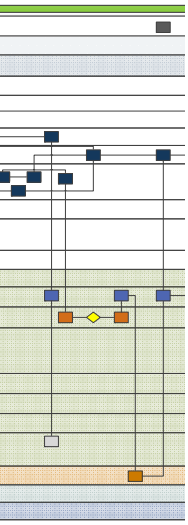
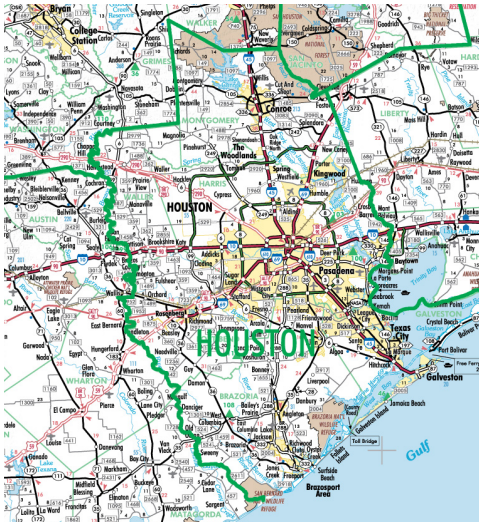
TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS (TSMO)





HOUSTON DISTRICT PROGRAM PLAN

March 2021

Texas Department of Transportation

Texas Department of Transportation

MEMO

February 5, 2021

To: HOU-ALL

From: Eliza C. Paul, P.E.
District Engineer, Houston District

Subject: Houston District Transportation Systems Management and Operations (TSMO) Program

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As part of a statewide initiative, we have just completed the Houston District TSMO Program Plan, which identifies ways to integrate TSMO into existing district processes to reach Vision Zero 2050 and improve mobility performance of our district's transportation network.

Your continued participation is needed as the program now shifts from planning to implementation. Your support and collaboration with our District TSMO Champion Ugonna Ughanze, Director of Transportation Operations (DTO), and District TSMO Coordinator Valerie Taylor, Director of Transportation Management Systems (TMS), will be key to implement the Houston District TSMO Program Plan to address our specific Houston District transportation needs.

The Houston District has been a leader in using technology to deliver better customer service since the 1960s. In 2019, our TSMO activities saved motorists 19 million vehicle-hours of delay and 36 million gallons of fuel with a benefit/cost ratio of 22:1. There is a significant return on investment of TSMO activities. Example opportunities to incorporate additional TSMO oriented-strategies and performance measures include:

- ***Planning:*** Develop a data tactical plan to identify District data needs and sources (examples: existing, ConnectSmart, and/or third party generated data) to help prioritize investments and support functions across multiple District practices.
- ***Design:*** Identify prioritized deployments and District design preferences for intelligent transportation systems to help inform the design process.
- ***Maintenance and Construction:*** Use third-party traffic volume and speed data to improve situational awareness in maintenance and construction work zones.
- ***Operations:*** Develop and implement signal timing strategies for incidents, evacuations, and planned special events and enhance overall incident management capabilities.

For the program to be successful, active participation is needed from Houston District staff and we will be working with external partner agencies as we begin to implement the early actions from the TSMO Program Plan. Additional guidance on how you can contribute to the goals and objectives of the program will be shared as part of the upcoming rollout events scheduled for February 2021.

Questions or feedback about the Houston District's TSMO initiatives should be addressed to Ugonna Ughanze at (ugonna.ughanze@txdot.gov) or Valerie Taylor at (valerie.taylor@txdot.gov).

We look forward to your continued participation in this initiative. Please share information about the Houston District TSMO Program Plan with your state, regional, and local partners.

For more information:

TxDOT TSMO: www.txdot.gov/inside-txdot/division/traffic/tsmo.html

Houston District: https://www.txdot.gov/inside-txdot/district/houston.html

CC: Varuna A. Singh, P.E., Deputy District Engineer, Houston District

Document Control

Version	Date	Description of Change	Author
0.1	08/07/2020	Outline for review by Working Group	DKS Associates team
0.2	08/31/2020	Initial draft for TxDOT Project Manager review	DKS Associates team
0.3	09/04/2020	Revised draft for TxDOT Project Manager review with action items in document	DKS Associates team
0.4	11/13/2020	Revised draft for Working Group and expanded stakeholder review	DKS Associates team
0.5	02/05/2021	Incorporated Working Group review and internal quality control review	DKS Associates team
1.0	03/11/2021	Incorporated final TxDOT Project Manager comments	DKS Associates team

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List of Acronyms

Acronym	Definition
AASHTO	American Association of State Highway and Transportation Officials
AOE	Arterial Operations Engineer
ATDM	Active Transportation Demand Management
ATSPM	Automated Traffic Signal Performance Measure
AVI	Automatic Vehicle Identification
BMT	TxDOT Beaumont District
BP	Business Processes
BRY	TxDOT Bryan District
C2C	Center to Center
CAD	Computer-Aided Dispatch
CAT	Cooperative Automated Transportation
CAV	Connected and Autonomous Vehicles
CCTV	Closed-Circuit Television
CDL	Commercial Driver's License
CMF	Capability Maturity Framework
CMM	Capability Maturity Model
CO	Collaboration
COG	Council of Governments
CRIS	Crash Records Information System
CU	Culture
DDE	Deputy District Engineer
DE	District Engineer
DMS	Dynamic Message Sign
DOT	Department of Transportation
DPS	Department of Public Safety
DTO	Director of Transportation Operations
EOC	Emergency Operations Center
FHWA	Federal Highway Administration
FOE	Freeway Operations Engineer
FTE	Full Time Equivalent (referring to full-time staff position)
FWD	Flood Warning Detection
FY	Fiscal Year
HCRS	Highway Condition Reporting System

Acronym	Definition
HCTRA	Harris County Toll Road Authority
H-GAC	Houston-Galveston Area Council
HOT	High Occupancy Toll
HOU	TxDOT Houston District
HOV	High Occupancy Vehicle
HPD	Houston Police Department
HR	Human Resources
ICM	Integrated Corridor Management
ICS	Incident Command System
IMD	Information Management Division
IT	Information Technology
ITD	Information Technology Division
ITS	Intelligent Transportation System
IVHS	Intelligent Vehicle Highway System
JPO	Joint Program Office
KSA	Knowledge, Skills and Abilities
LFK	TxDOT Lufkin District
MAP	Motorist Assistance Program
METRO	Metropolitan Transit Authority of Harris County
MPO	Metropolitan Planning Organization
MVDS	Microwave Vehicle Detection System
NHS	National Highway System
NOCoE	National Operations Center of Excellence
NWS	National Weather Service
O&M	Operations & Maintenance
OVDS	Overheight Vehicle Detection System
OW	Organization and Workforce
PE	Professional Engineer
PIO	Public Involvement Office
PM	Performance Measurement
PS&E	Plans, Specifications & Estimates
PTOE	Professional Transportation Operations Engineer
RIMS	Regional Incident Management System
ROI	Return on Investment
RWIS	Roadway Weather Information System

Acronym	Definition
SHRP	Strategic Highway Research Program
Small Cell	Small Cellular Tower
SMART	Specific, Measurable, Agreed Upon, Realistic, and Time Bound
SOP	Standard Operating Procedure
SPaT	Signal Phasing and Timing
SPSS	Statistical Package for Social Sciences
ST	Systems and Technology
TAMS	TranStar ITS Asset Management System
TBD	To Be Determined
TexITE	Texas District of the Institute of Transportation Engineers
TIM	Traffic Incident Management
TIP	Transportation Improvement Program
TMC	Transportation Management Center
TMP	Traffic Management Plan
TMS	Traffic Management System
TNC	Transportation Network Company
TP&D	Transportation Planning and Development
TPP	Transportation Planning and Programming
TRF	Traffic Division (Central Office)
TSMO	Transportation Systems Management and Operations
TTI	Texas A&M Transportation Institute
TxDOT	Texas Department of Transportation
US DOT	United States Department of Transportation
UTP	Unified Transportation Program
V2I	Vehicle-to-Infrastructure
WWD	Wrong Way Detection
WZDx	Work Zone Data Exchange
YKM	TxDOT Yoakum District

Executive Summary

For more than 25 years, the TxDOT Houston District has been a leader in using technology and coordinated management and operations strategies to deliver better transportation customer service for the Houston region. The Houston District Transportation Systems Management and Operations (TSMO) Program Plan (TSMO Plan) documents the district's TSMO strategic vision, goals, current processes, and recommended actions. The purpose of the plan is to implement data-driven decisions to make the transportation network safer, more efficient, and more reliable over the next four years.

WHAT IS TSMO?

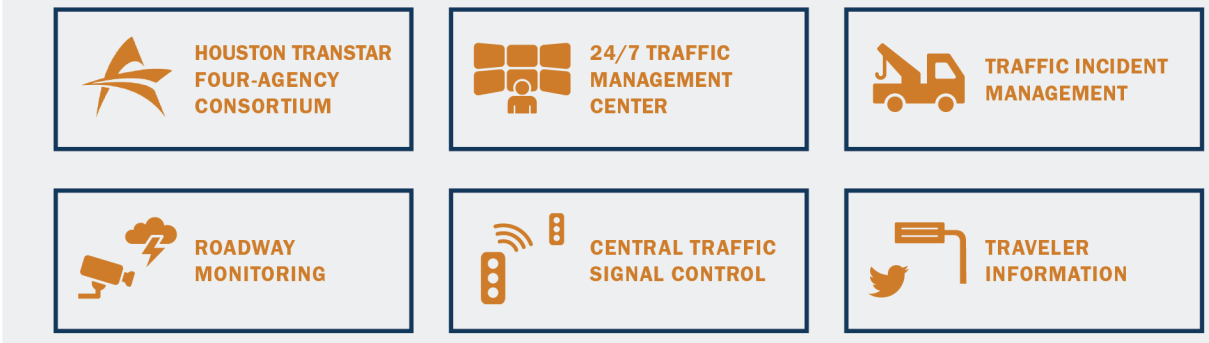
TSMO is "an integrated set of strategies to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services, and projects designed to preserve capacity and improve security, safety, and reliability of the transportation system." (United States Department of Transportation)

The TSMO Plan includes recommendations to improve workforce development, business practices, systems and technology, collaboration, culture, and performance measurement to continue to support, streamline, and institutionalize TSMO projects and practices.

This Executive Summary highlights:

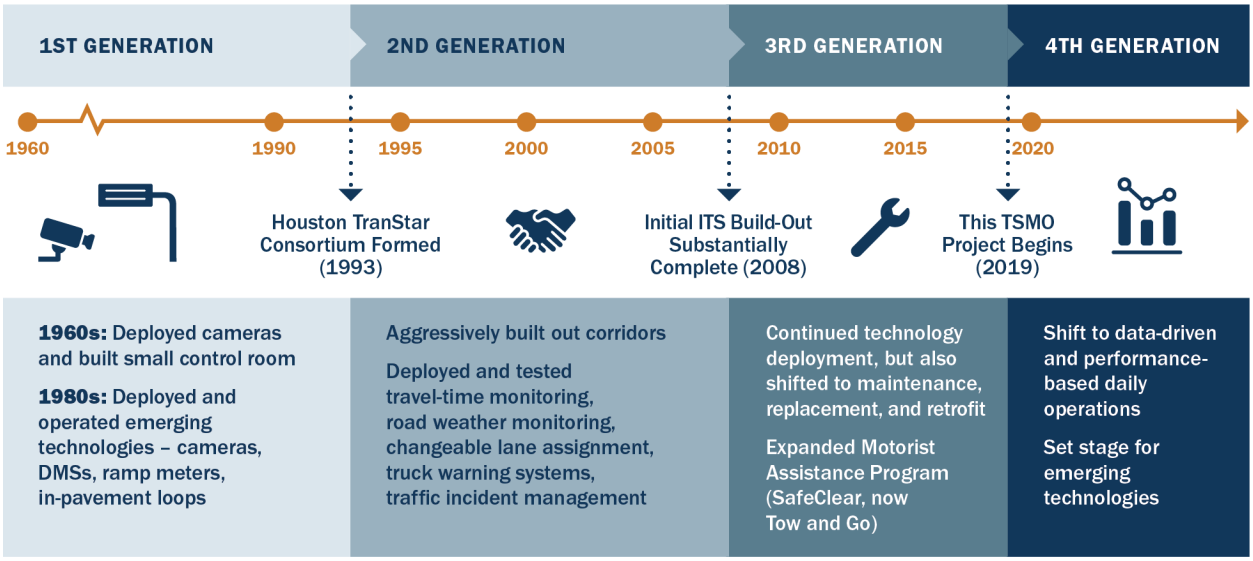
- Example TSMO strategies in use
- TSMO timeline of the Houston region
- TSMO benefits
- TSMO vision, mission, and goals
- Proposed early action items
- Project life cycle revisions to enhance TSMO
- Plan update process

EXAMPLES OF TSMO STRATEGIES CURRENTLY IN USE



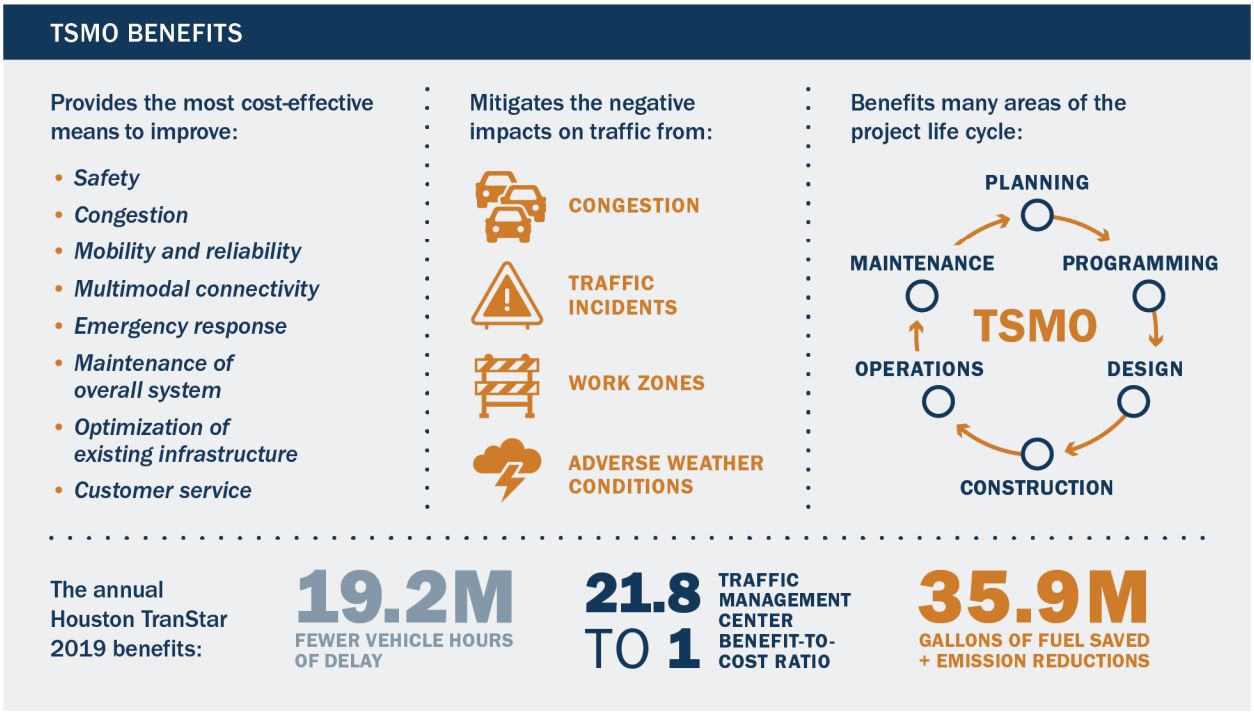
TSMO Timeline

Although the TSMO acronym may be new to some staff, the Houston District has been a leader in transportation systems management and operations since the 1960s.



TSMO Benefits

The Houston TranStar consortium includes the TxDOT Houston District, City of Houston, Harris County, and METRO. Together, they demonstrate daily implementation of coordinated TSMO strategies with numerous benefits reported annually (Houston TranStar, 2020).



TSMO Vision, Mission, and Goals

The Houston District's TSMO vision, mission, and goals support those of TxDOT's statewide TSMO program, the Houston TranStar consortium, and the Houston-Galveston Area Council's (H-GAC's) regional TSMO program. For each goal, targeted objectives, many of them measurable, are included in the main body of the report.

HOUSTON DISTRICT TSMO VISION

Provide safety and mobility for all modes of travel by:

1) Integrating planning, design, construction, operations, and maintenance activities
2) Promoting opportunities for innovation
3) Cooperating with regional transportation and emergency management partners to proactively manage planned and unplanned events

HOUSTON DISTRICT TSMO MISSION

Deliver safe and cost-effective transportation facilities to move people and goods in the region through collaboration, innovation, and data-driven decision-making.

HOUSTON DISTRICT TSMO GOALS AIM TO IMPROVE:

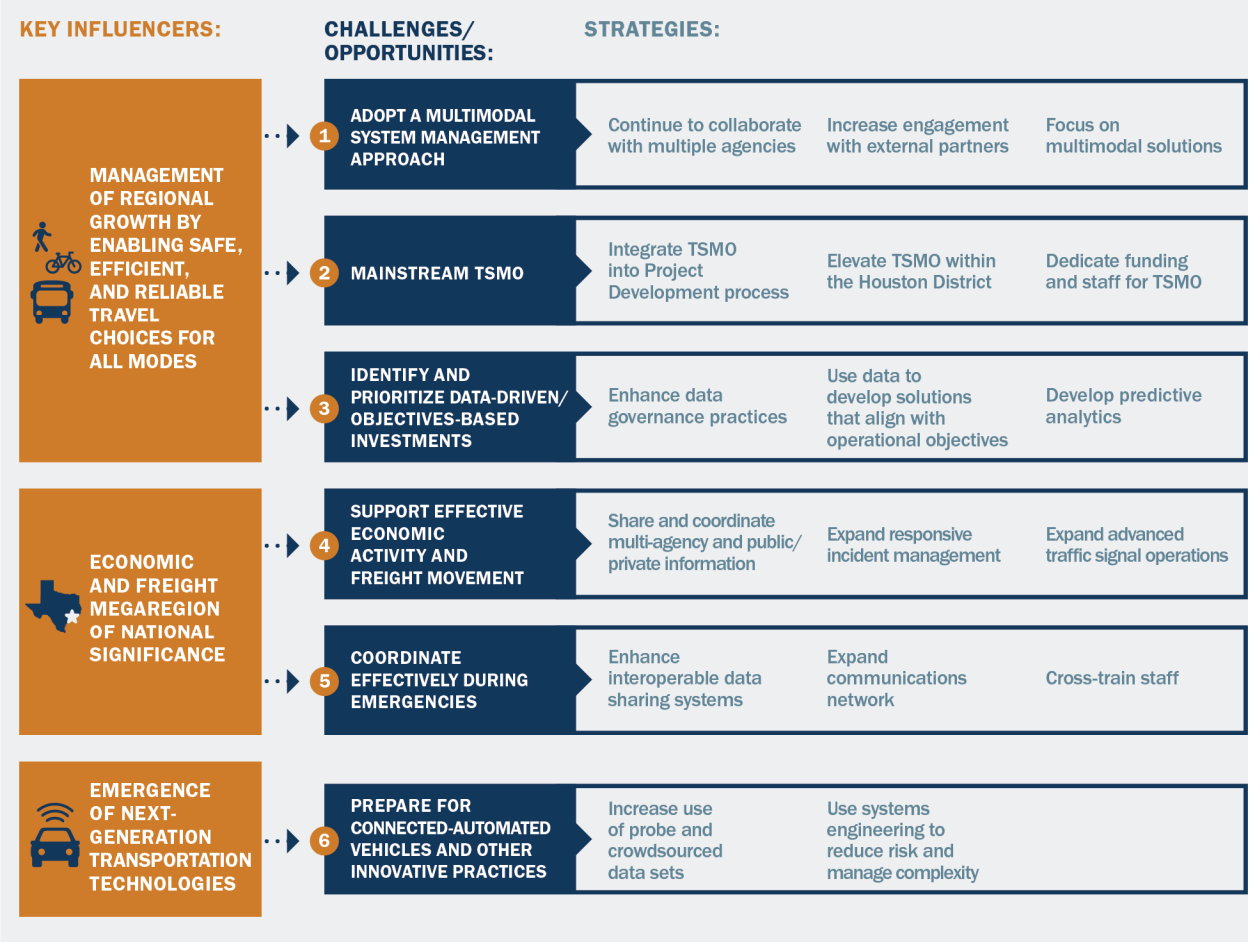
- SAFETY
- RELIABILITY
- EFFICIENCY
- CUSTOMER SERVICE
- COLLABORATION
- EMERGENCY PLANNING
- FINANCIAL RESOURCES
- TRAFFIC INCIDENT MANAGEMENT
- TECHNOLOGY & INNOVATION
- INTEGRATION

BY TAKING ACTION IN THESE AREAS:

- BUSINESS PROCESSES
- SYSTEMS & TECHNOLOGY
- PERFORMANCE MEASUREMENT
- ORGANIZATION & WORKFORCE
- CULTURE
- COLLABORATION

The Business Case for TSMO

The Houston District has successfully used TSMO strategies for decades to mitigate the fast population growth in the region. The strategies in this TSMO plan are aimed at the current key influencers shown below.



Proposed Early Actions

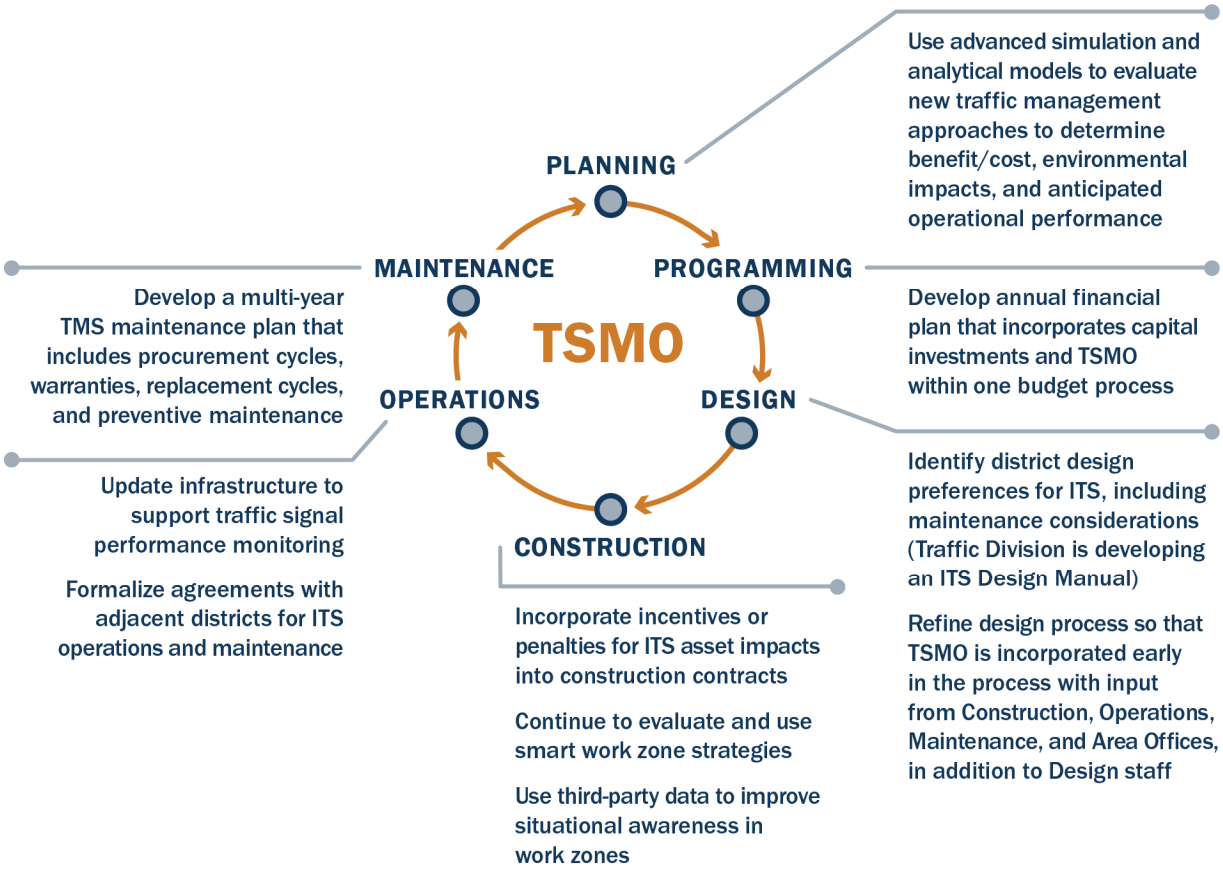
The TSMO Implementation Plan section includes action items for the next four years. Action items identified for implementation by the Houston District within the next 12 to 18 months:

	Business Processes (BP)
BP-01	Develop an annual financial plan that incorporates capital investments and TSMO within one budget process.
BP-02	Develop a multi-year Traffic Management System (TMS) maintenance plan that includes procurement cycles, warranties, replacement cycles, and preventive maintenance.
BP-03	Develop standards or guidelines for signal operations (flashing yellow arrow use, coordination thresholds, railroad timings, etc.)
BP-04	Develop and implement evacuation/incident/special event signal timing strategies.
BP-05	Develop a Houston District Intelligent Transportation System (ITS) Master Plan. Identify where to fill gaps in current TMS infrastructure coverage to support funding decisions and project development processes.
	Systems and Technology (ST)
ST-01	Use third-party data in Lonestar™ to improve situational awareness in construction work zones and to populate DMS messages. A pilot project is underway. Consider phased rollout based on performance of pilot project.
ST-03	Evaluate interoperability to expand data sharing beyond Houston TranStar partnership agencies. While many agencies receive TxDOT data, TxDOT could benefit from gathering data from other agencies. Next steps: * Update list of TxDOT data-sharing agreements. * Use H-GAC TSMO Subcommittee as conduit to start conversations.
	Performance Measurement (PM)
PM-01	Evaluate additional options for Houston TranStar data consumption (e.g., crowdsourcing data, third-party data). Identify opportunities for acquiring data from external sources such as other partner agencies and the private sector and establish data-sharing agreements.
PM-12	Develop Data Tactical Plan. Elements to consider: * literature review of state of the practice, * district data needs, * phased implementation effort.
	Organization and Workforce (OW)
OW-05	Develop staff retention plan for maintenance positions requiring a commercial driver's license (CDL).
	Collaboration (CO)
CO-01	Enhance existing data sharing agreement process to make it easier to execute future data sharing agreements with TxDOT.

In addition to the Houston TranStar consortium, the Houston District is also working with regional partners to advance TSMO through the Houston-Galveston Area Council (H-GAC) TSMO Subcommittee and Traffic Incident Management (TIM) Committee. A timeline has not been set but H-GAC is planning to lead the development of a regional ITS plan.

Project Life Cycle Revisions to Enhance TSMO

The following revisions have been identified to enhance the use of TSMO strategies throughout the project life cycle from start to finish and with a feedback loop between activities:

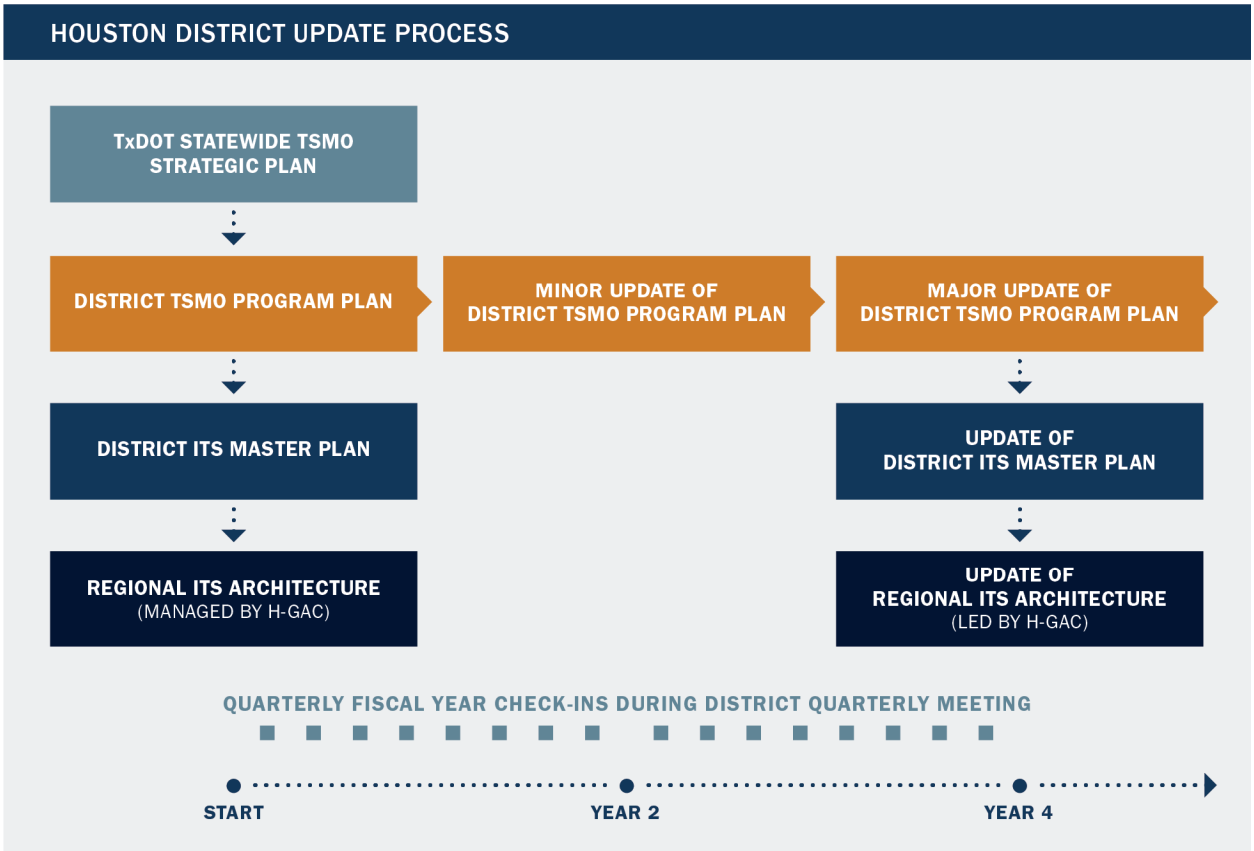


ALL STEPS

- Hire additional FTEs
- Identify or create training courses/seminars that focus on critical aspects of all TSMO functions
- Contract support (research engineers, professional services)
- Measure performance to evaluate how well the TSMO action items are meeting the TSMO Plan objectives
- Develop staff retention plan (e.g., TSMO support positions, ITS and signal technicians, maintenance positions requiring a commercial driver's license)

The Update Process

The Houston District plans to review TSMO action item implementation status on a quarterly basis during the District Quarterly Meeting, which includes directors and supervisors throughout the district, and to update the entire plan on a four-year cycle.



Introduction

The Houston District Transportation System Management and Operations Plan (Houston TSMO Plan) prioritizes reliable strategies for operations and management of transportation infrastructure so that it can be used at its full potential. The Houston TSMO Plan supports the TxDOT TSMO Statewide Strategic Plan (TxDOT, 2018) by providing a focused, district-level approach. TSMO strategies, including traffic incident management, traveler information, work zone management, and freight management, help transportation engineers and planners proactively manage the system in real time and improve system efficiency. As such, they are key tools to address increasing congestion and limited funding.

The Houston TSMO Plan includes recommendations to improve various process and institutional dimensions within the district:

- Business processes
- Systems and technology
- Performance measurement
- Culture
- Organization and workforce
- Collaboration (both internal and external)

These improvements will support, streamline, and institutionalize TSMO projects and practices across the district and with external stakeholders. Implementing the Houston TSMO Plan will improve project delivery processes by integrating mobility-focused solutions throughout planning, programming, design, construction, operations, and maintenance phases of project life cycles. By continuing collaboration with external stakeholders and implementing processes that support data-driven decisions, the movement of people and goods will be safer, more efficient, and more reliable.

Program Plan Format

Key components of the Houston TSMO Plan:

- An introduction to TSMO and a description of the Houston District boundaries and key stakeholders
- The business case for why TSMO is needed in the Houston District
- The Houston District TSMO mission, vision, goals, and objectives developed to support district, TxDOT Statewide, Houston TranStar, and Houston-Galveston Area Council regional TSMO programs
- A discussion of the six dimensions of the capability maturity model (CMM) with discussion of the successes and challenges of function areas identified in each of the six dimensions
- A TSMO Implementation Plan, which includes a list of action items with a description of timeline, lead Houston District staff, resources, and partners (e.g., Houston TranStar, adjacent districts, the TxDOT Traffic Division (TRF), external agencies) required for implementation; a maintenance plan is also included for continuous implementation and improvement between plan updates
- Recommendations for the development of tactical plans in multiple functional areas of the district, including data sharing with partner agencies, use of third-party data, and enhanced data for real-time situational awareness

Why Develop a TSMO Program Plan?

Traditionally in many transportation agencies, roadway capacity expansion has been the primary tool for managing transportation congestion and operations. However, facilities in the Houston District have long been capacity-restrained. As a result, capacity expansion cannot solely be relied upon to address the needs of the modern transportation system. Other fundamental issues that argue for TSMO-based solutions rather than capacity expansion are:

- **Induced travel demand**, which can overwhelm new capacity projects even before completion
- **Limited funding,** which often requires departments to choose between maintaining the system or adding more capacity
- **Expanding capabilities of technology**, which can be leveraged to address future mobility needs; including connected and automated vehicles, traveler information, system maintenance, crash mitigation, and other safety improvements

TSMO PROGRAM BENEFITS

"TSMO programs incorporate skills and capabilities of project delivery with effective systems management, traffic operations, technological innovations, and other activities that improve travel safety and reliability, enhance traveler information and user experience, and maximize the agency's return on capital investments."
(Federal Highway Administration, 2017)

Implementing a TSMO program plan encourages the Houston District and its partners to evaluate a broad range of options to solve safety, mobility, and reliability challenges.

The Houston TSMO Plan supports district Traffic Management Systems performance measures, a priority identified by TxDOT's Chief Engineer. Initial metrics identified include TMS asset operational uptime, incident clearance times, level of travel time reliability, and geographic coverage. The Chief Engineer's memos are included in the appendix of the TxDOT TSMO Statewide Strategic Plan (TxDOT, 2018).

History of TSMO in the Houston Region

Many of the strategies that comprise a modern TSMO Plan were either initially developed or refined in Houston. But while IVHS (Intelligent Vehicle/Highway System) and ITS (Intelligent Transportation System) were acronyms that defined generations of deployment of technology to the roadway, TSMO is the term now used to describe a wide-ranging program of strategies, projects, and services to plan, manage, and operate integrated and coordinated transportation networks for optimal system performance. As illustrated in Figure 1, the Houston District has been doing TSMO well before the coinage of the term.

The district's efforts to optimize the use of highway capacity predate the current TSMO frameworks, beginning in the Houston region in the 1960s, with a small control room in the "old annex" building on Katy Road and a few cameras set up on the Gulf Freeway (I-45) to monitor traffic flow. As the Houston region struggled with boom-and-bust cycles in the 1980s, and as technology emerged to enable more widespread traffic management capability, the Houston District aggressively deployed closed-circuit television (CCTV) cameras, in-pavement loops, ramp meters, and dynamic message signs (DMS) to help manage traffic. Key political and agency management stakeholders, recognizing the potential for multi-agency coordination in the areas of transportation and emergency management, ultimately delivered Houston TranStar that partnered the TxDOT Houston District, Metropolitan Transit Authority of Harris County (METRO), Harris County, and the City of Houston in the mid-1990s.

The physical construction of the Houston TranStar facility in 1993 was the springboard for 15 years of ongoing ITS deployment, development, and testing of many technologies that are currently in use around the country: probe-based travel-time monitoring, roadway weather monitoring systems, changeable lane assignment, direct connector truck warning systems, and coordinated traffic incident management, among others. Many of these systems were funded, deployed, and tested under the Federal Highway Administration's (FHWA's) Intelligent Transportation System Priority Corridor Program — a series of 28 projects implemented cooperatively by all four agencies at Houston TranStar at a cumulative cost of $43 million. Significant local funding contributed to these programs as well.

Once the Houston District ITS infrastructure was largely built-out by the mid- to late-2000s, the focus shifted to maintenance, replacement, and retrofit of those "first-generation" systems. The district and partner agencies continued technology deployment, evaluation, and testing. This was at mildly slower pace limited by traditional federal, state, and local funding priorities. With a mature ITS network in place, the district's and partner agencies' focus shifted to management of the roadway system, particularly in the traffic incident management arena, with expansion of the Motorist Assistance Program (MAP), creating the SafeClear free towing program (now replaced by the Tow-and-Go program), with recent expansion of Tow-and-Go into greater Harris County.

The evolution of ITS in Houston can be broadly defined into three generations: 1) Pre-Houston TranStar (pre-1993); 2) Houston TranStar/ITS Expansion (1993 to 2008); and 3) Consolidation and Operation (2008 to date). This TSMO Plan offers the opportunity to define a fourth generation of ITS, one that:

1) Infuses operations into and across the district's planning and project development processes
2) Leads to a more collaborative, data-driven, and performance-based daily operation
3) Sets the stage for addressing emerging technologies (connected and automated vehicles, third-party data advances, and others) that have the potential to transform mobility

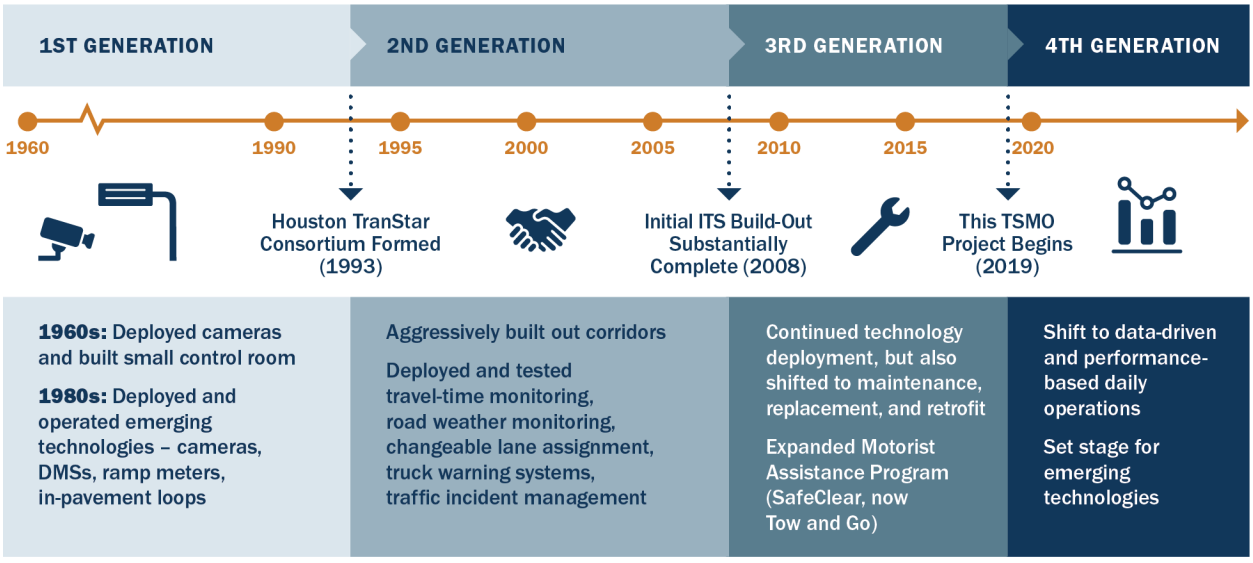


FIGURE 1: HOUSTON DISTRICT TSMO TIMELINE

In the Houston District, TSMO has been focused on the Operations Section, but programmatic TSMO now encourages increased efficiency and collaboration through a system-level and districtwide view – spanning planning, design, construction, operations, and maintenance as well.

Current Houston District TSMO State of the Practice

The TxDOT Houston District is responsible for planning, programming, design, construction, operations, and maintenance of transportation and other related projects within the district. Within each of these areas, the district is already applying TSMO tools at varying levels and consistency.

Current TSMO districtwide activities and TSMO-related transportation planning and development (TP&D), construction, and operations activities are summarized in Table 1. Additional details and supporting documents are provided in the Houston District State of the Practice Report (TxDOT Houston District, 2020). The current TSMO activities were reviewed as part of the Capability Maturity Model, described later in this Plan.

TABLE 1. HOUSTON DISTRICT TSMO CURRENT STATE OF THE PRACTICE

Group	TSMO Activity
Districtwide	▪ District developed a Safety Plan to support the statewide "Road to Zero" initiative to reduce fatalities on state highways by half by 2035 and to zero by 2050 (TxDOT Houston District, 2020) ▪ Robust traveler information program through the District's Public Information Office (PIO), HoustonTranStar.org, DriveTexas.org and the upcoming ConnectSmart app (Metropia, 2019); Information is fed to DriveTexas.org through input in TxDOT's Highway Conditions Reporting System (HCRS) ▪ Districtwide transportation and emergency management activities through Houston TranStar ▪ Houston District collaborates with local jurisdictions including cities, counties, transit, and other agencies during planning, design, construction, operations, and maintenance efforts
TP&D	▪ Permanent ITS devices and systems to support TSMO strategies are included during project planning and programming phases ▪ Travelshed planning to look at subregions or "complete corridors" to evaluate multimodal, emerging technology, and various demand impacts on travel throughout the travelshed ▪ District uses H-GAC's macroscopic travel demand model as well as mesoscopic and microscopic models in various analyses ▪ Applies access management requiring compliance with TxDOT's Access Management Manual guidelines ▪ Preparing to deploy ConnectSmart, a technology and mobility platform with a built-in mobile app that will integrate TSMO and active demand management strategies with multimodal demand and mobility management ▪ District Operations section has a dedicated ITS design section that develops in-house plans, specifications, and estimates (PS&E) in addition to using consultants for ITS design; They coordinate with the TP&D's Design section ▪ Exploring connected and autonomous vehicles (CAV) technologies along freeway managed lanes
Construction	▪ Statewide tools used to determine use of law enforcement and posted speed limit reduction in construction zones ▪ Statewide decision tool used to identify Smart Work Zone applications- several pilot projects are underway now in both urban and suburban work zones

Group	TSMO Activity
	▪ Alternate procurement methods to increase flexibility for including TSMO strategies in construction projects ▪ Robust construction training provided for Area Offices and inspectors ▪ Plans to implement statewide annual performance review for contractors based on state legislation when available
Maintenance	▪ TranStar Asset Management System (TAMS) tracks device issues and asset uptime, generates work orders and assigns calls to maintenance staff ▪ Regional fiber and video sharing agreements in place with partner agencies ▪ Uses three ITS maintenance contracts for preventive and reactive maintenance of ITS devices and fiber networks ▪ CCTV cameras used for visual diagnosis and decision making before responding to a call on site ▪ Plan to increase maintenance and operations workforce at Houston TranStar ▪ Traffic signal preventive maintenance performed every two years or more frequently
Operations	▪ District staff active in Houston TranStar's Traffic Incident Management Team ▪ District supports multi-agency operations for special events ▪ Flood warning systems deployed at key low-water crossings ▪ Collaboration with METRO and Harris County Toll Road Authority (HCTRA) on accommodating transit and managed lane operations ▪ Use of over-height detection systems to reduce bridge hit rates ▪ Concept of operations developed to deploy Active Traffic Management System (ATMS) strategies on I-69 (TxDOT, 2017) ▪ Use of freeway adaptive systems, central signal management systems (Centracs and TACTICS), and adaptive signal control for traffic signal coordination ▪ Efforts underway to broadcast Signal Phase and Timing (SPaT) data at 90 intersections ▪ More than 60 ramp meters on freeways ▪ Addressing traffic operations and safety issues by deploying technology to improve pedestrian safety and to mitigate wrong way driving and run-off-the-road crashes ▪ Tracking system and device uptime through Houston TranStar operational systems

Houston District Boundaries

The TxDOT Houston District is shown in Figure 2, and includes six counties. Figure 2 highlights the seven Area Offices as well as the five ports within the district. All six counties in the Houston District fall within the Houston-Galveston Area Council, which encompasses a larger 13-county region.

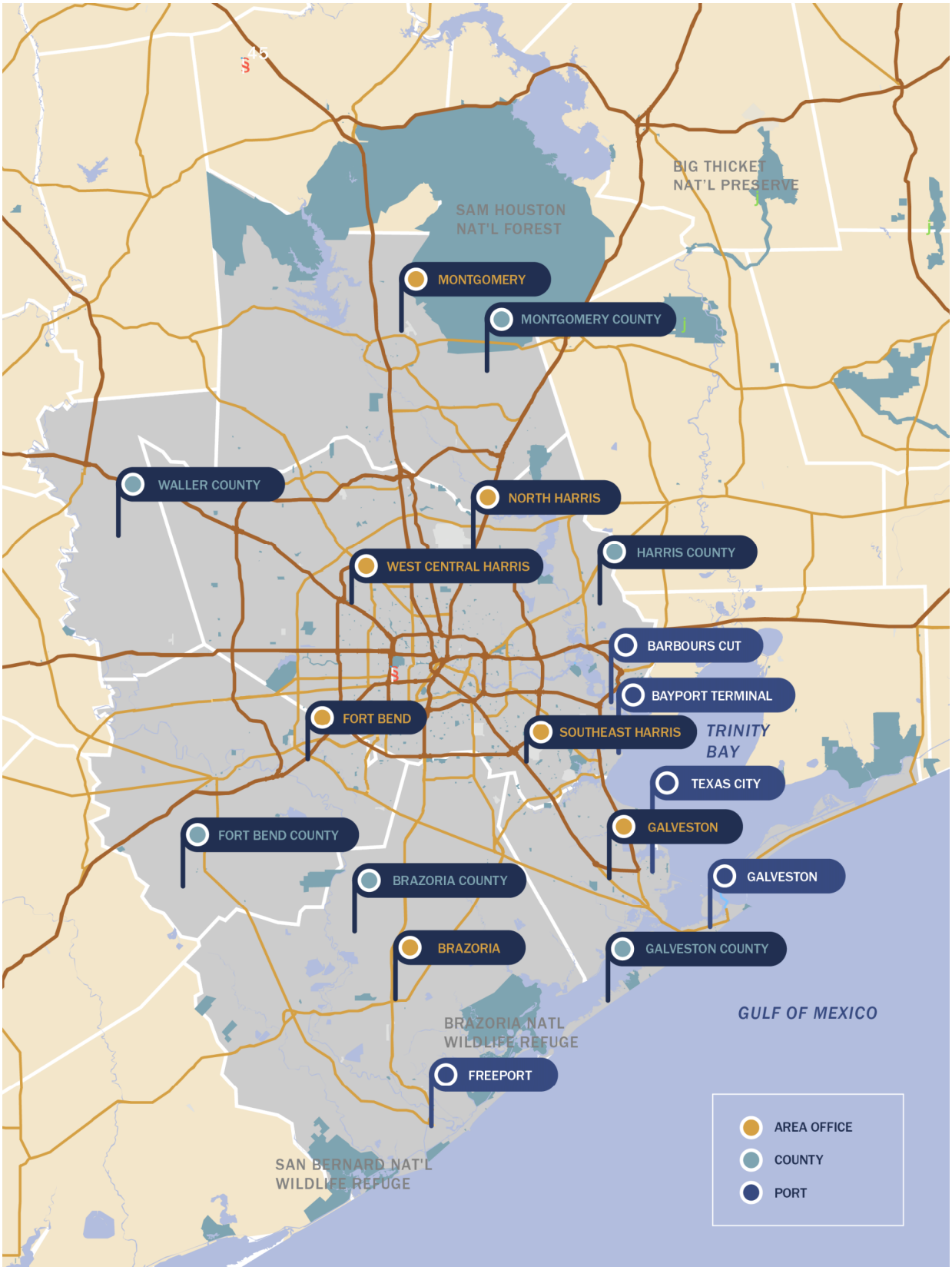


FIGURE 2. HOUSTON DISTRICT AREA MAP

Stakeholder Involvement

Stakeholders from each practice area within the Houston District participated in a Working Group to develop the Houston TSMO Plan through a series of meetings, workshops, and phone calls between October 2019 and December 2020.

The workshops included participation with numerous external stakeholders from area cities, counties, ports, and law enforcement agencies. The stakeholder process is shown in Figure 3 and stakeholders are acknowledged in Appendix A.

FIGURE 3. STAKEHOLDER OUTREACH PROCESS

Houston TranStar Partnership

Representatives from the TxDOT Houston District, Harris County, City of Houston, and METRO have a 28-year partnership through the Houston TranStar consortium to share resources and information to operate and manage the region's transportation system. There are three tiers of leadership at Houston TranStar. The three tiers with respect to TxDOT participation include:

1. **Executive Committee** – TxDOT Houston District Engineer
2. **Leadership Team** – TxDOT Houston Director of Transportation Operations
3. **Agency Manager** – TxDOT Director and Assistant Director of Transportation Management Systems and TxDOT Freeway Operations Supervisor

Business Case for TSMO in the Houston District

For decades, the Houston region has been one of the fastest growing areas of Texas and of the United States. Building new highway capacity has not been enough to keep up with travel demand of people and goods in the area. For this reason, the district has employed numerous strategies, often collaboratively with partner agencies, to address regional transportation needs. While the district has certainly expanded highway capacity in the last 30 years, it has also employed a robust set of programs to make the most effective use of capacity by using strategies to directly address recurring and nonrecurring congestion.

Figure 4 summarizes the business case for TSMO in the Houston District, highlighting the key influencers in the district, challenges and/or opportunities resulting from these influencers, and relevant TSMO strategies to address them. The paragraphs that follow provide additional discussion about the business case.

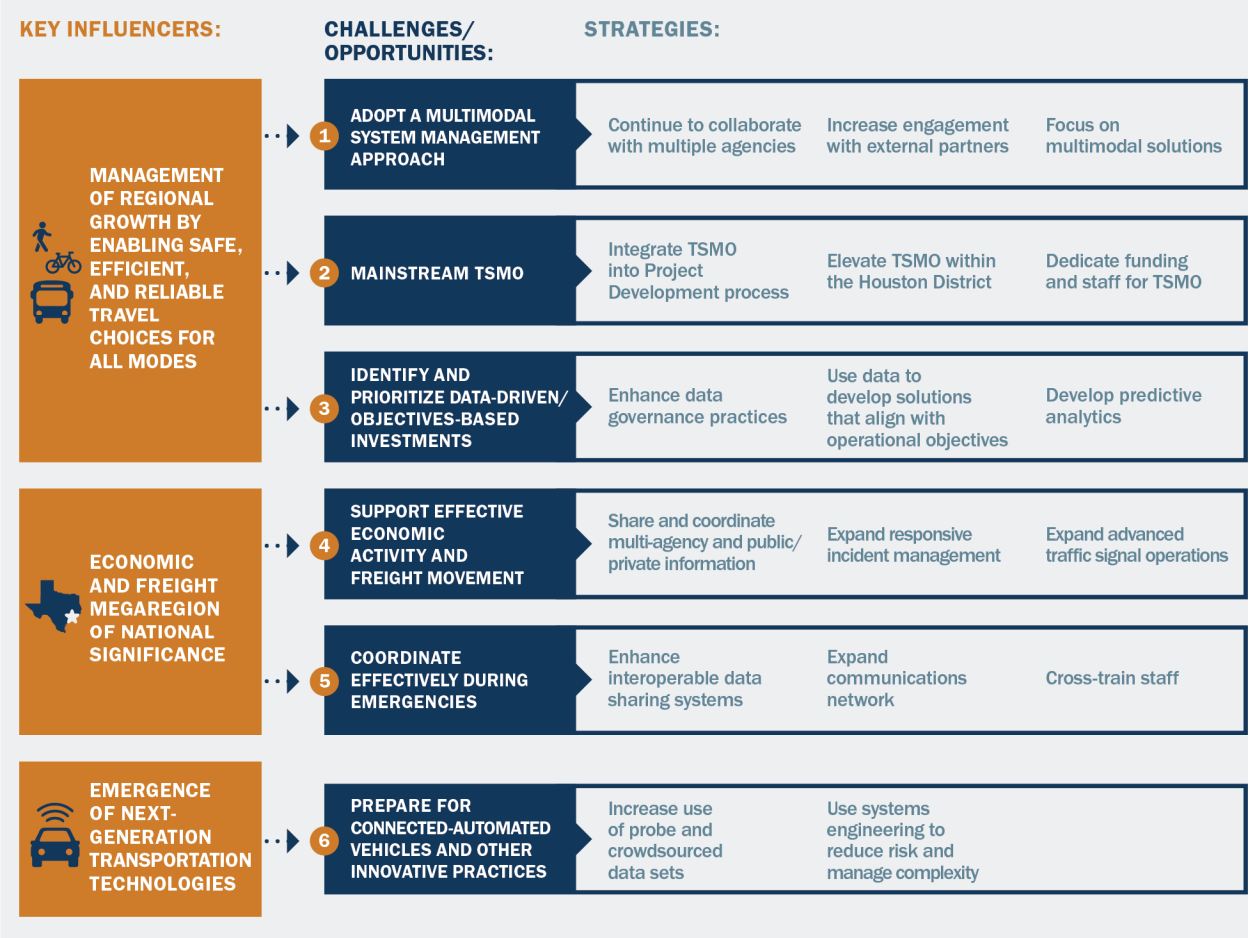


FIGURE 4. HOUSTON DISTRICT BUSINESS CASE FOR TSMO — KEY INFLUENCERS, CHALLENGES/OPPORTUNITIES, AND STRATEGIES

Why TSMO?

Through practice area meetings with district staff and larger Working Groups and individual interviews with key staff and stakeholders, participants identified various issues that a TSMO Plan could help address. Common themes include:

- The Operations section does provide enough early input into the project development process, which would benefit from earlier consideration of unique ITS operations and maintenance aspects of some projects.
- The district needs a Master ITS Plan that can be referenced by other practice areas. A need for an ITS design manual was also identified; The Traffic Safety Division is currently developing one for statewide use.
- Maintenance of ITS devices and fiber optic communications during construction has been a major ongoing challenge, posing operational difficulties and customer service disruptions when assets are offline.
- Additional dedicated resources (staff retention, additional staff, training, funding stream, etc.) are needed to continue the advancement of TSMO.

In addition to the functional justifications to implement TSMO strategies, the July 1, 2016 and April 7, 2017 memoranda from Chief Engineer Bill Hale provided clear directives, specifically that:

- Traffic management systems should be included in new construction, and
- TMS should provide for incident and work zone management, traveler information, and other strategies to improve traffic flow, including traffic signal integration, Integrated Corridor Management (ICM) operations, and Active Transportation Demand Management (ATDM).

Both memoranda encouraged the adoption of TSMO concepts from TxDOT Administration in Austin, directed the regular implementation of TSMO strategies, and established regular progress review of TMS and TSMO strategy implementation. In support of these directives, several TMS and TSMO performance metrics are already included in the District Engineer's (DE's) performance reviews. These metrics are discussed in the Performance Measurement section.

How will TSMO Benefit the Houston District?

While TSMO can be complementary to traditional capacity expansion (e.g., added lanes) projects, TSMO strategies can also be implemented as stand-alone projects. TSMO can be used to stretch the time needed to implement added-capacity projects when funding is constrained and other priorities dominate. TSMO strategies applied to both new and existing facilities can improve throughput with marginal increases in cost, relative to other potential capacity expansion. However, TSMO strategies require a dedication to operations functions and in many cases require additional staff and funding to be effective. Finally, if it is observed that congestion continues to increase even as TSMO strategies are implemented, stakeholders can more easily justify added-capacity projects that provide additional throughput.

What High-Level Changes are Needed with this Plan?

Effective deployment of TSMO strategies requires some change to existing business activities and technical processes in the Houston District. The successful development and execution of TSMO strategies is dependent on institutional process changes, added staff capabilities, and an organizational structure that recognizes the

adjustments needed. TSMO will be most successful when, along with increased funding, TSMO and operations are elevated to the program level — alongside planning, programming design, construction, operations, and maintenance —and are considered in each step of the project life cycle. The Houston District has traditionally considered operations as a key function, but mainstreaming TSMO relies on committing to significant changes:

- Clearly demonstrating leadership (District Engineer & Deputy District Engineer) commitment regarding TSMO importance, mission, and resources
- Incorporating data-driven operational performance measurements in districtwide processes and decision-making
- Providing consistent and predictable funding, staff resources, and training to sustain a TSMO program
- Developing projects that incorporate TSMO applications and processes
- Identifying TSMO strategies in use that are effective in mitigating recurring and non-recurring incidents, and leveraging those strategies in the project life cycle across planning, programming, design, construction, operations, and maintenance sections of the district
- Increasing utilization of systems engineering to reduce risk
- Implementing state-of-the-art proven technologies to solve complex problems
- Increasing cross-cutting staff training on TSMO systems, procedures, and multi-agency collaboration
- Increasing engagement with partner agencies and key stakeholders in the region to solve multi-disciplinary, multimodal, mobility issues

There are demonstrated benefits to implementing TSMO strategies. The TxDOT Houston District functions at Houston TranStar (ITS deployment, roadway monitoring, traveler information, and incident management) have consistently shown benefit/cost ratios of more than 15 to 1 for many years and grown to more than 20 to 1 the past two years (Houston TranStar, 2020). Implementing changes to the project development process will enhance the ability to deploy TSMO strategies. The changes identified in the CMM and capability maturity framework (CMF) workshops are important to address and consider in the plan. "Low hanging fruit" actions were identified that have existing leadership support and are fairly easy to implement.

Note that institutional commitment to TSMO — including reorganization, staffing, and changes in processes to accommodate TSMO — are outside the control of the Operations section staff who manage the TSMO functions. Implementing these changes will require the District Engineer's and Deputy District Engineer's support and authorization. There will need to be high-level direction to all staff that the changes needed to deploy and implement TSMO strategies are important and that those strategies should cut across all sections of the Houston District.

Expected Benefits of TSMO

The changes described above can provide measurable benefits to the Houston District. Internally, the benefits of implementing TSMO can be measured by obvious key performance indicators, such as an increase in the quantity of incidents managed, an increase in number of ITS devices deployed, and an increase in centerline miles of coverage. These measures can be normalized to staffing levels as the system is expanded or enhanced. Some outcome-focused measures of improvement may include reduced recurring and non-recurring congestion, reduced crashes, and improved response times to traffic incidents. Other, less obvious measures of improvement include:

- Increasing workplace satisfaction and staff retention
- Improved coordination across sections to minimize staff overlap, address experience gaps, and to clarify responsibilities
- Formalization of partnership agreements to support cooperative objectives
- Realization of positive traveler feedback regarding improved services, through user surveys and at public meetings

TSMO Vision, Mission, Goals, and Objectives

The Houston District supports:

- TxDOT's statewide TSMO vision, mission, goals, and objectives (TxDOT, 2018)
- Houston TranStar consortium's mission, vision, and goals (Houston TranStar, 2019)
- H-GAC's regional TSMO vision, mission, goals, and objectives (H-GAC, 2018)

District-specific vision and mission statements as well as goals and objectives were developed to merge this support of statewide, Houston TranStar, and H-GAC TSMO programs as described in this section. While the district TSMO vision and mission statements are newly formulated, they capture the district's TSMO program purpose and shared intention and direction for TSMO that the district has been following for several decades.

Table 2 describes the Houston District's 10 goals and supporting objectives to continue to deliver the district's TSMO vision and mission. The Houston District included each of the six statewide TSMO goals (safety, reliability, efficiency, customer service, collaboration, and integration) and added four additional goals (emergency planning, financial resources, traffic incident management, and technology and innovation) for alignment with Houston TranStar's and H-GAC's goals. A strategic objective is identified for each goal along with program objectives to support ongoing monitoring of the effectiveness of TSMO implementation in the Houston District. SMART (Specific, Measurable, Agreed Upon, Realistic, and Timebound) objectives have been set where baseline data is available to track performance. Other objectives are aspirational and should be revisited with future TSMO Plan updates once the district has established more performance metrics and data sources.

TABLE 2. HOUSTON DISTRICT TSMO GOALS AND OBJECTIVES

TSMO Goal	Strategic Objectives	Houston District TSMO Program Objectives
Safety	Reduce crashes and fatalities through continuous improvement of traffic management systems and procedures.	▪ Reduce 5-year rolling average crash fatalities by half by 2035 ▪ Reduce crash fatalities to approach zero by 2050 ▪ Reduce crash serious injuries (both incapacitating and non-incapacitating) ▪ Reduce work zone crashes
Reliability	Optimize travel time reliability on transportation systems in critical corridors to ensure travelers are reaching their destinations in the amount of time they expected for the journey.	▪ Increase percent of person-miles traveled on the Interstate system that are reliable ▪ Increase percent of person-miles traveled on the non-Interstate national highway system (NHS) that are reliable ▪ Provide traveler information to influence when, where, how, and how much travel occurs (travel demand management)
Efficiency	Implement projects that optimize existing transportation system capacity and vehicular throughput.	▪ Reduce system bottlenecks ▪ Increase Motorist Assistance Program (MAP) vehicle deployment by corridor and by time of day
Customer Service	Provide timely and accurate travel information to customers so they can make informed mobility decisions.	▪ Increase user satisfaction with Houston TranStar website/mobile application ▪ Create a traveler information roadmap for improvements ▪ Increase third-party partnerships for enhancing traveler information services ▪ Identify opportunities to use ConnectSmart data and analytics to enhance traveler information capabilities

TSMO Goal	Strategic Objectives	Houston District TSMO Program Objectives
Collaboration 	Proactively manage and operate an integrated transportation system through multi-jurisdictional coordination, internal collaboration, and cooperation between various transportation disciplines and partner agencies.	▪ Meet once per fiscal year quarter with district representatives from the core practice areas and the Area Offices to review TSMO implementation status ▪ Achieve 100% participation in Traffic Incident Management Team meetings ▪ Seek out regular input on TxDOT systems/functions that can be cooperatively used by partner agencies ▪ Seek out opportunities to enhance TxDOT TSMO operations with other partner agency data (e.g., live connections to Houston Police Department (HPD)/911 Computer-Aided Dispatch (CAD) system)
Integration 	Prioritize TSMO as a core objective in the district's planning, design, construction, operations, and maintenance activities.	▪ Maintain 95% or greater TMS asset operational uptime annually ▪ Expand network monitoring to 100 percent of traffic signals over the next five years ▪ Track mean time to respond to corrective maintenance work orders: o Achieve 90% or greater of corrective work orders completed on-time o Achieve 90% or greater of all corrective work orders completed within 30 days ▪ Track average time to repair for corrective maintenance work orders: o Achieve 90% or greater of corrective work orders repaired within time limits set by priority ▪ Perform preventive maintenance on all traffic signals at least once per year ▪ Ensure technicians are trained annually in their areas of responsibilities to keep up to date on newer technology and software ▪ Create Standard Operating Procedures (SOPs) for critical Operations and Maintenance (O&M) tasks, especially ones that have a high employee turnover to ensure consistency in O&M across systems
Emergency Planning 	Enhance emergency planning, coordination of resources and delivery of information during hazardous events.	▪ Meet performance targets for asset uptime and availability during emergencies for strategic infrastructure ▪ Work cooperatively with partner agencies to identify additional infrastructure needed to enhance operational awareness during emergency events and/or incidents

TSMO Goal	Strategic Objectives	Houston District TSMO Program Objectives
Financial Resources 	Ensure sustainable financial resources for TSMO activities.	▪ Identify opportunities to fund TSMO activities (e.g., carve-outs from district maintenance funds and/or dedicated ITS/TSMO funding from TxDOT statewide funds) ▪ Identify sustainable resources needed to support staff TSMO training and development
Traffic Incident Management 	Implement strategies to reduce incident response times	▪ Reduce incident clearance times: o Achieve 10% reduction in incident clearance times every 3 years ▪ Reduce secondary crashes through faster detection of primary incidents and quicker primary response: o Achieve 10% reduction in secondary crashes every 3 years ▪ Use targeted incident detection technologies (video-analytics or similar technologies) at historically high-frequency incident locations to detect and respond more quickly ▪ Apply technology to quickly restore capacity during incidents (planned or unplanned)
Technology and Innovation 	Institutionalize use of technology for strategic mobility and operations opportunities.	▪ Encourage initial deployment or implementation of emerging technology that can provide safety and mobility benefits ▪ Annually conduct market survey of emerging or innovative technology solutions ▪ Conduct at least one evaluation of emerging or innovative technology annually ▪ Fill gaps in current TMS coverage by year 2025

Capability Maturity Model

This section includes an introduction to the CMM process and summarizes the assessment of how each of the six dimensions applies to the Houston District: 1) business processes, 2) systems and technology, 3) performance measurement, 4) organization and workforce, 5) culture, and 6) collaboration (FHWA, 2020).

Introduction to the CMM Process

Adapted from the software development world, the notion of capability maturity frameworks rests on three tenets (FHWA, 2016):

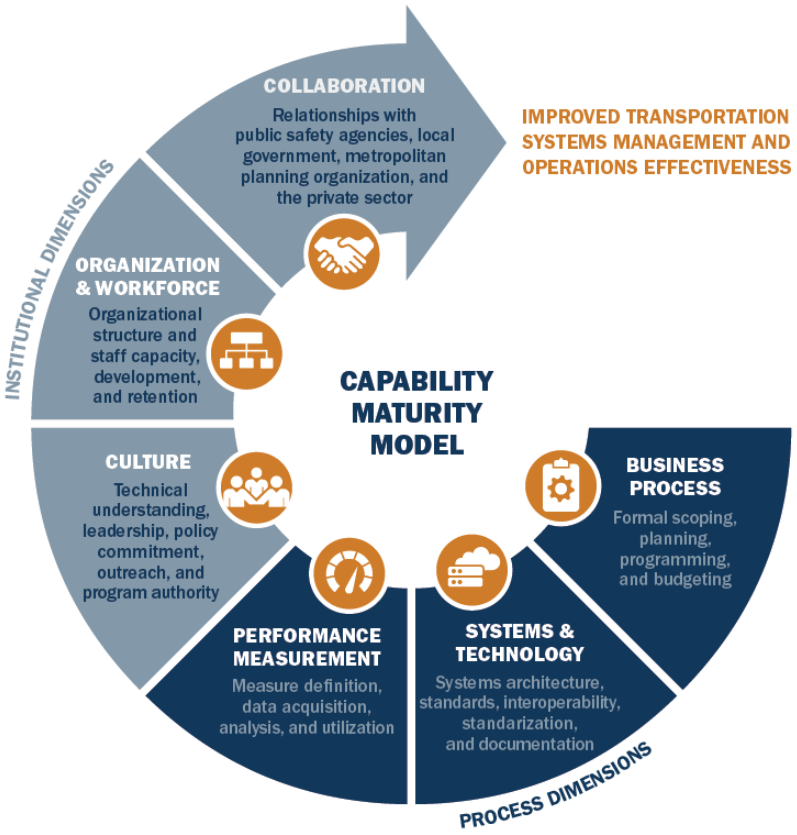
1) Process matters: Projects fail or do not achieve desired functionality for a variety of reasons unrelated to the technology
2) Prioritizing the right action is important: Is an agency ready? How do they know? What should they do next?
3) Focus on the weakest link: What is holding an agency back in becoming a leader in a particular area?

Assessing an agency's existing capability maturity is the first step in improving internal and external operations. Existing capabilities, gaps and needs for TSMO in the Houston District were identified through a combination of interviews and workshops using the TSMO capability maturity model and program area frameworks. The CMM self-assessment framework, shown in Figure 5, is comprised of six dimensions of capability—three process-oriented dimensions and three institutional dimensions. The CMFs are based on the same six dimensions but are focused on specific aspects of TSMO.

The use of the capability maturity concepts provides an approach to review common barriers to adoption and success of TSMO. It allows agencies to understand and identify actions for improvement of institutional issues that an agency faces on a continual and consistent basis. The process fosters an agency's ability to develop consensus around needed agency improvements; identify their immediate priorities for improvements; and identify concrete actions to continuously improve capabilities to plan, design, and implement TSMO.

Consistent with the Strategic Highway Research Program 2 (SHRP2, 2017) guidance and other federal CMM and CMF guidance (American Association of State Highway and Transportation Officials (AASHTO), 2014; FHWA, 2017), the capabilities for each dimension are described as a matrix that defines the process improvement areas and levels (from Level 1 - ad-hoc, to Level 4 - optimized level of capability). Table 4 includes this matrix, which shows how each of the six dimensions are assessed for each level. Following a self-assessment process, specific actions are identified to increase capabilities across the desired process areas.

The capability assessment process, tool, and instructions were discussed with stakeholders during the pre-workshop webinar. The overall assessment of capability for the Houston District provided in Table 3 below is based on the input provided during the CMM workshop. Stakeholders at the workshop focused on Houston TranStar and rated themselves near a Level 3 for business processes and at a Level 3 for systems and technology, performance management, and organization and workforce. They rated themselves a Level 2 for culture and a Level 4 for collaboration.



Source: Strategic Highway Research Program (SHRP2), American Association of State and Highway Officials (AASHTO), and Federal Highway Administration (FHWA-HOP-17-017)

FIGURE 5. CAPABILITY MATURITY DIMENSIONS

Table 3 also shows how the capabilities will become more advanced by 2025, especially as the district implements the actions in this plan over the next four fiscal years. When assessed at the end of the four-year implementation cycle, the district will have achieved things such as an ITS master plan upon which to measure progress, three or four pilot projects to address critical needs to keep the Houston District at the forefront of TSMO in Texas and the US, a workforce with the latest training to operate the newest technologies and strategies, more performance measures and the use of big data to support data-driven decisions, a culture with an even greater emphasis on operations, and new partnerships that build upon the district's strong collaboration efforts.

TABLE 3. CAPABILITY MATURITY SELF-ASSESSMENT BY WORKSHOP STAKEHOLDERS

Dimension	Level 1 Performed	Level 2 Managed	Level 3 Integrated	Level 4 Optimized
Business Processes				
Systems and Technology				
Performance Measurement				
Organization and Workforce				
Culture				
Collaboration				

= 2020 = 2025

TABLE 4. CMM ASSESSMENT CRITERIA

Dimension	Level 1 Performed	Level 2 Managed	Level 3 Integrated	Level 4 Optimized
Business Processes	Processes related to TSMO activities ad hoc and un-integrated	Multiyear statewide TSMO plan and program exists with deficiencies, evaluation, and strategies	Programming, budgeting, and project development processes for TSMO standardized and documented	Processes streamlined and subject to continuous improvement
Systems & Technology	Ad hoc approaches outside systematic systems engineering	Systems engineering employed and consistently used for Concept of Operations, architecture and systems development	Systems and technology standardized, documented and trained statewide, and new technology incorporated	Systems and technology routinely upgraded and utilized to improve efficiency performance
Performance Measurement	No regular performance measurement related to TSMO	TSMO strategies measurement largely via outputs, with limited after-action analyses	Outcome measures identified and consistently used for TSMO strategies improvement	Mission-related outputs/ outcomes data routinely utilized for management, reported internally and externally, and archived
Organization & Workforce	Fragmented roles based on legacy organization and available skills	Relationship among roles and units rationalized and core staff capacities identified	Top level management position and core staff for TSMO established in central office and districts	Professionalization and certification of operations core capacity positions including performance incentives
Culture	Value of TSMO not widely understood beyond champions	Agency-wide appreciation of the value and role of TSMO	TSMO accepted as a formal core program	Explicit agency commitment to TSMO as key strategy to achieve full range of mobility, safety and liveability/ sustainability objectives
Collaboration	Relationships on informal, infrequent and personal basis	Regular collaboration at regional level	Collaborative interagency adjustment of roles/ responsibilities by formal interagency agreements	High level of operations coordination institutionalized among key players – public and private

The following sections break down the district's existing capabilities and needs across the six dimensions.

Business Processes

In the Houston District, the TSMO program is championed by the Director of Operations with key support from the Director and Assistant Director of Traffic Management Systems. The TSMO program at the TxDOT Houston District has full support from the District Engineer and Deputy District Engineer. Directors of Maintenance, Construction, Transportation Planning and Development, and Transportation Operations sections report to the District Engineer and Deputy District Engineer and conduct TSMO practices in their domain. As TSMO is related to all four divisions within the district, all four directors practice TSMO to varying degrees.

The seven Area Offices coordinate the TSMO process at the field level. The Area Engineer for each Area Office reports directly to the District Engineer and Deputy District Engineer but also coordinates TSMO efforts with the Directors and support staff of the four core sections. The Safety Office and Public Information Office report directly to the District Engineer and Deputy District Engineer and support all districtwide functions, including TSMO.

Figure 6 provides a high-level overview of the Houston District's organizational chart. Staff at the district may find the current detailed organizational chart with additional sub-sections, names of district leadership, and full-time equivalent (FTE) staffing numbers at any time on TxDOT's Intranet.

The Houston District is responsible for planning, programming, design, construction, operations, and maintenance of projects within the district, which includes six counties: Brazoria, Fort Bend, Galveston, Harris, Montgomery, and Waller. Within each of these functional areas, the Houston District already applies TSMO tools at varying levels and consistency. At the CMM workshop, participants rated the business processes at a Level 2 and noted they are approaching Level 3. The Houston District has a four-year plan, and the district meets with each Area Office annually to discuss projects and priorities. The Houston District has a documented process in place for project development, programming, and budgeting.

The project development process at the TxDOT Houston District comprises six primary steps: Planning, Programming, Design, Construction, Operations, and Maintenance. While this process has typically been used to develop more traditional capital improvement projects, it also supports the development of projects that use TSMO strategies. Projects are identified through the planning process and prioritized projects progress through the process as funding and resources permit. Figure 7 illustrates that successes or challenges experienced in the process are communicated back to groups responsible for earlier stages so that practices are improved. Some performance metrics are also used to support the project development cycle. In the Houston District, this feedback loop is functional especially for larger projects.

During practice area meetings and interviews, it was noted there is a desire for more varied input from Operations and ITS staff during critical points in the project development process, particularly during planning and design. There is input now, but sometimes not early enough and at enough depth. This is not because of a lack of desire to provide input (or the opportunity to request input), but often due to workload levels of key staff and tight project schedules.

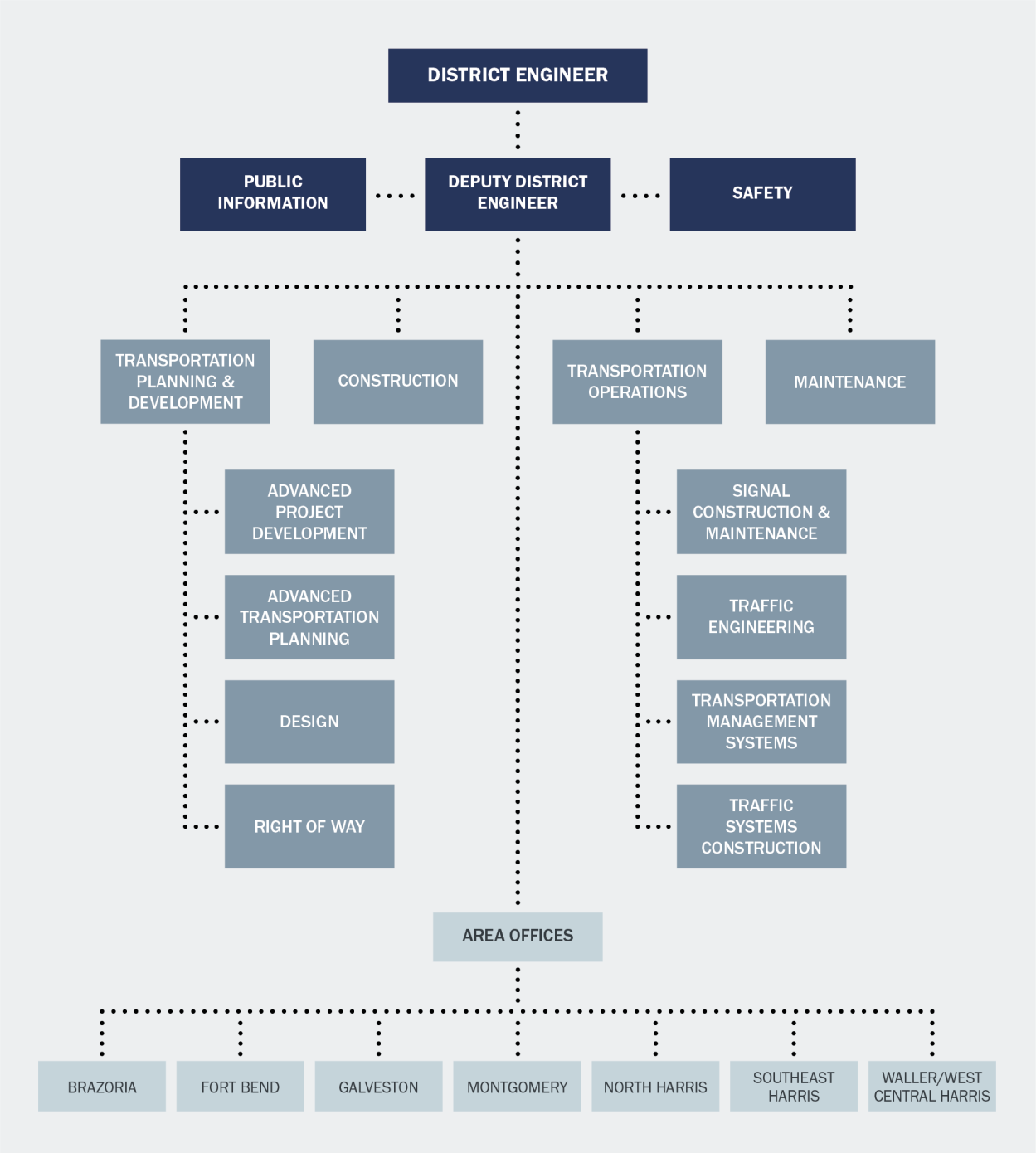


FIGURE 6. HOUSTON DISTRICT ORGANIZATIONAL CHART

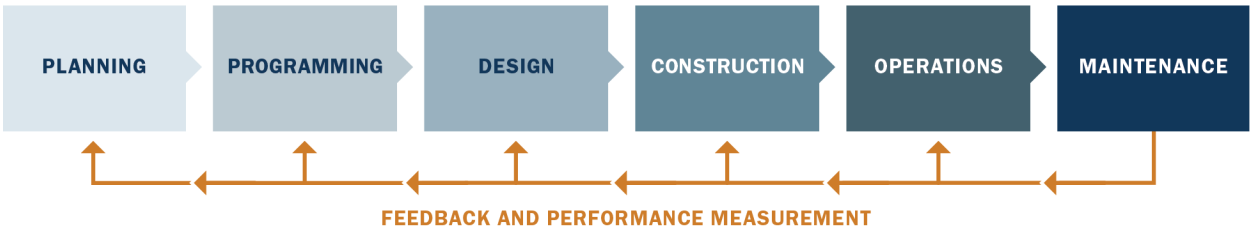


FIGURE 7. PROJECT DEVELOPMENT PROCESS AND FEEDBACK LOOP

Systems and Technology

This section describes the systems engineering analysis process, processes to vet innovative technologies, the regional ITS architecture, and existing and planned tools for traffic management systems.

Systems Engineering Analysis Process

As applied to ITS, systems engineering assesses the value and functionality of a high-technology project, service, or system from inception to end of life and considers what the system requires operationally throughout its lifespan. The systems engineering approach defines project requirements before technology choices are made and the system is implemented.

Systems engineering results in better project cost and schedule adherence, ensures that stakeholder needs are met, reduces the risk of schedule and cost overruns, and increases the likelihood that the implementation will meet the user's needs. A detailed systems engineering process gives ITS program managers the information to identify life cycle costs for near-term and long-term budget preparation.

Systems engineering is an interdisciplinary approach to enable the realization of successful systems that:

- Focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem
- Integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation
- Considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs

In 2002, the United States Department of Transportation (US DOT) established requirements for systems engineering analysis for any ITS projects that use funds from the Highway Trust Fund (US DOT, 2002). Currently the systems engineering process is a mature process. US DOT policy specifies that the systems engineering process should include seven components:

1) Identification of portions of the regional ITS architecture being implemented
2) Identification of participating agencies' roles and responsibilities
3) Requirements definitions
4) Analysis of alternative system configurations and technology options to meet requirements
5) Procurement options
6) Identification of applicable ITS standards and testing procedures
7) Procedures and resources

Benefits of the systems engineering process:

- Improved stakeholder participation
- More adaptable, resilient systems
- Verified functionality and fewer defects
- Higher level of reuse from one project to the next
- Better documentation
- Cost efficiencies

The systems engineering process represented by the "V" (or "Vee") model shown in Figure 8 has been broadly adopted in the transportation industry. On the left side of the V, the system definition progresses from a general user view of the system to a detailed specification of the system design. Here, the regional ITS architecture, feasibility studies, and concept exploration are conducted to support initial identification and scoping of an ITS project based on regional needs. A gap follows the regional architecture step because the regional architecture is a broader product of the planning process that covers all ITS projects in the region. The system is then parsed into distinct subsystems, and the subsystems into components. As the distinct subsystems are identified, the requirements for each subsystem requirements that are allocated to the system components, and documented baselines are established.

The central core of the V shows the project definition, implementation, and verification processes. The system hardware and software are implemented here.

The right wing shows the operations and maintenance, changes and upgrades, and ultimate retirement of the system. Here, the components of the system are integrated and verified in an iterative fashion. Ultimately, the completed system is validated to measure how well it meets the agency's needs.

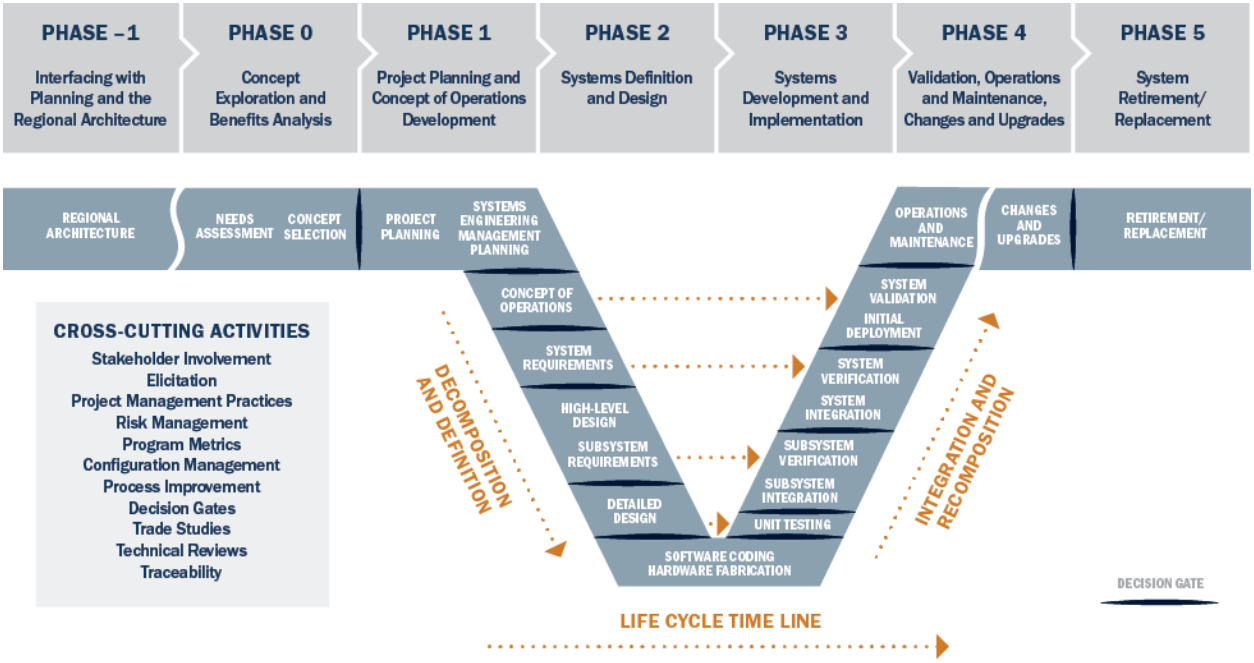


FIGURE 8. SYSTEMS ENGINEERING "V" DIAGRAM

The Houston District has significant institutional experience with implementing ITS. Common ITS elements (e.g., cameras, DMS, travel time monitoring, radar detection) are deployed as standard practice and typically

do not require use of the formal systems engineering processes. Because these devices are operated by well-established systems, there is very low risk to the agency in delivering those systems. Even on deployments with higher risk, the district has been successful at mitigating potential issues due to longstanding experience with implementation and management of technology systems. However, as new technologies are evaluated and tested for possible implementation, the use of the systems engineering process is encouraged to mitigate project and delivery risks and to meet user needs.

Processes to Vet Innovative Technologies

The Houston District has an established systems engineering process to vet integration of new technologies into the Houston TranStar system. An example of this is the transition of freeway travel time data collection: moving from toll system-based Automatic Vehicle Identification (AVI) readers to mobile Bluetooth data readers. Working with Texas A&M Transportation Institute (TTI), the district compared the installation and testing process and overall performance of the two systems. The team found that the Bluetooth approach provided accurate data at lower deployment and operation cost and offered significantly lower maintenance costs.

Regional ITS Architecture

The Houston Region ITS Architecture Update (H-GAC, 2018), led by H-GAC, provided a framework for a systematic approach to accommodate regional needs. It is a framework for TMS and ITS integration in project planning and it also defines the ITS needs and existing inventory of the region. The Regional ITS Architecture directly encourages intelligence sharing among the area's stakeholders to execute the most efficient ITS plan for the region. It also provides guidance that lists the roles and responsibilities of each stakeholder regarding various transportation services.

Per the Chief Engineer's memo from July 2016, all new roadway construction projects should include infrastructure that supports TMS, including the underground conduit that supports a fiber optic-based communications network (TxDOT, 2016). The Chief Engineer's memo from April 2017 requires that TMS be included in each project's planning, programming, design, construction, maintenance, and operation (TxDOT, 2017). Specific TMS projects must be identified where gaps exist between typical road and bridge projects. The regional architecture should be updated at regular intervals, no less than every five years. The Regional Architecture for ITS for the Houston Region including TxDOT is managed by the Houston-Galveston Area Council (H-GAC, 2018).

Existing and Planned Tools for Traffic Management Systems

As directed by TxDOT's Chief Engineer, all TxDOT districts are required to provide biannual updates on the District's TMS. In collaboration with the Information Management Division (IMD), the Tableau system was implemented across TxDOT districts to monitor and report the required performance measures. Tableau summarizes data and uses data visualization with drill-down metrics to help districts identify needs and challenges regarding TMS. In addition, the Houston District has established performance metric tools available through TTI that provide performance metrics for traffic incidents, travel times, work zone issues, traveler information, and towing services.

Established systems in use by the Houston District:

- Fiber optic cable plant
- Wireless communications radios
- Traffic signals (isolated and systems)

- Adaptive traffic signal control systems
- Ramp metering
- Travel time systems (Bluetooth and AVI readers)
- DMS systems
- Queue warning systems
- Speed feedback signs
- CCTV cameras
- Houston TranStar traveler information systems (website, social media, etc.)
- Roadway Weather Information Systems (RWIS)
- Roadway Flood Warning Detection (FWD) system
- Truck Rollover Warning System
- Overheight Vehicle Detection Systems (OVDS)
- Wrong Way Detection (WWD) System
- Central traffic management systems (Lonestar™, RIMS, HCRS, Centracs, TACTICS, etc.)

TxDOT's Information Management Division working with the Traffic Safety Division/Traffic Management section is implementing multiple initiatives that support TMS:

- Network monitoring system
- Asset management
- Fiber mapping and fiber asset management
- End of life network equipment upgrades
- Lonestar™ redundancy improvements to traveler information
- 4G cellular deployment
- Video sharing
- Automated traffic signal performance measures (ATSPMs)

Emerging Technologies:

- Connected vehicles
- Automated vehicles
- Pavement markings to support CAV
- Permanent roadside signs to support CAV
- Electric vehicle charging infrastructure
- Private sector data integration
- 5G and small cellular tower (small cell) wireless communications
- Drone technology to reach and support evaluation and monitoring of incidents in remote areas without cameras

The Houston District has the Houston-Galveston area's Regional ITS Architecture, a performance metrics-based approach, and the Houston TranStar Annual Report in place to provide a systemic approach to evaluation of existing technologies and a path for implementation of new technologies for the Houston region.

Performance Measurement

TxDOT has adopted a statewide "Road to Zero" initiative to reduce fatalities on all Texas roadways by half by 2035 and to zero by 2050. The public messaging for this initiative is *#EndTheStreakTX*. The Houston District recently developed a

District Safety Plan (TxDOT HOU, 2020) to support this initiative that includes TSMO strategies. TTI is developing a new safety-driven data tool to support safety analysis statewide.

The TxDOT Houston District consistently uses TSMO-oriented performance measures to improve TSMO strategy deployment in the region, and they are advancing to optimized levels of capability. At a high level, the Houston TranStar Annual Report[1] includes measures on system coverage, smart work zone activation, traveler information output (website users, mobile application downloads, and CCTV views), annual crashes, average incident clearance time, Tow-and-Go assists, MAP assists, Houston TranStar benefits in terms of freeway motorist delay savings, and an overall benefit/cost evaluation of the Houston TranStar program.

The Houston District also reports on specific measures through the TMS Status Report, and the results are tied to the District Engineer's performance evaluation:

- TMS asset operational uptime
- Incident clearance time
- Level of travel time reliability
- TMS system coverage

The district's existing goal for asset operational uptime is to have 90 percent of devices operational; they currently exceed this goal at 95 percent. Asset uptime is measured through the TranStar ITS Asset Management System (TAMS), which also includes devices maintained by the Houston District in adjacent TxDOT districts. They also have a goal to address traffic signal issues within two hours of a call being received.

The district is continually working to improve its traffic incident management capabilities. Houston TranStar regional partners have a robust traffic incident management program that includes collecting incident clearance time data and performance metrics, conducting monthly and quarterly meetings, performing after-action reviews, and performing an annual self-assessment. Incident timeline data is logged in the Regional Incident Management System (RIMS), and their goal is to reduce incident clearance time by 10 percent every three years.

Robust travel time and speed data, both real-time and historical, is available for major facilities in the district. The City of Houston and Harris County supplement travel time and speed data on toll roads and major arterials in the urbanized and suburban core of the Houston District. However, the District reported that traffic volume data is difficult to collect due to maintenance required (validating radar sensors) and a backlog of maintenance requirements. Currently, the Houston District is not measuring person throughput aside from the high occupancy vehicle (HOV) Quarterly Reports (funded by METRO and the Houston District cooperatively). There are some issues with data reliability, but it has improved. They are also looking into improving their capabilities through origin-destination data from INRIX (via TTI). The ConnectSmart platform under development by the Advanced Transportation Planning section will also generate a variety of data.

Staff depend on TxDOT's Crash Records Information System (CRIS) for crash data, although there are many inconsistencies between reporting agencies.

Performance Measures

Table 5 identifies performance measures to support ongoing monitoring of the effectiveness of TSMO strategies in the region. The table shows how each measure supports the District's TSMO Program objectives, as well as potential data sources to support measure development.

[1] Available at: http://www.houstontranstar.org/about_transtar/

TABLE 5. HOUSTON DISTRICT TSMO PERFORMANCE MEASURES

Goal	Houston District TSMO Program Objectives	TSMO Performance Measures	Potential Data Source
Safety 	Reduce 5-year rolling average crash fatalities by half by 2035 Reduce crash fatalities to approach zero by 2050	Number of crash fatalities	TxDOT Crash Records Information System (CRIS)
	Reduce crash serious injuries (both incapacitating and non-incapacitating)	Number of crash serious injuries	CRIS
	Reduce work zone crashes	Number of work zone crashes	CRIS
Reliability 	Increase percent of person-miles traveled on the Interstate system that are reliable	Percent of person-miles travelled on the Interstate system that are reliable	INRIX travel time data TranStar Bluetooth/AVI travel time reporting system
	Increase percent of person-miles traveled on the non-Interstate NHS that are reliable	Percent of person-miles travelled on the non-Interstate NHS that are reliable	INRIX travel time data TranStar Bluetooth/AVI travel time reporting system
	Provide traveler information to influence when, where, how, and how much travel occurs (travel demand management)	TranStar Traffic Map pages served (hits) TranStar Traffic Map unique users TranStar mobile application users CCTV images served DMS messages posted	TranStar Traffic Management Portal / Traveler Information
Efficiency 	Reduce system bottlenecks	Number of bottleneck reduction studies completed per year. Number of bottleneck projects completed per year.	Data sources to identify bottlenecks: ▪ TranStar reliability metrics ▪ TranStar speed data ▪ RIMS/CRIS data
	Increase MAP vehicle deployment by corridor and by time of day	Number of MAP Assists by corridor and time of day	TranStar Traffic Management Portal / MAP stats

Goal	Houston District TSMO Program Objectives	TSMO Performance Measures	Potential Data Source
Customer Service 	Increase user satisfaction with Houston TranStar website/mobile application	Website/mobile application user satisfaction	Online/mobile application survey of user satisfaction (every 3 years)
	Create a traveler information roadmap for improvements	Identification of key traveler information improvements through website/mobile application survey	Online/mobile application survey of user satisfaction (every 3 years)
	Increase third-party partnerships for enhancing traveler information services	Completion of market survey of third-party traffic information services.	To be determined (TBD) during program development
	Identify opportunities to use ConnectSmart data and analytics to enhance traveler information capabilities	Use of ConnectSmart data within existing traveler information processes	TBD from ConnectSmart project, such as a technical memorandum to identify potential traveler information data from ConnectSmart
Collaboration 	Meet once per fiscal year quarter with district representatives from the core practice areas and the Area Offices to review TSMO implementation status	Number of Houston District supervisors' meetings that included TSMO status discussions	District supervisors' meeting minutes
	Achieve 100% participation in TIM Team meetings	Number of TIM Team meetings attended	TIM meeting minutes
	Seek out regular input on TxDOT systems/functions that can be cooperatively used by partner agencies	Summary of interviews with key stakeholder agencies (annually) Development of implementation actions from input	TBD during program development
	Seek out opportunities to enhance TxDOT TSMO operations with other partner agency data (e.g., live connections to HPD/911 CAD system)	Summary of interviews with key stakeholder agencies (annually) Development of implementation actions from input	TBD during program development

Goal	Houston District TSMO Program Objectives	TSMO Performance Measures	Potential Data Source
Integration 	Maintain 95% or greater TMS asset operational uptime annually	Percent TMS asset operational uptime ITS asset uptime during construction	TranStar ITS Asset Management System (TAMS)
	Expand network monitoring to 100 percent of traffic signals over the next five years	Percent traffic signals equipped with automatic failure alerts and monitored through the network	Centracs TACTICS
	Track mean time to respond to corrective maintenance work orders	Mean response time to corrective maintenance work orders	TAMS
	Track mean time to repair for corrective maintenance work orders	Mean repair time for corrective maintenance work orders	TAMS
	Perform preventive maintenance on all traffic signals at least once per year	Percent of traffic signals repaired under preventive maintenance program annually	TAMS / Centracs / TACTICS
	Ensure technicians are trained annually in their areas of responsibilities to keep up to date on newer technology and software	Percent of technicians trained annually	TxDOT Human Resources (HR)
	Create SOPs for critical O&M tasks, especially ones that have a high employee turnover to ensure consistency in O&M across systems	Number of Standard Operating Procedures for critical O&M tasks completed or updated annually	TxDOT Houston District Director of Operations; Consider integration with work order documentation or TAMS
Emergency Planning 	Ensure that performance targets for asset uptime and availability are being met for strategic infrastructure	Percent TMS asset operational uptime for strategic infrastructure	TAMS
	Work cooperatively with partner agencies to identify additional infrastructure needed to enhance operational awareness during incidents	Summary of interviews with key stakeholder agencies (annually) Development of implementation actions from input	TBD during program development

Goal	Houston District TSMO Program Objectives	TSMO Performance Measures	Potential Data Source
Financial Resources 	Identify opportunities to fund TSMO activities (e.g., carve-outs from district maintenance funds and/or dedicated ITS/TSMO funding from TxDOT statewide funds)	Annual and 3-year rolling average of ITS/TSMO funding and support	TBD during program development
	Identify resources needed to support staff TSMO training and development	Annual program of training and development for district staff	TBD during program development
Traffic Incident Management 	Reduce incident clearance times: achieve 10% reduction in incident clearance times every 3 years	3-year average incident clearance time	Regional Incident Management System (RIMS) database
	Reduce secondary crashes through faster detection of primary incidents and quicker primary response: achieve 10% reduction in secondary crashes every 3 years	Number of secondary crashes (3-year period)	RIMS database Need to develop parameters for automated tracking of secondary crashes Need method to incorporate CRIS data in determination of secondary crashes
	Use targeted video-analytics or other incident detection technologies at historically high-frequency crash locations to faster detect and respond to incidents	Average incident detection time	Detection system in RIMS database
	Apply technology to quickly restore capacity during incidents (planned or unplanned)	Average roadway clearance time (lanes re-open to traffic)	RIMS database

Goal	Houston District TSMO Program Objectives	TSMO Performance Measures	Potential Data Source
Technology and Innovation 	Encourage initial deployment or implementation of emerging technology that can provide safety and mobility benefits	Completion of pilot study of emerging or innovative technology solutions	TBD during program development
	Annually conduct market survey of emerging or innovative technology solutions	Completion of market survey of emerging or innovative technology solutions (annually)	TBD during program development
	Conduct at least one evaluation of emerging or innovative technology annually	Number of evaluations of emerging or innovative technology	TBD during program development
	Fill gaps in current TMS coverage by year 2025	TMS system coverage	Assess gaps as part of the development of a TxDOT Houston District ITS Master Plan

Organization and Workforce

This section describes potential organization structure revisions to accommodate TSMO, key TSMO roles, a staffing plan for recruitment and retention, and a training plan.

Revise Organization Structure to Accommodate TSMO

A specific organizational approach to accommodate TSMO could include a district TSMO Steering Committee chaired by the district TSMO Champion or TSMO Coordinator. TSMO Steering Committee members may include district staff from Planning, Design, Construction, Maintenance, and Operations. The Steering Committee would be responsible for ensuring that appropriate training and communications with the staff in their areas were implemented to achieve the strategic, programmatic, and institutional integration required to carry out the TSMO Program. The TSMO Champion or Coordinator would provide support to the TSMO Steering Committee and has day-to-day responsibility for working with the TSMO representatives to carry out the TSMO Program.

Alternately, TSMO activities could be coordinated at a high level at the District Quarterly Meeting, which includes directors and supervisors throughout the district, and small committees could be developed to advance individual action items or groups of action items. Those committees could include or report back to the TSMO Champion or Coordinator. TSMO activities within the Operations section may also be coordinated during the Director of Transportation Operations (DTO) Quarterly Meeting. The Operations section includes TMS, Traffic Engineering, Traffic Systems Construction, and Signal Construction and Maintenance.

Key TSMO Roles

This section describes how key roles in the Houston District support TSMO: traffic engineers, traffic signal engineers, freeway operations engineers, arterial operations engineers, ITS design engineers, ITS planners, and transportation planners.

Traffic Engineers through education, training, and professional practice are responsible for applying principles and practices from civil engineering for the traffic operations on roads, streets, highways, and their networks to achieve a safe, efficient, and convenient movement of people and goods. This position is also responsible for traffic operations studies, such as safety studies, intersection operations studies, traffic impact studies, interstate operation studies, interchange modification reports, traffic signal timing studies, and signal warrant studies. Building upon that experience, future roles and responsibilities for Traffic Engineers to support the TSMO program include:

- Use spatial data, such as geographic information system and relevant spatial analyses and statistics, for data-driven decision making
- Identify appropriate TSMO countermeasures and tactics during the planning, design, and construction of highway projects as appropriate
- Consider CAV impacts on traffic operations, including developments in signing and pavement marking technologies and standards to support CAV and Vehicle-to-Infrastructure (V2I) technologies to support pedestrians and bicycles

Traffic Signal Engineers through education, training, and professional practice are responsible for all aspects of traffic signals, from design to operation. These individuals have extensive experience in the field of traffic signal design, implementation, maintenance, and operations. This position may also be responsible for performing operations activities at the Traffic Management Center (TMC) and

coordinating the activities of assigned staff to respond to citizens' complaints regarding traffic signal issues and coordinating signal operations with transit agencies for interfaces with transit operations (e.g., bus rapid transit, light rail transit). This position is also responsible for emergency traffic signal operations within the region. Building upon that experience, future roles and responsibilities for Traffic Signal Engineers to support the TSMO program include:

- Incorporate integrated corridor management techniques into the operations of traffic signals
- Consider connected and automated vehicles impacts on traffic signal operations
- Effectively use geographic information system and other analytical tools, such as Excel, SPSS/STATA, traffic simulation and signal timing software (e.g., Vissim, CORSIM, Synchro), etc., to create information from data that enhances operational decision-making
- Use real-time data to make real-time operational decisions

Freeway Operations/ITS Engineer (FOE) is a position that has emerged more recently, over the last 20 years. The FOE is primarily responsible for development, evaluation, deployment, and operations of new technology related to traffic engineering and ITS along the freeway system, and the operation of the telecommunications networks connecting the ITS to the Houston TranStar TMC (fiber, leased lines, wireless network). Systems engineering is a critical aspect of the work of the FOE. This position is also responsible for overseeing and monitoring the continued deployment and enhancement of incident management and other active traffic management techniques with an emphasis on system efficiency, cost effectiveness, and community acceptance. The FOE's responsibilities may include planning, design, construction management, systems testing, operations and program maintenance for the ITS program. Building upon that experience, future roles and responsibilities for the FOE to support the TSMO program include:

- Incorporate integrated corridor management (ICM) techniques into the operations of freeway facilities
- Consider connected and automated vehicle impacts on freeway operations; consider and manage new techniques such as automated vehicle only lanes
- Use a systems engineering approach for evaluating and purchasing new technologies
- Take a multimodal approach to freeway operations and person throughput
- Use real-time data to make real-time operational decisions
- Implement and use prediction software to make operational decisions
- Coordinate the DOT's Traffic Incident Management program

Arterial Operations Engineer (AOE) through education, training, and professional practice is a position responsible for development, evaluation, and deployment of new technology related to traffic engineering and ITS along the arterial roadway network. Due to the requirement in Texas that traffic signals in cities with a population greater than 50,000 be operated by the local jurisdiction[2], this may not be a TxDOT position, or would be responsible for major corridor operations in unincorporated areas and in cities with less than 50,000 in population. The AOE will liaison with other governmental agencies and the public for coordination of active arterial management projects and programs in the region. This position is also responsible for performing field observations of traffic conditions to validate concerns or inquiries and evaluate

[2] TxDOT Traffic Signals Manual, Section 1: Traffic Signal Policy

and make recommendations relating to the application of new technology to support the agency's vision and mission. Building upon that experience, future roles and responsibilities for the AOE to support the TSMO program include:

- Incorporate integrated corridor management techniques into the operations of arterial facilities
- Consider connected and automated vehicle impacts on arterial operations
- Take a multimodal approach to arterial operations and person throughput
- Use real-time data to make real-time operational decisions; implement and use prediction software to make operational decisions
- Identify, analyze, and interpret trends or patterns in complex data sets

The **ITS Design Engineer** through education, training, and professional practice is primarily responsible for the design of ITS projects. This engineer will perform systems engineering and prepare project plans and specifications related to ITS elements such as fiber optic cable systems, CCTV cameras, Microwave Vehicle Detection System (MVDS), DMS, etc., while applying the systems engineering process. Building upon that experience, future roles and responsibilities for the ITS Design Engineer to support the TSMO program include:

- Integrate connected vehicles into ITS design (e.g., add dedicated short-range communication or 5G connectivity as needed)
- Through continuing education, understand the appropriate time to incorporate emerging technologies in ITS design including CAV hardware to support V2I communications

The **ITS Planner** is responsible for planning and developing ITS projects, including preparing documents that follow the FHWA systems engineering process. This has not been a separate position in the past within TxDOT, and the duties have been accomplished by the FOE and/or ITS designer. Metropolitan Planning Organizations (MPOs) and Councils of Governments (COGs) may have this as a staff position. The ITS Planner is responsible for completing transportation planning and feasibility studies for DOTs, MPOs, and local municipalities. Building upon that experience, future roles and responsibilities for the ITS Planner to support the TSMO program include:

- Utilize big data to analyze benefits of TSMO strategies and implement, if feasible
- Analyze TSMO performance metrics
- Mainstream TSMO into the project planning process
- Implement modeling for analysis, visualization, planning, and training related to TSMO programs
- Perform scenario planning to plan for connected and automated vehicles

The **Transportation Planner** is responsible for long-range transportation planning and considering safety, environmental, and efficiency issues in areas such as land use, infrastructure analysis, environmental compliance, and corridor planning. This position is under the district and division planning sections. The Transportation Planner initiates and develops projects, and is responsible for the identification of needs, the preparation of plans and estimates, and adherence to regulations. In order for the TSMO program to be successful, it is critical that the Transportation Planners are trained in and buy into the TSMO program. Future roles and responsibilities for the Transportation Planner to support the TSMO program include:

- Mainstream TSMO into the project planning process
- Integrate management and operations strategies into the metropolitan transportation planning process to maximize the performance of the existing and planned transportation system
- Implement modeling for analysis, visualization, planning, and training related to TSMO programs
- Take a multimodal approach to transportation planning and person throughput
- Use scenario planning to understand range of potential TSMO impacts

Staffing Plan for Recruitment, Retention, and Revised Position Responsibilities to Accommodate TSMO Activities

Adopting a culture of workforce retention and developing a personalized retention plan for each employee will address career and personal needs to enhance job satisfaction and greater commitment to the organization. Emerging TSMO positions are often recruited from outside the transportation public agency arena, and it may be challenging to retain employees more familiar and comfortable with the practices in the emerging technology fields. TxDOT offers competitive benefits packages but has a modestly set salary structure for technology-centric positions. It is critical that TSMO positions be developed in salary groups that, along with the creative work environments for TSMO professionals, will help ensure retention of qualified individuals. Consider establishing a TSMO career path, with defined education and job performance goals for next advancement steps, so that current staff are not simply retitled as TSMO Engineers. Consider modeling a Professional TSMO Engineer description after the Professional Traffic Operations Engineer (PTOE) designation as it relates to the Professional Engineer (PE) designation. TxDOT's Human Resources section has active recruiting practices. The current process can be enhanced through working with professional organizations including LinkedIn, ITS America, ITS Texas, and the Texas District for the Institute of Transportation Engineers (TexITE) to advertise the defined staffing positions. The National Operations Center of Excellence (NOCoE) also has a wealth of online TSMO workforce development resources that have been vetted with HR professionals (NOCoE, 2020).

The following is a list of retention strategies that should be considered across the organization and specifically for TSMO:

- Accommodate ongoing professional development
- Establish mentoring programs connecting young professionals and experienced leaders
- Provide training, including cross-functional training
- Consider flexible work hours and work-from-home opportunities
- Establish employee and team recognition programs, both internal and external (e.g., ITS Texas, TexITE)
- Encourage active participation in professional societies
- Clearly define expectations and policies, including regular feedback
- Provide clear two-way communications
- Ensure organizational diversity practices are considered during recruitment
- Ensure workplace safety is priority one
- Define career path advancement opportunities

The Houston District currently augments its staff by using indefinite deliverable contracts for professional services: traffic and ITS engineering, traffic signal timing, traffic signal maintenance, and ITS maintenance. While it is common for state DOTs to supplement their capabilities with professional services contracts, it is

important to maintain a strong in-house TSMO knowledge base at the Houston District for the most effective TSMO implementation.

Training Plan

Professional development can be used to support existing staff and recruit from within an organization by supporting the development of Knowledge, Skills, and Abilities (KSAs) within traditional positions and allowing employees to evolve into new and emerging positions. Professional development focused on specialized TSMO KSAs within more traditional positions can be used to support the evolution of TSMO programs in smaller agencies. For example, a traditional traffic engineer position can be expanded to take on the responsibilities of integrated corridor management by developing KSAs that include advanced traffic management, transit management, and traffic incident management. ITE, ITS America, and the US DOT Office of Operations and ITS Joint Program Office (JPO) offer webinar-based training programs and these can be taken in real-time or by viewing recorded sessions later.

Training to support TSMO will provide a basic level of understanding of TSMO and what it offers to the organization for TSMO-related functions (planning, traffic operations, maintenance, performance management, ITS), and specialized training for specific TSMO functional areas. Basic training should be developed and offered in-house as part of ongoing professional development. More specialized training can be provided in-house or obtained through outside sources such as professional organizations, universities, or FHWA workshops. A strategic approach to TSMO training will require the development of a formal training plan, which will require an investment in time by TSMO management and HR staff to determine the specific and general training needs, sources, and associated policies for training. Existing training and certification programs should be used to augment TSMO workforce professional development. Given the wide spectrum of knowledge required to operate a TSMO program, there are many organizations that provide training, certification, and research related to TSMO. Additionally, TxDOT's Traffic Division is evaluating strategies for supporting TSMO training throughout the state.

Culture

Decisions are often determined by an organization based on its culture, which is made up of the organization's values and beliefs.

TxDOT's Houston District puts an emphasis on the value of transparency, collaboration, and accuracy when communicating with stakeholders. As the TxDOT district with the largest population, the greatest vehicle miles traveled and the most registered vehicles, its culture of openness is beneficial.

However, it is this growing strain on the transportation system that requires the district to continually inform and engage staff to meet transportation needs and department objectives.

The Houston District has developed relationships with external stakeholders; including elected officials, emergency responders, Houston TranStar partners, local business leaders, neighborhood associations, the media and others to collect and disseminate meaningful information regarding transportation issues and conditions with transportation users.

Still, relationships alone will not be sufficient to collect, coordinate and distribute real-time information about the transportation network to users that need it. It will require:

- Outreach – to seek out opportunities to discuss the value of TSMO

- **Leadership** – to collaborate and learn about the benefits of TSMO and advocating for them throughout the district
- **Internal Buy-in** – to find opportunities to encourage collaboration between multiple district units (i.e. design, construction, traffic, maintenance) as early as possible
- **Coordination with Public Agencies and MPOs** – to identify where regional TSMO efforts can support existing goals
- **Public-Private Partnerships** – to promote mobility as a service or provide transportation data

Also, it is important to supplement effective personal communication with new technology.

The Houston District Public Involvement Office provides a strong link between information and stakeholders. The PIO uses a variety of resources to collect traffic information, but it would be beneficial to make information gathering easier and faster. Houston TranStar is an excellent source of information but requires continuous improvement on communication between agencies.

In emergencies, DriveTexas.org is a statewide major resource for road condition information but is limited to on-system information. HoustonTranStar.org and associated traveler information systems (mobile app, social media) has a long-standing role in traveler and emergency management information in the Houston region and continued emphasis on support of these systems is important.

The existing good relationships between the Houston District PIO, Houston TranStar PIO, and traffic reporters for radio and TV stations are a benefit to the district.

Given its history as a leader in TxDOT communication, and the statewide focus on TSMO, the Houston District expects to continue to improve the culture for quality transportation decisions.

Collaboration

The Houston region has long history with being a leader in TSMO. Since 1993, Houston TranStar has been seen as a model for multi-agency collaboration. This consortium of representatives from the TxDOT Houston District, METRO, City of Houston, and Harris County shares resources and exchanges information in support of transportation and emergency management. Additionally, each of the individual jurisdictions in the Houston TranStar partnership also has a long history with TSMO and ITS deployment leading to a significant shared investment and use of TSMO and ITS technologies, systems, and strategies. These strategies support robust traffic incident management programs, traveler information and emergency management throughout the region. Houston TranStar has also been at the center of TSMO innovation, including participation in Integrated Corridor Management initiatives and developing an award-winning flood warning application.

Enhancing Collaboration for TSMO within the Houston Region

Within the CMM, the Houston District's collaboration is at Level 4 through Houston TranStar and is one of the exemplars nationally. Within this context, advancing collaboration should be viewed as the vital next steps for innovation and continued national leadership in TSMO. Based on the workshops and information gathered from the interviews, the greatest opportunities to continue to innovate and advance TSMO in the region are summarized below.

Opportunity #1:

MULTIMODAL OPERATIONS/INTEGRATED CORRIDORS THAT FOCUS ON BOTH DEMAND AND SUPPLY MANAGEMENT

RATIONALE: During the CMM workshop, Houston District and other Houston TranStar partners identified the opportunity to expand agency collaboration along corridors. The district uses travelshed planning to look at "complete corridors" to evaluate multimodal travel throughout the travelshed, which may include the supporting arterial network adjacent to the freeway network and also looks at how local roadways tie into the state system and ramps.

VALUE TO THE REGION:

- Involving local municipalities along these corridors can increase reliability and safety on the corridor
- Tracking corridor-specific performance metrics fosters continuous improvement

Opportunity #2:

REGIONAL TRAFFIC SIGNAL MANAGEMENT

RATIONALE: Arterial management and deployment of recent advances in traffic signal management practices, such as automated traffic signal performance measures (ATSPM), have a dual purpose — increasing traffic signal management capability in the region and also enabling new ways for TxDOT and cities to work together for regional signal management.

VALUE TO THE REGION:

- Using ATSPM to directly measure what is currently estimated and modeled enhances opportunities to improve regional signal management
- Using ATSPM to proactively identify maintenance issues (detection, timing, construction) improves efficiency of signal operations by making sure it operates as intended
- Using ATSPM to monitor corridor operations (across jurisdictional boundaries) based on objectives improves efficiency of signal operations
- Using ATSPM to retime signals based on real-time data (need) reduces the cost of unneeded retiming

Opportunity #3:

INNOVATION CORRIDORS

RATIONALE: Houston TranStar can identify innovation corridors that allow for more coordinated testing of new technologies. The Katy Freeway (I-10) high occupancy toll (HOT)/HOV lanes are physically separated from the general-purpose lanes, and Houston METRO is currently constructing its first bus rapid transit route along Post Oak Boulevard that will connect Uptown Houston to two major transit centers. These corridors can be targeted for advanced TSMO strategies that leverage connectivity, multimodal automation, and freight movement.

VALUE TO THE REGION:

- Identifying innovation corridors could improve Houston TranStar's readiness to test new technologies

Opportunity #4:

WORK ZONE/CONSTRUCTION COORDINATION

RATIONALE: The Houston District's construction section coordinates with other agencies to ensure that detour routes do not overlap or conflict with one another. District maintenance works to support recovery efforts from weather events and works collaboratively with law enforcement agencies to provide resources for roadway closures and clearance. While there is a strong basis for and history of collaboration in this area, utilizing emerging specifications like the Work Zone Data Exchange (WZDx) can create more common ways to share and distribute information between regional agencies and external stakeholders.

VALUE TO THE REGION:

- Ongoing efforts around Smart Work Zones in Texas and the Houston District may provide immediate opportunities to collect detailed work zone data that could serve as a starting point for high-fidelity data collection for future CAVs

Opportunity #5:

REGIONAL TSMO WORKFORCE DEVELOPMENT

RATIONALE: During the CMM workshop, stakeholders noted a highly trained level of staff at each organization supporting Houston TranStar and identified the need to improve the depth of staff and succession plans to bring up the next generation. There is a significant opportunity for TranStar to serve as a workforce development resource for TSMO to smaller city staff as well adjoining TxDOT districts.

VALUE TO THE REGION:

- Identifying a career path for TSMO within each agency in the Houston TranStar consortium supports improved depth of knowledge and succession planning
- Sharing technical knowledge between different agency staff builds the overall knowledge base and creates a sustainable program

Opportunity #6:

REGIONAL GUIDELINES/STANDARDS/SPECIFICATIONS

RATIONALE: As cities grow their own ITS programs, it is important for TxDOT and Houston TranStar to play a guiding role in ensuring compliance and interoperability with the regional ITS architecture. While a prescribed set of guidelines and standards may be ambitious, there is great value in defining the interoperability and interface requirements that ITS devices need to support the region.

VALUE TO THE REGION:

- Consistency among systems technology enhances collaboration by removing barriers for data sharing
- Guidelines and standards reduce the need for each agency to test and select their own devices

Opportunity #7:

REGIONAL DATA MANAGEMENT/GOVERNANCE

RATIONALE: A major shift is occurring in terms of TSMO data management. For example, cities like Atlanta have explored TSMO data governance practices that emphasize the enterprise role of data (ARC, 2019). Data sharing for enhanced situational awareness is key to implementing many TSMO strategies; moreover, sharing real-time data and predictive analytics with the public and private sectors plays an important role in influencing travel decisions.

VALUE TO THE REGION:

- Data is becoming a major asset and investment. Houston TranStar has an opportunity to serve as a regional data hub, which further highlights the importance of a data governance plan that provides guidelines on how to describe, organize, and share data; access procedures; and data user and owner roles.

Opportunity #8:

ADJACENT DISTRICT SUPPORT AND GUIDANCE

RATIONALE: The Houston District currently supports its adjacent districts, Beaumont, Lufkin, Bryan, and Yoakum, in various ways. For the Beaumont and Bryan Districts, Houston TranStar monitors ITS infrastructure after hours. For the Yoakum and Lufkin Districts, Houston TranStar operates the district's ITS devices, and for Yoakum, the Houston District maintains the ITS devices. As these districts implement their TSMO Program Plans, the Houston District can continue to collaborate with these districts to share effective practices that are scalable to the less densely developed areas.

VALUE TO THE REGION:

- Sharing information related to data collection and development of performance metrics can support implementation of TSMO practices and foster continuous improvement in these districts
- Enhancing TSMO capabilities and understanding in adjoining districts has a direct payoff during emergencies

TSMO Implementation Plan

This section includes a prioritized implementation plan for advancing TSMO in the Houston District over the next four years. Based on the discussions and action needs for the Houston District brought forward in the Working Group meetings, stakeholder meetings within the district, and then further discussed through the CMM and CMF surveys and workshops, numerous action items were identified. This section summarizes TSMO strategy action items for implementation within the next four years, longer-term actions that should be assessed during the next major TSMO program plan update, regional TSMO efforts that may be championed by partners, links to efforts in adjacent districts, statewide TSMO efforts, and the process for implementing and update the TSMO program plan.

Houston District Four-Year TSMO Action Plan

Table 6 includes the following information as it relates to each of the TSMO strategy action items identified for implementation by the Houston District:

- **Action Number:** Provides a number for identification and tracking of the action. The initials stand for the related CMM dimension: business processes (BP), systems and technology (ST), performance measurement (PM), culture (CU), organization and workforce (OW) and collaboration (CO).
- **Action Description:** Provides a brief description of the action, which may include multiple steps
- **Supports District TSMO Goals:** Identifies which of the TSMO goals the action supports. Some actions may not directly support a goal but their implementation would help in achieving the goal. The 10 district TSMO goals are described in Table 2: safety, reliability, efficiency, customer service, collaboration, integration, emergency planning, financial resources, traffic incident management, and technology and innovation.
- **Timeline:** A target fiscal year (FY), September 1 through August 31, has been identified within the next four years. These targets were set based on the time it will take to implement an action, the urgency of the action, whether there are dependencies on other actions, or available resources. Priorities may shift as major events occur or staffing and funding resources change.
- **TxDOT Houston District Lead:** Identifies the individual at the Houston District who will take ownership of the action and will oversee that implementation progresses as planned
- **Partners:** Identifies TxDOT Districts or Divisions or external stakeholders needed for coordination or resources for successful action implementation
- **Resources:** Identifies staff, funding, and other tools needed to support the action
- **Measures of Success:** Provides performance metrics that will help action tracking and reporting

This Houston TSMO Plan includes actions to advance the TSMO program within the district.

TABLE 6. HOUSTON DISTRICT TSMO IMPLEMENTATION PLAN ACTIONS

ACTION NUMBER	ACTION DESCRIPTION	SUPPORTS HOUSTON DISTRICT TSMO GOALS										TIMELINE	TxDOT HOUSTON DISTRICT LEAD	PARTNERS	RESOURCES	MEASURES OF SUCCESS
		SAFETY	RELIABILITY	EFFICIENCY	CUSTOMER SERVICE	COLLABORATION	INTEGRATION	EMERGENCY PLANNING	FINANCIAL RESOURCES	TRAFFIC INCIDENT MANAGEMENT	TECHNOLOGY & INNOVATION					
BUSINESS PROCESSES (BP)																
BP-01	Develop an annual financial plan that incorporates capital investments and TSMO within one budget process.			✓					✓			FY 2021	Director of Operations	DE, DDE	Staff hours	% complete until finalized
BP-02	Develop a multi-year TMS maintenance plan that includes procurement cycles, warranties, replacement cycles, and preventive maintenance.	✓	✓						✓			FY 2021	Director of Operations	Director of Signal Construction & Maintenance, Director of Traffic Systems Construction	Staff hours, budget expenditures	% complete until finalized
BP-03	Develop standards or guidelines for signal operations (for example, when to implement Flashing Yellow Arrow, when coordination is warranted, railroad timings, etc.)	✓	✓	✓								FY 2021	Director of Traffic Engineering	TRF	Staff hours	% complete until finalized
BP-04	Invest in developing evacuation/incident/special event signal timing strategies.	✓	✓	✓			✓	✓		✓	✓	FY 2021	Director of Operations	Director of Traffic Engineering	Staff hours	% complete until finalized
BP-05	Develop a Houston District ITS Master Plan. Identify where to fill gaps in current TMS infrastructure coverage to support funding decisions and project development processes.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	FY 2022	Director of Operations, Director of TMS, Director of Traffic Engineering	Director of TP&D	Staff hours, mapping of existing infrastructure	% complete until finalized
BP-06	Organize current TSMO deployment guidance to support project development. Consider process improvements to: ▪ Planning (e.g., planning and environmental linkage studies) ▪ Programming guidelines ▪ District design preferences (TRF developing ITS manual), including maintenance considerations			✓		✓			✓			FY 2022 – FY 2023	Director of Operations, Director of TMS, Director of TP&D	TRF, Transportation Planning and Programming (TPP)	Staff hours	% complete until finalized
BP-07	Create a process whereby new traffic management approaches are modeled internally to determine benefit/cost, environmental impacts, and anticipated operational performance measures. Coordinate with existing H-GAC modeling efforts.	✓	✓	✓						✓	✓	FY 2024	Director of TMS, Director of Advanced Transportation Planning	H-GAC	Staff hours	% complete until finalized
BP-08	Use business intelligence to automate alarms that show deficiencies such as detector issues, short/long splits, cycle optimization.		✓	✓			✓				✓	FY 2023	Director of Traffic Engineering	TRF	Staff hours and technology	% complete until finalized

ACTION NUMBER	ACTION DESCRIPTION	SUPPORTS HOUSTON DISTRICT TSMO GOALS										TIMELINE	TxDOT HOUSTON DISTRICT LEAD	PARTNERS	RESOURCES	MEASURES OF SUCCESS
		SAFETY	RELIABILITY	EFFICIENCY	CUSTOMER SERVICE	COLLABORATION	INTEGRATION	EMERGENCY PLANNING	FINANCIAL RESOURCES	TRAFFIC INCIDENT MANAGEMENT	TECHNOLOGY & INNOVATION					
BP-09	Incorporate person throughput into TSMO guidance. Consider a Concept of Operations to define the guidance.		✓	✓		✓	✓				✓	FY 2022	Director of Operations, Director of Advanced Transportation Planning	H-GAC Transit Subcommittee, METRO	Staff hours	% complete until finalized
SYSTEMS & TECHNOLOGY (ST)																
ST-01	Use third-party data in Lonestar™ to improve situational awareness in construction work zones and to populate DMS messages. A pilot project is underway. Consider phased rollout based on performance of pilot project.	✓	✓	✓	✓	✓	✓			✓	✓	FY 2021	Director of TMS	Construction Director, Area Engineers, TRF, Information Technology Division (ITD) third party data sources	Staff hours	% complete until finalized
ST-02	Develop resource inventory for ITS/Operations (e.g., message signs, cameras) to assist with traffic management planning for planned special events.						✓		✓		✓	FY 2023	Director of TMS	Area Engineers	Staff hours	% complete until finalized
ST-03	Evaluate interoperability to expand data sharing beyond Houston TranStar partnership agencies. While many agencies receive TxDOT data, TxDOT could benefit from gathering data from other agencies. Next steps: ▪ Update list of TxDOT data-sharing agreements. ▪ Use H-GAC TSMO Subcommittee as conduit to start conversations.					✓	✓	✓	✓	✓		FY 2021	Director of TMS	Houston TranStar, TTI, H-GAC TSMO Subcommittee	Staff hours, IT support	% complete until finalized
ST-04	Consider management of traffic signals from Houston TranStar facility rather than the Houston District Office.			✓		✓	✓		✓			FY 2022	Director of Operations, Director of Traffic Engineering	Houston TranStar	Staff hours, legal documentation	% complete until finalized
ST-05	Develop a methodology for sharing critical data among all traffic management functions using established open-standard interfaces, regardless of data origin or type. Establish a common traffic management data warehouse capability where all management applications supply data to the core warehouse. *Cross-referenced to CO-1.			✓		✓	✓				✓	FY 2022	Director of TMS	TTI, Director of Advanced Transportation Planning	Staff hours, IT support	% complete until finalized
ST-06	Develop a core integration roadmap that moves the traffic management functions from independent systems to common platforms for data sharing and operational information.			✓		✓	✓				✓	FY 2022	Director of TMS		Staff hours	% complete until finalized
ST-07	Conduct regular training on systems engineering with staff.					✓					✓	FY 2022	Director of TMS	TRF	Staff hours	% staff finished the training

ACTION NUMBER	ACTION DESCRIPTION	SUPPORTS HOUSTON DISTRICT TSMO GOALS										TIMELINE	TxDOT HOUSTON DISTRICT LEAD	PARTNERS	RESOURCES	MEASURES OF SUCCESS
		SAFETY	RELIABILITY	EFFICIENCY	CUSTOMER SERVICE	COLLABORATION	INTEGRATION	EMERGENCY PLANNING	FINANCIAL RESOURCES	TRAFFIC INCIDENT MANAGEMENT	TECHNOLOGY & INNOVATION					
ST-08	Build up infrastructure in terms of detection and communication to support performance management. Develop a plan to upgrade detection and communications.	✓	✓	✓		✓	✓				✓	FY 2022	Director of TMS		Staff hours and equipment	% detection and communication upgraded
ST-09	Implement Connected Vehicle technologies that do not need major upgrades to existing infrastructure and can use available communications network.	✓	✓	✓		✓	✓			✓	✓	FY 2022	Director of TMS	TRF	Staff hours, knowledge of communication networks	% complete until finalized
ST-10	Consider developing a process to monitor real-time traffic conditions, especially incident reports from agency and third-party sources for planned special events.	✓	✓	✓		✓	✓	✓		✓	✓	FY 2022	Director of TMS	TRF, third party data sources	Staff hours	% complete until finalized
ST-11	Consider the use of microscopic- and mesoscopic modeling techniques to assess spatial and temporal distribution of traffic to support planned special event traffic management plans and identify potential bottlenecks. Compare modeling results with what happened at the actual event.	✓	✓	✓			✓	✓		✓	✓	FY 2023	Director of Advanced Transportation Planning	TMS	Staff hours and modeling skills/software	% complete until finalized
PERFORMANCE MEASURES (PM)																
PM-01	Evaluate additional options for Houston TranStar data consumption (e.g., crowdsourcing data, third-party data). Identify opportunities for acquiring data from external sources such as other partner agencies and the private sector and establish data-sharing agreements. Use Houston TranStar Leadership Team meeting as venue to advance this effort.		✓			✓	✓	✓		✓	✓	FY 2021	Director of TMS	Houston TranStar, Harris County, City of Houston, TRF, Partner Agencies, third party data sources	Staff hours	% complete until finalized
PM-02	Implement a performance measure for ITS asset uptime during construction. Perform this action item after CU-01.	✓	✓	✓								FY 2023	Director of TMS	Director of Construction, Area Engineers	Staff hours	% complete until finalized
PM-03	Develop process to incorporate operations output/outcome and reliability performance into district decision-making processes. Abide by all federal and H-GAC performance measure requirements. Use Houston TranStar Leadership Team meeting as venue to discuss.			✓								FY 2022	Director of Operations, Director of Advanced Transportation Planning	DE, DDE, Director of TP&D, TTI, H-GAC, Partner Agencies	Staff hours	% complete until finalized
PM-04	Develop consistent performance data analysis process to continually track the performance of the system in relation to the established targets and benchmarks.		✓									FY 2022	Director of TMS	TRF	Staff hours and data	% complete until finalized
PM-05	Work to update infrastructure in the region to support tracking traffic signal performance. Replace traffic signal controllers with appropriate hardware to collect the high-resolution data needed for ATSPMs.		✓	✓		✓	✓				✓	FY 2022	Director of Traffic Engineering		Staff hours and equipment	% signals able to track ATSPMs

ACTION NUMBER	ACTION DESCRIPTION	SUPPORTS HOUSTON DISTRICT TSMO GOALS										TIMELINE	TxDOT HOUSTON DISTRICT LEAD	PARTNERS	RESOURCES	MEASURES OF SUCCESS
		SAFETY	RELIABILITY	EFFICIENCY	CUSTOMER SERVICE	COLLABORATION	INTEGRATION	EMERGENCY PLANNING	FINANCIAL RESOURCES	TRAFFIC INCIDENT MANAGEMENT	TECHNOLOGY & INNOVATION					
PM-06	Develop a performance management plan to determine what metrics (active and passive) to track for specified traffic signal operational strategies. Some considerations: • Automatic notification of traffic signal equipment outages and service interruptions • Active detection status • Maintenance issue tracking	✓	✓	✓			✓				✓	FY 2022	Director of Traffic Engineering		Staff hours, technology and equipment	% complete until finalized % equipment that can provide automatic notifications
PM-07	Identify traffic signal asset management blind spots and improve systems that monitor assets.		✓									FY 2022	Director of Traffic Engineering		Staff hours, technology and equipment	% asset management blind spots addressed
PM-08	Develop a system for real-time data collection and performance measurement to support multi-discipline operational decisions and improvements for planned special events.		✓	✓		✓	✓	✓		✓	✓	FY 2024	Director of TMS		Staff hours	% complete until finalized
PM-09	Use advanced simulation and analytical model to support the analysis of traffic management strategies/options.			✓							✓	FY 2023	Director of Advanced Transportation Planning	TMS, TRF	Staff hours, technology	% complete until finalized
PM-10	Develop formal policy and action plan that tie performance measures to all aspects of system operations and maintenance.			✓					✓			FY 2023	Director of Operations, Director of Maintenance	DE, DDE	Staff hours	% complete until finalized
PM-11	Upgrade Houston TranStar traffic signal map to reflect real-time status. Add more jurisdictions to the map. Export data from multiple central software systems into a common mapping system.		✓			✓	✓					FY 2023	Director of Traffic Engineering	TTI, H-GAC TSMO Subcommittee	Staff hours, technology and equipment	% complete until finalized
PM-12	Develop Data Tactical Plan. *(See Tactical Plan Assessment section)* Elements to consider: ▪ Literature review of state of the practice ▪ District data needs assessment ▪ Phased implementation effort		✓	✓								FY 2022	Director of TMS, Director of Advanced Transportation Planning	TRF, ITD, TTI	Staff hours	% complete until finalized
CULTURE (CU)																
CU-01	Incorporate incentives or penalties for ITS asset impacts into construction contracts.		✓						✓		✓	FY 2022	Director of Construction	Director of Operations, Area Engineers	Staff hours and legal documentation	% complete until finalized

ACTION NUMBER	ACTION DESCRIPTION	SUPPORTS HOUSTON DISTRICT TSMO GOALS										TIMELINE	TxDOT HOUSTON DISTRICT LEAD	PARTNERS	RESOURCES	MEASURES OF SUCCESS
		SAFETY	RELIABILITY	EFFICIENCY	CUSTOMER SERVICE	COLLABORATION	INTEGRATION	EMERGENCY PLANNING	FINANCIAL RESOURCES	TRAFFIC INCIDENT MANAGEMENT	TECHNOLOGY & INNOVATION					
CU-02	Collaborate and share resources to innovate (based on the latest research) and continue to provide public education for safety in work zones.	✓			✓	✓						FY 2022	Safety Supervisor, Behavioral Traffic Safety Section Liaison for HOU	Houston TranStar, Area Engineers, PIO, TRF, Media, public (schools, neighborhoods, business, etc.)	Staff hours, education materials	Attendance at safety events
CU-03	Offer traffic managers financial and administrative support and the authority to participate in federal pilot and pooled-fund projects to assess new and emerging traffic management practices.					✓			✓		✓	FY 2022	DE, Director of Operations	TRF	Staff hours	% complete until finalized
CU-04	Generate a comprehensive outreach program that provides critical performance measure information across all audiences via diverse platforms for overall agency activities related to TSMO.				✓	✓	✓					FY 2022	Director of TMS, PIO	HOU Directors	Staff hours	% complete until finalized
CU-05	Refine design process so that TSMO is incorporated early in the process with input from Construction, Operations, Maintenance, and Area Offices staff in addition to Design staff.		✓			✓	✓					FY 2023	Director of Design	Directors of TP&D, Construction, Operations, Maintenance); Area Engineers	Staff hours	% of ITS and signal plans reviewed by all practice areas in the design process
ORGANIZATION & WORKFORCE (OW)																
OW-01	Identify or create training courses/seminars that focus on critical aspects of all traffic management functions, including technology aspects. Develop or update training plans by position.					✓			✓			FY 2024	Director of Operations	Directors of TP&D, Construction, Operations, Maintenance; Area Engineers, H-GAC, Cities and Counties, TRF	Staff hours	% complete until finalized
OW-02	Build and develop the workforce needed to operate and maintain advanced signal systems.					✓			✓			FY 2022	DE, Director of Operations, Director of Traffic Engineering		Staff hours	# of staff that can operate and maintain advanced signal systems
OW-03	Increase workforce to handle day-to-day traffic signal maintenance issues, potentially using contractors for long-term maintenance work.		✓	✓					✓			FY 2022	DE, Director of Operations, Director of Maintenance		Staff hours, legal documentation	% signal maintenance issues addressed in 24 hours
OW-04	Develop staff retention plan for key TSMO support positions: • Traffic engineers • Traffic signal engineers • Freeway operations/ITS engineer • Arterial operations engineer • ITS design engineer • ITS planner • Technicians (ITS, signal)					✓			✓		✓	FY 2022	Director of Operations	DE, DDE, HR, TRF	Staff hours	% of Operations staff retained annually

ACTION NUMBER	ACTION DESCRIPTION	SUPPORTS HOUSTON DISTRICT TSMO GOALS										TIMELINE	TxDOT HOUSTON DISTRICT LEAD	PARTNERS	RESOURCES	MEASURES OF SUCCESS
		SAFETY	RELIABILITY	EFFICIENCY	CUSTOMER SERVICE	COLLABORATION	INTEGRATION	EMERGENCY PLANNING	FINANCIAL RESOURCES	TRAFFIC INCIDENT MANAGEMENT	TECHNOLOGY & INNOVATION					
OW-05	Develop staff retention plan for maintenance positions requiring a commercial driver's license (CDL).								✓			FY 2021	Director of Maintenance	Maintenance Division, DE, DDE, HR, TRF	Staff hours	% complete until finalized; annual % staff with CDL retained
COLLABORATION (CO)																
CO-01	Enhance existing data sharing agreement process to make it easier to execute future data sharing agreements with TxDOT. ▪ Share templates for infrastructure sharing contracts (e.g., ingress/egress of fiber. ▪ Develop a brief document with directions for establishing a TxDOT data/fiber sharing agreement. ▪ Execute additional data sharing agreements.			✓		✓	✓		✓			FY 2022	Director of Operations, Director of TMS	Other districts, partner agencies	Staff hours, technology and equipment	% complete until finalized
CO-02	Investigate the use of social media to fill gaps in existing data collection plan and information delivery. Establish guidelines for use.		✓			✓	✓				✓	FY 2022	Director of TMS, PIO	TRF	Staff hours	% complete until finalized
CO-03	Identify methods to engage other counties and cities in the Houston metropolitan region beyond Harris County. Consider engagement around Area Office functions, corridor travel sheds, hurricane evacuation routes, work zones, traffic incident management, etc.					✓	✓					FY 2022	Area Engineers	Directors of TP&D, Construction, Operations, Maintenance); PIO, Cities and Counties, H-GAC	Staff hours	% complete until finalized

Not all of the actions may be achievable in a four-year cycle. The Houston District may want to include a list of longer-term actions to re-consider during the next major plan update.

Longer Term TSMO Action Items

The following TSMO action items were identified as a lower priority and may be advanced at any time or assessed during future updates to the TSMO program plan:

- Consider creating a Center-to-Center (C2C) data hub so that system interoperability is not an issue
- Identify a core communications link
- Use business intelligence applications to produce return-on-investment (ROI) annual reports for traffic signals
- Enhance installed technology solutions to allow for autonomous operations without operator oversight
- Develop a template for planned special event traffic management approach - 1) lane closures, 2) routing people to parking areas, and 3) pushing people through who are not going to the event (circumvent the event)
- Develop a process to improve planned special event wayfinding to get public to venues at the correct location on preferred routes and to use diverse mode choices
- Develop and maintain a planned special event-oriented matrix that includes lessons learned, a process for assessing concurrent impacts (e.g., work zones or other events), and identify a list of external factors affecting the scope of events (e.g., weather, possibility of attendance from high security individuals
- Consider small traffic management center (TMC) or mobile command post with access to ITS devices for planned special events
- Consider developing a process to monitor real-time traffic conditions, especially incident reports from agency and third-party sources for planned special events
- Develop additional capabilities for planned special event situational awareness tools
- Improve ability for traffic signal management including more remote capabilities, automation tools and strategies to prioritize progressions and throughput during planned special events
- Consistently apply Incident Command System (ICS) structure to establish agency functional responsibilities for planned special events
- Develop and conduct operational exercises for planned special events that focus on training and knowledge transfer

Regional TSMO Actions that may be Championed by Partners

A number of action items with regional implications were identified during the capability workshops. Some of these, particularly related to broader regional planning efforts or planned special events with a larger impact on local agency roadway networks, may be best championed by other partners. These were circulated to the stakeholders in the Appendix and many were discussed at a September 29, 2020 workshop. Table 7 summarizes actions to advance through other forums.

TABLE 7. REGIONAL ACTION ITEMS

Action Item	Desired Timeline	Next Steps
H-GAC TSMO SUBCOMMITTEE		
Develop a multi-agency ITS Master Plan with a multimodal focus. Identify special corridors to deploy advanced ITS capabilities.	TBD	▪ H-GAC has already identified a need to develop an ITS Master Plan and will advance it through its work plan.
Establish traffic management body of knowledge, including public and private sectors, to generate creative solutions to traffic management challenges.	Ongoing	▪ Continue to develop and promote H-GAC's TSMO Clearinghouse (H-GAC, 2018). ▪ Promote regional TSMO training opportunities.
Engage smaller cities to expand the use of ITS architecture.	TBD	▪ Continue regional outreach about the tools in H-GAC's TSMO Clearinghouse. ▪ Consider ITS architecture requirements as part of Transportation Improvement Program (TIP) project applications.
Identify needs for construction coordination tools and systems and processes for keeping work zone and construction data up to date across agencies in a timely and automated manner.	TBD	▪ Brainstorm ideas with Subcommittee.
TRAFFIC INCIDENT MANAGEMENT COMMITTEE		
Develop performance goals for event users and non-users and derive benefits of efficient and effective transportation operations during planned special events using performance measures [Note- this action may also be implemented by venues, organizers, single agencies, etc.]	FY 2022	▪ Identify existing performance measures. ▪ Identify performance measures of interest. ▪ Pick a recurring event involving multiple agencies and use that as a pilot to develop standard procedures/protocols. ▪ Explore existing performance measures, and determine if those, or additional performance measures are applicable to these types of events. ▪ Conduct special event after-action reviews to review performance. ▪ Planned special event organizers can present on events and agency coordination needs during TIM meetings. They have done that in the past. ▪ Elevate findings to Houston TranStar Leadership team as needed.

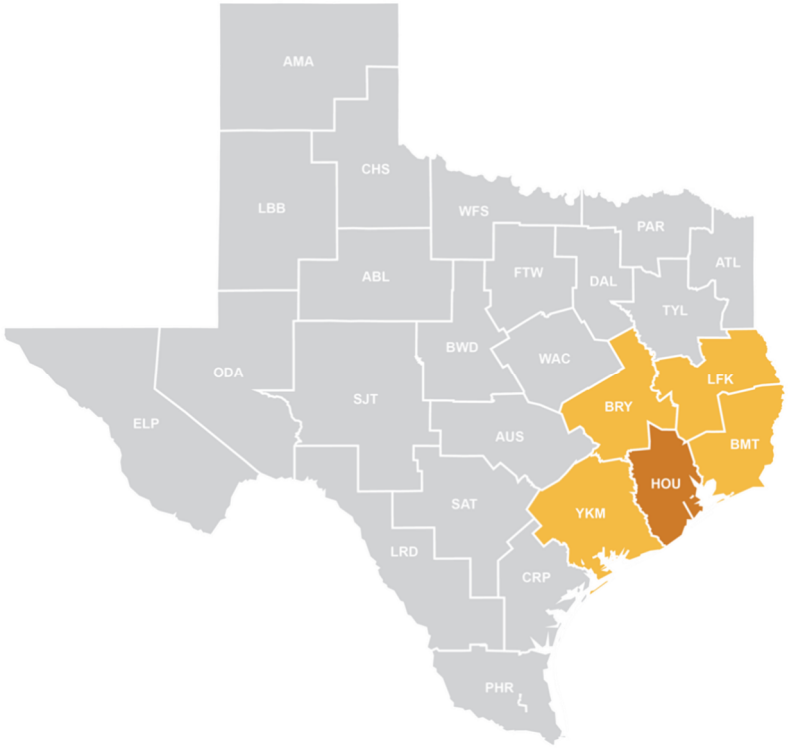
Action Item	Desired Timeline	Next Steps
Plan for Incident management for large-scale planned special events (e.g., pre-stage towing for congested areas and field staffing)	TBD	▪ Brainstorm ideas with Committee.
HOUSTON TRANSTAR LEADERSHIP TEAM		
Increase communication of pre-event information for planned special events available to the public through existing Houston TranStar media outlets (Know Before You Go) and DMS. This Includes communicating dedicated and unsafe/illegal locations for parking or viewing events. It also includes increasing the number of regional stakeholders that provide information to the Houston TranStar PIO.	TBD	▪ Brainstorm ideas with Leadership Team.

The following actions were identified during the Planned Special Events workshop, but should be advanced at the agency or venue level:

- Develop formal process for conducting and documenting planned special events after-action reviews that focus on traffic / travel (in addition to public safety).
- Consider implementing qualitative data collection instruments (such as customer or attendee surveys) to support planned special event performance evaluation
- Develop a plan for Transportation Network Company (TNC) pick-up and drop-off activity locations as well as enforcement for TNC violations
- Develop a planned special events Security Plan for traffic separation and restrictions, such as pedestrian, vehicle, and screening needs
- Consider small traffic management center or mobile command post with access to ITS devices for planned special events
- Consider dynamic parking pricing and associated wayfinding information systems for planned special events
- Consider potential linkage between toll services and planned special event services, such as parking or tickets

Links to TSMO Efforts in Adjacent Districts

The Houston District (HOU) coordinates TSMO activities across jurisdictional boundaries with four adjacent TxDOT districts and also provides varying degrees of operational and maintenance support. This section describes coordinated TSMO efforts with the Yoakum (YKM), Bryan (BRY), Lufkin (LFK), and Beaumont (BMT) Districts. All of these adjacent districts appreciate the Houston District's willingness to collaborate and provide operational and maintenance support. These districts also look to the many successes in the Houston District as examples for implementing TSMO in their districts.



Yoakum District

The Yoakum District TSMO Program Plan (TxDOT Yoakum District, 2021) identifies several action items that involve the Houston District:

- Formalize ITS operations and maintenance with the Houston District and Houston TranStar for the current operation and maintenance of ITS devices along I-10 in the eastern part of the district and programmed/future ITS devices on US 59/I-69; the Yoakum District also seeks to formalize relations with the San Antonio District (including the TransGuide TMC) to operate and maintain devices along I-10 in the western half of the district
- Coordinate with the Houston and San Antonio Districts to develop an operational plan for consistent operations of the I-10 corridor for through travelers between the three TxDOT districts or with origin-destination pairs between Houston and San Antonio
- Document the process for reporting traffic incidents to Houston TranStar so institutional knowledge can be passed on to future staff

The Yoakum District recently developed an ITS Master Plan (TxDOT Yoakum District, 2020). While the district does not plan to install a district TMC, they do have plans to install video walls in several strategic locations so that they may access camera views to support response to emergencies, major incidents, or reports of traffic signal issues. The Yoakum District plans to work with the Houston District and the Traffic Division to determine access and control logistics.

Bryan District

The Bryan District TSMO program planning process has identified a potential need to formalize an ITS operational agreement with the Houston District. Currently the Houston District operates some Bryan District ITS devices (cameras, Bluetooth) while the Dallas District operates DMS in the Bryan District. Recent discussions entertained the idea of shifting all operations to the Houston District while the Bryan District is also exploring local TMC option such as a small TMC at the district office or potential joint operations (e.g., City of College Station TMC).

In the meantime, the Bryan District will need operational support of ITS devices. They are currently developing ITS maintenance SOPs and training additional staff to perform ITS maintenance but do collaborate often with the Houston District when troubleshooting ITS maintenance issues. They sometimes borrow equipment from the Houston District since Bryan District bucket trucks are unable to reach cameras at 60-foot mounting heights.

Lufkin District

The Lufkin District plans to seek a formal agreement with the Houston District for ITS operational and maintenance support. The Houston District currently operates and monitors cameras on hurricane evacuation routes in the Lufkin District. While the Lufkin District has programmed ITS devices on future US 59/I-69 and other construction projects and is also developing an ITS Master Plan, expansion of their ITS network will take time and they will continue to need Houston District operations support, particularly after hours. In the long-term, the Lufkin District may consider taking on more operational responsibilities once their ITS infrastructure is large enough to support adding an FTE to take charge of operations.

Beaumont District

The Beaumont District TSMO Program Plan, nearly final, seeks to add a workstation-based traffic management center. There are numerous existing ITS devices on I-10 and programmed/planned with current and upcoming I-10 and I-69 construction projects. The Beaumont District is also working on an ITS master plan to identify long-term ITS infrastructure and communications needs. The TSMO Program Plan includes an action to develop a formal agreement with the Houston District and Houston TranStar to define operational roles and responsibilities such as having Houston TranStar continue to operate the Beaumont District's ITS infrastructure after hours.

Statewide TSMO Efforts

In addition to efforts led by the Houston District, part of the implementation plan includes working with TRF to roll out statewide initiatives at the district. Table 5 includes an overview of TRF statewide initiatives and the Houston District's role. This list will continue to evolve as more statewide initiatives are rolled out. The Houston District TSMO Champion and TSMO Coordinator should continue to work with district staff to support or roll out statewide initiatives as applicable.

TABLE 8. IMPLEMENTATION OF TSMO STATEWIDE INITIATIVES

Statewide Initiative	Houston District Role
TxDOT ITS Design Manual- The development of a statewide manual is underway. The Traffic Division has been reaching out to the districts to gather existing practices, standards, and specifications.	Provide existing documentation to the Traffic Division. Review draft manuals based on experience.
Third Party Data Integration- The Traffic Division is currently working with third party data providers to evaluate how to supplement TxDOT mobility data (e.g. volume, speed) to provide coverage where there are currently gaps.	HOU TSMO Coordinator & PIO: Provide input on gaps on system coverage as requested by The Traffic Division.
Data Lake- TxDOT is collecting data from several sources (including Lonestar™ and CRIS) to create a repository of unstructured data and also working to develop a Data Mart, which is a structured data platform that can be brokered for specific user needs.	Coordinate with TRF and ITD to incorporate Houston District data sources (e.g., RIMS, ConnectSmart)
TSMO Training- The Traffic Division has provided and will continue to provide training opportunities for TSMO, including presentations and discussions at the annual Traffic Safety/Operations/ Maintenance Conference and annual Short Course. TRF is currently developing 30 TSMO training modules. Other webinars or in-person trainings may also be available.	Participate in available training opportunities. Share new knowledge with applicable Houston District staff.
Develop Methodology to Allocate ITS/Signals O&M Funding to Align with TSMO Goals	Provide input and guidance for help allocating more TMS O&M funding.
Develop Statewide Standard Operating Procedures to Improve Operational Interoperability	Provide current SOPs for Houston TranStar and Houston District. Consider using SOPs to cover any gaps.
Improve Procurement Processes to Support TSMO Program Objectives	Provide existing procurement processes. Apply new processes as applicable.
Develop Emergency Response Plan to Improve Preparedness, Response, and Recovery	Provide current capabilities and provide feedback on areas to improve within the Houston District.
Develop Enhanced Traffic Signal System Implementation Plans	Provide existing enhanced traffic signal implementation plans and work to expand existing program.

Statewide Initiative	Houston District Role
Strengthen TIM Teams Collaboration with Stakeholders to Safely Reduce Incident Clearance Times	Work with the Traffic Division to expand interagency agreements in the region if deemed applicable. Provide guidance using the Houston TranStar agreement as a case study in regional TIM.

TSMO Implementation Plan Process

The Houston District TSMO Implementation Plan is intended to be a living document that is updated as implementation of action items progresses or as things change, as illustrated previously in Figure 7. A key activity in maintaining the plan is the quarterly check-in of progress of the implementation plan. The Director of Operations (the district's TSMO Champion) will coordinate with the district engineer or deputy district engineer to include TSMO Program Plan status as an agenda item during the District Quarterly Meeting. This meeting includes leadership throughout the district. Quarterly discussions will keep the momentum going for implementation and allow staff to provide status updates on progress made on action items, discuss if any changes are needed to upcoming action items, and assign action items (to identified lead, alternate lead, identify an action committee, etc.). Part of this check-in will include an ongoing performance assessment using the objectives and measures used today or established in this plan. As the district continues to refine performance metrics and include new data sources, existing and aspirational objectives should be revisited as part of the TSMO Program Plan update process.

Overall, the Houston District plans to update the TSMO Program Plan (including CMF surveys) and ITS Master Plan on a four-year cycle with an interim minor update to the TSMO Program Plan every two years as shown in Figure 9. The Houston District participated in the 2018 development of the Regional ITS Architecture led by H-GAC. A specific update timeframe has not been identified, but the H-GAC's TSMO clearinghouse website includes a change management process that identifies triggers for ITS architecture updates (H-GAC, 2020). The Houston District will continue to participate in that process.

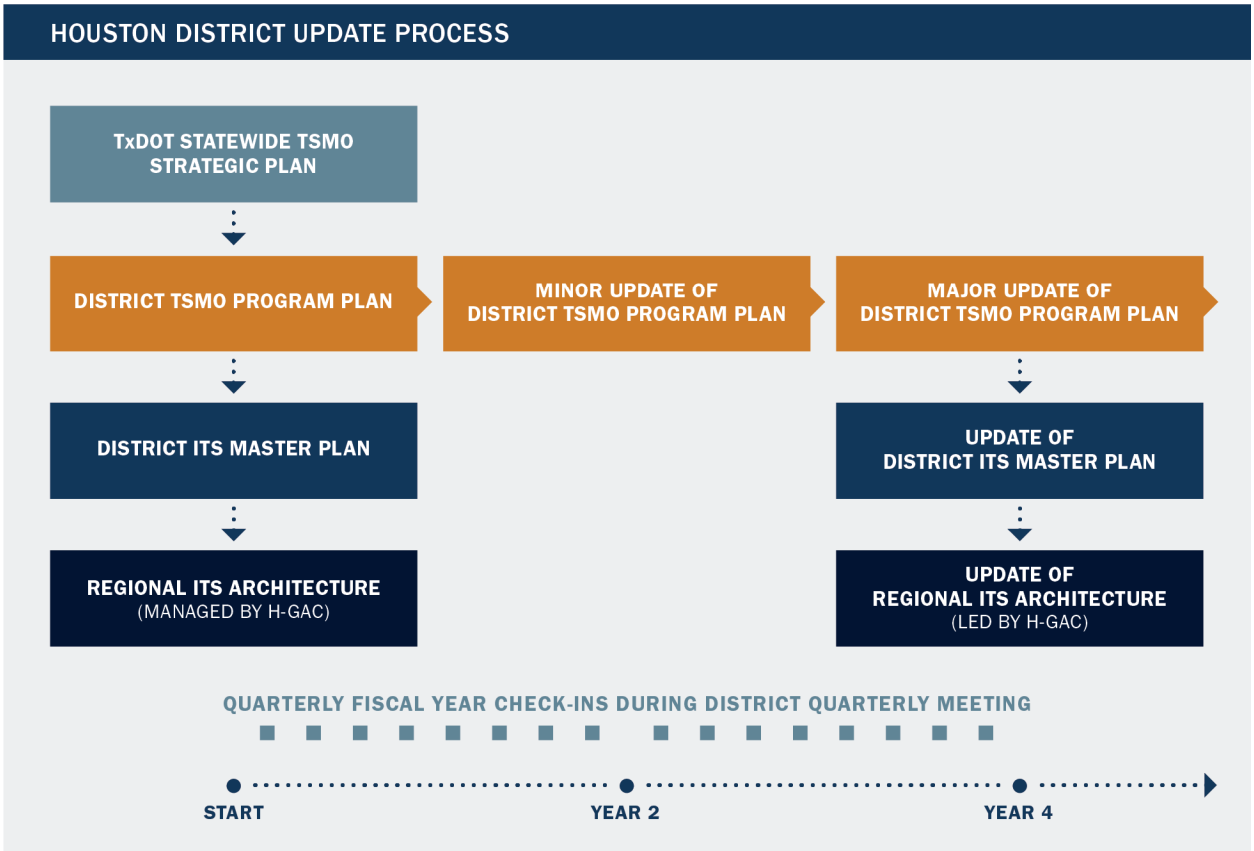


FIGURE 9. HOUSTON DISTRICT TSMO PLAN UPDATE PROCESS

TSMO Tactical Plan Assessment

This TSMO Program Plan has established the Houston District's strategic elements — relating TSMO strategies to the district's mission, vision, goals, and objectives — and programmatic elements — organizational structure and business processes necessary to support TSMO implementation. This final section focuses on the tactical elements — the actions necessary to operationalize the services, programs, and priorities identified in the Implementation Plan.

A TSMO Tactical Plan should be developed for each of the Houston District prioritized services, activities, or projects to be advanced in the near-term. This section describes tactical plan criteria, tactical plan components, and recommended tactical plans.

Tactical Plan Criteria

Tactical criteria were developed by the Traffic Division using qualitative descriptors with the intent that, as tactical plans advance to implementation, quantitative analyses will be performed (e.g., cost estimates, benefit-cost ratios, funding sources, detailed schedules). Criteria for tactical plans applied at the strategic plan level are as follows:

- Alignment with the district's mission, vision, and goals
- District staff support (e.g., low, medium, high)
- Stakeholder partnerships (e.g., internal, external, public vs. private)
- Costs (e.g., low, medium, or high for initial and recurring costs)
- Return on investment (e.g., low, medium, high)

Tactical Plan Components

A TSMO Tactical Plan will be developed for each of the Houston District's prioritized services, activities, or projects, as identified in the next section on Recommended Tactical Plans. Each Tactical Plan will contain the following components:

1. Description of the prioritized service, activity, or project
2. Identification of the key enabling implementation guidelines and policies
3. Investment/financial plan
4. Annual action/deployment plan
5. Identification of performance measures to be used to monitor and evaluate investments

These five tactical plan components are described more fully below.

Description of the Prioritized Service, Activity, or Project

Describe the initiative and how it supports the district's TSMO goals and objectives. Describe existing services such as devices and systems, staffing, priorities, and stakeholder coordination. Perform a gap analysis to review how emerging technologies, operating models, data acquisition and utilization, resources and staffing, and business process relate to the initiative. Describe the future of the initiative.

Supporting Implementation Policies and Guidelines

Identify the relevant TxDOT, district, or federal policies and guidelines needed for the specific service or strategy. Examples include standards and specifications for communications technologies, guidelines for

selection or deployment of ITS devices, policies and guidance on public/private data sharing initiatives, decision-making guidelines for implementation, and service levels standards for devices.

Investment/Financial Plan

Effective planning for TSMO involves identifying the costs associated with deployment of services, which may include new infrastructure investments, technology purchases, staff time and resources (initial and ongoing), or other resources. Use benefit/cost or other criteria analysis methods to support project prioritization and funding requests. Identify current funding resources for the deployment and any potential funding sources that could be matched to the initiative or each action item or project.

Annual Action Plans

Drawing from funding resources and opportunities to integrate TSMO in other activities and projects, develop a set of specific actions for deployment, on an annualized timeframe. These annual plans should be developed in coordination with larger district or agency planning efforts and integrated in standard programs, which often have a four-year timeframe.

Tracking Progress: Performance Assessment

Finally, the TSMO Tactical Plan should address how performance analysis will be conducted to measure the effectiveness of tactics in meeting program objectives. Select from the metrics identified earlier in this Program Plan to be used to conduct on-going monitoring of system performance and project evaluation. Clearly identify how we will measure how well we are meeting the program's stated objectives. Also identify what data are currently available and what additional data is still needed. Finally, consider ways that data can be used to tell success stories to justify future TSMO investments and to promote a TSMO culture within the district.

Recommended Tactical Plans

Two primary tactical plans are recommended for the Houston District and are described in the Tactical Plan Assessment section below.

- **Regional Data Management Plan,** to identify ways to enhance data sharing and institutional collaboration across the district to support more efficient, responsive, and data-driven services
- **Connected and Autonomous Vehicles (CAV) Plan,** to identify ways to prepare for emerging CAV technologies and adoption.

In addition, the district may consider developing tactical plans for other topics, including integrated corridor management, managed lanes, active traffic demand management, adaptive ramp metering, and travel time system expansion/enhancements.

Tactical Plan Assessment

The recommended tactical plans are assessed against the strategic level tactical criteria as shown in the tables below.

Regional Data Management Tactical Plan Assessment

Goal Alignment										Resources			
Safety	Reliability	Efficiency	Customer Service	Collaboration	Integration	Emergency Planning	Financial Resources	Traffic Incident Management	Technology & Innovation	District Staff Support	Partnerships	Costs	Return on Investment
✓	✓	✓		✓	✓		✓		✓	High	Internal & External	Medium	High

Key Considerations

- Development of a shared regional data warehouse
- Data sharing capabilities and supporting communications network
- Development of data ownership and sharing agreements
- Adopted data standards and best practices
- Establishment of collaborative partnerships and agreements with 3rd-party data providers
- Evaluation of private sector data platform solutions
- Established safety, traffic congestion, travel time, and reliability performance measures
- Workforce organization to support this effort
- Workforce development investments, including developing technical skills, education of existing staff
- Safety-related data should be included such as crash reports and connected vehicle data

Connected-Automated Vehicle Tactical Plan Assessment

Goal Alignment										Resources			
Safety	Reliability	Efficiency	Customer Service	Collaboration	Integration	Emergency Planning	Financial Resources	Traffic Incident Management	Technology & Innovation	District Staff Support	Partnerships	Costs	Return on Investment
✓	✓	✓			✓		✓		✓	Medium	Internal & External	High	Medium

Key Considerations

- Supporting high-speed and high-bandwidth communications network
- Advanced transportation controllers
- Data standards and common data sets to share and store connected vehicle data over any comms standards
- Monitoring of national automated vehicle developments, including state and federal policies and actions
- Monitoring of potential impacts to road infrastructure design
- Local and regional policies for automated vehicles

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Houston District TSMO Program

TSMO Program Plan

APPENDIX

Appendix: Contents

Appendix A: List of Stakeholders and Acknowledgments

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