TxDOT Statewide TSMO Information Management

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AECOM Imagine it. Delivered.

Document Control

Version	Date	Description of Change	Author
1.0	9-30-2020	Initial release	AECOM
2.0	10-12-2020	Addresses preliminary comments by ITD	AECOM
2.1	02-08-2021	Reformats per TxDOT's template.	AECOM

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List of Acronyms

Acronym	Definition
ACU	Age, Condition, Use
API	Application Programming Interface
ATM	Active Traffic Management
ATMS	Advanced Traffic Management System
ATSPM	Automated Traffic Signal Performance Measures
AVI	Automated Vehicle Identification
AWS	Amazon Web Services
CCTV	Close Circuit Television
CRIS	Crash Records Information System
DIIMS	Development, Integration, Implementation, and Maintenance Services for TMS
DMS	Dynamic Message Sign
DOT	Department of Transportation
DSRC	Dedicated Short Range Communication
DUSA	Data Updates & Sharing Application
EDC	Every Day Counts
EOR	Ease of Replacement
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
GIS	Geographic Information System
GPS	Global Positioning System
HPMS	Highway Performance Monitoring System
IP	Internet Protocol
IT	Information Technology
ITD	Information Technology Division
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITSFM	Intelligent Transportation System Facility Management

Acronym	Definition
KPI	Key Performance Indicator
LAN	Local Area Network
MPPM	Modernize Portfolio and Project Management
NOC	Network Operations Center
OR	Obsolescence Risk
RDE	Research Data Exchange
SLE	Service Life Extension
TIM	Traffic Incident Management
TMC	Transportation Management Center
TMS	Traffic Management System
TPP	Transportation Planning and Programming
TSMO	Transportation Systems Management and Operations
TxDOT	Texas Department of Transportation
V2X	Vehicle to Everything
WAN	Wide Area Network

1.0 Introduction

The Information Technology Division (ITD) supports the business operations of the Texas Department of Transportation (TxDOT) with innovative Information Technology (IT) and strategic information resource planning. ITD is divided into five functional areas (Reference 1):

- Customer Relationship Management - ensures that customer business needs are properly captured and incorporated into decision-making; sub-sections are Customer Outreach and Communications, Data Management, and Project Management.
- IT Operations - plans and coordinates the delivery of IT services and products to TxDOT employees and customers while ensuring the appropriate infrastructure and application support are available; sub-sections are Application Services, Infrastructure, and Service Desk.
- Vendor Management and Sourcing - provides critical oversight and management of TxDOT's contracted IT services, working closely with agency procurement to ensure prescribed processes are followed; sub-sections are Vendor Management and IT Sourcing.
- Information Security - implements a robust information security program to protect TxDOT systems and data from cybersecurity threats; sub-sections are Risk and Compliance, Cybersecurity Operations, and Toll Information Security.
- Financial Reporting and Asset Management - manages the division's budget and expenditures.

As Transportation Systems Management and Operations (TSMO) continues to change the way TxDOT does business, it is necessary to stay current on the latest trends in information management to achieve the Department's vision, mission, and goals. The purpose of this technical report is to provide TSMO input to ITD in several areas including:

- Traffic information system dashboard;
- Network monitoring;
- Asset management;
- Fiber mapping and fiber asset management;
- End-of-life network and Traffic Management System (TMS) equipment upgrades or replacements;
- Lonestar™ redundancy;
- Improvements to traveler information;
- 4G cellular deployment;
- Video sharing;
- Automated traffic signal performance measures;
- Modernize Portfolio and Project Management (MPPM) initiative;
- Data Lake;
- Sharing data between agencies; and
- TMS drill-down metrics through Tableau.

Each of the above topics are discussed in terms of existing conditions and high-level recommendations to support TSMO program goals.

2.0 Traffic Information System Dashboard (Reference 2)

The Statewide Traffic Analysis and Reporting System (STARS II) is a data analysis and reporting database with detailed traffic data and statistics. Annual average daily traffic data is also available on the transportation planning maps. STARS II provides public viewing of annually reported traffic data, as well as data and statistics which are not part of the annually validated data set. Traffic data submitted for Highway Performance Monitoring System (HPMS) reporting is collected and reported according to Federal requirements for Traffic Monitoring System and HPMS data collection and may be calculated differently from other figures which are used to evaluate transportation system use. STARS II is a live production database. STARS II displays mainlane and frontage road counts separately. Figure 1 presents current the dashboard tool used to access this traffic information.

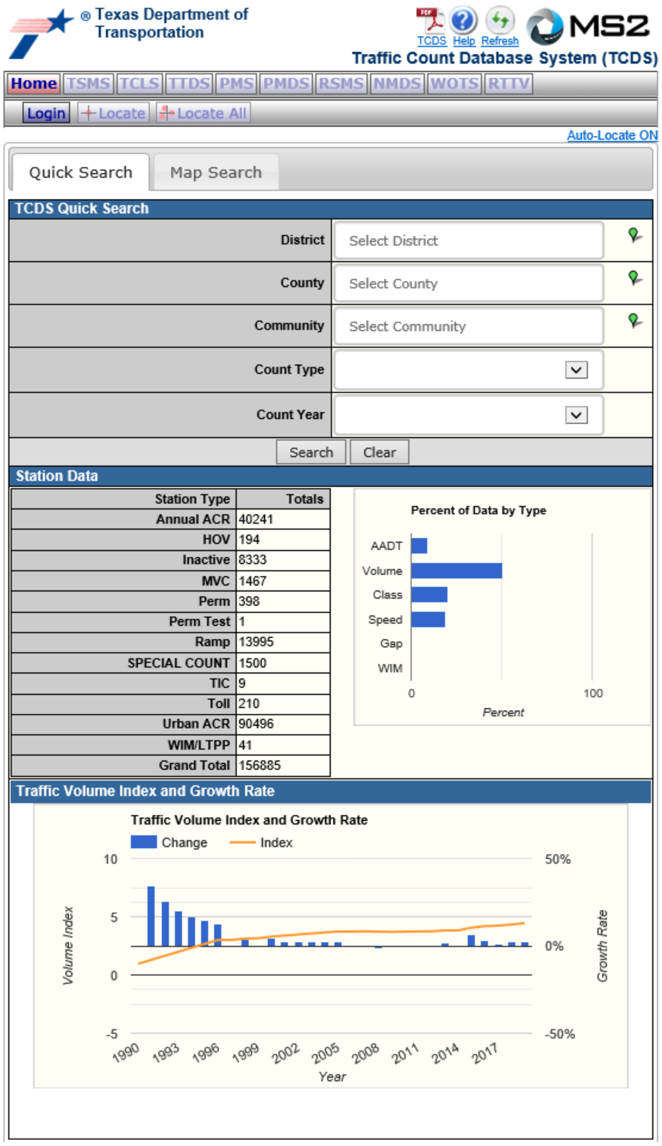

Figure 1: Statewide Traffic Analysis and Reporting Systems

Recommendation: Begin to integrate STARS II with other data systems being ingested in the data lake where users may analyze disparate data sets in combination to better understand traffic safety, congestion, and mobility issues and needs in support of the TSMO program. For example, real time traffic count data may be combined with historical traffic data, weather data and travel speed data to identify traffic safety problems and mitigation measures. As STARS II is managed primarily by the Transportation Planning & Programming (TPP) Division, this initiative would need to be coordinated with their staff. Preliminary conversations between the TPP and ITD have already occurred in discussing data lake applications pertaining to STARS II data and should be continued in advancing this initiative.

3.0 Network Monitoring

In 2018, TxDOT retained the contractor Skyline Technology Solutions to develop a Traffic Network Monitoring and Management system (Reference 3). The objectives of the system are as follows:

- Improve the reliability of the Traffic Network by increasing asset uptime;
- Reduce District staff's burden of keeping equipment in good repair through remote support;
- Improve the visibility of the Traffic Network to improve longer term strategic planning; and
- Improve security of the Traffic Network through centralized device security controls; vulnerabilities being identified; remediation plans being implemented remotely; and alerting when satellite buildings are accessed.

TxDOT applied this network monitoring system in the Dallas district as a pilot program. This reduced the district staff time remediating network issues and improving ITS network security. Prior to the pilot, Dallas district personnel spent large portions of their time troubleshooting issues across their ITS network. They would do manual checks of equipment, going to the webpage of each camera and checking if the camera came up and the quality of the video. They would make changes on network gear in attempts to resolve outages or drive hours to a location to check the status of a single switch or sign.

Once the Dallas pilot was live, the district gained access to live polled data in SolarWinds, a suite of alerts tailored to their needs, and a 24/7/365 network operations center. Skyline worked with the Dallas district to define their high priority devices in SolarWinds, so alerts on those devices would be high severity. SolarWinds also allowed Skyline to create dependencies among devices across the network. This prevented the districts from receiving a flurry of alerts when an upstream device went down. In the past the district would learn of a network outage and it would be an exercise of going from device to upstream device to see where it originated. Now, with SolarWinds dependencies, the staff knows the origin as soon as alerted.

In addition to implementing SolarWinds, the contractor also became the first responders to outages and alerts. This allowed them to define standard operating procedures, work instructions, and escalation paths, all with the end goal of remotely remediating as much as possible, allowing the district to spend more time on planning and projects and less time reacting to calls and outages.

Based on the success of both the Dallas Pilot and the Business Network Pilot, TxDOT decided to deploy SolarWinds monitoring as a service to all TxDOT. This required onboarding the remaining 15 Business Network districts, and the remainder of all the ITS Network districts. At the time of writing, TxDOT has the entirety of the Business Network in SolarWinds, and eight of the 25 traffic districts.

In addition to TMS equipment in the field, the Texas Connected Freight Corridors project (Reference 4) will add a significant number of connected vehicle devices that will require monitoring. It will create a sustainable connected vehicle deployment in Texas using I-35, I-10, and I-45 to showcase connected vehicle applications applicable to TxDOT and its partners throughout the “Texas Triangle.” The project will utilize a combination of technologies including cellular, Dedicated Short Range Communications (DSRC), and smart infrastructure to implement a suite of Vehicle to Everything (V2X) applications. These technologies are expected to enable a sustainable deployment where TxDOT will be able to acquire a rich set of traffic conditions data and in turn provide better information to its freight partners and the traveling public. In the near term, trucks operated by the freight partners will receive more timely and more accurate information about traffic and roadway conditions that greatly affect safety and mobility (e.g., traffic crashes, upcoming traffic queues, wrong-way drivers, pedestrians in the roadway), and unsafe weather conditions such as high crosswinds and low visibility. They will also experience benefits from smarter traffic intersections around their distribution centers which will enable the vehicles to interact with the traffic signals to reduce truck idling time.

Recommendation: Current expansion of the Traffic Network Monitoring and Management system is planned to continue as a district-by-district rollout of the combined Network and Asset Management solution at a pace of approximately one district per month. It is recommended that expansion of the Traffic Monitoring and Management system continues according to plan with lessons learned addressed along the way. As connected vehicle devices are deployed as part of Cooperative Automated Transportation projects, they should be added to the Traffic Network Monitoring and Management system to maintain connectivity as well as address safety and cyber security concerns. This is important as connected vehicle roadside units are planned to be incorporated into the Texas Connected Freight Corridors project.

4.0 Asset Management

Asset management plays a critical role in the success of a TSMO program by enabling more efficient tracking, management, and response to daily tasks. Asset management systems enable the tracking of a problem from detection through resolution as well as from the implementation of a new process or project to systems acceptance. These systems also help maintain an organized process of authorization and minimize downtime for affected network devices throughout the life of the ticket(s)/project. Asset management systems also helps one become accountable for their share of responsibility in strengthening the overall network’s performance and function. Having the ability to pull mean time-to repair metrics, past trouble history, performance data, and location information, along with detailed and customizable reports all with a couple clicks saves significant time that could otherwise be spent working on the optimization of TxDOT’s TSMO assets. Specifically, the benefits of an asset management system include improvements in:

- Work order and service request management;
- Task management, work process flow, assignment, and accountability;
- Asset and inventory management;

- Statistical reporting of assets and state of the TSMO systems and infrastructure;
- Reliability and reduction of downtime;
- Planning and scheduling of all maintenance and upgrades of assets;
- Cross-division communication; and
- Overall efficiency through sustainable asset management operations.

ServiceNow is an asset management software application that TxDOT began using for tracking trouble tickets during 2014 and is now using it for tracking district Intelligent Transportation System (ITS) and signal assets. These assets include Closed Circuit Television (CCTV) cameras, dynamic message signs (DMS), vehicle detectors, and signals.

Recommendations: ServiceNow, in combination with SolarWinds, will be expanded to monitor ITS and signal assets in all districts by the end of 2021. The following enhancements to this system should consider be considered:

- Interfacing ServiceNow with a funding component to forecast budgetary needs for life cycle maintenance and replacement of equipment;
- Interfacing ServiceNow with other civil asset management systems (e.g., roadway, bridge, and facility assets);
- Developing a map display for current information on field devices (e.g., location, status, icon for device type);
- Developing a database for storing historical data for assets including name, manufacturer, model, IP address, pictures, location data (i.e., latitude, longitude, roadway, cross street), and maintenance history;
- Providing the ability to drill down to assets from the map and integration with GIS tools;
- Developing a graphic display calendar to view scheduled work orders;
- Providing the capability to run on multiple platforms including Windows desktop/laptop and mobile devices such as cell phones (iPhone and Android) and tablets; and
- Providing the ability to track labor and material costs and preventive maintenance work orders.

5.0 Fiber Mapping and Fiber Asset Management

TxDOT has an ongoing effort with districts to expand fiber on main traffic corridors including IH-35, IH-20, and IH-10. As the fiber system expands, a Fiber Mapping and Fiber Asset Management system is needed to better manage important assets that are vital to the success of the statewide TSMO program.

TxDOT has initiated the development of a GIS database for Fiber Mapping and Fiber Asset Management with a pilot project in the Houston district to address fiber ownership. Recently, Austin had a fiber outage and relied on the City of Austin to share some of their fiber to maintain operations and continue to share fiber as part of a redundant network. This requires a Fiber Mapping and Fiber Asset Management system that documents who owns what fiber, where it is located, and fiber strands available to partners. TRF has contracted with the South West Research Institute (SWRI) to conduct a high-level fiber inventory to identify fiber available and gaps in the network. Furthermore, private firms are approaching TxDOT to discuss possible public-private partnerships in sharing fiber in exchange for right-of-way. These partnerships will require a more granular level of detail regarding fiber locations, equipment, conditions, who is using it, and how much capacity is available.

In Florida, the Florida DOT has deployed and maintains an ITS Facility Management (ITSFM) system that was adapted from the telecommunications industry to help them manage their overall ITS system (Reference 5). A similar approach may be considered for TxDOT.

The ITSFM configuration was designed by Florida DOT to meet its needs for assets, configuration, and as-built document management of the ITS system and the Statewide Telecommunication Network. ITSFM is a GIS web-based application that provides for the modeling of the fiber network facilities and connected fiber devices, as well as ITS devices and the electrical system powering the ITS device sites. The software is a web-based application that a valid user can access through a secure login from any computer connected to the Internet. The ITSFM is configured to support the subsystems presented in Table 1.

Table 1: ITS Fiber Management System as Configured by the Florida DOT

Fiber Optic Communication
GIS location and feature attributes (conduit duct banks and access points)
Fiber cable type, size, year installed
Fiber utilization (i.e., working, defective, reserved)
Fiber splice, termination, and patch panel assignments
Fiber path trace for dark fibers and active circuits
Outage locate tool to quickly determine fiber outage locations
Wireless Communication
GIS location and wireless shelter attributes
Tower attributes including coordinates, antennas, cables and warning lights
Wireless paths attributes including span length, frequency band, and polarization
Supporting electrical equipment including DC power supplies, batteries, surge protection, generators
Management of radios and Federal Communications Commission (FCC) licenses
ITS and Signal Devices
GIS location for Automatic Vehicle Identification (AVI)
GIS location for Beacons
GIS location for CCTV Cameras
GIS location for Dynamic Message Signs
GIS location for Electronic Display Signs
GIS location for Electronic Speed Feedback Signs
GIS location for Gates
GIS location for Roadway Weather Information Systems
GIS location for Safety Barrier Cable Systems
GIS location for Traffic Signals
GIS location for Vehicle Detector Systems (radar, video, traffic sensor, pavement sensor, AVI)
Equipment Sites
Regional Transportation Management Centers
Communications facilities (wired communication hubs and wireless communication shelters)
Roadside equipment sites
Electrical Equipment
GIS location and attributes for electrical cable, and electric sites (load center, meter point, service point)
Electrical circuits association to equipment cabinets
Utility service demarcation sites including utility company service information

Table 2: ITS Fiber Management System as Configured by the Florida DOT (cont.)

Toll Equipment
Toll equipment shelter and cabinet
Mainline and ramp gantries
AVI transceivers
Gate & warning lights
Statewide Telecommunications Network
GIS location and facility attributes for wireless shelters and towers
Supporting electrical equipment including DC power supplies, batteries, surge protection, generators
Tower attributes including coordinates, antennas, cables and warning lights
Management of radios and FCC licenses
Wireless path attributes including span length, frequency band, and polarization

The ITSFM compiles information about network assets into a single, accessible GIS based graphical and tabular database allowing the divisions, districts, and stakeholders to manage the entire system. The ITSFM is designed so maintenance technicians can update the database as changes and modifications are performed in the field "on the fly."

Recommendation: It is recommended that TxDOT renew their efforts in developing a Fiber Mapping and Fiber Asset Management system. It is suggested that the Florida DOT ITSFM system be considered for potential application in Texas. This review should consider lessons learned and desired features as applicable to support the TSMO program.

6.0 End-of-Life Network and TMS Equipment Upgrades or Equipment

Network and Traffic Management System (TMS) equipment reliability is critically important to the success of a TSMO program. As network and TMS equipment approach the end-of-life, a structured process should be established and applied to maintain functionality and user productivity in either upgrading or acquiring and decommissioning network equipment. Not having a plan is costly, primarily due to the reactive nature of fixing or replacing broken devices resulting in interruption of workflow.

The definition of "end-of-life" (or obsolescence) used herein is the loss or the impending loss of the manufacturer's and supplier's production units or repair parts. Obsolescence can be managed with the primary goal of controlling the increasing annual cost of maintaining and replacing existing network and TMS equipment. These costs increase significantly over time as the equipment moves closer to obsolescence.

An "End-of-Life Network and TMS Equipment Plan" (Plan) should be developed and applied for dealing with those TMS equipment units identified as critical obsolescence risks. This plan should offer retrofit and replacement options where available and replacement cost estimate information.

The Plan should be based on quantifiable metrics in making data-driven decisions in its implementation. For example, a numerical obsolescence risk (OR) ranking may be assigned to all network and TMS equipment, based primarily on condition and availability of replacement parts and assemblies. Systems and equipment units with the worst rankings would be deemed critical risks. The Plan would provide equipment life-cycle information, upgrade or replacement details, recommendations, and based on that information, include replacement strategies, limitations, options, and replacement cost estimates.

TSMO systems and technologies are subject to obsolescence due to the constant usage of equipment coupled with the accelerating rate of technological change. As some devices are no longer manufactured, because some particular models are no longer supported by the manufacturers, or because the manufacturer is no longer in business, the cost (both in labor hours and dollars) of meeting operational requirements becomes excessive and diverts resources away from other needs. In some cases, maintaining operation of some equipment may soon not be possible due to non-availability of spares or parts.

In order to evaluate the problem of obsolescence as it applies to network and TMS equipment, a score of 1-4 in each of four areas may be assigned to each part - herein, a part is an equipment unit; an assembly (a set of modules of specific function); a module (a circuit board, power supply, or cable with attached connectors); or a discrete component (integrated circuit chip, transformer, switch) used on a module. Assembly parts and module parts are usually products of a single manufacturer; components of these parts also carry an obsolescence risk. A possible scoring system is described below:

1. A score, based on age, condition, and use (ACU), with score = 1 corresponding to new, excellent condition, moderate use; through score = 2, corresponding to newer equipment in good condition, no excessive repairs required, and no unusual problems completing repairs when needed (parts are available); and score = 3, corresponding to older equipment in fair condition needing repair frequently and/or sometimes difficult to repair; finally to score = 4, corresponding to old, poor condition, and/or worn out. Usually the same for all units; an instance of a large supply of high quality and/or new spares would improve the ACU score somewhat for that part.

2. An ease of replacement code (EOR), wherein a code of 1 = an identical (same manufacturer, model, and software version) replacement is available, 2 = an equivalent replacement (same, or similar trusted manufacturer) is available at a reasonable cost, 3 = an identical (restarted production) or similar/backward compatible extra cost replacement is available, and 4 = cannot be replaced without substantial rework of structural, power, data communications or programming components. EOR is an external factor, not related to age or use.

3. A technology curve score, wherein a score = 1 for brand new technology, a score = 2 indicates the production rate of the particular model is increasing or being maintained; a score = 3 to represent declining production of models of a particular technology; and a score = 4 assigned to obsolete (out of production) technology. This is also an external factor.

4. A service life extension (SLE) score, provides for specific cases staff has identified, installed, and tested replacement parts and components for equipment that either failed to operate properly long term or for which regular repair procedures did not apply or no longer applied. Service life extension activities vary in scope and can be applied to equipment at any later life cycle stage. The modifier takes values between negative 4 (maximum extension of service life) and negative 1, lowering the overall score, and zero.

The four scores are added to determine an obsolescence risk (OR) ranking for each equipment unit or part. The higher the OR ranking, the more critical the obsolescence issue is for that part. Once the obsolescence status of network and TMS equipment is categorized by OR ranking and replacement cost estimates (for worst OR ranking units) are provided, TxDOT can plan and schedule replacements based on priorities, availability of funds, dependencies, and other considerations. The OR ranking value may include a fractional part because some ACU scores are mean values of scores from multiple sources.

Recommendation: It is recommended that TxDOT implement a structured "End-of-Life Network and TMS Equipment Plan" considering the methodology presented herein to be proactive in replacing equipment before maintenance issues become problematic. A periodic assessment of the technologies should be conducted, coupled with information generated by the asset maintenance system, to identify devices exhibiting high frequencies of failure or premature End-of-Life issues with components or products. The Plan would support and justify a rational funding program for preventive maintenance and scheduling equipment replacements in the future.

7.0 Lonestar™ Redundancy

The Lonestar™ Advanced Traffic Management System (ATMS) has been in existence for approximately 20 years and is maintained with software upgrades through the "Development, Integration, Implementation, and Maintenance Services for Traffic Management Systems" (DIIMS) contracts. Currently, there is no Lonestar™ ATMS redundancy architecture in place where the Lonestar™ system is deployed. This was exposed during the recent ransomware attack on May 14, 2020 where all districts, with the exception of the Houston district which has redundant capabilities within TranStar, were taken offline for several weeks until the infected servers could be cleaned and a safe standalone system could be established for each district to run Lonestar™.

TxDOT is currently working on an effort to consolidate district installations onto a cloud-based server farm hosted by Amazon Web Services (AWS). The plan consists of a pilot project in the El Paso district to test the architecture and resolve any technical issues with the software, network, and database. There are several phases in the plan with the first phase for consolidating rural districts with some of the larger districts. The next phase would be to move the consolidated districts to the cloud server and eventually move towards one consolidated system for the entire state. There are advantages and disadvantages for implementing such a plan.

Advantages

- No longer need to purchase and maintain hardware for the district Lonestar™ servers;
- Fewer Lonestar™ deployments to upgrade and maintain; and
- Easier to implement a redundant / failover system.

Disadvantages

- Consolidating databases leads to larger tables requiring more memory and frequent data purging;
- Results in single point of failure if Lonestar™ systems go down; more or all districts impacted; and
- Some performance issues may need to be overcome when migrating to fewer databases and eventually a single database for all districts.

Recommendation: It is recommended that TxDOT move off the business network and onto a separate traffic network to avoid similar impacts resulting from the recent ransomware event. In addition, TxDOT should develop and implement a structured plan for Lonestar™ ATMS redundancy. This will require failover capabilities by pairing districts to be on the same version of Lonestar™ as well as normalization of each District's database to establish consistency. Such consistency will need to be continuously maintained which is a significant effort and needs to consider latency impacts in application among districts. In addition, a Lonestar™ Software Users Group representing the needs of the districts should be established to present their requests to a statewide Configuration Management Board for approvals and follow-up implementations of upgrades and enhancements.

8.0 Traveler Information

TxDOT's traveler information systems aim to provide timely information to travelers to help them make informed decisions. Such decisions may involve changing routes, changing modes, or deciding not to make the trip. Whereas the Lonestar™ ATMS allows traffic managers to gather information and more efficiently operate the transportation network, traveler information systems enable travelers to receive such information and make their own decisions.

Within the metro districts, traveler information is being disseminated in a variety of ways, including DMSs, CCTV cameras, and websites. In general, most districts have media agreements that allow local news stations to utilize images from the district's CCTV cameras for newscasts and website applications. In addition to the statewide website, the Houston and San Antonio Districts have comprehensive websites, while Austin provides still images from cameras on a news station's website. The Fort Worth and Dallas Districts are developing a joint website which will provide traffic information for both districts. The Houston and San Antonio interactive traveler information systems offer comprehensive websites, which provide a wealth of information including speed maps, travel times, incident maps, and route-building options. San Antonio has placed several information kiosks at transit stops, shopping malls, and universities, where travelers can obtain information and print maps and narrative directions.

Table 2 summarizes the traveler information systems currently being deployed in the metro districts. Some of these systems, such as "In-Vehicle Signing," are being driven by the private sector, and TxDOT has limited ability to encourage such deployment. However, TxDOT does have the ability to deploy these technologies with its service vehicles or coordinate deployment with police or emergency vehicles. Such a strategy is used by San Antonio with in-vehicle signing technology.

Table 3: Traveler Information Systems in TxDOT Metro Districts (Reference 6)

Traveler Information Systems	Austin	Dallas	El Paso	Ft Worth	Houston	San Ant
Broadcast Traveler Information	●	●	●	●	●	●
Near real-time dissemination of all types of traffic, transit, weather, and parking information.						
Interactive Traveler Information					●	●
Request / response systems for all types of information, through any type of information provider.						
Autonomous Route Guidance	●	●	●	●	●	●
Route guidance based on static, stored information, market driven.						
Dynamic Route Guidance					●	●
Route guidance based on dynamic information for route guidance purposes.						
ISP-Based Route Guidance					●	●
Dynamic information obtained through an information service provider (ISP).						
Integrated Transportation Management/Route Guidance						
Allows TMC to continuously optimize control strategies using real-time information.						
Dynamic Ridesharing					●	
Ride-matching capability.						
In-Vehicle Signing						●
Providing information inside the vehicle.						

Recommendation: It is recommended that TxDOT leverage its past investments in deploying traveler information systems and combine it with traveler information generated by third-party providers in building a data platform that will provide expanded reach and services to underserved markets. As connected vehicle data becomes available, this information should be ingested into a data platform providing a more robust traveler information system that can be broadcast within the vehicle or other platforms such as Mobility on Demand applications.

9.0 4G Cellular Deployment

This initiative includes an ongoing effort to replace 3G cell modems with 4G modems in all districts. Approximately 2,850 new 4G cell modems are being shipped to the districts that need to be updated and installed by district personnel.

Recommendation: It is recommended that TxDOT continue the replacement of 3G to 4G cell modems according to the current plan. This will future proof this equipment to accommodate the needs of connected vehicles (i.e., DSRC, C-V2X, 5G capability).

10.0 Video Sharing

Claris is being used for an online website video sharing system as a TxDOT pilot program for the Dallas and Fort Worth Districts and the surrounding cities including Grand Prairie and Arlington. During the early phases of the COVID-19 pandemic, a contingency plan was formulated to expand the Claris system by another 600 – 700 cameras from the metro districts including Austin, El Paso, and San Antonio. This plan was developed in case one or more TMCs were infected and centers had to be temporarily shut down with operators working remotely.

The Claris portal is configurable to support the following requirements:

- Integration with complex Internet Protocol (IP) networks including Local Area Networks (LAN) and Wide Area Networks (WAN) to provide stable and secure transport of video stream;
- Video collection from diverse cameras, networks, and locations;
- Normalization of video to a common format that is easy to transport and share;
- Secure and efficient video distribution to the public, media, partners and first responders;
- Integration with multiple source and destination networks;
- Web based portals providing secure access to partners and operational support;
- Support for smart phones and tablets; and
- 24/7 monitoring and support in the Network Operations Center (NOC) and Service Desk.

Figure 2 presents a screenshot of the Claris video sharing system.

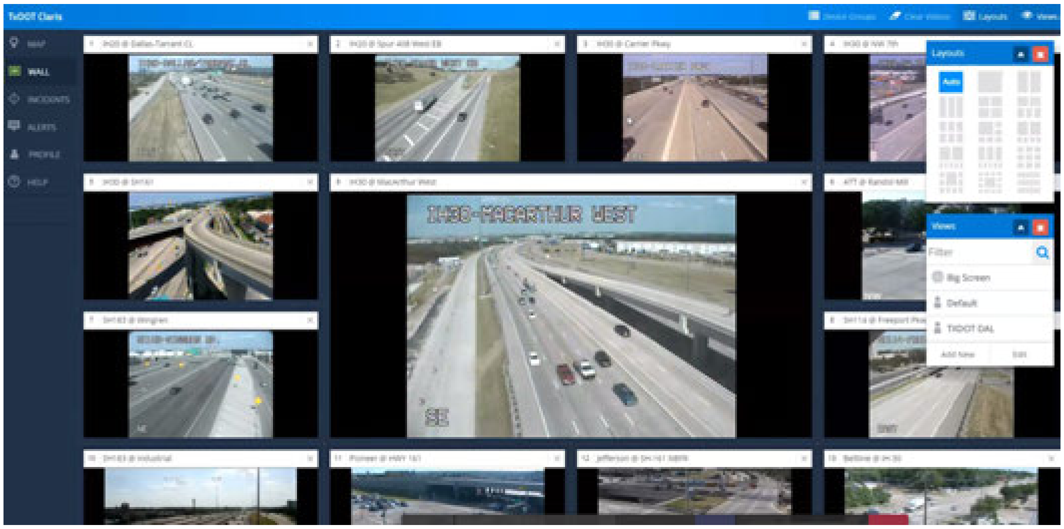

Figure 2: Claris Video Sharing System Screenshot

Recommendation: It is recommended that TxDOT roll out a video sharing system to all metro districts. This will require system requirements to be defined and a bandwidth analysis conducted to determine if sufficient capacity exists or needs to be upgraded to support full video sharing. Standard Operations Procedures and training should be provided to each district to enable operations staff to optimize the use of this system as well as provide input for future enhancements. Video sharing agreements should be encouraged with District stakeholders with policies, procedures, and protocols established for access and use of video images. These agreements should also address cost-sharing with external partners to cover the costs of operations and maintenance.

11.0 Automated Traffic Signal Performance Measures (Reference 7)

There are estimated to be over 25,000 signalized intersections in Texas, with thousands of these traffic signals operated by TxDOT. Most signals TxDOT operates tend to be in rural areas; most cities operate signals within metro areas.

TxDOT staff has limited budget and time to monitor and maintain these intersections and corridors. Further, when TxDOT staff and consultants conduct signal retiming projects, they rely on limited before and after travel-time data to demonstrate the effectiveness of optimization efforts. Typically, ongoing performance measurement capability rarely exists, and agencies rely on public feedback to reactively detect maintenance or operational deficiencies. This lack of active performance management compromises safety and efficiency and contributes to congestion. It also institutionalizes public dissatisfaction with the operation and maintenance of signalized intersections.

The United States DOT is promoting automated traffic signal performance measures (ATSPM) under its Every Day Counts (EDC) program as a means to improve traffic signal performance. ATSPMs consist of high-resolution data-logging capability added to existing traffic signal infrastructure and data analysis techniques. This system provides transportation operating agencies with the information needed to proactively identify and adjust operation of their traffic signal systems and can help with increased safety, targeted maintenance and improved operations.
ATSPMs use a suite of performance measures, data collection and data analysis tools to support objectives and performance-based approaches to traffic signal operations, maintenance, management and design. ATSPMs provide the data that TxDOT needs to adopt an objectives-driven, performance-based approach to managing traffic signal operations.

The collaborative development of ATSPMs has produced several implementation options to fit a range of agency capabilities and resources with the Utah DOT offering a public version that competes among several proprietary options. TxDOT is seeking to discover the optimal system requirements for software that will offer the benefits listed above and learn about any further data collection, analysis, and visualization possibilities that may augment these systems for TxDOT use.

TxDOT is currently applying ATSPMs in a few of the districts (e.g., Fort Worth). The Research & Technology Division is conducting a review of the state of practice related to the implementation and use of ATSPMs to enhance traffic signal performance. Three ATSPM software suites commonly available to the TxDOT will be compared to identify the use and implementation requirements of ATSPMs. Based on this assessment, prototype data-analysis techniques and tools to assist TxDOT identify strategies and techniques for enhancing traffic signals will be developed. Recommendations and guidelines for TxDOT districts on deploying and using ATSPMs to assess and improve traffic signal performance and operations will be based on the lessons learned and results of the assessment. The technical objectives of this research are as follows:

- Review EDC-suggested ATSPM analysis and comparison to TxDOT practice;
- Review at least three ATSPM software suites, identifying features that should be recommended for any software TXDOT chooses to implement, and compile a benefits analysis;
- Review the end-to-end collection system for ATSPM data. Consider security, hardware, and connectivity needs, and provide descriptions and cost analysis of a complete system;
- Review the ecosphere of ATSPM data and identify any limitations that may be associated with proprietary data and/or non-universal data schema;
- Analyze collected data collected via the ATSPM system and offer recommendations on data tools and analysis that could be used to further TxDOT's operations; and
- Compile an appropriate set of technical documentation that describes the data collected, the methodology of the analysis of the data, and the use cases of each analysis.

Recommendations: Based on the results of the research described herein, it is recommended that an assessment be conducted of select metro, urban, and rural districts to determine how useful and user-friendly the ATSPMs are. This will provide the information needed in developing or enhancing training; modifying business process and SOPs; and preparing a roll-out plan to all relevant districts.

12.0 Modernize Portfolio and Performance Management Initiative

The goal of the Modernize Portfolio and Project Management (MPPM) initiative is to automate the delivery of TxDOT's transportation programs including portfolio management, project management, contract management, asset management, and letting management. The vision of the MPPM initiative is presented in Figure 3 below (Reference 8).

System capabilities	Organizational capabilities	Process design	Decision support/analytics
Single source of truth for project data	Develop cross-functional teaming	Create phase gates, process controls	Facilitate data-driven decision making
Eliminate dual entry and automate low-value, manual tasks	Automate, enhance communication	Streamline workflows	Provide what-if scenario forecasting
Deliver intuitive, simple functionality	Ease information-sharing	Share best practices	Incorporate historical & forecasted data analytics in decisions
Increase visibility to public	Drive accountability for project outcomes	Reduce re-work	Implement common performance metrics
Move to reliable supportable software (from complex legacy)	Reduce employee on-boarding time	Standardize data & reporting formats	Track cost drivers, budget, payout, & earned value

Figure 3: Modernize Portfolio and Project Management Vision

The MPPM program developed the very successful TxDOTCONNECT system. The first release of TxDOTCONNECT (April 2019) focused on construction projects and consolidated Design and Construction Information System (DCIS) functionality. It introduced a web-based, user-friendly system with geo-spatial mapping, new reporting capabilities and automated workflows to assign resources to projects. The next release (October 2019) enabled TxDOT staff and external partners to create and manage the Engineer's Estimate in TxDOTCONNECT. The most recent release (June 2020) of system functionality consolidates Right of Way and Utilities project information in TxDOTCONNECT, eliminating dual data entry in multiple systems and spreadsheets, and improving collaboration among TxDOT staff and external partners. Key benefits of TxDOTCONNECT are:

- Modern, web-based, user-friendly, and custom system;
- Standardizes data and reporting formats;
- Automates workflow between stakeholders;
- Provides a single source for project data;
- Introduces geospatial mapping functions;
- Makes information easier to access and share; and
- Consolidates the functionality of up to 40 legacy systems with an enterprise-wide system to plan, manage and measure transportation programs.

Recommendations: Continue implementing system enhancements to introduce new functionalities and consolidate legacy systems. In addition, document lessons learned and apply applicable enhancements as part of a continuous improvement process.

13.0 Data Lake

TxDOT is currently collecting data from several sources and storing it in a Data Lake. The TXDOT Data Lake is a repository of unstructured data while the Data Mart is a structured data platform that is brokered for specific user needs. A high-level overview of the architecture is presented in Figure 4.

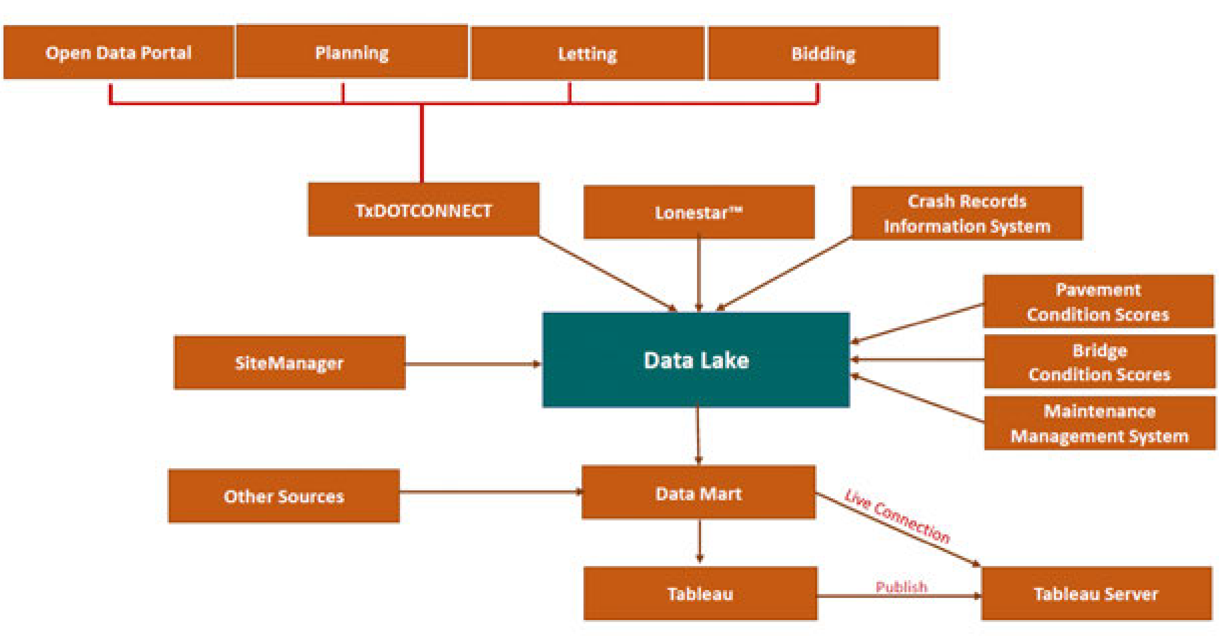

Figure 4: TxDOT Data Lake Architecture

A narrative description of each data source is described below. (Reference 9)

- **Open Data Portal:** The portal is TxDOT's platform for exploring and downloading **GIS** datasets. It allows searching for data using keywords or categories to quickly view and display content. The portal allows users to view datasets on a map, filter data using queries, and download data in various formats. The portal includes data on the following categories:
  - Assets: roadway assets such as reference markers and speed limits;
  - Boundaries: boundary datasets such as TxDOT districts, city limits, counties, legislative districts;
  - Highway Performance Reports: end-of-year roadway inventory, top 100 most congested roadways;
  - Infrastructure: datasets on infrastructure such as facilities, airports, seaports, etc.;
  - Planning: planning datasets including projects, freight networks, and Metropolitan Planning Organizations;
  - Projects: planned and upcoming roadway projects;
  - Roadways: roadway and network datasets, such as control sections and national highway system;
  - Safety: safety-related data (e.g., speed limits, guardrails, and hurricane evacuation routes); and
  - Traffic: data such as permanent count stations, annual average daily traffic, and congestion.

- **Planning:** TxDOT annually publishes its roadway inventory data in a variety of common GIS and tabular formats. Data includes GIS linework and all roadway inventory attributes. TxDOT submits this data annually to the FHWA as part of the Highway Performance Monitoring System program. TxDOT also publishes a series of roadway inventory reports on an annual basis that contain statistics on the use of public roadways in the state. Statistics include miles, lane miles, daily vehicle miles of travel and daily truck vehicle mileage of travel. These reports are summarized at county, district and state levels and are grouped by highway system, ownership, functional classification, population classification and national highway system categories. Historical chart and tabular summaries are available from 2013 forward. TxDOT also maintains the Statewide Traffic Analysis and Reporting System (STARS II) which is a data analysis and reporting database with detailed traffic data and statistics. Annual average daily traffic data is also available on transportation planning maps.
- **Letting:** TxDOT established its low-bid construction and maintenance contract letting process, which includes providing a public notice of the intent to offer work, issuing and receiving proposals, publicly opening bids, determining the apparent low bidder and executing contracts. Letting schedules and awards are posted on the TxDOT web site.
- **Bidding:** Average Low Bid Unit Prices are tables for individual bid items used in highway construction and highway maintenance projects. The data is organized statewide and by district, and the averages are based on three consecutive months and 12 consecutive months.
- **TXDOTCONNECT:** TXDOTCONNECT is a web-based, custom-built technology system used for automating the delivery of transportation programs, projects, and right of way. It standardizes TxDOT's business processes while providing transparency in performance measurement and serves as a one-stop shop for project information and tasks. TXDOTCONNECT provides a GIS database of all projects at a state, district, and county level; funding assigned by project and timeframe; project description and typical section if available; and status of project (e.g., planning, design, construction, letting, etc.).
- **Lonestar™:** Lonestar™ is TxDOT's ATMS software connecting TMCs with ITS field devices such as vehicle detectors, dynamic message signs, and CCTV cameras. Lonestar™ enables operational control of these devices and reports their health, status, and any operational data or responses back to the software, which sends commands and requests to the devices. Lonestar™ software makes real-time data received from devices available to all other processes via the command and status distribution process. The database contains configuration and other pertinent information about device identification, location, and communication parameters as well as other details of how the software should behave. Lonestar™ has a center-to-center interface for external systems to provide live traffic data in lieu of field devices as well as providing a channel to send information out for dissemination. The software integrates these devices and data interfaces in many ways that are useful to other operations. Lonestar™ has several software processes that are not device specific to process data and make it usable for various operations. Travel times and event management are two examples.
- **Crash Records Information System (CRIS):** TxDOT retains crash data from Jan. 1, 2010, to present, and will accrue data for ten calendar years. Records prior to Jan. 1, 2010 have been purged and are no longer available. Summary reports of Texas crash data are published annually. The previous year's data is published by June of the following year. Statistics contained in these reports are generated from data

provided by TxDOT's CRIS. The data may be presented in a variety of formats (i.e., location, type, fatalities, injuries, property damage only, etc.). Crash data is available for both highways and arterials.

- **Pavement Condition Score:** The Pavement Condition score is a combined index of ride quality and pavement surface distress, adjusted for traffic and speed. Ride quality is calculated from pavement roughness. Pavement distress is calculated from measuring rut data and surface deterioration such as cracking, patching and failures. Data is collected once a year to determine the surface distresses and ride quality of the pavement on Texas roadways. The data from surface defects and ride quality is then combined to provide an overall score ranging from 1 (worst condition) to 100 (best condition) per lane mile. Percentage of lane miles in good or better condition is the ratio of pavement lane miles on Texas roadways that scored above 70 to the total analyzed lane miles. Tracking pavement quality helps identify roads in need of repair and plan funding for their maintenance and rehabilitation.
- **Bridge Condition Score:** The Bridge Condition score is based on the most severe primary component condition rating. The primary bridge components are deck, superstructure and substructure. The component rating is assigned a value between 9 (excellent) and 0 (failed) based on the overall condition of the component. A combined score for all bridges on Texas roadways is calculated as the average of each individual bridge's numeric score, weighted by deck area, calculated as a bridge's length multiplied by its width. Bridge conditions are typically discussed as a function of primary bridge components. For span-type structures, there are three components that receive condition ratings: deck, superstructure and substructure. Culverts are drainage structures that, if twenty feet in length or longer, are considered bridges. Culverts receive a single condition rating. For both types of structures (span bridges and culverts), the lowest scoring component determines the individual bridge condition score. A corresponding numeric score is then assigned to the bridge. Tracking overall bridge asset condition allows forecasting network performance and determine trends given various funding scenarios for bridge maintenance, repair and replacement.
- **Maintenance Management System:** ServiceNow is an Asset Management software application that TxDOT began using for tracking trouble tickets during 2014 and is now using it for tracking district ITS and signal assets. ServiceNow is hosted on a cloud server system (TxDOTNOW). It recently added a map interface. Incident tickets are submitted and converted to work orders. District staff are being trained on how to use the system by ServiceNow personnel.
- **SiteManager:** This is a software program that automates and streamlines the management of highway construction contracts. A properly maintained daily account of all construction project activities provides valuable documentation of the prosecution of work and related events. The SiteManager Daily Work Report is the official project record for construction projects.

Recommendations: The Data Lake enables users to access transportation data in one location. The fusion of data sets into a single platform provides analysts with relief from tedious and repetitive data analytic tasks and provides managers with better information with which to make short-term and long-term decisions about the transportation system. The following recommendations are provided to advance the existing Data Lake into a Data Platform:

- The Data Platform should be designed to support its own migration to a more robust system considering the migration and evolution of data as sources change over time. The platform architecture should be developed with maximum scalability and extensibility to accommodate future data needs, including connected automated vehicles, while providing data safeguards, security, and appropriate access for system users.
- A Data Manager should be assigned to champion the development, implementation, and maintenance of the Data Platform in terms of quality control of data; normalization of disparate data sets generated by different sources; and development and maintenance of Application Programming Interfaces (API) for each user group (or data set type) by applying consistent methods.
- Apply the Systems Engineering process to develop a needs-based (current and anticipated) Concept of Operations and system requirements for the Data Platform by conducting formalized user workshops with the Planning, Design, Construction, Operations, and Maintenance Divisions as well as users representing Administrators and Commissioners.
- Establish a Systems User Group, to interface with the Configuration Management Board, to formalize the toolsets, processes applied, and checkpoints necessary to apply upgrades or insert new APIs to address evolving data needs. For example, this may include the need for machine learning algorithms and decision support systems in beginning to automate (or semi-automate) manual processes. The Systems User Group would identify needed changes and propose them to the Change Management Board for approval, funding, and implementation.

In summary, the Data Platform should be designed to *"deliver the right information to the right user at the right time to optimize decisions, enhance efficiency, and accelerate results."* The Data Platform has the potential to enable TxDOT staff, consultants, contractors, and stakeholders to be more entrepreneurial in applying data to innovate in performing their jobs more efficiently and creating new solutions to align with TxDOT's TSMO vision, mission, and goals.

14.0 Data Sharing Between Agencies

TxDOT collects transportation data that is used to provide insight into the many aspects of the transportation system as well as making such data available to other agencies and the public. Such data is used by TxDOT to better understand the following as it relates to TSMO:

- Transportation system assets and their physical condition;
- Safety, system operation, and performance;
- Travel behavior, demography, and modal data;
- Transportation economics, finance, and programming;
- Freight movement, volumes, and modes;
- Project planning and development; and
- Public opinion data (to reflect attitudes and awareness).

TxDOT shares data between agencies through a variety of initiatives including the Data Updates & Sharing Application; TxDOT Center-to-Center Data Sharing program; and the TxDOT's OneStop Data Shop.

Data Updates & Sharing Application (Reference 10)

The Transportation Planning and Programming (TPP) Division of TxDOT maintains a spatial dataset of roadway polylines for planning and asset inventory purposes, as well as for visualization and general mapping. This dataset covers the state of Texas and includes on-systems routes (those that TxDOT maintains), such as interstate highways, U.S. highways, state highways, and farm and ranch roads, as well as off-system routes, such as county roads and local streets.

The Data Updates & Sharing Application (DUSA) application serves as a communication tool for local, subject matter experts to review and acquire the GIS road network TxDOT currently has on file under their jurisdiction. The application provides multiple tools for the user to interact with the GIS inventory such as downloading a copy, uploading bulk changes to be implemented by TxDOT, or by directly marking up changes within the application to be implemented by TxDOT.

TxDOT Center-to Center Data Sharing (Reference 11)

The TxDOT Center-to-Center Data Sharing project is an effort to establish data sharing between the City of Austin and TxDOT by identifying existing open data feeds and ingesting them into each party's respective transportation management system. The goal is to enhance regional awareness of traffic conditions and promote better coordination among agencies managing traffic in central Texas.

TxDOT's OneDOT Data Shop (Reference 12)

TxDOT's OneDOT Data Shop includes various transportation-related data sets utilized in planning and decision-making. The web page is an example of a state effort to provide inventory information about its public data sets and includes the information described below.

Statewide Planning Maps

The Statewide Planning Map application contains a wide range of planning and geographic data. The site is available at http://www.txdot.gov/apps/statewide_mapping/StatewidePlanningMap.html. This TxDOT map application includes data for the following:

- Councils of Governments
- Control Sections
- Future Traffic Estimates
- Highways
- Imagery
- Legislative and Congressional Boundaries
- Metropolitan Planning Organizations
- National Highway System
- Planned Projects
- Railroads
- Texas Trunk System
- Traffic Counts

Roadway Inventory

TxDOT annually publishes its roadway inventory data in a variety of common GIS and tabular formats. Data includes GIS linework and all roadway inventory attributes. TxDOT submits this data annually to the FHWA as part of the Highway Performance Monitoring System program. http://www.txdot.gov/inside-txdot/division/transportation-planning/roadwayinventory.html.

Traffic Count Database System

TxDOT's Traffic Count Database System provides searchable and downloadable current and historical traffic count data for roadways on the state system. It allows uploading data from a traffic counter; view graphs, lists, and reports of historic traffic count data; search for count data using either the database or the Google map; and print or export data to your desktop.
http://txdot.ms2soft.com/tcds/tsearch.asp?loc=Txdot&mod=

Crash Records Information System

TxDOT is responsible for the collection and analysis of crash data submitted by Texas law enforcement officers. TxDOT maintains a statewide, automated database for reportable motor vehicle traffic crashes received by TxDOT. In Texas, the Crash Records Information System (CRIS) is the repository for this data. CRIS is an automated database used to compile and track crash data statewide, including:

- Collecting and maintaining crash reports submitted by law enforcement and drivers;
- Classifying traffic crashes in accordance with national standards;
- Entering the information from each report into CRIS; and
- Providing copies of crash reports as requested by the public.

Emerging Trends and Big Data

Big Data sources in transportation include probe data, Global Positioning System (GPS) data, Bluetooth sensors, mobile devices, and cameras. Big Data is notable because of its relational nature to other data. Due to advances in storage capacity and analytics that have allowed researchers to mine and aggregate data to degrees that were not previously possible, Big Data is fundamentally networked. Its value comes from the patterns that can be derived by making connections between pieces of data about an individual unit, about units in relation to others, or about groups of units. With the application of the right analytical tools, researchers can use this inherent relational nature to find unexpected connections and correlations, which can help to make much more accurate predictions about the future. One Big Data application in Texas is the use of probe data to understand congestion. Private sector data providers compile cell phone and in-vehicle GPS data to describe traffic patterns across time and geography. The individual unit of data here is the vehicle documented on a roadway segment. When combined, these allow the comparison of traffic patterns on that corridor to those of other corridors, and further aggregation provides understanding about congestion trends across different groups of roadways or regions.

Big Data and technology are also integral to understanding the emerging trends in congestion. Current research in ITS is working towards the development of environments that support the collection, management, integration, and application of new data sources originating from connected travelers, connected vehicles, and the infrastructure itself. In the near future, active acquisition and systematic provision of this integrated, multi-source data will enable enhanced operational practices and transform future surface transportation systems management. The real-time acquisition of data, such as vehicle and truck status, infrastructure status, weather, and transit data, will enable coordinated real-time deployment of dynamic traffic management strategies, such as transit signal priority, route guidance, signal phase and timing adjustments, and travel information. In order to support such a dynamic traffic management program, FHWA is considering the replacement of traditional static databases of well-organized research with a cloud-based Research Data Exchange (RDE) concept that supports real-time feeds and facilitates stakeholder interaction.

Recommendations: It is recommended that TxDOT continues to support FHWA in developing a cloud-based Research Data Exchange concept that ingests and provides access to real-time data feeds from multiple, heterogeneous sources and facilitates stakeholder interaction. In addition, it is recommended that TxDOT recruits and develops staff with advanced analytic capabilities necessary to properly interpret and analyze the data to implement TSMO strategies and tactical plans. This may include renewing discussions with the University of Texas "Center for Transportation Research" to expand this concept across multiple agencies.

15.0 TMS Drill-Down Metrics Through Tableau

TxDOT is using Tableau to create dashboards for tracking Key Performance Indicator (KPI) metrics based on data stored in its AWS Data Lake repository. Tableau is a data visualization tool used in the Business Intelligence industry. It helps in simplifying raw data into an understandable format. Data analysis and visualizations created are in the form of dashboards and worksheets. The data that is created using Tableau can be understood by professionals at any level in an organization. It also allows a non-technical user to create a customized dashboard. Tableau is being rolled out to TxDOT staff to empower users, increase usage, and drive data culture. Data is being collected from a variety of sources including Lonestar™, Crash Records Information System (CRIS), and Traffic Asset Management System (Houston District). The following three KPIs are being tracked for the metro and coastal districts on a monthly basis: TMS Asset Uptime, Average Incident Clearance Time, and Level of Travel Time Reliability. Figure 5 presents the TxDOT TMS Metrics Dashboard that reports these performance metrics.

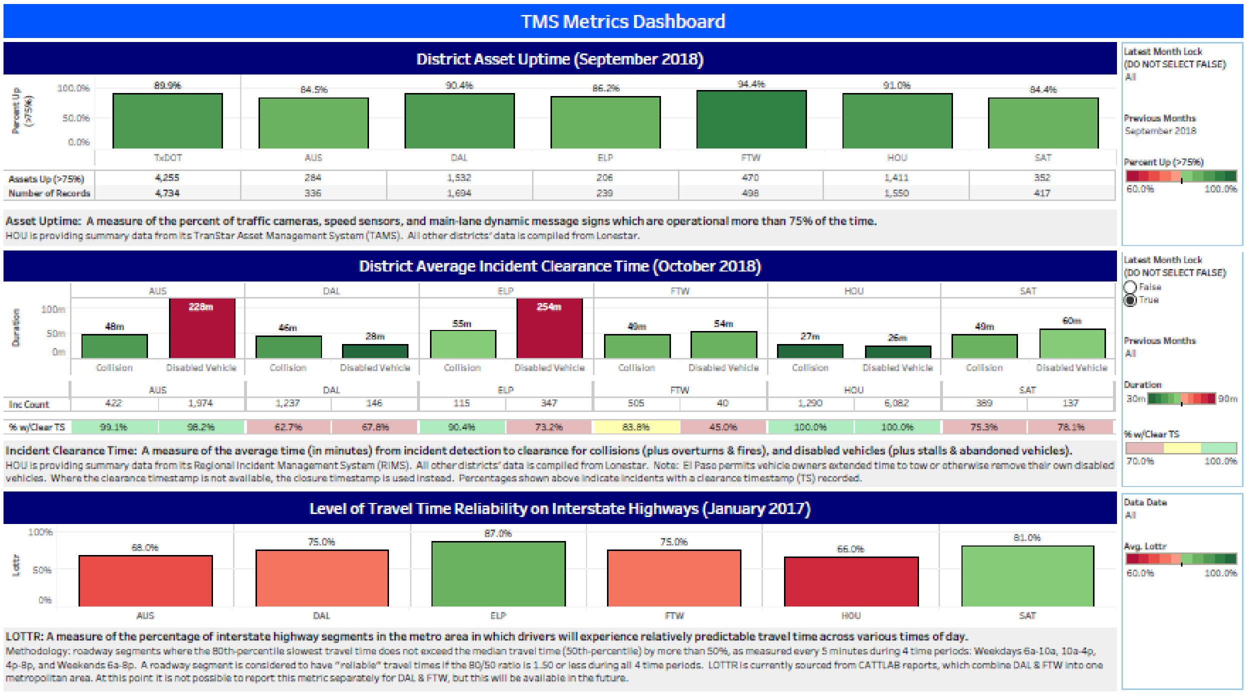

Figure 5: TxDOT TMS Metrics Dashboard

Recommendations: In addition to the executive-level TMS Metrics Dashboard, current efforts are underway in developing internal operational dashboards for the districts based on Lonestar™ data including incident statistics, HERO statistics, and DMS messages. It is recommended that TxDOT roll out both dashboards to cover other districts as well as expand the number and type of performance measures to align with the District TSMO Program Plans. Further, other business intelligence tools may be considered in addressing TSMO needs in the future.

16.0 Summary

TxDOT's TSMO program will require Central Office and the Districts to leverage existing and emerging information management systems to support data-driven decisions to continuously improve operational performance. While each of these information management systems are presented as individual chapters in this report, it is recognized that there is overlap, gaps, and potential synergy in fusing many of these systems together as part of a cohesive plan. The recommendations presented in this technical report, summarized in Table 3 below, provides initial input to ITD as a starting point to begin implementing needed changes.

Table 4: Summary of Recommendations

Traffic Information System Dashboard
Begin to integrate STARS II with other data systems being ingested in the data lake where users may analyze disparate data sets in combination to better understand traffic safety, congestion, and mobility issues and needs in support of the TSMO program. For example, real time traffic count data may be combined with historical traffic data, weather data and travel speed data to identify traffic safety problems and mitigation measures. As STARS II is managed primarily by the Transportation Planning & Programming (TPP) Division, this initiative would need to be coordinated with their staff. Preliminary conversations between the TPP and Information Technology Division (ITD) have already occurred in discussing data lake applications pertaining to STARS II data and will need to be continued in advancing this initiative.
Network Monitoring
Current expansion of the Traffic Network Monitoring and Management system is planned to continue as a district-by-district rollout of the combined Network and Asset Management solution at a pace of approximately one district per month. It is recommended that expansion of the Traffic Monitoring and Management system continues according to plan with lessons learned addressed along the way. As connected vehicle devices are deployed as part of Cooperative Automated Transportation projects, they should be added to the Traffic Network Monitoring and Management system to maintain connectivity as well as address safety and cyber security concerns. This is important as connected vehicle roadside units are planned to be incorporated into the Texas Connected Freight Corridors project.
Asset Management
ServiceNow, in combination with SolarWinds, will be deployed to monitor ITS and signal assets in all districts by the end of 2021. The following enhancements to this system should consider the following enhancements: ▪ Interfacing ServiceNow with a funding component to forecast budgetary needs for life cycle maintenance and replacement of equipment; ▪ Interfacing ServiceNow with other civil asset management systems (e.g., roadway, bridge, and facility assets); ▪ Developing a map display for current information on field devices (e.g., location, status, icon for device type); ▪ Developing a database for storing historical data for assets including name, manufacturer, model, IP address, pictures, location data (i.e., latitude, longitude, roadway, cross street), and maintenance history; ▪ Providing the ability to drill down to assets from the map and integration with GIS tools; ▪ Developing a graphic display calendar to view scheduled work orders; ▪ Providing the capability to run on multiple platforms including Windows desktop/laptop and mobile devices such as cell phones (iPhone and Android) and tablets; and ▪ Providing the ability to track labor and material costs and preventive maintenance work orders.

Table 5: Summary of Recommendations (cont.)

Fiber Mapping and Fiber Asset Management
It is recommended that TxDOT renew their efforts in developing a Fiber Mapping and Fiber Asset Management system. It is suggested that the Florida DOT ITSFM system be considered for potential application in Texas. This review should consider lessons learned and desired features as applicable to support the TSMO program.
End-of-Life Network and TMC Equipment Upgrades or Replacement
It is recommended that TxDOT implement a structured "End-of-Life Network and TMS Equipment Plan" considering the methodology presented herein to be proactive in replacing equipment before maintenance issues become problematic. A periodic assessment of the technologies should be conducted, coupled with information generated by the asset maintenance system, to identify devices exhibiting high frequencies of failure or premature End-of-Life issues with components or products. The Plan would support and justify a rational funding program for preventive maintenance and scheduling equipment replacements in the future.
Lonestar™ Redundancy
It is recommended that TxDOT move off the business network and onto a separate traffic network to avoid similar impacts resulting from the recent ransomware event. In addition, TxDOT should develop and implement a structured plan for Lonestar™ ATMS redundancy. This will require failover capabilities by pairing districts to be on the same version of Lonestar™ as well as normalization of each District's database to establish consistency. Such consistency will need to be continuously maintained which is a significant effort and needs to consider latency impacts in application among districts. In addition, a Lonestar™ Software Users Group representing the needs of the districts should be established to present their requests to a statewide Configuration Management Board for approvals and follow-up implementations of upgrades and enhancements.
Improvements to Traveler Information
It is recommended that TxDOT leverage its past investments in deploying traveler information systems and combine it with traveler information generated by third-party providers in building a data platform that will provide expanded reach and services to underserved markets. As connected vehicle data becomes available, this information should be ingested into a data platform providing a more robust traveler information system that can be broadcast within the vehicle or other platforms such as Mobility on Demand applications.
4G Cellular Deployment
It is recommended that TxDOT continue the replacement of 3G to 4G cell modems according to the current plan. This will future proof this equipment to accommodate the needs of connected vehicles (i.e., DSRC, C-V2X, 5G capability).
Video Sharing
It is recommended that TxDOT roll out a video sharing system to all metro districts. This will require system requirements to be defined and a bandwidth analysis conducted to determine if sufficient capacity exists or needs to be upgraded to support full video sharing. Standard Operations Procedures and training should be provided to each district to enable operations staff to optimize the use of this system as well as provide input for future enhancements. Video sharing agreements should be encouraged with District stakeholders with policies, procedures, and protocols established for access and use of video images. These agreements should also address cost-sharing with external partners to cover the costs of operations and maintenance.

Table 6: Summary of Recommendations (cont.)

Automated Traffic Signal Performance Measures
Based on the results of the research described herein, it is recommended that an assessment be conducted of select metro, urban, and rural districts to determine how useful and user-friendly the ATSPMs are. This will provide the information needed in developing or enhancing training; modifying business process and SOPs; and preparing a roll-out plan to all relevant districts.
Modernize Portfolio and Project Management
Continue implementing system enhancements to introduce new functionalities and consolidate legacy systems. In addition, document lessons learned and apply applicable enhancements as part of a continuous improvement process.
Data Lake
The Data Platform should be designed to support its own migration to a more robust system considering the migration and evolution of data as sources change over time. The platform architecture should be developed with maximum scalability and extensibility to accommodate future data needs, including connected automated vehicles, while providing data safeguards, security, and appropriate access for system users. A Data Manager should be assigned to champion the development, implementation, and maintenance of the Data Platform in terms of quality control of data; normalization of disparate data sets generated by different sources; and development and maintenance of Application Programming Interfaces (API) for each user group (or data set type) by applying consistent methods. Apply the Systems Engineering process to develop a needs-based (current and anticipated) Concept of Operations and system requirements for the Data Platform by conducting formalized user workshops with the Planning, Design, Construction, Operations, and Maintenance Divisions as well as users representing Administrators and Commissioners. Establish a Systems User Group, to interface with the Configuration Management Board, to formalize the toolsets, processes applied, and checkpoints necessary to apply upgrades or insert new APIs to address evolving data needs. For example, this may include the need for machine learning algorithms and decision support systems in beginning to automate (or semi-automate) manual processes. The Systems User Group would identify needed changes and propose them to the Change Management Board for approval, funding, and implementation.
Sharing Data Between Agencies
It is recommended that TxDOT continues to support FHWA in developing a cloud-based Research Data Exchange concept that ingests and provides access to real-time data feeds from multiple, heterogeneous sources and facilitates stakeholder interaction. In addition, it is recommended that TxDOT recruits and develops staff with advanced analytic capabilities necessary to properly interpret and analyze the data to implement TSMO strategies and tactical plans. This may include renewing discussions with the University of Texas "Center for Transportation Research" to expand this concept across multiple agencies.

Table 7: Summary of Recommendations (cont.)

Traffic Management System (TMS) Drill-Down Metrics through Tableau
In addition to the executive-level TMS Metrics Dashboard, current efforts are underway in developing internal operational dashboards for the districts based on Lonestar™ data including incident statistics, HERO statistics, and DMS messages. It is recommended that TxDOT roll out both dashboards to cover other districts as well as expand the number and type of performance measures to align with the District TSMO Program Plans. Further, other business intelligence tools may be considered in addressing TSMO needs in the future.

In summary, it is suggested that a series of workshops be conducted between TRF and ITD to perform a deep dive into the current status and future plans for each of these information management systems; review, critique, modify, and agree on workshop outcomes and recommendations; then develop a structured and funded plan for its implementation.

References

1. TxDOT website, https://www.txdot.gov/inside-txdot/division/information-technology.html

2. TxDOT website, "Statewide Traffic Analysis Reporting System", https://www.txdot.gov/inside-txdot/division/transportation-planning/stars.html

3. TxDOT, "Network Monitoring and Management", presentation by NTT Data / Skyline Technology Solutions, August 2020.

4. TxDOT, "Texas Connected Freight Corridors Project, Frequently Asked Questions", https://ftp.dot.state.tx.us/pub/txdot-info/trf/freight-corridors/faq.pdf

5. FDOT website: https://www.fdot.gov/traffic/itsfm/newusersagencies/about-itsfm

6. USDOT, "The National ITS Architecture: A Framework for Integrated Transportation into the 21st Century", CD-ROM, Version 3.0, Market Packages.

7. TxDOT, "Implementation of Automated Traffic Signal Performance Measures", prepared for the Research Project Statement 19-406, FY2019 Annual Program: http://ftp.txdot.gov/pub/txdot-info/rti/statements/2019/rfp3/19-406.pdf

8. TxDOT, "Modernize Portfolio Project Management", presented by Erika K. Kemp, PMP.

9. TxDOT website: http://www.dot.state.tx.us/dashboard/

10. TxDOT, "Data Updates and Sharing Application, Instruction Manual", TPP Data Management Section.

11. TxDOT, "Center-to-Center Data Sharing", https://github.com/cityofaustin/atd-data-tech/issues/144

12. Texas A&M Transportation Institute, "An Overview of Transportation Data", prepared by Kristi Miller, Transportation Policy Research Center, February 2018.