TxDOT Statewide TSMO Interoperability

February 2021

Version 2.0

Prepared By

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Date	Version	Description
7-30-20	1.0	Traffic Operations Safety Division Review (Prepared by AECOM)
2-15-21	2.0	Addresses AECOM Review Comments

List of Acronyms

Acronym	Definition
AI	Artificial Intelligence
API	Application Programming Interface
ATMS	Advanced Traffic Management System
CAT	Cooperative Automated Transportation
CCTV	Closed Circuit Television
CMM	Capability Maturity Model
ConOps	Concept of Operations
DMS	Dynamic Message Sign
DOT	Department of Transportation
FHWA	Federal Highway Administration
ICM	Integrated Corridor Management
IT	Information Technology
ITD	Information Technology Division
ITS	Intelligent Transportation Systems
NTCIP	National Transportation Communications for ITS Protocol
TIM	Traffic Incident Management
TMC	Transportation Management Center
TRF	Traffic Division
TSMO	Transportation Systems Management & Operations
TxDOT	Texas Department of Transportation
USDOT	United States Department of Transportation
RITIS	Regional Integrated Transportation Information System

1. Introduction

The purpose of this technical report is to provide support to the Texas Department of Transportation (TxDOT) Traffic Division (TRF) and Information Technology Division (ITD) to implement "data and system" interoperability among districts. This scope is focused on evaluating and making recommendations for interoperability between the districts at logical interface points. Interoperability within the Transportation Systems Management & Operations (TSMO) realm may apply to many different strategies, functions, and applications. These include the functions shown in Figure 1 below.

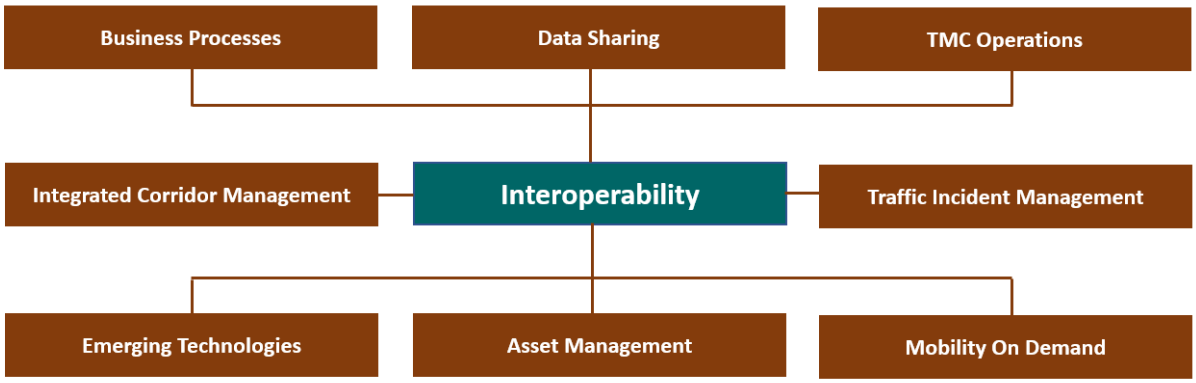

Figure 1: Interoperability

Each of the various TSMO functions benefiting from interoperability is discussed below. It is recognized that this is not an all-inclusive list but representative of the more common TSMO functions that TxDOT Divisions and Districts will encounter.

- **Business Processes** - Consistency in developing and applying business processes across the 25 districts is important to provide efficiency in procurement of services and products. Specifically, this includes the formal scoping, planning, design criteria, programming, and budgeting processes for systems and technology as well as roadway, bridge, and other facility projects. This will enable consistency of transportation components so the motorists traveling across Texas will have similar experiences on all roadways resulting in more harmonized traffic flow, less unanticipated conditions, and fewer crashes. Furthermore, traditional systems should be procured where they are interoperable with emerging technologies. For example, smart work zone management systems, inclusive of Closed-Circuit Television (CCTV) cameras, dynamic messages signs, and vehicle detectors, should be interoperable with connected vehicles.
- **Data Sharing** - Interoperability in data sharing is important so that data provided by public or private sources may be used by others to address their needs. This will require a common data exchange platform where authorized users may have access to the data and be able to develop Application Programming Interface (API) systems to customize the data formats and conventions to use for their specific needs. For example, vehicle detection data (e.g., traffic volume, speed, occupancy) generated by ramp meters should be interoperable with vehicle detection along the freeway mainline as well as nearby traffic signals to optimize traffic flow and reduce delays along the freeway, ramp, and adjacent arterials.

- **Transportation Management Center (TMC) Operations** - Interoperability in TMC operations is critical to ensure that each TMC has individual systems that can communicate with each other in real time. Standard operating procedures and training should be consistent among the districts while enabling flexibility for each district to provide customization as needed. This is important in addressing incident management in providing integrated operations with emergency responders; providing coordination among freeways, arterials, toll roads, and other transportation modes; and disseminating traveler information that is consistent, reliable, accurate, timely and useful. For example, during the COVID-19 pandemic, many TMCs were forced to operate remotely requiring operations staff to have the interoperable resources necessary to mimic on-site TMC operations from their homes.
- **Traffic Incident Management (TIM)** - Interoperability in applying consistent policies and procedures is important specifically when traffic lanes or the complete roadway is closed for a significant amount of time due to a traffic incident. Freeways and diversion routes will need to have systems that are interoperable in sharing real time CCTV camera images, dynamic message signs, and detection data as well as signal phasing and timing data. TIM activities crossing multiple districts will also need a certain level of interoperability when dealing with super loads (i.e., truck's load exceeds the dimensions of routine permit limits), transport of hazardous materials as well as special and emergency events. For example, during an emergency evacuation that impacts multiple districts, individual TIM teams need to be coordinated in their response so evacuees don't receive conflicting information.
- **Mobility On Demand (MOD)** - MOD is an innovative, user-focused approach which leverages emerging mobility services, integrated transit networks and operations, real-time data, connected travelers, and cooperative Intelligent Transportation Systems (ITS) to allow for a traveler-centric transportation system-of-systems approach, providing improved mobility options to all travelers and users of the system in an efficient and safe manner. Subsystems need to be interoperable among modes and districts in order for these systems to be effective and user friendly. For example, a traveler may access their smartphone mobility app prior to traveling to the airport to determine the optimum trip itinerary (e.g., best mode(s), route(s), schedule, travel cost) based on their user preferences, then pay the fare (e.g., tolls, transit, parking) through the app's interoperable payment system.
- **Asset Management:** An effective "asset management system" has the capability to empower TxDOT TSMO staff by streamlining work order management, optimizing preventive maintenance tasks, and generating performance metric reports. They provide ease of tracking work orders and assets digitally, making it easier to organize and view data, as well as assign appropriate labor and response. Costs savings and data-driven decision making are just two of the benefits. The "asset management system" should be interoperable between TxDOT districts and divisions and interoperable with the Lonestar™ Advanced Traffic Management System (ATMS) software. For example, an "asset management system" that is integrated with the Lonestar™ ATMS software would automate many of the processes in providing data-driven decisions for ITS and signals maintenance.
- **Emerging Technologies:** In recent years, auto manufacturers and technology companies have introduced many emerging technologies to the transportation sector to address traffic safety, mobility, and congestion management. These emerging technologies include, but is not limited to, the following:

- Connected Vehicles
- Automated Vehicles
- Wrong Way Driving Detection Systems
- Smart Work Zones
- All Electronic Tolling
- Advanced Traffic Controllers
- Active Traffic Management Systems
- Curbside Management Systems
- Dynamic Electric Vehicle Charging Systems
- Truck Advisory Parking Systems
- Smart Mobility Hubs

As the above emerging technologies, and many others, come online they will need to be interoperable with the overall TSMO program to realize the full potential of these integrated strategies. For example, as connected vehicle data is integrated with traffic signals the edge computing algorithms residing in the controllers will need to be interoperable with more traditional detection and data systems to optimize signal phasing and timing at individual intersections and be coordinated with signals located upstream and downstream of the intersections.

- **Integrated Corridor Management (ICM) -** ICM is an approach designed to actively monitor for the most severe atypical nonrecurring events that impact traffic on already congested highways or freeways that define a corridor. ICM requires the institutional, operational, and technical integration of as many participating agencies as are available to combine their assets into one unified real-time response. Although ICM is typically a district-level strategy, it may have application across multiple districts, thereby requiring interoperability across more than one district. For example, a corridor may contain a freeway management system, several arterial signal systems, transit bus routes, and a commuter rail system within one or more districts. At various times, all of these systems may participate in an ICM response.

In summary, the above list addresses the core functions of TSMO programs. Other functions include, but are not limited to freight management systems, bus and rail operations, toll operations, and interoperability among rural, urban, and metro TSMO systems.

2. Interoperability Processes

Systems engineering is a comprehensive planning and management process which encompasses all major phases of the system lifecycle. A key focus of this process is an objective, needs-driven requirements development approach and an emphasis on ensuring that the requirements used to design the system can be traced to documented stakeholder needs and goals. This focus, along with the comprehensive nature of the overall process, has led the Federal Highway Administration (FHWA) to mandate the use of the systems engineering process when using federal funding on certain types of transportation projects. An overview of the process elements typically used in transportation projects is shown below in Figure 2 below.

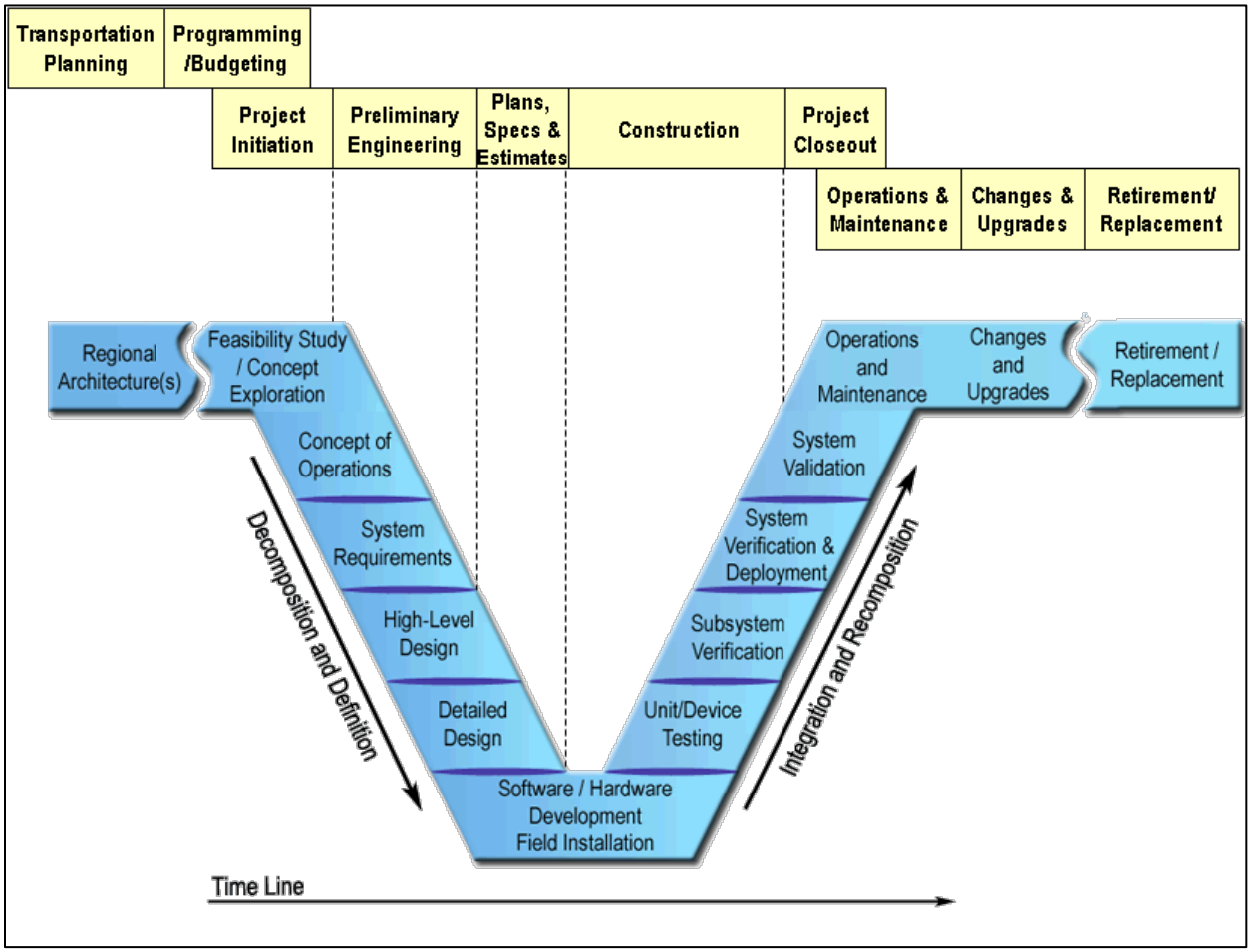

Figure 2: FHWA Systems Engineering Process "V" Diagram

The systems engineering process should be used to incorporate interoperability among integrated TSMO strategies. This process includes development of or updating the ITS architecture, concept of operations (ConOps), and system requirements to design, build, and maintain interoperability for the overall system.

Development of a ConOps is an initial, critical step in the systems engineering process. In developing the ConOps, several operational scenarios should be developed and discussed among stakeholders to identify and map the

users' needs in terms of functionality and interoperability requirements. These operational scenarios may be selected from the list shown below or include others as agreed upon by the operational stakeholders.

- Normal Daily Operations
- Lane Closure Incident
- Road Closure Incident
- Special Event
- Emergency Event
- Pandemic Event
- Work Zone
- ITS, Signal or Communications Failure Event
- Weather Event
- Operations and Maintenance Budget Reduction

The specific roles and responsibilities of each stakeholder should be identified along with the systems, technologies, processes, and interoperable requirements needed to improve the efficiency and effectiveness of operations in a coordinated manner. In addition to applying the systems engineering process, the Capability Maturity Model (CMM) process may also be used. This analysis would broaden the interoperability discussion among the stakeholders to address CMM dimensions other than "systems and technology" as addressed below.

- **Business Processes:** Identifying business processes that would improve interoperability among TxDOT systems, districts, divisions, and staff to enhance efficiency, For example, procuring emerging technologies and ITS devices that are compliant with the National Transportation Communications for ITS Protocol (NTCIP), and compatible with the Lonestar™ ATMS software, may reduce the need for extensive system upgrades.
- **Performance Measures:** Identifying performance measures that are interoperable with automated data collection systems to evaluate the effectiveness of integrated TSMO strategies. For example, defining specific performance metrics that optimize "people" throughput, rather than "vehicle" throughput, for ICM strategies may be better aligned with TSMO goals.
- **Organization and Workforce:** Identifying skill sets that are lacking with current staff, or additional training needed, to support TSMO systems so they are interoperable with similar systems within the same or other districts. For example, a more comprehensive training program may be developed to enhance the skills of staff to provide more effective preventive, corrective, and emergency maintenance for ITS devices so system availability is at least 90% among all districts.
- **Culture:** Identifying the needs of TSMO Champions and Coordinators to provide leadership to promote consistent and interoperable operations across districts. For example, although TSMO needs among rural,

urban, and metro districts are different, TSMO strategies should provide interoperability to make these strategies effective on a statewide basis.

- **Collaboration:** Identifying strengths and weaknesses in collaborating with Traffic Incident Management (TIM) partners to improve incident clearance times impacting multiple districts. For example, TxDOT and TIM partners should use the annual FHWA TIM Self-Assessment survey as a tool to address gaps and conflicting overlaps in providing effective incident management across multiple districts throughout the state of Texas.

This analysis will enable TRF and TxDOT Districts to develop and refine TSMO strategies to address all six CMM dimensions and mainstream them into addressing the interoperable needs of TxDOT Planning, Design, Constriction, Operations, and Maintenance Divisions.

3. Data Exchange Platform

TxDOT has adopted a TSMO vision and mission statement as presented below.

- **TSMO Vision Statement:** Improve safety and mobility for all modes of transportation by integrating planning, design, operations, construction, and maintenance activities and acknowledging all opportunities for innovation.
- **TSMO Mission Statement:** Through innovation, collaboration, and performance-based decision making, transportation facilities are developed, constructed, maintained, and operated cost-effectively, with the end user in mind.

In support of the above TSMO vision and mission statements, the "TxDOT Statewide TSMO Strategic Plan" was prepared and recently updated. TxDOT has an active TSMO program that includes a broad range of integrated strategies as listed below.

- Work Zone Management
- Traffic Incident Management
- Service Patrols
- Special Event Management
- Road Weather Management
- Transit Management
- Freight Management
- Traffic Signal Coordination
- Traveler Information
- Ramp Management
- Managed Lanes
- Active Traffic Management
- Integrated Corridor Management
- Rural Emergency Management

Each of these TSMO strategies, individually and collectively, generate significant amounts of data. As emerging technologies, such as connected and automated vehicles come online in the future, this will generate substantially more information in real time (e.g., 10 data per second). Therefore, development of a Data Exchange Platform is needed to collect and store all data generated from these programs and create a user-friendly, reliable, and repeatable data analytics and reporting platform. This data platform could be used by TxDOT Divisions and Districts, as well as other stakeholders, for multiple purposes including real-time decision-

making, short and long-term planning, and performance assessment. The Data Exchange Platform will require TxDOT to conduct the following activities (Reference 1):

- Collect and ingest all data generated from TSMO projects.
- Develop device drivers, as needed, to ingest data from field devices into the data exchange.
- Support development of data compression platforms such as edge or fog computing to manage the impact of massive data collection from field devices on the communication infrastructure and networks.
- Manage data security at the field level and integrate data transmission through the districtwide and statewide ITS communication networks.
- Coordinate with and integrate additional data sources and systems.
- Develop APIs, as needed, to ingest data from other systems into the Data Exchange Platform.
- Provide data storage, security, normalization, filtering, and aggregation.
- Develop real-time and predictive analytics and tools with real-time and historical visualization dashboards and reporting capabilities.
- Write and publish data requirements, APIs, and specifications needed for future Cooperative Automated Transportation (CAT) deployments.

The Data Exchange Platform will provide holistic management of data originated from a variety of sources resulting in useful real time information for all TxDOT TSMO projects. It will leverage existing infrastructure such as traffic signal controllers and detection devices to extract information and develop useful analytics for TSMO project outcome assessments at the required resolution and distribute data processing capabilities throughout the state of Texas. The following example scenarios further visualize the expected operational outcomes of the Data Exchange Platform:

- A District Engineer receives a call or an email from a citizen about traffic congestion on a state road with TSMO infrastructure. The District Engineer views performance measures of the road in real time and pulls its historical information. The District Engineer discusses the current and past traffic volumes, congestion, and other information obtained from other sources, with the citizen.
- A District Traffic Operations Engineer is preparing a list of projects to be considered for the upcoming work program. He views information on his dashboard on locations which have the worst recurring congestion, traffic signals that need upgrading for an upcoming TSMO project, and related performance measures.
- A Traffic Engineer is responsible for managing hundreds of signals in her agency. She views the information on her screen with ITS devices that indicates a queue is forming on the Interstate Highway that could potentially lead to a crash. It presents her with choices to notify law enforcement and issue warning messages on dynamic message signs about heavy congestion ahead. At this point, the Lonestar™ ATMS

software issues the message and the Data Exchange Platform would carry out analytics using TSMO data to provide the appropriate message to Lonestar™.

- TxDOT receives a grant from the United States Department of Transportation (USDOT) for a model deployment that requires a before-and-after study to evaluate the effectiveness of the program. The USDOT and their independent evaluator can use the Data Exchange Platform to store data and provide the necessary analytics to determine the benefits.
- A Private Sector Partner desires to explore a partnership with the TxDOT. This partner requests to receive the data it sees on the Data Exchange Platform after discussing it with TxDOT representatives. In turn, TxDOT would like to ingest the private sector partner's data into the Data Exchange Platform.

The Data Exchange Platform would perform analytics using the ingested data and other systems such as Lonestar™, the Regional Integrated Transportation Information System (RITIS), and other sources. A fully integrated data exchange including both traditional TSMO data and data from emerging CAT sources will provide the most opportunities for innovative data analytics.

The Data Exchange Platform would provide back-end solutions to data management and analytics for TSMO operational type scenarios. The Data Exchange Platform is not intended to provide safety-critical applications where microsecond (or less) latency is required. In the context of this initiative, therefore, "near" real-time is intended to mean that when data becomes available to the Data Exchange Platform, that it is readily usable and that the analytics tools developed have minimal operational latency.

4. Benefits

Interoperability among districts will support the goals of the TxDOT TSMO program. Specifically, the following benefits are anticipated to be realized:

- **Consistency** - Interoperability provides consistency across TxDOT districts and divisions in the processes used to collect, store, analyze, and apply data to improve operations. While there may be differences in such applications between rural, urban, and metro districts, the Data Exchange Platform will provide a consistent data management system to customize applications as needed to fit uses by the district or division. Similarly, Standard Operating Procedures and Training Programs should be consistent statewide.
- **Fail Over Operations** - Interoperability provides an opportunity for one TMC to take over operations of another when the primary TMC is unable to function due to an emergency where the TMC is not accessible (e.g., hurricane evacuation), where remote operations are required (e.g., COVID-19 pandemic), during a systems failure (e.g., communications outage), or staff shortages (e.g., major event).
- **Traveler Information** - Interoperability in sharing multimodal information from both public and private sources will provide travelers the ability to make more informed, data-driven decisions that adapt to their specific needs and preferences such as travel route, mode, time of day, cost, number of transfers, etc.
- **Emergency Evacuation** - Interoperability in emergency management policies and procedures, data and video sharing, and software tools would facilitate emergency evacuations across multiple districts using a common platform. This would include vital information such as tracking weather event trajectories, impact on traffic, monitoring status of lane and road closures, reversible operations, locating emergency responders in the field, availability of shelters and fuel at gas stations.
- **Data Sharing** - Interoperability provides an opportunity to leverage TxDOT generated data with other public and private sources. This more robust data platform would be useful for several TxDOT Divisions including planning, design, construction, operations, and maintenance. Furthermore, applicable data may be extracted from the data platform to provide input to performance measures to continuously improve operations.
- **Asset Management** - Interoperability between TxDOT districts, divisions, and with the Lonestar™ ATMS software will improve the efficiency of work order and service request management; 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.

In addition to the above list of benefits, interoperability provides an opportunity to begin to develop predictive algorithms to stay ahead of congestion, rather than reacting to it, applying machine learning and artificial intelligence to begin automating routine processes, and serving as a precursor to gamification methods to provide incentives and disincentives to travelers in balancing travel supply and demand in real time across multimodal networks.

5. Summary

In summary, interoperability is a critical component of a successful TSMO program. This technical report focuses on evaluating and making recommendations for interoperability between the TxDOT districts and divisions at logical interface points and should be used as a basis to coordinate efforts between TRF and ITD to implement "data and system" interoperability. It is recognized that districts will continue to coordinate with partner agencies including local agencies, tolling agencies, and neighboring districts to support interoperability of systems, potentially through a statewide data sharing platform or existing memoranda of understanding. This allows agencies to access data for supporting analyses and performance measures.

References

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