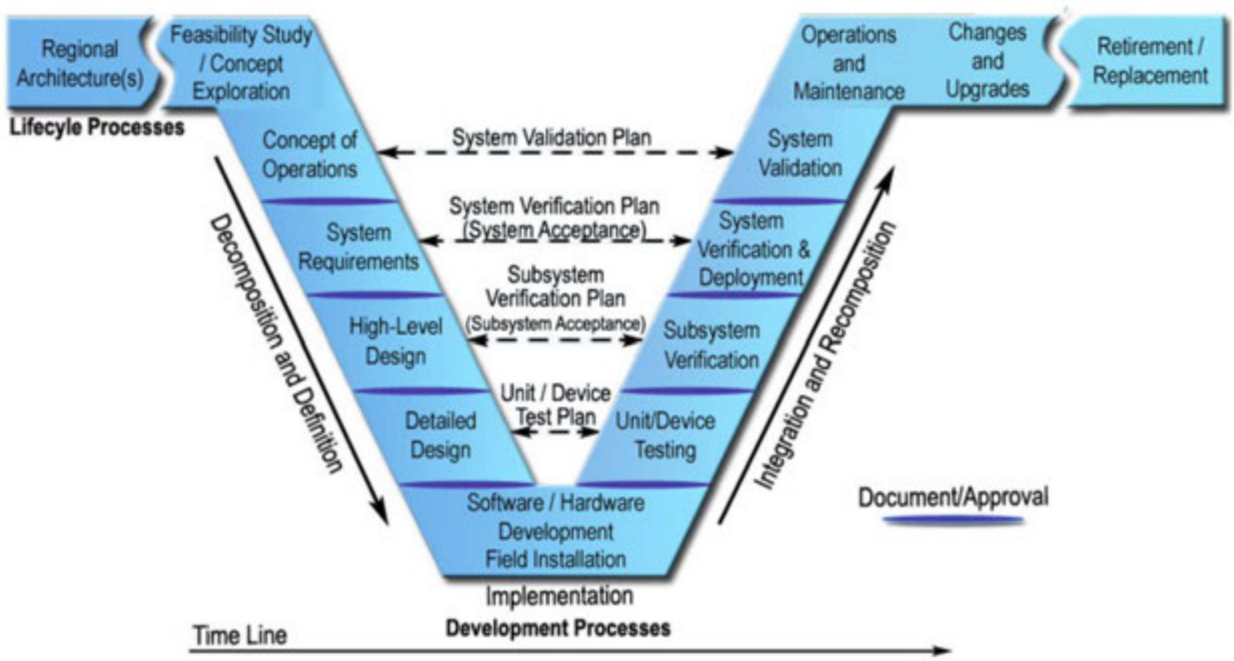


Figure 19: Systems Engineering V Diagram (Source: FHWA Office of Operations)

The following subsections highlight some of the key SE considerations for developing SJT's ITS projects.

SE Planning

Prior to embarking on any ITS project development, SJT and project partners should develop a Systems Engineering Management Plan (SEMP). This plan will identify goals and objectives, provide a roadmap for system development, provide the project management methodology to be used, and outline key tasks and procedures that will occur at each stage of the project to ensure compliance with the SE process. If required, high-level information regarding integration and software upgrade procedures should also be included. In addition, the SEMP may include a high-level review of existing/legacy technologies, standard operating procedures, system architecture, preferred data routing exchange points, and cross-jurisdiction operational requirements.

Moreover, the project development team should also develop a Concept of Operations (ConOps) document which outlines how users will use the system. Typically, the ConOps will include:

- Scope and background of the project

- Description of the proposed system and alternatives
- User-oriented operational description
- Operational Needs
- System Overview
- Description of the Operational Environment and Operational Scenarios

The design and development of each project must also consider the lifecycle of the strategy and technology being deployed. ITS equipment lifecycles are typically shorter than roadway infrastructure projects, consideration must be made to ensure that the system is based on an open architecture to accommodate a phased design, including integration of future technologies. Overall, the SEMP and ConOps will ensure that these considerations are taken into account.

Funding

Development of ITS projects and programs requires funding for every phase of development, from concept to deployment, maintenance, and operations. ITS benefits can only be realized when systems are reliably operating and providing service to system users as planned. The project and strategies outlined in this Master Plan may require collaborative funding strategies, partnerships, and agreements. **Table 14** shows some of the typical funding types that are available to fund ITS projects/programs from local, state, and federal sources.

Table 14: ITS Funding Sources

Program	Funding Type
State/Local	Local Tax Funds and Fees
	Transportation Annual Budget
	State Highway Fund
	Texas Mobility Fund
	Pass-through Financing Program
	Transportation Reinvestment Zones (TRZs)
	State Infrastructure Bank Loans
	Comprehensive Development Agreements and Public-Private Partnership
	Statewide Transportation Improvement Program
Federal	BUILD Grant program (formerly known as TIGER Grants)

	Transportation Development Credits
	National Highway Traffic Safety Administration (NHTSA) grants

The appropriation of funds from each of the funding types are generally secured by various state, local government/departments, or planning organizations in the region. TxDOT generally receives project funding following the guidelines outlined in the Texas Administrative Code (TAC). Title 43, Part 1, Chapter 16 of the TAC. Chapter 16 outlines the minimum standards for metropolitan and rural transportation planning and program development. Program funds are distributed through the rules developed under the following six programs:

- Transportation Improvement Program (TIP)
- Rural Transportation Improvement Program (RTIP)
- Statewide Transportation Improvement Program (STIP)
- Ten-Year Transportation Programming Recommendations for Non-Metropolitan Areas
- Unified Transportation Program (UTP)
- Major Transportation Projects

One of the more utilized programs is the UTP, which allocates funding through twelve categories as outlined in Subchapter D, Rule §16.153. The twelve categories identified are as follows:

- Category 1 - Preventive Maintenance and Rehabilitation
- Category 2 - Metropolitan and Urban Corridor Projects
- Category 3 - Non-Traditionally Funded Transportation Projects
- Category 4 - Statewide Connectivity Corridor Projects
- Category 5 - Congestion Mitigation and Air Quality Improvement
- Category 6 - Structures Replacement and Rehabilitation
- Category 7 - Metropolitan Mobility and Rehabilitation (TMA)
- Category 8 - Safety
- Category 9 - Transportation Alternatives
- Category 10 - Supplemental Transportation Projects
- Category 11 - District Discretionary
- Category 12 - Strategic Priority

Allocations of funds are selected by various agencies in the region. These can range from FHWA, SJT, SA-MPO, state and local legislation/minute orders, Texas Transportation Commission, TxDOT Bridge Division, and TxDOT Finance Division. The various eligibility guidelines for each category demand that requirements for each project are reviewed throughout the system or program's life-cycle. This would ensure projects and programs are properly implemented and ensure that the proposed system provides the envisioned benefits and return on investment. One of the major risks in developing ITS projects is the continued funding for Operations and Maintenance (O&M). This cost typically increases as system elements get older and legacy technology becomes obsolete. As such, it is important that the project development team develops funding strategies that could make the necessary O&M commitment to ensure services are provided throughout the project or program's life-cycle. The following are some of the project and cost considerations when developing O&M cost for a project:

- Garner support from upper management
- Collaborate and share the cost with other agencies
- If warranted, contract out maintenance to reduce costs
- Dedicate annual budget for O&M and ensure that there is a yearly plan to maintain the system to support the O&M annual budget
- Coordinate the purchase of ITS equipment and parts with other projects
- Purchase extended warranties if available to mitigate the cost of unplanned repair
- Budget and perform preventative maintenance

Procurement

ITS projects are unique when compared to typical roadway projects since development requires complex integration of hardware, software, and transportation infrastructure. As such, project procurement typically requires pre-qualification of vendors and contractors to ensure that they can deliver the project based on recent expertise, deployment, work history, warranty support, maintenance capabilities, workforce availabilities, and other factors. By pre-qualifying potential contractors, agencies are in a better position to mitigate risk, especially for projects that require multi-year deployments. The National Cooperative Highway Research Program (NCHRP) has published Report 560: Guide to Contracting ITS Projects to provide guidance for procuring ITS projects. **Figure 20** provides a summary of procurement considerations laid out in the report. The purpose of Report 560 is to provide guidance on how to select a combination of procurement methods that are appropriate for ITS projects and the agency's capabilities.

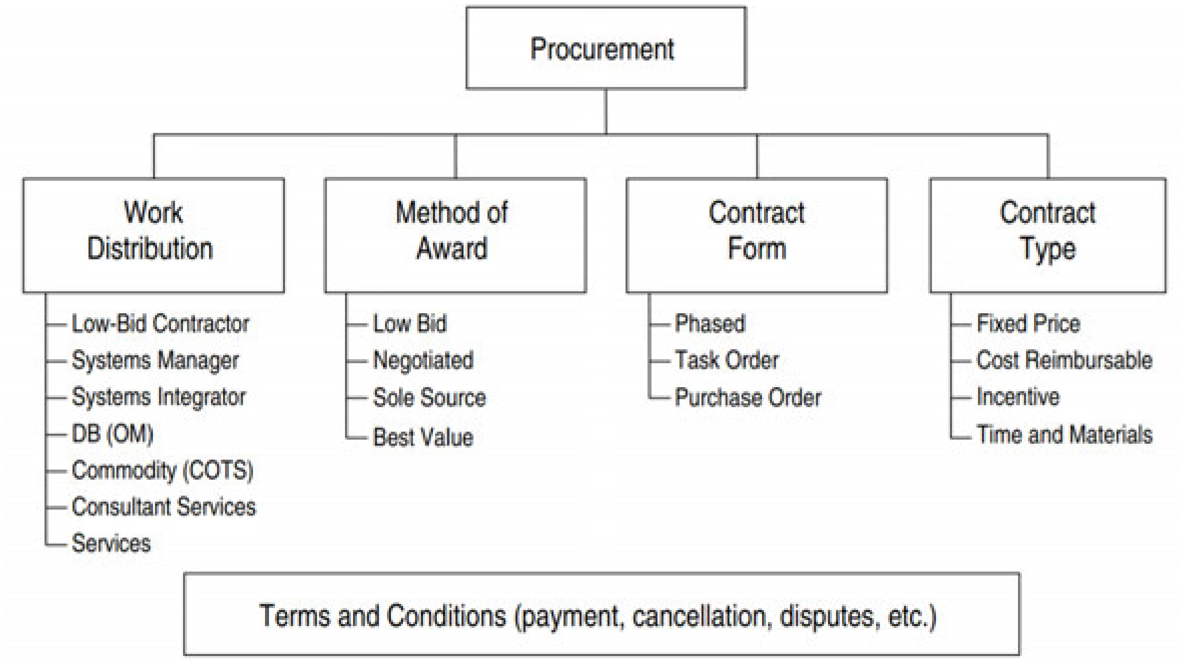


Figure 20: Four Dimensions of Procurement per Report 560

The project development team would have to provide details for each of these dimensions to determine the best strategy for ensuring that the system is completed and that services are provided throughout the system's anticipated lifecycle. Some of the procurement considerations may include:

- Service packages and regional architecture compliance
- Product specifications
- Construction impact on facility and road users
- Products/technology requirements/changes or upgrades
- System integration requirements
- Open architecture and specification requirements
- Pre-qualification of vendors
- Schedule
- Deliverables
- Software integration
- Validation/verification requirements
- System/warranty support
- Contract terms

Regional ITS Architecture Consistency and Compliance

The San Angelo Regional ITS Architecture was las updated in 2004. This document served as a planning tool for developing ITS projects for the region. It provided general guidance for meeting federal requirements to qualify ITS projects for federal funding. Title 23, Part 940 of the Code of Federal Regulations (Title 23 CFR Part 940) outlines the regulation for systems engineering and ITS architectures to qualify projects for federal funding. As such, it is important that all ITS projects can be traced back to the San Angelo Regional ITS Architecture 2003 Update to ensure compliance with both regional and federal regulations. At a minimum, each project should incorporate the Title 23 CFR Part 940.11(c) requirements, which includes:

- Identification of portions of the regional ITS architecture being implemented (or if a regional ITS architecture does not exist, the applicable portions of the National ITS Architecture)
- Identification of participating agencies roles and responsibilities
- Requirements definitions
- Analysis of alternative system configurations and technology options to meet requirements
- Procurement options
- Identification of applicable ITS standards and testing procedures
- Procedures and resources necessary for operations and management of the system.

Following the prescribed systems engineering approach and the San Angelo Regional ITS Architecture would enable the system owner/operator to qualify projects or programs for federal funds and offset some of the required cost, potentially including operation and maintenance costs that are sometimes limited, but required to maintain service to users.

9 PROPOSED ITS DEPLOYMENTS

In this section, projects that implement the strategies from **Section 7 Identified ITS Strategies** are presented. The input received from the District during the ITS Planning Mini Workshop was used to create a list of projects with associated 5-year timelines as shown in the following pages. The overarching goal is to provide actionable steps for the District's ITS Master Plan. Each project sheet contains the goals the project addresses, a brief description of the project, relevant performance measures, expected benefits, and a high-level implementation time frame.

Flood Warning / Low Water Crossings

Goals		
	1	Mobility and Reliability
	2	Safety
	3	Multimodal Connectivity
	4	Asset Management
	5	Interagency Collaboration and Public Communication

Flood warning / low water crossing systems deployed at key locations in the District would improve safety near low water crossings by warning motorists before they approach hazardous road flooding conditions. In addition, the system would improve the situational awareness of the staff at the District by sending timely and effective notifications to SJT Operations, SJT Area Engineers, and emergency management personnel of the flooded roadway conditions. A typical system includes roadside equipment to monitor the field conditions and software to remotely monitor and control the roadside equipment.

Performance Measures

- Improve accessibility to real time ITS data
- Reduce incidents involving flooding
- Evaluate and deploy more effective traveler information dissemination technologies

Benefits

- Reduction of flood-related incident frequency and severity.
- Improved situational awareness for Operations, Area Engineers, and emergency management personnel.

Recommended Steps

	Approximate Time Frame	Project Implementation
0 5 Years	Year 1	Systems engineering analysis (high-level design).
	Year 2	Detailed project plans, specifications, and estimate (PS&E).
	Year 3	Project bidding and construction letting process.
	Year 4	Deployment and system integration.

Over Height Detection System

Goals		
	1	Mobility and Reliability
	2	Safety
	3	Multimodal Connectivity
	4	Asset Management
	5	Interagency Collaboration and Public Communication

An over height detection system provides the traveling public or commercial vehicle drivers with an early warning that a vehicle load may exceed height restrictions (14 feet as specified by TxDOT) with respect to a structure in the vehicle's path of travel. The District has several locations near San Angelo that have experienced incidents involving over height vehicles and this has warranted an interest in expanding the coverage of over height detection systems.

Performance Measures

- Reduce incidents involving over height vehicles
- Improve accessibility to real time ITS data

Benefits

- Improvement in safety related to incidents involving over height vehicles
- Substantial savings in maintenance and construction costs related to vehicles hitting bridges or overpasses.

Recommended Steps

	Approximate Time Frame	Project Implementation
0 5 Years	Year 1	Systems engineering analysis (high-level design).
	Year 2	Detailed project PS&E.
	Year 3	Project bidding and construction letting process.
	Year 4	Deployment and system integration.

Update Regional ITS Architecture

Goals		
	1	Mobility and Reliability
	2	Safety
	3	Multimodal Connectivity
	4	Asset Management
	5	Interagency Collaboration and Public Communication

Update the District's Regional ITS Architecture to be compliant with ARC-IT 9.0 to ensure that proposed ITS projects are better positioned for success. In addition, demonstrating consistency between proposed ITS projects and the updated regional architecture is a pre-requisite for the District to request federal funding for ITS projects as explained in Title 23, Part 940.11 of the Code of Federal Regulations.

Performance Measures

Develop routine asset inventory review procedures

Develop routine asset inventory reporting procedures

Benefits

- Improve organization and coordination of ITS activities within the District and among partner agencies.
- Better position the District to qualify for federal funding for ITS projects.

Recommended Steps

	Approximate Time Frame	Project Implementation
0 5 Years	Year 1	Data gathering and analysis (gather data, identify stakeholders, define inventory, determine needs)
	Year 2	Define interfaces and implementation (develop operational concept, define functional requirements, define information flows)

APPENDIX A

Roadway Lighting Monitoring System Specification

Special Specification

Roadway Lighting Monitoring System

1. DESCRIPTION

The Roadway Lighting Monitoring System (RLMS) is a real-time system used to monitor and control roadway lighting. The RLMS is composed of a lighting monitoring and control node mounted on a roadway luminaire, software used to monitor and control the node, and a cellular communications link between the node and the system management software. The goal of this system is to provide remote monitoring and control for roadway luminaires. This system must be in operation 24 hr. per day, 7 days per week.

2. MATERIALS

2.1 Lighting Monitoring and Control Node. Provide a lighting monitoring and control node that has the functionality described below:

- 2.1.1 Compatible with 3, 5, and 7 pin NEMA streetlight photocell receptacles.
- 2.1.2 Compatible with LED or HID luminaires.
- 2.1.3 Integrated light sensor with provisions to prevent day lighting due to dirt accumulation on the sensor.
- 2.1.4 Light dimming using both digital (DALI, DALI2) or analog (0-10V) interface.
- 2.1.5 Power consumption detection.
- 2.1.6 Photocell levels detection.
- 2.1.7 Luminaire fault detection.
- 2.1.8 Tilt and vibration detection.
- 2.1.9 Able to communicate with management software using built-in cellular modem compatible with major carriers.
- 2.1.10 Built-in GPS unit to enable automatic location setup in management software.
- 2.1.11 Capability to receive ‘over the air’ firmware updates.
- 2.1.12 Built in surge protection (at least 6kV/3kA).
- 2.1.13 Power supply able to run from universal voltage standard (120-480v).
- 2.1.14 Built-in network security capabilities (including but not limited to log in requirements and end-to-end encryption).
- 2.1.15 Minimum five-year warranty.

2.2 Management Software. Provide cloud-based management software that has the functionality described below:

- 2.2.1 Visualize the location of monitoring and control nodes on a map.
- 2.2.2 Monitor the status of luminaires and setup alerts to automatically inform the user of any fault.
- 2.2.3 Meter energy usage and produce reports summarizing the information.
- 2.2.4 Control and program lighting levels for each node.
- 2.2.5 Application Programming Interface (API) to integrate RLMS into existing systems.
- 2.2.6 Secure network connection between user and monitoring and control node (including but not limited to log in requirements and end-to-end encryption).

3. CONSTRUCTION

3.1 System Requirements. Install the RLMS at the specified luminaire locations as shown in the plans. The RLMS must consist of the following as a minimum:

3.1.1 Installation on luminaires.

3.1.2 Integration with existing systems.

3.2 General. Submit to the Engineer for approval a written and illustrated RLMS Submittal. Include in the RLMS Submittal the items required in this specification. Do not start any installation activities that will affect traffic on the project until the RLMS Submittal is approved by the Engineer.

3.3 Content of the Submittal. The RLMS Submittal must include, at a minimum, the following items:

3.3.1 Monitoring and Control Node documentation meeting the RLMS requirement.

3.3.2 Management Software documentation meeting the RLMS requirement.

3.4 **Approval of Submittal.** Obtain approval of the RLMS Submittal by the Engineer before placing any RLMS devices. Approval is conditional and will be predicated on satisfactory performance during installation. The Engineer reserves the right to require the Contractor to make changes in the RLMS Submittal and operations, at no additional cost to the Department, including removal of personnel, as necessary, to obtain the quality specified. The Contractor must notify the Engineer in writing a minimum of seven calendar days before any proposed changes in the RLMS Submittal. Proposed changes are subject to approval by the Engineer.

3.5 Testing. Once the RLMS is installed, it must undergo a five-day operational test. The operational test must include a test of the system in operation to ensure that the RLMS is operating in a fully functional manner for a minimum duration of five calendar days. Provide for complete operations support from the vendor during the operational test and provide verification that the RLMS accurately reports luminaire status and allows luminaires to be controlled. If any equipment malfunctions occur for a combined period of 4 hr. or more during this operational test on any day, no credit will be given for that day, for the operational test period, and the five-day operational test will reset.

3.6 Report. Submit a report to the Engineer detailing the daily activity of the system during the operational test. The report must indicate the date and time of any activity necessary to maintain operation of the RLMS during the operational test period. Each entry must include the following information:

- Identity of the equipment on which work was performed.
- Cause of equipment malfunction (if known).
- Description of the type of work performed.
- Time required to repair equipment malfunction.

4. MEASUREMENT

RLMS will be measured by the each.

5. PAYMENT

The work performed and materials furnished in accordance with the Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Roadway Lighting Monitoring System”. This price is full compensation for furnishing, installing, operating, maintaining, testing, monitoring, and providing historical data including labor, tools, equipment, and incidentals required for proper operation of this installation.

Version 1.1