GUIDEBOOK ON PRESERVING THE FUNCTIONALITY OF STATE HIGHWAYS IN TEXAS

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Product 0-6208-P1
Project 0-6208
Project Title: Preserving Functionality/Asset Value of the State Highway System

Prepared in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

March 2009
Published: May 2010
http://tti.tamu.edu/documents/0-6208-P1.pdf

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ACKNOWLEDGMENTS

This project was conducted in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The research reported herein was performed by the Texas Transportation Institute (TTI). Mr. Blair Haynie, district transportation planning engineer of TxDOT's Abilene District, served as the research project director and TxDOT's Transportation Planning and Programming Division, directed by Mr. Jim Randall, was the Office of Primary Responsibility for the project.

The authors would like to thank the members of the Project Monitoring Committee for their advisement and guidance:

- Mr. Robert Appleton, Bryan District, Texas Department of Transportation;
- Ms. Maria Burke, Design Division, Texas Department of Transportation;
- Ms. Melisa Montemayor, Laredo District, Texas Department of Transportation;
- Mr. Kenneth Petr, Amarillo District, Texas Department of Transportation;
- Ms. Peggy Thurin, Transportation Planning and Programming Division, Texas Department of Transportation;
- Mr. Henry Wickes, Traffic Division, Texas Department of Transportation; and
- Mr. Doug Woodall, Texas Turnpike Authority, Texas Department of Transportation;

The authors would like to provide special thanks to Duncan Stewart and Sylvia Medina of TxDOT's Research and Technology Implementation (RTI) Division for their assistance in this project. They would also like to thank the following individuals for providing their time and insights:

- Ms. Catherine McCreight – Houston District;
- Ms. Elvia Cardinal – Houston District;
- Ms. Karen Baker – Conroe Area Office;
- Mr. Jim Heacock – Houston District;
- Ms. Francis Willams – Houston District;
- Mr. Dan Wilds – Montgomery County Engineers Office; and
- Mr. Amar Mohite – Planning and Development, City of Houston.

The following individuals are acknowledged for their research and written contributions in the final report of this research report from which portions of this guidebook are based.

- Dr. Yi Qi, Department of Transportation Studies, Texas Southern University and
- Dr. Ivan Damnjanovic, Department of Construction and Engineering Management, Texas A&M University.

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PROJECT PURPOSE AND BACKGROUND

The purpose of this project was to identify the sources of deterioration of state highway functionality that occur over time and what actions can be taken to preserve, recover, and enhance functionality. Congestion and operational problems slow traffic, resulting in wasted fuel and time. Safety problems endanger goods and people and poor pavement can affect both travel speed and safety. In light of this, it is important that functionality be considered in all stages of a highway's lifecycle and that it be protected, preserved, and where possible enhanced during the course of planning, growth and development, operations, and maintenance.

This report provides guidelines through an extensive list of actions for how TxDOT, MPOs, local jurisdictions, and other transportation stakeholders and agencies can protect, preserve, and enhance the functionality of the state highway system. It represents product P1 of TxDOT research project 0-6208, Preserving Functionality/Asset Value of the State Highway System. Relative to the full 0-6208-1 research report, this document is intended to serve as a reference document.

ROLE AND IMPORTANCE OF HIGHWAY FUNCTIONALITY

Highway functionality determines how well highway facilities serve Texas and its many highway corridors. With Texas' population and economy spread far and wide across the state, our state highways are the lifeblood of Texas. Achieving a high level of functionality across the Texas highway system is important to the state's residents and businesses for many reasons:

- Mobility and accessibility are major factors in making Texas economically competitive and successful as well as delivering a desirable quality of life.
- Highway safety is greater when highways function efficiently, and safety is important to the health and welfare of all Texans.
- Efficiently functioning state highways make for cost-effective use of investments made with Texas tax dollars.
- Preserving efficient operations and good physical condition of state highways protects the value of existing state highway assets.
- Preserving highway functionality and condition helps to avoid the need for undue or premature major highway improvements or replacements, which is especially important with highway funding already short of current needs.

How well our streets and highways operate depends to a large extent on how each functions in its role among all of the roadways in the transportation network. The functionality of the state's freeway and highway system is impacted, to varying degrees, by (1) how well it is integrated with off-system roadways, such as city and county streets and thoroughfares, and (2) how private facilities such as access driveways and parking lots distribute traffic from adjacent developments to public streets and highways. To preserve and enhance the functionality of the state highway system, each of the elements of the transportation system and how they are planned, designed, integrated, and maintained must be given careful attention.

Functional classification is the means by which streets and highways are grouped into classes or categories according to the amounts and types of traffic and level of access they are intended to provide. A widely used system of functional classification in communities includes six hierarchal levels, which are freeway, major arterial, minor arterial, major collector, minor collector, and local street. An expressway is a lesser design that from a functionality standpoint falls between a freeway and an arterial. Under this system, freeways and arterials provide a higher level of mobility with greater access control, while collectors and local streets allow for higher levels of land access with a lower level of mobility. As part of this system, roadways should only transition from one functional class to the next in order to properly serve different types of trips, such as shorter and slower local trips verses longer and faster through travel.

Maintaining, preserving, and enhancing the functionality of state and local roadways of our transportation system is important because it:

- maintains capacity and efficiency;
- reduces potential for congestion;
- maintains safety;
- protects the value of our investments in both transportation infrastructure and adjacent land development;

- reduces the need for further (or unplanned) improvements;
- reduces the need for replacement or supplemental facilities;
- helps avoid the need for additional personnel time and monetary resources to address congestion or safety problems;
- facilitates land use planning and growth management; and
- reduces pollution and extensive maintenance needs caused by congestion.

It is also important to note that functional class and related design of an existing roadway may reflect a decision made decades ago under different conditions. With continual increases in traffic growth and land development, it is important that the designated functional classes of roadways on local and regional plans be re-assessed from time-to-time.

Five Components Affecting Highway Functionality

In the practice of transportation planning, roads are classified according to their intended function. The functional classification defines the priority of mobility over accessibility and vice-versa. In order for roadways to serve their planned or intended function—such as a freeway, expressway, or arterial—there must be an appropriate balance or level of mobility and accessibility in relation to their functional role in the system. The primary components and practices of the highway system that contribute to and affect functionality include:

1. Planning and Land Development,
2. Operations and Capacity,
3. Right-of-Way,
4. Infrastructure and Maintenance, and
5. Safety.

While the operations/capacity and the planning components are the most apparent areas that impact highway functionality, right-of-way availability, infrastructure conditions, and safety also play a role. That being said, each of the five areas plays a part in establishing how well or poorly a highway may function and in meeting or preserving its intended function. Table 1 provides an overview of the practices and subareas by component that impact functionality.

Table 1. Practices by Component Affecting Functionality.

Planning	Operations	Right-of-Way	Infrastructure	Safety
• TxDOT - Statewide - District level • TxDOT/local coordination • MPO/regional • City/comprehensive - Long-range - Short-range • Development review - Subdivision/plats - Site plans • County transportation • Access management • Corridor management • Corridor preservation	• Signal coordination and optimization • Facility design • Rehabilitations and retrofits • Minor enhancements - Ramps, interchanges - Turn lanes - Geometrics • Traffic control and management • TSM, TDM, and ITS Measures • Network enhancements - Parallel facilities - Gap completion - Bottleneck fixes	• Preservation/ protection • Acquisition • Protection • Utility location and maintenance • Coordination with Stakeholders	• Maintenance practices - Corrective - Preventative • Work zone traffic management • Contracting strategies • Life cycle cost decision making • Sustainable materials, equipment, designs • Low maintenance infrastructure components	• Road safety audits - Design - Periodic • Operational assessments • Crash assessments • Sight distance review • Sign assessments and maintenance - Traffic control - Wayfinding • Lighting assessments • Traffic control

Functionality Cycle

Functionality is not a constant. A new or newly upgraded facility normally operates at or close to the levels for which it was designed. In fact, new facilities often operate above design levels because traffic volumes are below design levels. Pavement is new, so there are no defects. Access is as planned when the project was designed. The right of way contains the intended widths for pavement, drainage, utilities, side slopes, etc. Sight distances and sight lines are as intended.

Over time things change. Traffic volumes grow, and sometimes travel patterns change. Heavy loading, water, or other environmental factors begin to affect pavement wear and roadbases. Development occurs along the road, more access is granted, and more turning conflicts are introduced. Trees mature and expand, and brush grows beside or in the right of way. New utility lines running parallel to the road need to be accommodated within the right of way. As time passes these and other changes occur. Level of service begins to decline. Maintenance needs and frequency may start to increase. Operation needs to be refined and sight distances may be impacted. Increasing traffic volumes and turning conflicts may increase crash frequency. Right-of-way and utility coordination management become more demanding. Figure 1 illustrates

some of the changes that occur in this functionality cycle, along with indicators that can quantify or otherwise show changes as they occur.

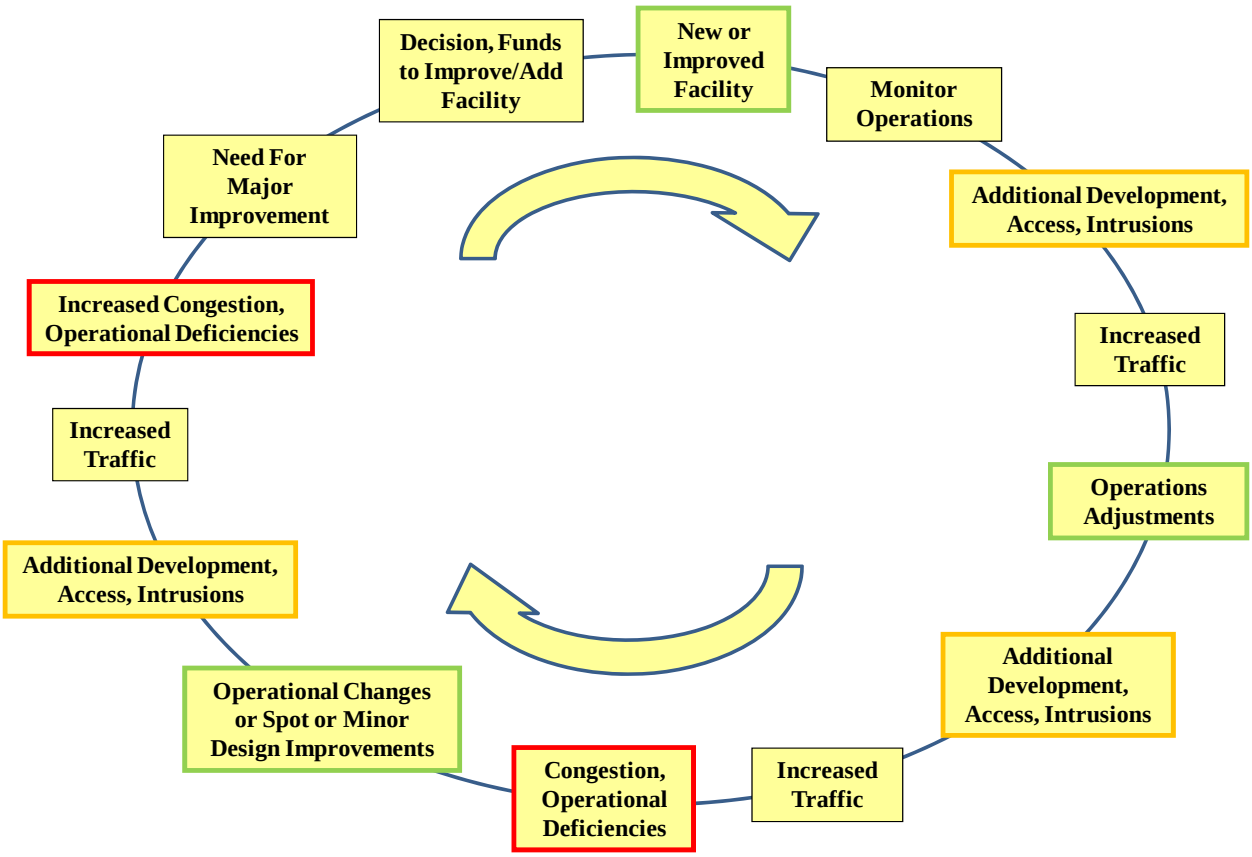

Figure 1. Operational Functionality Cycle.

Under the best circumstances, a highway will remain functional through its intended service life. However, to maintain a high level of functionality, factors that cause deterioration (e.g., increased access, more high volume at-grade intersections, and frequent overweight trucks) need to be minimized, managed, or accommodated with incremental improvements. Unless there is an active process of monitoring functionality followed by actions to restore or enhance deteriorating components, operational functionality can deteriorate to the point where a parallel or replacement facility (or reconstruction) will be needed much earlier that would otherwise be the case. That outcome can be wasteful and unnecessarily costly.

Use Performance Measures to Monitor Functionality

A transportation agency may assess the value of its assets by monitoring their functionality. For roads, functionality can be measured in terms of pavement condition, safety, operations, congestion, and other factors. By monitoring road functionality through established performance measures, TxDOT and its transportation partners can plan maintenance, respond to problems, and improve design standards to maximize the value of existing and future road assets.

In the context of maintaining and enhancing highway functionality, performance measures can be used to identify highway segments where functionality is deteriorating, help prioritize where actions should be taken to preserve or enhance functionality, and confirm that actions taken have improved conditions and are effective. Performance measures can be used to measure accessibility, mobility, economic development, quality of life, safety, and other characteristics. Commonly used performance measures quantify the quantity or quality of travel. Some of these include:

- vehicle-miles traveled,
- person-miles traveled,
- average travel time,
- average travel speed,
- average trip length,
- driveway density per mile,
- time lost due to congestion,
- fuel consumption per vehicle miles traveled, and
- level of service (defined by the Highway Capacity Manual).

All agencies involved in transportation decision making can benefit from and take a role in creating and tracking performance measures, including state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and cities. The performance measures should explicitly reflect visions and goals that have been established through a planning process, which includes stakeholders and the public. Once performance measures are established, they can strongly influence the goals of the planning process, so performance measures should be chosen carefully.

PLANNING TO MAINTAIN FUNCTIONALITY

The planning process is very important to the development and preservation of the functionality of the state's road network. Decisions, actions, and practices made or not made during the planning stage of the highway lifecycle arguably have the greatest impact and influence on highway functionality of any of the five major components. The sections to follow identify the roles in and actions to address functionality by planning policies and practices for MPO and statewide efforts, TxDOT, and local jurisdictions.

MPO and Statewide Efforts

The statewide and metropolitan transportation planning process in Texas and other states across the USA plays an important role in shaping a state's, region's, or community's vision for its future. Maintaining and preserving highway functionality is an underlying and vital aspect of these transportation plans and programs.

Preparation of the statewide transportation plan (STP) is required by state legislation and federal law. TxDOT's STP serves as the framework for long-term planning and preservation of the Texas' transportation system. The statewide plan is not a plan per se but rather a coordinated collection of approved Metropolitan Transportation Plans (MTPs) from the 25 MPOs around the state combined with the statewide rural transportation and multimodal plans. In addition to projects, the statewide plan can also include system-wide transportation goals, policies, or special initiatives to address highway functionality.

The primary functions of MPOs include carrying out the agency's Unified Planning Work Program (UPWP), preparing and maintaining a long-range Metropolitan Transportation Plan and developing a Transportation Improvement Plan (TIP) based on the MTP (*1*). Each of these important MPO activities either addresses or considers highway functionality as part of their process or development. MTPs must be consistent with TxDOT's statewide plan and must be updated every four to five years depending on air quality nonattainment status. Table 2 includes planning practices, roles, and actions as part of MPO and statewide planning efforts that can or should address highway functionality.

Table 2. MPO and Statewide Planning Practices, Roles, and Actions to Address Functionality.

Subcomponent or Practice	Roles in Functionality	Actions to Address Functionality
TxDOT Statewide Transportation Plan (STP)	• The statewide MTP coordinates MTPs of all MPOs and could establish statewide goals and policies on transportation planning and functionality.	• Develop statewide transportation plan map and functional categories for state roadways. • Develop statewide goals, policies, and initiatives to support functionality. • Develop district plan maps illustrating existing and planned highways by functional category. • Establish policies for adherence to functional criteria.
MPO Metropolitan Transportation Plans (MTPs) and Regional Transportation Planning	• MPO MTPs consider and coordinate the functionality and connectivity of all local transportation plans within the MPOs study area. They should coordinate functionality of state roads on local plans with MPO plans.	• Develop MTP map illustrating existing and future thoroughfares by functional category. • Include goals and policies related to adherence to functional criteria, access management, corridor management and preservation, and other initiatives that enhance or preserve functionality. • Develop a corridor preservation strategy that involves working with cities, counties, MPOs, RMAs, and other transportation authorities or stakeholders as appropriate to preserve or protect future transportation corridors prior to environmental clearance. Such corridors should be identified and prioritized through the MPO process.
MPO Unified Planning Work Programs (UPWP)	• UPWPs can serve as a mechanism to ensure that functionality is included and addressed in MPO planning and projects.	• Establish work and project priorities or strategies in UPWPs that enhance functionality such as access management, context sensitive design, transit oriented development, smart growth, travel demand management, and arterial/corridor management, corridor preservation, and others.
MPO Practices	• MPOs serve as a coordinating body that considers the functionality of the roadway network at a regional level.	• Facilitate interagency coordination. • Facilitate education and outreach to policy boards, public, and general stakeholders on importance and benefits of highway functionality in planning and project prioritization. • Assist TxDOT in finding funding sources such as Congestion Mitigation and Air Quality (CMAQ) moneys to fund studies on TSM, TDM, or ITS strategies as well as for implementing recommended improvements.
MPO and Statewide TIPs	• MPO and statewide TIPs identify transportation projects to be undertaken for next 4 years.	• Include benefits to functionality enhancement or preservation as a factor in project selection.
MPO Congestion Management Process in TMAs	• MPO congestion management process in TMAs improves functionality by identifying and addressing congestion locations and facilitating partnerships between stakeholders.	• Develop travel demand reduction strategies and operational management strategies as part of regional planning process. • Larger MPOs, in coordination with TxDOT and other transportation authorities, should provide information to decision-makers on system performance and effectiveness of implemented TDM, TSM, and ITS strategies. • Implement safety and congestion mitigation strategies using corridor /access management studies.
Travel Demand Modeling and Data Collection	• Travel demand modeling is used to estimate future roadway capacity needs in order that the proper functional class of roadway can be planned.	• TxDOT representatives on MPO technical and policy boards, particularly in non-metropolitan areas of the stages, should: - advocate the use and importance of up to date travel demand models in long range transportation planning, alternatives analyses, and TDM strategies; - advocate the importance of developing and training MPO technical staff on maintaining and utilizing TxDOT supported models.

TxDOT and Local Practices and Policies

Current TxDOT practices and policies that most impact urban surface highway functionality include:

- increased access management and access control in facility upgrades;
- facility design practices and policies;
- coordination activities with local jurisdictions on local and regional transportation planning and development adjacent to state facilities; and
- traffic management in high volume urban freeway corridors.

Other activities undertaken by TxDOT that address highway functionality in planning include travel demand modeling and various traffic data collection activities.

Policies, practices, and actions at the local level in the areas of planning and land development have a major bearing of the functionality of TxDOT roadways. Cities have authority to adopt comprehensive plans and subdivision regulations governing land use and development and the layout of local roads. Texas counties, on the other hand, have limited powers regarding land use and development but have subdivision regulations and some transportation planning ability. Local planning, subdivision, and development authorities and practices have significant impacts on on-system facilities and can play an important role in TxDOT efforts to preserve, restore, and enhance highway functionality (*2*). Table 3 lists many of the coordinated and cooperative planning practices, roles, and actions that TxDOT and local planning efforts can use to address highway functionality.

Table 3. District and Local Planning Practices and Actions to Address Functionality.

Practice or Policy	Roles in Functionality	Actions to Address Functionality
Access Management	• TxDOT access guidelines and most local access ordinances regulate the spacing and design of driveway access by functional class of roadway. • Connections between adjacent developments remove conflicts and short trips off of main routes. • Many small communities have business-friendly development policies and politics that have detrimental impacts to functionality.	• TxDOT should continue to pursue compliance with its access manual through coordination on site development plans and plats, and in roadway upgrades, rehabilitation projects, and new facilities. • TxDOT should continue to foster partnerships to use local ordinances or regulations for increased driveway throat length, internal access for outparcels, and connectivity between adjacent developments along state routes. • Provide outside support to rural or non-urban districts to implement and uphold TxDOT's access management guidelines. • TxDOT should involve senior level local staff in development of preliminary design schematics to consider future land use, development, and access. • See other access management related actions in the facility design section.
Local Comprehensive Planning	• Land use plans can be used to help coordinate land use intensity with roadway function and design. • Comprehensive plans impact the direction of growth and infrastructure that can have major impacts the functionality of state routes.	• Districts should be involved in development or updates to local comprehensive plans to: - promote policies and practices that preserve, restore, or enhance roadway functionality; - coordinate land use intensity with roadway design and function; and - have input on the development of transportation and land use goals, policies, and objectives such as direction of future growth or utility extensions. • Promote activity-based instead of strip-type development along corridors.
Corridor Management Planning and Studies	• Corridor management planning brings together transportation and land use planning. • Corridor management plans can coordinate land development with roadway design to help preserve and enhance functionality. • Adopted corridor management plans can be used so that local development decisions are based on the ultimate design and function of the highway.	• Initiate and corridor management planning along TxDOT roadways with MPOs and local jurisdictions. • Develop corridor management plans on TxDOT roadways that include non-traversable medians, minimum spacing requirements for traffic signals, and connectivity between developments. • Advocate adoption of corridor management plans as part of local comprehensive plans and incorporate related implementation projects into MPO UPWPs. • Work with locals on development of zoning overlays to help implements corridor plans.
Local Thoroughfare Plans and Planning	• Local access spacing and design regulation are often based on the functional classes of roadways on the thoroughfare plan. • Overlapping jurisdictions, mutual interest and benefit, and the importance of utilizing local planning and development authorities necessitate a cooperative, multijurisdictional approach for corridor preservation.	• Promote layouts of local street plans that follow the functional hierarchy where minor street connections to major roadways are limited or avoided and subdivisions are connected by local streets. • Since TxDOT roads on included on local thoroughfare plans (city and county), coordinate on local thoroughfare design and minimum right-of-way standards to ensure they are adequate for TxDOT needs and consider future state widenings. • A representative from TxDOT districts and/or area offices should be included on technical advisory panels utilized in the development or updates to local comprehensive or thoroughfare plans.
Involvement in Local Development Review	• The number and location of access points are typically determined or established in early conceptual site plans or plats.	• TxDOT should be involved in the earliest stages of development review to provide input during the conceptual or planning stages of developments. • TxDOT should routinely review subdivision plats and site plans that impact TxDOT facilities to help implement TxDOT access guidelines and to acquire or protect needed right of way where possible. • TxDOT should review plats adjacent to TxDOT roads to help prevent creation of lots that cannot meet access spacing guidelines.

OPERATIONS AND FUNCTIONALITY

TxDOT operates one of the largest highway systems in the country. The functionality of this system relies on the traffic operational performance of roadway segments and intersections. Despite the extensive efforts to improve highway functionality, roadways in many areas experience extended periods of congestion. Much of the congestion is attributable to operations and capacity deficiencies, such as ineffective or inefficient traffic control, underutilization of alternative travel modes, poorly maintained or outdated traffic signals, or facility design that does not meet current operational needs.

TxDOT practices in traffic operations and their impact to highway functionality are addressed in the following three categories:

1) traffic control and management;
2) traffic signal optimization and coordination; and
3) facility design and enhancement.

Traffic Control and Management

To address network operational issues, TxDOT has implemented a variety of operational strategies over the years, with a focus on both improving existing practices and implementing research innovations. In addition to the traditional traffic control measures, TxDOT has been using various intelligent traffic systems (ITS) such as Advanced Traffic Management Systems (ATMS) (*3*) to enhance the traffic and incident management on Texas highways. At present, ITS applications in Texas are focused primarily on freeways where operations are monitored and conditions made available to transportation agencies and travelers. To more effectively use the existing highways, TxDOT has been continuously exploring other strategies, such as toll roads, high-occupancy vehicle (HOV) or toll (HOT) lanes, and public transit, to increase capacity, improve efficiency and reliability, and mitigate traffic congestion.

TxDOT has also developed strategies to facilitate incident management and emergency evacuation. Many major urban areas, such as Houston, San Antonio, Fort Worth, Dallas, Austin, and El Paso, have developed freeway management systems utilizing ATMS for rapid detection and response of traffic incidents (*4*).

Many other efforts in Texas also help to improve mobility and safety across the state. Texas Transportation Code has included provisions such as the driver removal requirement (*5*) that requires a driver to move the vehicle off the major roadway when an accident occurs on a main lane, ramp, shoulder, median, or adjacent area of a freeway in a metropolitan area. In conjunction with local agencies, TxDOT developed motorist assistance programs to better help travelers in case of incidents, such as the Motorist Assistance Program (MAP) in Houston that involved TxDOT, Harris County, and private parties (*6*). The program sends vehicles equipped to handle minor automotive incidents upon requests by phone during weekdays at no cost. It provides convenience to travelers and reduces stalled vehicles that may otherwise affect mobility. Table 4 includes practices, roles, and actions in the areas of traffic control and management that address highway functionality.

Table 4. Traffic Control and Management and Actions to Address Functionality.

Practice or Policy	Roles in Functionality	Actions to Address Functionality
Traffic Control and Management	• Improving traffic operations and efficiency helps mitigate congestion • Effective traffic control optimizes capacity • ITS practices such as electronic toll collection and monitoring of operational conditions to relay traveler information and manage incidents helps mitigate congestion and delay • Use of toll roads, HOV lanes, HOT lanes, transit lanes increases person-trips, reduces auto-driver trips and helps mitigate congestion • Driver assistance programs helps to quickly remove stalled or disabled vehicles that may cause lane closure or bottlenecks	• Use high-visibility traffic control devices. For example, an evaluation showed that a high-visibility flashing LED stop sign was able to effectively reduce the speeds of approaching vehicles especially during nighttime (*7*). • Utilize ITS applications. Explore and utilize more intelligent and advanced technologies for real-time system monitoring and fast incident response. • Continuously develop public education programs and campaigns to improve public awareness and understanding of traffic control and related safety issues. • Consider unconventional operations or design (e.g., reversible lanes, time-managed ramps), or other innovative techniques that are adaptable to special situations. • Use traffic control strategies that encourage transit or ride sharing such as HOV/T lanes. • Develop research projects to improve the effectiveness of existing traffic control devices, explore more cost-effective control devices, and develop more effective traffic control plans.

Signal Coordination and Optimization

Inefficient traffic signal timing accounts for an estimated 10 percent of all traffic delay on major roadways in the United States. The Institute of Transportation Engineers recommends that traffic signals be retimed every three years. However, among the approximate 330,000 traffic signals in the nation, about 75 percent are overdue to be optimized through improved timing and signal coordination (*8*).

TxDOT maintains and operates approximately 6200 traffic signals in Texas (*9*) and is responsible for authorizing traffic signals to be installed on the state highway system at the cities' cost in incorporated cities of 50,000 or more population (*10*). Because it involves multiple jurisdictions and agencies, operating and maintaining the entire signal system in the state requires extensive multijurisdictional and interagency collaboration. Good practices on timing and coordinating this signal network can reduce system-wide traffic delays, increase average running speeds, and improve intersection capacities.

Proper signal phasing and timing is needed not only initially but also as traffic volumes increase and traffic patterns evolve. In order to achieve proper phasing and timing, adequate spacing and separation distances are needed between signal installations and should be considered as part of the warranting and approval process. Table 5 includes practices and roles of signal coordination and optimization in functionality and actions to address this measure.

Table 5. Signal Coordination and Optimization and Actions to Address Functionality.

Practice or Policy	Roles in Functionality	Actions to Address Functionality
Maintenance and operation of signals in cities with <50,000	• Proper signal operations and timing are needed to maintain good progression.	• Conduct routine signal timing evaluations and retime traffic signals at least every three years; do so following any significant change in traffic flow patterns.
Signal Design and Coordination Use of software to timing, phasing	• Adherence to proper signal spacing guidelines is key to preserving the functionality on arterials. • Good timing and coordination of signals and signal networks can reduce system-wide traffic delays, increase average running speeds, and improve intersection capacities.	• Use a traffic signal system audit (TSSA) program during signal planning and design. TSSAs can be used as a peer-review method to identify problems of a signal timing plan or design. Qualified TSSA teams may also introduce better practices, software, hardware, and other related technologies to the design team to improve signal timing and coordination (*11*). • Use ITS to enhance the design and operation of traffic signals. ITS applications that can be used for traffic signals include communication systems, adaptive control systems, real-time data collection and analysis, and maintenance management systems. • Improve traffic monitoring and data collection. Sufficient and timely traffic data are critical information for traffic signal system monitoring and improvement. • Establish leadership and partnership during traffic signal planning and design. Cross-jurisdictional cooperation for signal design and operation can improve system-wide signal coordination and resource/workforce allocation.
Signal authorization on state roads	• A long uniform spacing of traffic signals on arterials and highways is crucial to maintaining good traffic progression and preserving the roadways primary function of mobility.	• Minimum separation distances between signals should be established and applied in warranting and new signal installations. • Districts should partner on corridor management plans that establish minimum signal spacing and/or future signal locations.
Signal hardware and software	• Well designed and maintained signal hardware and software help to ensure signals work properly and in turn improve operations and safety.	• Select appropriate traffic signal hardware with up-to-date technologies that lasts long, produces minimum malfunctions, and requires minimum maintenance. • Conduct routine signal hardware inspection and maintenance to minimize malfunctions and hardware failures. • Use advanced signal communication and operation software/technology to improve traffic signal operations and management. • Update signal hardware and software periodically in consistency with the latest operational and technological trends for better traffic signal operations and management and cross-jurisdictional signal coordination.

Facility Design and Enhancement

Roadway expansion, reconstruction, or other minor or major improvements are necessary when operational improvements can no longer recapture or enhance the functionality of an existing roadway to meet the continuously growing demand. To improve system mobility and traffic capacities, TxDOT has constructed bypass or parallel facilities for many highways and freeways. It has improved or is planning to expand several strategic highways across the state such as IH 69, SH 130, and the Loop 9 corridors to improve state-wide mobility and meet long-term transportation needs. However, improvement needs far exceed available funds, so using minor operational improvements to optimize operational efficiency and functionality is critically important.

Instead of significantly expanding existing facilities or building new roadways, minor geometric and operational enhancements, such as re-striping, ramp modifications, interchange improvements, and intersection and other bottleneck improvements can be a cost-effective alternative for increasing highway functionality. In Texas, different districts have different practices on using minor enhancements and frequently these enhancements are results of assessments for individual cases. When used properly, these measures can yield many benefits including capacity increase and safety improvement.

To provide the financial foundation for highway enhancement or construction in the state, Texas has various funding options including comprehensive development agreements, regional mobility authorities, pass-through financing, and tolling (*12*). TxDOT also established many funding programs for highway projects either independently or jointly with FHWA, such as the Texas Mobility Fund, Statewide Transportation Enhancement Program, and Participation-Waived/Equivalent-Match Project Program. However, improvement needs far exceed available funds, so using operational improvements to optimize operational efficiency and functionality is critically important. Table 6 provides practices and roles of facility design and enhancement in functionality and actions to address this measure.

Table 6. Facility Design and Enhancement and Actions to Address Functionality.

Practice or Policy	Roles in Functionality	Actions to Address Functionality
Expansion of strategic highways	• Conversion of regional highway links from undivided to divided sections improves safety, mobility, and capacity, and enhances functionality.	• Continue TxDOT's practice of 'four-laning' major links in the state highway system with divided highway section.
Arterial rehabilitation and upgrades, including measures to manage access	• Incorporating access management measures into facility design is an optimal means to preserve or enhance roadway functionality. • Reduction in access points through driveway consolidation removes conflict points and improves functionality.	• Establish a statewide policies on the use of non-traversable medians on surface arterial designs including the following: • All designs that include three or more dedicated through lanes in each direction must contain a center non-traversable median. • All designs must include a center non-traversable median when the existing or projected average weekday traffic volume is greater than 25,000. • TxDOT design of rehabilitation projects should include consolidation of access points as needed for compliance with TxDOT access guidelines. If needed, TxDOT should request local subdivision and development ordinances to achieve compliance.
Minor geometric and operational enhancements	• The use of ramp braiding on urban frontage can improve the functionality of freeways and frontage roads by reducing frontage road intersection congestion and reducing on-freeway weaving.	• Consider minor geometric and operational enhancement approaches, such as re-striping, adding auxiliary lanes, ramp metering, and using HOV lanes as quick solutions to bottlenecks and other congestion problems. • For new and upgraded urban frontage roads, utilize ramp braiding (the 'X' ramp configuration) where exit ramps are located on the downstream side of interchanges and entrance ramps are located on the upstream side.
Enhancement of two-lane highways to super two sections	• Modifying two-lane roadways to super two sections improves functionality by removing turning conflicts.	• Where feasible, modify two-lane state highways and farm-to-market roads to super two sections by adding shoulders, turn-lanes at key intersections, or passing lanes to help reduce turning conflicts, improve safety and progression, and provide added capacity. This low cost form of upgrade should continue to be used as an interim upgrade measure or an option when there are no funds for a major widening or rehabilitation.
Expressway and super arterial designs	• Expressway designs ensure a high level of long-term functionality since access is gained only through widely spaced intersections and abutting access rights have been purchased.	• Increase the use of expressway designs to achieve a high degree of functionality where all abutting private access rights have been purchased and access to the facility is gained through widely spaced intersections with major thoroughfares.
Funding for roadway improvements	• Limited funding availability from traditional sources frequently delays roadway improvements and causes foreseeable or existing functionality losses to not be prevented or restored.	• Consider innovative and non-traditional options for highway projects. These options may include highway pricing, unconventional operations or design (e.g., reversible lanes, time-managed ramps), or other techniques that are adaptable to special situations.
Design of community loops and bypasses	• Loops and bypasses divert through traffic, namely long heavy commercial vehicles, from populated communities and provide operational and safety benefits, which consequently improve system-wide functionality.	• New highway loops around communities should be planned and designed as controlled access facilities with a minimum of one mile spacing for grade separated interchanges. If new loops are to be surface arterials, they should be designed with center non-traversable medians with a minimum of one mile spacing for signalized cross streets. • TxDOT should no longer allow or fund upgrades to surface arterial loops around communities that do not include non-traversable medians or that are not conversions to a controlled access facility.

RIGHT OF WAY, UTILITIES, AND FUNCTIONALITY

Highways are built and improved on highway right of way. Effectively acquiring, preserving and protecting the right of way are critical for maintaining the functionality of the state highway system. Several broad topics that can be of particular concern to TxDOT and other transportation agencies include right-of-way protection/preservation, right-of-way acquisition, and rights of way for utilities.

Passive practices when dealing with these aspects can and have caused noteworthy loss of highway life cycle functionality. For example, poor right-of-way protection can accelerate infrastructure deterioration by reducing improvement options or compromising design, operational, or maintenance opportunities. They can also introduce environmental issues. Ineffective practices in right-of-way protection, acquisition, and utility accommodation and relocation can cause significant increase of project costs, delays to highway construction or maintenance, and sensitive social issues. Constraints to right of way due to adjacent conditions (for example, noise tolerability, drainage, and encroachment from development) can also cause difficulties, both for current operation and for proposed highway enhancements.

Right-of-Way Acquisition

Right-of-way acquisition is a critical component in TxDOT's project development process. It can be and time consuming, socially sensitive, and be the source increased project costs and delay. Proactive practices for right-of-way acquisition allow highway projects to maintain the schedule and to be better accepted by the public.

TxDOT has developed numerous tools to support and facilitate right-of-way acquisition including the Right of Way Information System (ROWIS), the Advance Planning Risk Analysis (APRA) tool (*13*), a Right-of-Way Acquisition and Utility Adjustment Duration Information (RUDI) tool (*14*), and a cost estimation tool for right-of-way acquisition (*15*). Table 7 lists actions to address highway functionality via practices and policies related to right-of-way acquisition.

Table 7. Right-of-Way Acqusition and Actions to Address Functionality.

Practice or Policy	Roles in Functionality	Actions to Address Functionality
Early project planning/project development activities	• Acquiring right of way for the ultimate roadway cross section will ensure right of way will not be a constraint to subsequent improvements and functionality.	• Make sure adequate right-of-way is planned not only for the current improvement, but also to accommodate ultimate needs. Do not just rely on a 20-year traffic forecast. • Develop a multi-disciplinary and multi-jurisdictional partnered approach that brings engineering, transportation planning, and land use decision-making together to develop ultimate roadway design and right-of-way needs.
Evaluation of alternative alignments	• Consider ease and cost of acquiring right of way as project development progresses. Project delays and increased costs related to right-of-way acquisition can impact roadway function by impacting project design and extending the duration of unimproved congested conditions.	• If feasible, consider adopting an alignment or other features that shift the right of way to parcels known to have willing sellers. • Where possible, avoid alignments with right-of-way requirements that cause environmental impacts that will either require extensive work (and time) to pass through the environmental process or mitigation.
Methods and analysis for acquisition	• Consolidated parcels may be acquired at once, which may save time and efforts on negotiation and documentation otherwise required for individual parcel. • Use of the latest in database, geospatial, and internet resources can expedite preparation for right-of-way acquisition. • Using the same agent throughout the right-of-way acquisition process minimizes the redundancy on various tasks and shortens the acquisition duration.	• Use land consolidation strategies to reduce the number of parcels to be acquired. TxDOT may develop programs to consolidate parcels into larger tracts on a voluntary basis. • Where possible, get right of way dedicated or reserved as part of the local platting process. • Utilize available computer technologies to expedite right-of-way acquisition. Computer technologies such as GIS, database management systems, and internet/intranet have been widely available. • Use the same agent throughout the acquisition process to ensure consistency, efficiency, and accountability during the acquisition process.

Right-of-Way Protection

Right-of-way protection can involve several broad areas of concern, such as roadside management, local and advanced right-of-way acquisition methods, and coordination in local planning and land development. TxDOT has various policies, guidelines, and regulations in place that can be used to help protect and preserve right of way along TxDOT facilities. Table 8 lists actions to address highway functionality via practices and policies related to right-of-way protection.

Table 8. Right-of-Way Protection and Actions to Address Functionality.

Practice or Policy	Roles in Functionality	Actions to Address Functionality
Project identification and prioritization in planning to protect right of way	• Failing to protect or preserve right of way early could preclude new facilities and expansion of highways to improve mobility and functionality.	• Identify priority transportation corridors for rehabilitation or widening during long-range transportation planning. • Use a multi-jurisdiction partnering approach to preserve, protect, or acquire (additional) right of way needed for the ultimate configuration of the facility. • Identify fatal flaws, critical parcels, and probable alignments early to facilitate advanced or early acquisition.
Protecting right of way using early or advanced acquisition methods	• The delay beginning project-wide right-of-way acquisition until after environmental clearance can result in paying higher costs for and reduce funds that can be used on measures to improve functionality. • Restrictions on the use of advanced acquisition methods and the increases resources and advanced level of experience needed to undertake them can preclude.	• Seek funds, such as what might be available for use in protective and hardship right-of-way purchases, so future parcels within designated right-of-way can be purchased. • Seek funds for limited strategic advanced right-of-way acquisition where protective purchases cannot be used to protect future alignments. • Address legal and resource limitations in advanced acquisition practices. Legal and political concerns have been one of the major hurdles to this activity in many states.
Protection via local thoroughfare plans and authority	• Insufficient minimum right-of-way requirements for major local thoroughfares can prevent opportunities for right-of-way dedication or reservations along TxDOT roadways and impact design cross-sections, significantly increase project costs, and impact functionality.	• The amount of right of way required for state roadways via functional designations on adopted local plans should be reviewed and changed as necessary to accommodate future TxDOT cross-sections. • Where possible, protect needed right of way via right-of-way reservations in the local platting process, as well as through donations to locals for future use by TxDOT. • TxDOT or mutually agreed upon ROW and/or design requirements could also be incorporated into local development regulations.
Roadside management	• Development and outdoor advertising activities along roadways and right-of-way encroachments may affect traffic operations, safety, and asset value, and can cause functionality loss over time.	• Utilize computer technology such as GIS, database, and Internet to facilitate outdoor advertising permitting and management. • Pursue the use and enforcement of local building and parking setbacks and sign ordinances to prevent encroachment in TxDOT right of way.

Utility Accommodation

Several laws regulate the utilities and their rights on TxDOT right of way. The Utility Accommodation Rules (UAR) (*16*) include the minimum requirements for the accommodation, method, materials, and location for the installation, adjustment, and maintenance of public and private utilities within the right of way of the Texas state highway system. Other Texas statutes

such as the Transportation Code (*17*), the Utilities Code (*18*), and the Local Government Code (*19*) also contain provisions pertaining to right-of-way utilities. In addition, the ROW Utility Manual (*20*) further provides specific guidelines and regulations for dealing with issues associated with the utilities on the TxDOT-owned or managed right of way.

To enable efficient accommodation of utilities and minimize delays both before letting and during the construction phase, TxDOT uses the Utility Cooperative Management Process (UCMP), a partnership between TxDOT, local public authorities (LPAs) when applicable, and the utility industry (*16*). The process encourages the inclusion of the utility accommodation considerations in project planning, right-of-way, design, and construction functions at the district level. Through the process, TxDOT also promotes early involvement of and sufficient coordination with utility owners during the project development process.

The utility coordination process frequently involves a large number of stakeholders exchanging a myriad of information in forms such as communications, agreements, contracts, permits, maps, schematics, images, and design files. Challenges affecting utility coordination activities and causing relocation delays can include limited staffing and fiscal resources, late project notification to utility owners, failure of utility conflict identification, unresponsive or uncooperative utility owners, and lack of expertise of utility staff. The lengthy process of obtaining required agreements for reimbursable utility relocations compared to that for non-reimbursable relocations can also be a challenge.

Utility conflicts contribute to project cost increase, project delay, and additional burden on TxDOT and the utility industry. Table 9 lists actions to address highway functionality via practices and policies related to utility accommodation.

Table 9. Utility Accomodation and Actions to Address Functionality.

Practice or Policy	Roles in Functionality	Actions to Address Functionality
Utility coordination	• Well-established coordination with utility owners is important for supporting utility accommodation and relocation and helps to avoid utility-related project delays.	• Involve public utility companies and franchises early to ensure for adequate involvement. This may include involving utilities during the project planning and programming stage, effectively and frequently coordinating with utilities throughout project development process, and establishing fast and efficient channels for utility information acquiring. • Develop good working relationships with utilities to reduce communication hurdles and improve the willingness of utilities for early and frequent involvements.
Utility conflict detection and management	• Early and accurate detection of utility conflicts would give utility companies sufficient time to budget and conduct utility relocations. • Effective utility conflict management practices help engineers to accurately manage the information of utility conflicts throughout the project development and construction and therefore avoid highway functionality loss caused by project delays.	• Detect utility conflicts early and accurately to keep projects within schedule. Various techniques may benefit utility conflict detection, such as GIS, SUE, and other sophisticated information systems. • Use advanced technologies such as GIS, Global Positioning System (GPS), and Radio Frequency Identification (RFID) for utility mapping and inventory. • Use utility conflict management systems supported with technologies such as GIS and database management systems to effectively inventory and track utility conflicts throughout projects to avoid project delays.
Utility relocation	• Avoiding unnecessary utility relocations can help highway engineers to save time and project cost.	• Avoid needs for utility relocation through mechanisms such as minor modifications to highway designs. • Use automated utility installation permitting process such as the Utility Installation Review (UIR) system developed by TxDOT that has been used in several districts.
Utility accommodation restriction for roadway protection	• Restricting certain utilities in congested right of way or use innovative strategies for utility accommodation simplify utility accommodation and ease right-of-way congestion caused by utilities.	• Consider protecting certain urban arterial highways from new utility installations to improve safety and operations of existing highways, mitigate the competition from utility facilities for right of way needed for highway enhancement or expansion, and reduce maintenance activities and work zones. • Consider innovative utility accommodation practices such as utility corridors or joint trenching to simplify utility accommodation and ease right-of-way congestion caused by utilities. • Acquire right of way for utility accommodations to simplify the utility accommodation process and reduce utility-related interruptions to roadway construction and operations.

SAFETY AND FUNCTIONALITY

Crashes on Texas roads kill about 3500 people and cause millions of dollars in damage each year. Roads that have safety problems are considered to hinder the safe and efficient movement of goods and people, hence the functionality of the highway. Crashes interrupt the trips of vehicles involved and delay trips of other vehicles that are detoured, slowed, and/or stopped due to the incidents. The safety function of roads can be addressed during the design phase of a project, as well as by monitoring safety issues on existing roads.

Geometric design elements and crash occurrence are two primary areas considered when assessing the safety functionality of a road. Crash occurrences can be measured by crash rate, frequency, and severity. Primary geometric design factors that impact highway safety functionality include access density, horizontal and vertical alignment, and roadway cross-section—including travel lanes, shoulders, side slopes, clear zones, and ditches. All these can affect the highway safety functionality.

Another factor affecting highway safety is the inconsistencies that arise over time such as variations in pavement surface and friction, shoulder width, deceleration lane lengths, signing, ramp merges, and weaving sections. Consistency makes the roads predictable and easier to drive safely, and inconsistencies introduce uncertainties and surprises.

As part of its infrastructure management program, TxDOT can identify road segments that have safety problems in order to prioritize them for funding to address the problems. TxDOT district offices submit projects for safety-related projects through the Hazard Eliminations (HES) Program. District offices identify road segments that have experienced safety problems and submit them in response to a call for projects. Table 10 provides practices and roles of safety in highway functionality and actions relating to safety that address preserving or enhancing functionality.

Table 10. Safety and Actions to Address Functionality.

Practice or Policy	Roles in Functionality	Actions to Address Functionality
Consideration of safety in geometric design	• Features of geometric design such as access control, horizontal and vertical curves, lane widths, and clear zones can create inconsistencies between design speeds and operating speeds that impact safety and functionality.	• TxDOT should improve safety in highway geometric design focusing on access reduction and spacing, use of turn lanes to separate turning traffic, design features of curves, and increasing roadside recovery distances. Relative to curves, consideration should be given for wider lanes, shoulders, smoothing for proper design speed and function, and increased sight distances. • Conduct Road Safety Audits (RSAs) for each new highway project design to further increase the resulting safety characteristics.
Incident management	• Highway safety service patrols (SSPs) respond to and work to clear incidents that can further affect safety and mobility on highways.	• Strengthen the roles and responsibilities of traffic safety organizations and agencies such as the highway SSPs.
Monitoring crash location and frequency and use of safety performance measures	• Readily available data on crash frequency and how, when, where, and why crashes have occurred is important in order for better safety policies and measures to be developed and implemented.	• Improve the decision making process and information systems by making optimal use of traffic safety information. • Improve timeliness, thoroughness, and accuracy of data collection, analysis processes, and systems including the linkage of crash, roadway, driver, medical, Crash Outcome Data Evaluation System (CODES), enforcement, conviction, homeland security data, etc. • Improve and expand the warehousing and accessibility of safety data.
Take corrective actions to address hazardous conditions on existing highways through a regular safety program	• Identifies hazardous locations and segments. • Identifies corrective actions that can reduce existing safety hazards.	• Review system-wide crash data (frequency, rate, severity) to identify high hazard locations and segments. • Conduct road safety review and assess in-field conditions and determine causes of high crash frequency, rate, or severity. Determine appropriate corrective actions. • Improve hazardous conditions with spot improvements or improvements to highway segments. These may be separate safety projects or part of highway upgrades. • Program safety improvements as part of the overall TxDOT program with a goal of addressing all locations and segments with high crash occurrence.

INFRASTRUCTURE AFFECTS ON FUNCTIONALITY

TxDOT manages a vast network of pavements and bridges and related transportation assets over wide geographical areas that are subjected to different utilization and environmental conditions. To support and preserve operational function of such an extensive network of assets, TxDOT annually invests over one billion dollars in repair and replacement of aging structures and reconstruction and maintenance of pavements. Overseeing the upkeep of these assets involves a process of integrating traditional engineering functions and principles with sound business practices to manage them in a cost-effective manner and in ways that meets the expectation of the public.

TxDOT utilizes a Pavement Management Information System (PMIS) to store pavement condition data on TxDOT's Pavement Evaluation System (PES) to support decision makers at the division, district, area, and maintenance office levels. PMIS uses analytical models to predict the development of pavement distress with time. Based on the results from the prediction, the system prioritizes pavements requiring rehabilitation and also predicts their future needs. Though TxDOT maintains a robust system for pavement management, it lacks a similar system for its bridges.

To help minimize the impacts of construction zones on highway functionality, TxDOT can use cost-plus-time bidding, shorten construction schedules, add incentives to motivate contractors to finish early, or add penalties when contractors do not finish on time.

A preventive rather than reactive maintenance approach would cause a significant increase in the life of pavements and bridges at reduced cost and disruption to road users. Proactive preventative maintenance combined with innovative contracting strategies will help minimize infrastructure impact to highway functionality. Table 11 lists actions to address highway functionality via practices and policies related to workzones and the maintenance of pavements and bridges.

Table 11. Pavements, Bridges, and Actions to Address Functionality.

Practice or Policy	Roles in Functionality	Actions to Address Functionality
Pavements and Bridges	• A proactive maintenance approach to pavements and bridges will increase the life of these assets at a lesser cost and reduced disruption to road users. • Management information systems for pavements and bridges help prioritize and allocate maintenance resources considering cost-effectiveness and physical needs and condition.	• Use pavement management system to take a proactive in lieu of a reactive approach. • Use pavement performance measures such as the IRI in the PMIS to aid in making proactive decisions relative to preventative, in lieu of corrective, maintenance practices. • TxDOT should complete the development of its Bridge Management Information System and practice a robust bridge management system similar to what it does for pavement management. • TxDOT should undertake a pavement preservation program that encompasses a range of preventive maintenance techniques and that includes regularly scheduled preventative maintenance activities.
Work Zone Traffic Management and Contracting Strategies	• Management information systems for pavements and bridges help prioritize and allocate maintenance resources considering cost-effectiveness and physical needs and condition. • Work zone traffic management techniques can be used to reduce exposure between motorists and highway workers and reduce crash rates and motorists delays in work zones.	• Reduce the volume of traffic going through the work zone (e.g., using detours or schedule work during lower volume periods). • Reduce the length of time work zones are in place. • Reduce the frequency that work zones are established to perform construction and maintenance operations. • TxDOT should use or continue to use contracting strategies that consider road user costs such as: - shortening the construction schedule to reduce the duration of impeded traffic flow during construction; - utilizing cost plus time (A+B) bidding; - charging lane rental fees for occupying lanes to do work when construction extends beyond the project's planned duration; and - offer incentives to finish projects early and charge liquidated damages for late completion.
Other Work Zone Traffic Management Actions	• Changes in temporary design and work periods, and getting the word out to motorists can be used to improve operations through construction areas.	• Use narrower rather than fewer lanes where possible. • Perform work at night or in off peak periods. • Use normal design criteria for temporary road conditions where possible (e.g., curves, tapers, merge sections, etc.). • Increase the amount and helpfulness of motorist information.

CONCLUSIONS

Texas has need for far more highways that we can afford to build. It has gotten increasingly difficult to even improve the highways we have. In fact, highway maintenance, including corrective maintenance and reconstruction, now consumes most of TxDOT's capital budget. Hence, it is extremely important to keep Texas highways—those that we have—functioning at a high level of efficiency. That can be a challenge, given competing pressures for staff time and attention and also competition for available funds.

The good news is that preserving and maintaining functionality does not have to cost a lot of money. In fact, as demonstrated in the previous sections, *preserving a high level of functionality is more tied to how things are done than how much money might be available*.

Choices

TxDOT, and indeed all transportation agencies, have two basic choices when it comes to addressing functionality of the highway system and its component highways:

1. Preserve functionality at a high level through effective planning, operational and safety management, refinement, and proactive infrastructure maintenance.
2. Adopt a reactive and corrective approach to fix things after they deteriorate.

Functional Preservation: The Proactive Approach

TxDOT's motto is to "Keep Texas Moving." Goal 5 of TxDOT's current strategic plan is to preserve the asset value of transportation assets (*21*). The plan states that "preserving these (highway) assets and increasing their value to the public is critical for Texas' economic health and safety." Further, the plan says that one of TxDOT's goals is to "minimize costs over time of managing and maintaining the transportation system."

Functionality preservation takes a proactive, preservative, or preventative approach to keep the highway functioning at a high level. Performance is monitored and actions are taken to keep functionality at or near the level intended at the design stage. This keeps operations efficient and safer and also keeps the physical infrastructure—pavement, structures, traffic control devices, etc.—all in condition to meet or exceed specified levels. Choice 1, functional preservation, uses the proactive approach to not let assets deteriorate to the point where they operate significantly below the intended design levels.

Corrective Improvements: The Reactive Approach

Choice 2 above, corrective improvements after deterioration is much easier on a day-to-day basis but can result in higher long term cost and effort. TxDOT's strategic plan states that "(facilities) that are allowed to deteriorate for too long must be replaced or rebuilt at a much higher cost…" While this statement in the plan is aimed at infrastructure maintenance, it is equally applicable when directed toward operations and safety. The longer a facility's operational or safety is allowed to deteriorate, the more serious the shortfall or deficiency gets and the more re-investment will usually be needed to restore the original functionality.

For example, if access is well coordinated and managed along a section of state highway, it is likely that a fair amount of development and associated access traffic can be accommodated with limited impact on operational efficiency. However, if driveways are permitted to be built anywhere requested and left turn access points are closely spaced, it is likely that conflicts will arise and operation efficiency will decline and crashes will increase. The longer the laissez faire approach continues, the more operating conditions will decline. At some point, either more lanes or even a replacement or supplemental highway may be needed. This approach is more costly in the long term.

The Right Choice

According to the TxDOT strategic plan, the first choice—functional preservation—is the correct choice. Much of it can be achieved through either original or ongoing planning or regular operations and maintenance programs. It is more cost-effective and alleviates the need for as many major projects, many of which take years to get through programming and project development.

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