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16. Abstract

A primary product of this research was the *Asset Management Guidebook* that TxDOT division and district personnel can use to help them define, develop, and implement asset management across all levels—particularly as it relates to establishing performance measures for safety and operations. The guidebook is a stand-alone product and contains easy-to-use, practical guidelines that TxDOT personnel can use to identify the best approach to asset management on three possible levels if feasible and practical: (1) total asset management for large urban areas encompassing multiple counties, (2) asset management of critical functions on a smaller regional scale—such as maintenance of roadside components excluding the pavement, and (3) asset management for specific types of assets—such as pavement markings or light emitting diode (LED) signal indications—that may be based on warranty specifications. The research team also recommends that they present to TxDOT district engineers the results of the project to facilitate the dissemination of this research and present the potential benefits of asset management for safety and operations in the organization and the effective use of all of its resources.

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ASSET MANAGEMENT GUIDEBOOK FOR SAFETY AND OPERATIONS

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CHAPTER 1: INTRODUCTION

The Texas Department of Transportation (TxDOT) is challenged with managing a wide range of transportation safety and operations assets in order to respond to public and other outside interests. These assets include, but are not limited to:

- Pavements.
- Pavement markings.
- Raised pavement markers.
- Structures.
- Roadside signs.
- Traffic signals.
- Roadway illumination.
- Traffic barriers.
- Guard fences.
- Attenuators.
- Maintenance equipment.
- Vehicles.
- Intelligent transportation system (ITS) equipment.
- Traffic detection equipment.
- Real estate.
- Corporate data.
- Materials.

Asset management is a comprehensive strategic approach to documenting and managing these assets, as well as using information gathered during the process to assist TxDOT in making cost-effective investment decisions.

PLANNING FOR TRANSPORTATION THROUGH BETTER MANAGEMENT

Congress, through the *Intermodal Surface Transportation Efficiency Act* (*ISTEA*) of 1991, required states to develop and implement six management systems in response to aging infrastructure, tight financial constraints, and increased environmental concerns (*1*). These management systems included:

- Pavement management systems (PMS).
- Bridge management systems (BMS).
- Safety management systems (SMS).
- Congestion management systems (CMS).
- Public transportation management systems (PTMS).
- Intermodal management systems (IMS).

Planning was a key component of ISTEA, with a renewed focus on how to use existing transportation systems more effectively. Management systems—most of them focused on managing assets—were considered to be inherently linked to planning as a means of addressing these concerns.

ISTEA initially required congestion management systems for all metropolitan areas of greater than 50,000 people (all metropolitan planning organization [MPO] areas) and the remainder of the individual states as a whole. Due to considerable state department of transportation (DOT) concerns regarding the data and process requirements, Congress later rescinded (as a rider to the National Highways System legislation) most of the requirements for management systems by allowing their development to be optional. CMS for Transportation Management Areas (TMAs)—MPOs with greater than 200,000 people—remained a requirement of the transportation planning process and persisted in the *Transportation Equity Act for the 21st Century* (TEA-21), enacted in 1998 (*2*).

As modified and enhanced by ISTEA, the modern transportation planning process works to improve the transportation system and investment decision making associated with transportation projects. Based on the paradigm shift from construction to system preservation, ISTEA identified critical issues related to transportation planning, including but not limited to:

- Linking transportation to the economic, mobility, and accessibility needs of the country.
- Emphasizing the participation of key stakeholders in the transportation planning process.
- Recognizing the constraints limiting expansion.
- Protecting the human and natural environments while providing accessibility to transportation services.
- Linking transportation planning to the air quality objectives in the Clean Air Act Amendments and state air quality plans (*3*).

Congress changed the congestion management system requirement in 2005 through the passage of the *Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users* (SAFETEA-LU) to become the congestion management process (CMP) (*4*). The change reflected a philosophy that the inclusion of management and operational (M&O) objectives in the planning process, and the CMP should be integrated with a number of other initiatives in the planning process and not be a stand-alone requirement that the transportation planning community often considers as being of limited value. Comprehensive asset management, though not mandated by federal legislation, can serve as an integral part of the congestion management process to ensure that agencies efficiently and effectively manage the enormous investment in the transportation infrastructure.

PLANNING PROCESS ELEMENTS

The elements of the metropolitan transportation planning process include public involvement, planning factors, alternatives analysis, the air quality conformity process, the financial plan, and management systems input—the focal point of the pending research—as

illustrated in Figure 1. Ways in which asset management for operations and safety impacts these elements are as follows:

- Public involvement when transportation agencies debate asset management-, operations-, and safety-related strategies helps ensure that agencies consider all of the social, economic, and environmental consequences of infrastructure investment decisions in light of current conditions and needs and that the MPO has the broad support of the community.
- The goals and objectives of asset management-, operations-, and safety-related strategies easily fit within the general planning factors in the transportation planning process.
- Asset management systems should include operations- and safety-related strategies, whose goals and objectives work in concert with the system to maximize the efficiency potential for the transportation network.
- Incorporating asset management-, operations-, and safety-related strategies as potential solutions in the major investment study can help address the factors influencing project solutions while efficiently and effectively meeting the needs of the community.
- Asset management-, operations-, and safety-related strategies that are part of the transportation plan and the Transportation Improvement Program (TIP) can help an MPO achieve air quality conformity and increase the likelihood of projects reaching implementation.

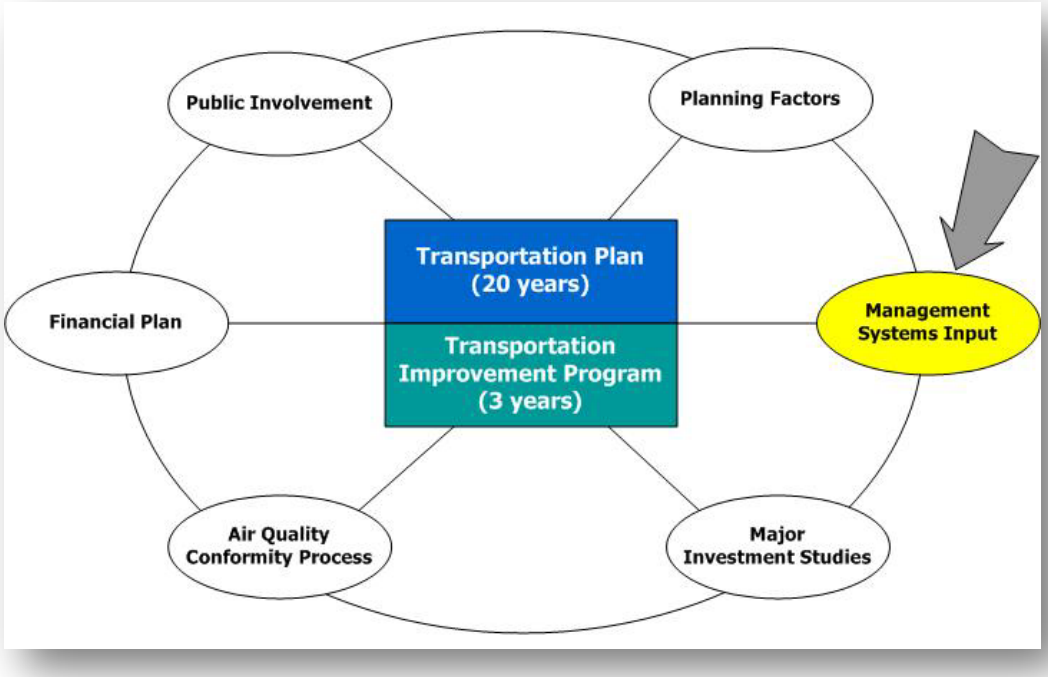


Figure 1. Metropolitan Transportation Planning Process.

ASSET MANAGEMENT DEFINED

As generally defined, asset management is a business process. Asset management uses a decision-making framework that covers an extended time horizon. The asset management approach draws from best practices in economics, engineering, and business. In 2001, Madeline Bloom, then the Director of the Federal Highway Administration (FHWA) Office of Asset Management, remarked that the bottom line goal of asset management is cost-effective resource allocation and programming decisions (*5*). Asset management allows transportation agencies to focus on strategic goals and consider assets comprehensively. In other words, it allows decision makers to see the big picture and make decisions in that context.

Today, growing congestion, limited resources, funding shortfalls, aging infrastructure, and an increasing focus on system performance impact transportation. If the current trends continue, state DOTs, as well as other public sector transportation agencies, will face increased system and budget needs with limited resources. At the same time, states will have to deal with increasing system complexity and increased public demands for accountability and levels of service. The application of asset management to transportation will allow agencies to meet these demands (*6*). Figure 2 depicts an effective asset management framework as a balance of (a) goals, policies, and budgets, (b) technical information, and (c) integration—all connected via technology in the form of powerful computer systems capable of managing the breadth and depth of state DOT-managed infrastructure information.

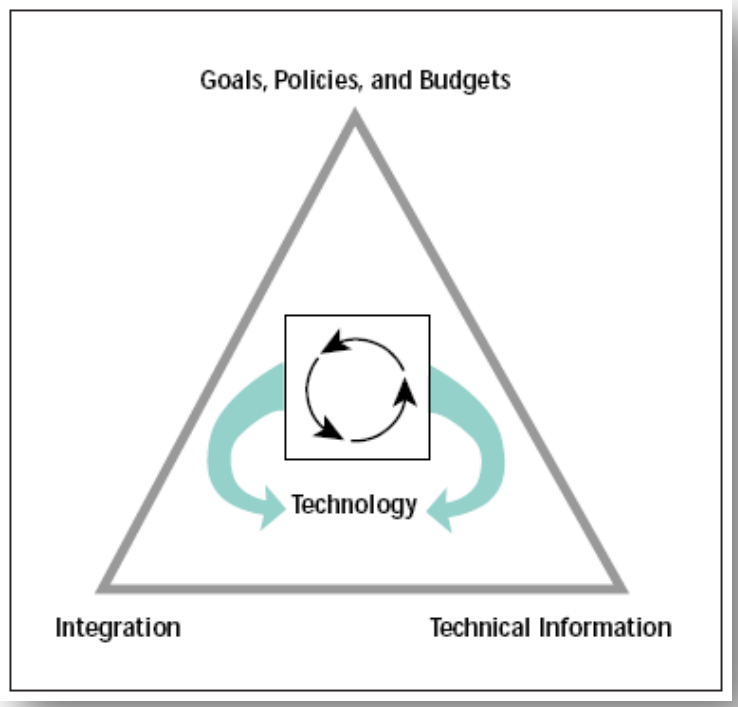


Figure 2. Asset Management Framework (*6*).

As noted in *Asset Management Overview*, which the FHWA published in 2007 (*7*), transportation professionals focus on three primary goals: maintaining infrastructure, logical capital improvement, and containing costs. Transportation asset management focuses on transportation infrastructure and system performance. By comparing performance measures with desired performance and considering all assets comprehensively, it provides decision makers with the information necessary to implement a logical capital improvement plan for the future while containing costs. Asset management also provides an opportunity for fact-based dialogue between system users and stakeholders.

A successful transportation asset management plan should address a number of core questions including:

- What is the current state of my assets?
- What is the required level of service?
- Which assets are critical to sustained performance?
- What are my best investment strategies for operations and maintenance and for capital improvement?
- What is my best long-term funding strategy? (*8*)

The information gathered when answering these questions can be utilized to develop an initial set of goals. These goals can then be incorporated into the transportation improvement plan, which is a short-range planning document, and the statewide transportation improvement program (STIP), which is a longer range plan. Figure 3 illustrates the regional planning process and where asset management fits into the overall framework. Transportation agencies can also use data gathered through asset management in decision making for operations, preservation, and maintenance of assets, as well as performance measurement and evaluation (*8*). Therefore, a well-designed asset management system should be a critical component of a DOT's plan for providing for the mobility of its customers, preserving the infrastructure already in place, planning for future improvements of that infrastructure, and being responsive and accountable to the public regarding the investment of their tax dollars.

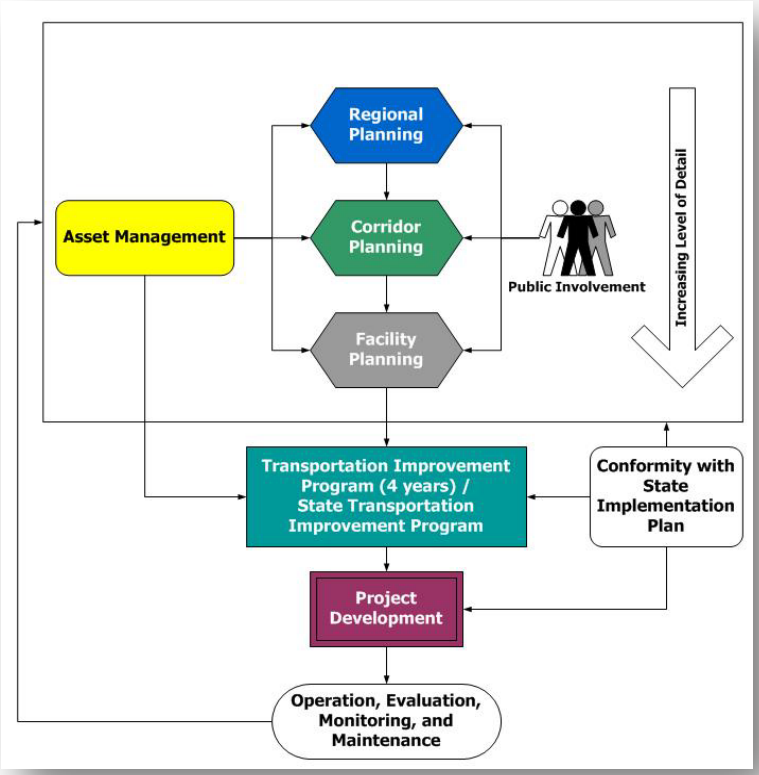


Figure 3. Regional Planning Process and Asset Management.

ASSET MANAGEMENT APPROACHES

In recent years, numerous states have implemented either comprehensive or limited asset management plans. States that have some form of asset management plans include Washington, Louisiana, Colorado, Utah, Idaho, Indiana, Georgia, Oregon, Virginia, Florida, New York, Michigan, Maryland, Pennsylvania, North Carolina, New Mexico, and Rhode Island. An international scan tour of countries employing asset management techniques in 2005 included Australia, Canada, England, and New Zealand as prominent stops. The scan tour (*9*) found that each site had made a long-term commitment to asset management and that the primary impetus for employing asset management was limited resources in the face of growing demand. The scan tour also found that asset management programs have helped transportation agencies focus on network performance and have helped identify the best value for the dollar of limited investment resources (*9*). In addition to its Pavement Management Information System (PMIS), TxDOT has several systems and programs in place that address various facets of asset management, including but not limited to maintenance management, material specifications, quality assurance, roadside vegetation management, and right-of-way property management. The following sections highlight three common facets of asset management that agencies across the country are implementing.

Pavement and Bridge Management Programs

Pavement and bridge management programs are currently the most prevalent types of asset management that transportation agencies use. These programs manage road miles and bridges. The most common type of asset management used in these programs is documenting performance measures as these relate to condition, function, and capacity of the assets. Agencies have a wide range of management programs that vary from simple inventories to complex and comprehensive documentation.

In their simplest forms, pavement and bridge management systems provide an inventory of the amount of pavement in road miles and the number of bridges in a defined geographical area. An assessment of the history and condition of the assets is also recorded. This inventory provides information essential to planners, decision makers, and maintenance personnel, and allows them to preserve, maintain, and replace critical infrastructure in an efficient manner. These programs also provide information on performance, condition, and costs as well as providing data crucial for predictive models for long-range budgeting.

A number of the more comprehensive asset management programs developed by transportation agencies originated from initial pavement and bridge management systems. Once strong pavement or bridge management systems were in place, the agencies recognized the need for a larger and more comprehensive system to manage assets. Georgia and Pennsylvania DOTs are key examples of this transition. Both agencies recognized the need to improve their management systems to support broader decision making. The management systems were used to determine that by reallocating funds from roadways to bridges, the overall quality of bridges improved without significantly reducing the quality of pavements (*10*).

Traffic Signal Asset Management

Agencies can also apply the asset management approach to other components of the transportation system. Markow (*11*) identified current United States and international practices in asset management for traffic signals. The study reviewed basic management practices, budgeting methods, ways of measuring asset performance, estimates of asset service life, information technology support for data management and decision making, and perceived knowledge gaps and research needs. The study found that asset management was helpful in managing signal system assets; however, a broader view of asset management techniques was needed to reflect electronic system components (rather than just the physical infrastructure elements constituting pavements and bridges) (*11*). Portland, Oregon, implemented a comprehensive asset management program that includes over 568,000 assets in 29 feature classes. In 2005, at a presentation to the Institute of Transportation Engineers (ITE), the Portland Division Manager for Signals and Street Lighting reported that using asset management of signals and street lighting allowed the city to reconstruct three to four signals for the cost of one replacement (*12*).

Pavement Marking Asset Management

Pavement marking retroreflectivity is one of the performance measures that agencies can use to manage pavement markings. Handheld retroreflectometers can measure pavement marking retroreflectivity but require personnel on the roadway and are not efficient to manage a

large system such as the TxDOT roadway network. Recent advancement in mobile retroreflectometer technology provides transportation agencies with an objective field measurement technique to monitor and manage pavement marking retroreflectivity. As a result, some state agencies have initiated pavement marking management programs using mobile pavement marking retroreflectometers. Some of these management systems are part of a larger asset management program. The agency with jurisdiction determines acceptable levels of retroreflectivity, often based on performance or warranty specifications. Some key components for a successful pavement marking asset management system include having an adequate sampling plan and having an effective way to manage (i.e., store and analyze) the data, which can be overwhelming if there is not an efficient system established beforehand.

ASSET MANAGEMENT GUIDEBOOK

This *Asset Management Guidebook* is intended to help TxDOT division and district personnel define, develop, and implement asset management across all levels—particularly as it relates to establishing performance measures for safety and operations. The guidebook is a stand-alone product and contains easy-to-use, practical guidelines that TxDOT personnel can use to identify the best approach to asset management on three possible levels if feasible and practical:

- Total asset management for large urban areas encompassing multiple counties.
- Asset management of critical functions on a smaller regional scale—such as maintenance of roadside components excluding the pavement.
- Asset management for specific types of assets—such as pavement markings or light emitting diode (LED) signal indications—that may be based on warranty specifications.

This document can help TxDOT district engineers and other key staff to understand the potential benefits of asset management for safety and operations in the organization, and the effective use of all of its resources.

ASSET MANAGEMENT SCREENING TOOL

The companion product to the *Asset Management Guidebook* is the *Asset Management Screening Tool.* The research on which these products were based examined the best practices and approaches to asset management for safety and operations. It also assessed various tools that agencies used for this purpose, including those tools that TxDOT already has in place to manage different components of the infrastructure that are critical to the safety and operation of the transportation network. The *Asset Management Screening Tool* is based on the information in the *Asset Management Guidebook* and is software capable of operation on any typical desktop computer without the need for server interface. The screening tool facilitates implementation by TxDOT staff members in an easy-to-use format. The remaining chapters in this guidebook provide background information and a stepwise approach to asset management for TxDOT.

CHAPTER 2: BACKGROUND

Transportation agencies are challenged with managing a wide range of transportation safety and operations assets in order to respond to public and other outside interests. These assets include, but are not limited to, pavements, pavement markings, raised pavement markers, structures, roadside signs, traffic signals, roadway illumination, traffic barriers, guard fences, attenuators, maintenance equipment, vehicles, ITS equipment, traffic detection equipment, real estate, corporate data, and materials. Asset management is a comprehensive strategic approach to documenting and managing these assets as well as using information gathered by the process to assist TxDOT in making cost-effective investment decisions.

TYPES OF INVESTMENT CATEGORIES

State transportation agencies generally consider the following three types of investment categories—preservation, operations, and capacity expansion:

- **Preservation** encompasses work to extend the life of existing facilities (and associated hardware and equipment), or to repair damage that impedes mobility or safety. System preservation seeks to retain the existing value of an asset and its ability to perform as designed. Also, system preservation counters the wear and tear of physical infrastructure that occurs over time due to traffic loading, climate, crashes, and aging. Transportation agencies accomplish this goal through both capital projects and maintenance actions (*13, 14*).

- **Operations** focus on the real-time service and operational efficiency that the transportation system provides for both people and freight movement on a day-to-day basis. Examples of operations actions include real-time traffic surveillance, monitoring, control, and response; intelligent transportation systems; signal phasing and real-time signal controllers at intersections; high-occupancy vehicle (HOV) lane monitoring and control; ramp metering; weigh-in-motion (WIM); road weather management; and traveler information systems. Although operations focus on system management, the infrastructure needed to provide this capability may be substantial (e.g., traffic control centers; ITS hardware; environmental sensors and fire control systems in tunnels). Thus, an operations strategy requires capital and operating budget as well as substantial staff resources (*13*, *14*).

- **Capacity expansion** focuses on the actions needed to expand the service that the existing system provided for both people and freight. Agencies can achieve capacity expansion either by adding physical capacity to an existing asset, or acquiring/constructing a new facility (*13*, *14*).

Historically, asset management within state transportation agencies has focused on a single key investment area—preservation. Significant investments were made to expand the country's transportation infrastructure. As new facilities were completed, the resources required to maintain, repair, and rehabilitate existing facilities grew concurrently with continued expansion. When significant portions of the system aged, competition for resources likewise increased. The need to develop the knowledge and tools to preserve the existing system as cost-

effectively as possible stimulated a wide range of research/development efforts as well as the development of new applications and approaches and integrated system management tools.

The application of asset management principles to safety and operations functions has been more limited. Associated challenges precluding more widespread implementation of asset management for safety and operations within state transportation agencies are described below.

Safety Asset Management

Safety is viewed as integral to all program areas within a state transportation agency. All projects that agencies develop and deliver—involving preservation, operations, or capital expenditure—are designed with safety in mind. For example:

- **Preservation** actions keep infrastructure in safe, serviceable condition. Road surfaces with rutting, major distresses (e.g., potholes), or low skid resistance can adversely impact safety. Pavement repair, resurfacing, and rehabilitation activities reduce the likelihood of crashes related to road surface conditions. Bridge maintenance, rehabilitation, and replacement programs keep important safety features (bridge railings) in good repair and reduce risks of structural failure (*14*).

- **Operations** include actions to maintain the safe and efficient flow of traffic. Agencies implement a wide range of operations strategies to address safety objectives, including:
  - Geometric improvements, access management, traffic control, coordination with law enforcement for installation and monitoring of red light cameras.
  - Real-time motorist warning systems at intersections.
  - Road weather management.
  - Traveler information and roadway reports.
  - Physical safety improvements such as rumble strips;
  - Deployment of guardrails, impact attenuators, lighting, signs, signals, and pavement markings (*14*).

- **Preservation** and **Operations** investments are frequently combined. For example, many state transportation agencies implement improvements such as shoulder paving, slope flattening, installation of guardrails, etc. in conjunction with resurfacing projects to improve safety and operational efficiency (*14*).

- **Capacity Expansion** investments offer state transportation agencies the opportunity to utilize safety best practices and examine design options with respect to potential safety benefits. Safety-related design considerations may also include provisions for emergency response and enforcement (e.g., pull-off locations for HOV lane enforcement). Agencies may also consider alternatives for providing instrumentation to support better traffic management and operations within the project scope (*14*).

Work zone safety is an important consideration within each of these areas.

Transportation safety programs have traditionally encompassed aspects of engineering, enforcement, education, and emergency response. While state transportation agency safety offices have primary responsibility for the engineering aspect of safety (geometric design, traffic control, barriers, signs, etc.), they work in coordination with various other agencies—including local public works departments, departments of motor vehicles, law enforcement, emergency services, hospitals—on implementation of broader safety programs.

State transportation agencies have several significant guidance documents at their disposal to assist in improving transportation safety programs. In 1998, the American Association of State Highway and Transportation Officials (AASHTO) developed the *Strategic Highway Safety Plan* (SHSP) to provide a comprehensive approach to improving transportation safety (*15*). The SHSP promotes a mix of engineering, enforcement, education, and emergency response strategies across six key areas—drivers, vulnerable users, vehicles, highways, emergency medical services, and safety management. The Safety Management area includes improvements to information and decision support systems, and safety program management. Developed as a companion document, *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan* presents specific objectives and strategies for addressing different types of highway crashes or factors that cause crashes (*16*). Comparatively, *NCHRP Report 501: Integrated Management Process to Reduce Highway Injuries and Fatalities Statewide* provides an overall framework and management process for coordinating and integrating safety programs, independent of where they reside within a governmental organization (*17*). *NCHRP Synthesis Report 322: Safety Management Systems* describes current agency practices and reviews two model state SMS initiatives (*18*). This latter document noted that while states generally track safety investment, they do not evaluate safety investment on a regular basis. Each of these guidance documents largely focuses on improving safety outcomes rather than enhancing the management of safety assets within state transportation agencies or across a broader set of participating agencies.

Operations Asset Management

State transportation agencies typically include the following types of activities within the scope of operations:

- Arterial management.
- Freeway management.
- Traffic incident management.
- Road weather management.
- Work zone management.
- Emergency management.
- Freight management.

Each of these operations program areas require physical hardware and equipment—traffic signals, variable message signs, computers, communications equipment, etc. Management of these physical operations assets is an important operations activity within each of the program areas. However, there is an important distinction between the management of operations assets and the application of transportation asset management principles to operations.

Effective operations asset management takes a holistic, integrated view of the physical, system, and personnel aspects of operations (*13*). These components are interrelated in that an investment in one typically necessitates investments in the others. For example, upgrading a traffic signal system requires both physical and system investments, as well as additional staff to operate and maintain it (or training of existing staff at a minimum). Improving operations performance requires coordinated investments in physical equipment; systems to monitor, control and connect this equipment; and skilled, effectively deployed staff.

Effective operations management requires consideration of how best to deploy available resources within and across each of these areas. Questions related to cross-area tradeoffs include:

- What is the best mix of in-house versus contract labor?
- Should we invest more in expanding coverage of operations programs or in replacing equipment?
- Can we reduce personnel costs by implementing more sophisticated technology?
- Can we reduce personnel costs by investing more in preventive maintenance and planned replacement of equipment (thereby improving reliability and reducing repair needs)?
- When we expand an operations program, what are the long-term implications for maintenance and repair of physical operations equipment? What are the implications for personnel, in terms of numbers, geographic distribution and skill sets?

While operations has always been a component of state transportation agency management, responsibility for operations has been fragmented, both within and across agencies and jurisdictions, and not effectively integrated into an overall system management strategy.

TEXAS ASSET MANAGEMENT PRACTICES

In late 1998, TxDOT implemented a *Total Maintenance Contract* for highway maintenance outsourcing. The contract was a performance-based agreement, whereby the contractor was required to maintain a prescribed level of service for a lump sum bid. In effect, the contractor took over operation of a prescribed stretch of the highway and had authority to make all decisions about the maintenance and operation of the highway. They determined what work to perform and what materials and methods to use. Also, the contractor planned and scheduled work, subcontracted for work, had the authority to utilize experimental materials, filed claims to collect for third-party damages, and so forth (*19*).

In 1999, TxDOT awarded two contracts for the total maintenance and operation of two sections of the state's interstate highways. Unlike previous method-based contracts, the new contracts developed a set of well-defined performance standards, which defined the minimum level of service acceptable. Because TxDOT had not previously measured maintenance conditions, it had to develop a system to measure the existing and resulting level of service. The outcome was the development of the Texas Maintenance Assessment Program (TxMAP) (*19*), which proved to be a useful tool for evaluating contractor performance as well as for evaluating the overall level of service on numerous other roads in Texas. Graff (*19*) also reported that "Although TxDOT anticipated the cost of these projects would be higher than previous costs, the

bids came in lower than expected." Ribreau (*20*) further noted that "[A]lthough TxDOT considers asset-management contracts with sufficient performance evaluations and substantial disincentive–incentive clauses as another useful tool; it will not enter into them as a money-saving endeavor."

In a study, the Center for Transportation Research (CTR) (*21*) identified three components that make up a maintenance contracting strategy: delivery method, type of contract specification, and pricing strategy. The study also identified a list of the following 13 delivery methods for maintenance contracts that have been implemented within TxDOT.

- Individual Activity Contract Method—Single maintenance activity is outsourced (19 districts).
- Activity Based Maintenance Contract Method—A specific activity or activities are outsourced (17 districts).
- Moderately Bundled Activities Contract Method—Similar maintenance activities that are often sequential in work are let together in a single outsourced contract (10 districts).
- Significantly Bundled Activities Contract Method—Nearly all maintenance activities, with the exception of a few special activities, are bundled and outsourced in a single contract (two districts).
- Partial Competitive Maintenance Contract Method—TxDOT personnel perform a certain percentage of the maintenance and outsources the remainder (one district).
- Jointly Performed Maintenance Contract Method—TxDOT personnel perform a portion of a specific activity and outsource the remainder of the activity (eight districts).
- Routine Maintenance Contract Method—All routine maintenance activities are bundled into one contract and outsourced (two districts).
- Total Asset Management Contract Method—Operations, maintenance, upgrades, and expansion of a road asset are outsourced in a single contract (also called Total Maintenance Contracting) (one district).
- Integrated Maintenance Contract Method—A combination of routine and preventive maintenance activities are bundled and outsourced in one contract (two districts).
- CREMA Contract Method—Combined Rehabilitation and Maintenance (CREMA) contract requires contractors to rehabilitate and subsequently maintain a sub-network of roads under a lump sum contract for a total period of five years (0 district).
- Long-Term Separate Maintenance Contract Method—A single activity is outsourced for a long-term period (five or more years) and may span a large area (one district).
- Framework Contract Method—Several contractors are pre-approved and receive nominal contracts that make them eligible for maintenance projects (one district).
- Alliance Contract Method—TxDOT selects a contractor based entirely on qualifications and has the opportunity to gain or lose 15 percent of the contract value depending on performance (0 districts) (*21*).

In a subsequent survey, the CTR study team found that TxDOT widely uses method-based contract specifications for maintenance contracting as opposed to performance-based or warranty contract specifications. The team also found that TxDOT used unit price more commonly as the

pricing strategy for maintenance contracting as opposed to lump sum or cost plus fee and that nearly all districts indicated that the delivery methods they use are performed successfully. However, one district indicated a Significantly Bundled Activities Contract was not performed successfully (*21*).

The study also found that there were three types of contract specifications, three pricing strategies, and two contract award strategies. The contract specifications identified were method-based, performance-based, and warranty specification (*21*).

The method-based contract specification allows the contracting agency to specify the methods, materials, and quantities that a contractor can use to perform a special maintenance activity, and payment is based on the amount of work the contractor has completed. The performance-based contract enables the contracting agency to define a set of measurable outcomes, allowing the contractor to decide which methods and materials to use for achieving that outcome. The contracting agency must establish a set of minimum performance standards or targets, and payment is based on the performance, typically with options for penalties and rewards. Finally, the warranty specification requires the contractor to warrant the work for a specified length of time (*21*).

The three pricing strategies were unit price, fixed price or lump sum, and cost plus fee. The unit price enables the contracting agency to pay the contractor for the number of units completed based on the unit price for each maintenance activity or line item. The fixed price allows the contracting agency to pay the contractor on a monthly basis over the contract period based on a lump sum amount. Reductions or increases in payments may occur if the contract includes disincentives or incentives, respectively, for falling short or exceeding the performance standard or target. The cost plus fee enables the contracting agency to pay the contractor in accordance with the cost it incurs for performing the maintenance work plus a fee for profit (*21*).

The award strategies were low bid and best value. Low bid selects contractors solely on price, where the lowest bidding contractor is selected. Best value, on the other hand, is based on a combination of factors including experience, bid price, and work plan (*21*).

SUMMARY

In recent years, numerous states have implemented comprehensive and/or focused asset management systems. Focused asset management systems are commonly motivated by infrastructure preservation needs and consider pavements, bridges, or to a lesser extent, culverts. A second area of asset management system development relates to economics and includes the use of FHWA's state version of the Highway Economic Requirements System (HERS) and lifecycle cost analyses. Select states have also developed asset management systems focused on data integration and sharing.

In general, asset management systems that focused on safety and/or operations were observed to be limited among state transportation agencies in the United States. The breadth of potential strategies, resources, and agency involvement all challenge safety asset management systems that focus on safety-related assets rather than outcomes. Asset management systems focused on operations present a similar challenge. This guidebook is an effort to improve asset management from this perspective for TxDOT in the coming years.

CHAPTER 3: ASSET MANAGEMENT APPROACH

GUIDANCE ON GENERAL STATEWIDE POLICY

Agencies have developed asset management systems to manage a large volume of data and to help make the information applicable to diverse management needs such as assessment of current conditions and needs based on inspection, programming of maintenance and repair activities, planning facility replacement, and valuation of the depreciated assets. The introduction of automated management systems for various assets in the state departments of transportation has the potential to:

- Ensure attentive responses to transportation facility needs.
- Improve coordination among the many specialized staff groups responsible for the facilities.
- Program repairs and replacements efficiently. Each type of asset—such as pavement, traffic signal, bridge, or tunnel—has many unique features which are oftentimes related.

To efficiently manage these assets, state DOTs and metropolitan planning organizations have implemented either comprehensive or limited asset management systems.

A THREE-TIERED APPROACH FRAMEWORK

In developing the matrix of best asset management practices for this Guidebook for TxDOT, the research team used a three-tiered structure to capture the evolving management strategies that TxDOT considers critical to guiding future asset management contractual activities. TxDOT believes that this structure will enhance the districts' flexibility to manage assets depending on the conditions and needs of each region. TxDOT's proposed three-tiered approach to asset management consists of:

- Total asset management for large urban areas encompassing multiple counties.
- Asset management of critical functions on a smaller regional scale.
- Asset management for specific types of assets.

Total Asset Management

Total asset management, or comprehensive transportation asset management, is focused on large urban areas encompassing multiple counties. It seeks to approach asset management on a large scale to take advantage of economies of scale and efficiency in contract management.

Asset Management of Critical Regional Functions

Asset management of critical functions on a smaller regional scale is intended to bundle critical functions across a region into one contract. An example might be to combine the maintenance of all roadside components (excluding the pavement) into one contract.

Asset Management for Specific Types of Assets

Asset management for specific types of assets are very focused and may include items such as pavement markings or LED signals indicators and may be based on warranty specifications.

GUIDEBOOK OVERVIEW

This guidebook provides an introduction to the concept of asset management along with background information on the types of investment categories of asset management. Within the three-tiered approach, it provides guidance and information on critical considerations TxDOT must address throughout the asset management process, including the identification of goals and objectives, and assessment of potential asset management strategies, the identification of organizational conditions that may impact asset management, the selection of contract terms, and the selection performance measures to determine success. The subsequent chapters provide detail on these issues in a stepwise approach that is also reflected in the screening tool, which is a companion to the guidebook.

CHAPTER 4: CRITICAL CONSIDERATIONS

A successful transportation asset management plan should address a number of core questions including:

- What is the current state of my assets?
- What is the required level of service?
- Which assets are critical to sustained performance?
- What are my best investment strategies for operations and maintenance and for capital improvement?
- What is my best long-term funding strategy? (*22*)

Once TxDOT answers these questions, it can develop and apply asset management strategies to the transportation infrastructure. TxDOT can use the data gathered through asset management in decision making for operations, preservation, and maintenance of assets (*22*).

ASSET MANAGEMENT GOALS

The first step in the asset management process is the selection of goals. These goals drive the entire process and help TxDOT ensure that asset management practices are helping the agency move forward toward meeting the intent of effective asset management. Based on agency responses to the questions above, TxDOT can develop an initial set of goals. These goals can then be incorporate into the transportation improvement program (TIP), which is a short-range planning document, and the statewide transportation improvement program (STIP), which is a longer range plan. Specific goals may include:

- **Build a more cost-effective infrastructure**. TxDOT wants to ensure that the limited resources are used wisely to build assets that will meet specifications yet be fiscally responsible to the citizens of Texas.
- **Preserve existing infrastructure.** TxDOT wants to take care of existing assets to ensure the investment is not wasted.
- **Operate existing infrastructure more cost-effectively.** TxDOT wants to be fiscally responsible when operating the infrastructure so as to be responsible to the citizens of Texas while enhancing their mobility.
- **Improve safety.** TxDOT wants to save lives of the traveling public as well as its workforce.
- **Improve asset performance.** TxDOT wants to boost the performance of all assets so that they meet their full potential in meeting the goals of the agency.
- **Enhance agency credibility.** TxDOT as an agency wants to maintain and improve its credibility as a quality DOT with the taxpayers and the traveling public.
- **Enhance agency accountability.** TxDOT as an agency wants to maintain and improve the manner in which it is accountable to the citizens of Texas for the resources it expands, the decisions it makes to allocate those resources, and the assets it manages.

- **Support smart long-term decision making.** TxDOT wants to be able to make informed decisions regarding the long-term investment in the management of its assets.
- **Enhance system sustainability.** TxDOT wants to provide a sustainable system that meets the needs of its customers while minimizing the overall negative impacts on the community.
- **Improve agency agility.** TxDOT seeks to manage its assets with flexibility across regions and assets depending on regional needs, system conditions, and agency limitations.
- **Ensure equitability/objectivity.** TxDOT wants to ensure that decisions to expend resources are made objectively and that these are deployed in an equitable manner across the state.
- **Enhance agency transparency.** TxDOT wants to provide transparency in all investment decisions and processes to enhance the agency's accountability and credibility with the citizens of Texas.

ASSET MANAGEMENT OBJECTIVES

Once TxDOT has selected goals for asset management, it can then identify specific objectives to support each of the goals mentioned in the previous section. When properly defined, objectives are used to articulate a clear, measurable, outcome of the asset management process either in the short- or long-term future. Asset management objectives typically fall into three general categories that are detailed below: system performance, financial, and analysis.

System Performance Objectives

System performance objectives pertain to how the transportation system performs overall. The specific system performance objectives may include:

- **Meet present system demands.** TxDOT wants to ensure that the system meets current demands in an efficient manner.
- **Meet future system demands.** As the population in the state continues to grow, TxDOT wants to ensure that the system will be able to meet future demands and not suffer the growing pains of the past.
- **Identify current system deficiencies.** TxDOT needs to be able to quickly and efficiently identify then address deficiencies in the system before these become catastrophic.
- **Identify future system deficiencies.** TxDOT needs to be able to identify future system deficiencies so that they can address in a timely manner and reduce the likelihood of them becoming significant hurdles in the future.
- **Ensure specified percentage of assets meet agency performance levels.** TxDOT wants to maintain the performance of assets and set benchmarks to ensure the majority of the system meets performance expectations from the agency perspective.
- **Maintain acceptable levels of service.** TxDOT wants to be able to meet the expectations of the traveling public to have an efficient, reliable transportation system.

- **Minimize motorist delay during work activities.** TxDOT realizes that the work activities impact travelers, and that it must minimize the negative impacts of those activities as much as possible.
- **Establish performance measures to ensure that goals are being met.** To ensure efficient asset management, TxDOT needs to utilize performance measures to clearly determine if asset management goals and objectives are being met.
- **Perform condition assessments at useful intervals.** The backbone of an asset management system is accurate and readily available information, which is only feasible through periodic condition assessments.

Financial Objectives

Financial objectives incorporate the monetary component of managing transportation system assets. The specific financial objectives may include:

- **Establish accurate valuation of assets.** TxDOT needs to have a clear accounting of the value of its assets to identify priorities for future investment.
- **Improve resource allocation.** TxDOT needs to ensure that its scarce resources are invested wisely to increase productivity and optimize system performance.
- **Estimate the backlog of investment requirements.** TxDOT needs to determine the investments that are critical for system optimization but have been delayed.
- **Enable cost-effective solutions.** TxDOT wants to ensure that resources are allocated in a cost-effective manner and yield the best return on investment.
- **Accurately project future requirements.** TxDOT needs to be able to predict what improvements to assets will be needed in the future and when, so that it can plan accordingly.

Analysis Objectives

TxDOT can include defined analytical processes by which its transportation system assets will be managed. The specific analysis objectives may include:

- **Develop decision framework.** TxDOT wants a streamlined approached to making decisions in an effective manner.
- **Provide continuous feedback procedures.** Procedures for including feedback on asset performance and conditions are needed to have the most accurate information possible.
- **Establish means to eliminate or mitigate impacts of constraints.** Constraints can create challenges to asset management, and TxDOT needs to have clear approaches to mitigating these whenever possible.
- **Establish accurate inventory of assets.** The best asset management system depends on an accurate assessment of assets and their condition, with a periodic process for updating that information.
- **Utilize advanced technology where appropriate.** Technology can be a powerful ally to TxDOT in the management of assets and it should be exploited whenever possible to enhance efficiency.

- **Utilize appropriate data collection processes.** Clearly defined processes for collecting data support an efficient asset management system that optimized resource allocation.
- **Utilize appropriate data evaluation system.** Once TxDOT gathers asset-related data, it needs to be able to evaluate the data to make informed and effective decisions related to asset management.
- **Support network level analysis (benefit/cost for entire system).** Analyzing the benefits and costs of the entire system is essential to asset management.
- **Support project level analysis (specific to project).** Districts and divisions need to be able to effectively manage the benefits and costs of specific projects with respect to asset management to ensure efficient resource investment.

POTENTIAL ASSET MANAGEMENT STRATEGIES

Once TxDOT establishes the agency goals and objectives, it must then consider available contracting strategies. In accordance with the desired three-tiered management strategy, specific contracting strategies are categorized into three main groups: comprehensive transportation asset management, asset management for critical functions on a regional scale, and asset management for specific assets. **Comprehensive transportation asset management** is focused on large urban areas encompassing multiple counties, while **asset management of critical functions on a smaller regional scale** may include maintenance of roadside components excluding the pavement. **Asset management for specific assets** are very focused and may include items such as pavement markings or LED signal indicators and may be based on warranty specifications.

Comprehensive Transportation Asset Management

The specific contracting strategies that are included under comprehensive transportation asset management are:

- Routine maintenance.
- Total asset management.
- Integrated asset management.

Critical Functions – Regional Scale

The specific contracting strategies that are included under critical functions on a regional scale are as follows:

- Moderately bundled/ activity-based.
- Significantly bundled.
- Partial competitive.*
- Jointly performed.
- Routine maintenance.
- Integrated.
- Framework.

**TxDOT does not currently use partial competitive contracts. However, the project team and the Project Monitoring Committee elected to include this strategy in the list of potential options in the event that TxDOT determines it is appropriate for specific functions at some future date.*

Specific Assets

The specific contracting strategies that are included in the specific assets category are as follows:

- Individual activity.
- Long-term separate.
- Framework.

Strategies Defined

Contracting strategies are taken from TxDOT Project 0-6388 literature (*21*) and are defined as follows:

- ***Jointly Performed Maintenance Contract Method:*** In-house personnel perform a portion of a specific maintenance activity and the remainder is outsourced to a contractor, typically due to a lack of sufficient equipment or labor. For example, snow removal or small rehabilitation projects can be jointly performed.

- ***Long-Term Separate Maintenance Contract Method:*** A single maintenance activity is outsourced across many areas, regions, or even the entire county for a long duration, typically more than five years, often because it is unique or risky. For example, it is common to outsource rest area maintenance for up to 10 years.

- ***Framework Contract Method:*** Several contractors are pre-approved and receive nominal contracts that make them eligible for award of maintenance projects. The method is often called a Multi-Agency Contract (MAC) and is used widely in the U.S. military. Some states use this model for traffic control contracts.

- ***Moderately Bundled Activities Contract Method:*** A few maintenance activities that are of a similar nature and have a compatible sequence of work are let out together, such as mowing, sweeping, and litter pick-up.

- ***Partial Competitive Maintenance Contract Method:*** A certain percentage of the in-house workforce is retained to perform various routine maintenance activities, while the rest of the activities are bid out. In this method, in-house forces can competitively bid against contractors for the work. Often, the scope of work is large and may include all maintenance activities or a very large bundle of activities.

- ***Routine Maintenance Contract Method:*** All routine maintenance activities are outsourced together as one contract. If a performance-based specification and lump-sum pricing are used, the method can be regarded as a Total Asset Management Contract Method. If a method-based specification and unit pricing are used, the method can be regarded as Significantly Bundled Activities Contract Method.

- ***Integrated Maintenance Contract Method:*** A combination of both routine and preventive maintenance activities are outsourced together as one contract. If a

performance-based specification and lump-sum pricing are used, the method can be regarded as a Total Asset Management Contract Method. If a method-based specification and unit pricing are used, the method can be regarded as a Significantly Bundled Activities Contract Method.

- ***Significantly Bundled Activities Contract Method:*** Nearly all maintenance activities are let out together, other than a few activities that are special or unique. A method-based specification and unit price are required to implement this method. This contract method has also been called a General Maintenance Contract.

- ***Total Asset Management Contract Method:*** A strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their life cycle (Source: AASHTO Subcommittee on Asset Management in January 2006). In the context of contracting, Total Asset Management involves outsourcing operations, maintenance, upgrades to, and expansion of, a road asset. A performance-based specification and lump-sum pricing are required to implement this method. Florida calls this method Total Asset Maintenance Contracting and Texas calls this method Total Maintenance Contracting.

- ***Alliance Contract Method:*** A contractor is selected based entirely on qualifications and has the opportunity to gain or lose 15 percent of the contract value depending on performance. This method typically carries out performance-based specification and used cost plus fee as the pricing strategy.

AGENCY ORGANIZATION CONDITIONS

Once TxDOT considers its available contracting strategies, the prevailing conditions within the organization must also be recognized, since these conditions may dictate or eliminate specific asset management contract strategies from consideration. These organizational conditions fall into six categories, which are detailed below: in-house contracting administration and purchasing processes, in-house personnel, in-house equipment, work location, time constraint, and contractor.

In-House Contract Administration and Purchasing Processes

Specific organizational conditions may exist under in-house contract administration and purchasing processes are as follows:

- TxDOT has a need to increase bid competition.
- TxDOT has a need to meet state mandated 105/144 budget distributions.
- TxDOT has a need to reduce contract administration overhead costs.
- TxDOT has a need to reduce the number of bid packages and requests for proposals (RFPs) issued.
- Work can be assigned by a simple purchase of services.
- Work is awarded to multiple contractors awaiting work orders.

- TxDOT must be willing to pay awardees even if no work orders are issued against contract.
- TxDOT has a good method for evaluating contractors.
- TxDOT has developed a well-defined set of maintenance specifications.
- TxDOT's outsourcing experience is limited.
- TxDOT's outsourcing experience is plentiful.

In-House Personnel

The specific organizational conditions that are included under in-house personnel are as follows:

- TxDOT has a need for additional labor that is only temporary.
- Qualified staff is available to perform inspections.
- TxDOT lacks qualified staff to manage contracts.
- TxDOT lacks in-house expertise.
- TxDOT lacks qualified staff to perform maintenance work in-house.

In-House Equipment

The specific organizational conditions that are included under in-house equipment are as follows:

- TxDOT lacks in-house equipment.
- TxDOT has a need to reduce equipment costs.
- Work requires specialized equipment that is expensive to acquire.

Work Location

The only organizational condition included under work location is that the work may be too spread out (i.e., statewide rest area maintenance).

Time Constraint

The specific organizational conditions that are included under time constraint are as follows:

- Must make a quick selection.
- Severe weather.
- Seasonal work.
- Emergency work.

Contractor

The specific organizational conditions that are included under contractor are as follows:

- Contractors are unable to perform all work in an activity bundle.
- Few contractors are qualified and willing to bid.

CONTRACT TERMS FOR EACH STRATEGY

Once TxDOT has selected appropriate asset management contracting strategies based on the selected organizational conditions, they must identify specific contract terms for each strategy identified. The contract terms fall into three categories—specification, pricing, and award—detailed below.

Specification

The specific contract terms included under specification are as follows:

- Method-Based.
- Performance-Based.
- Warranty-Based.

Pricing

The specific contract terms included under pricing are as follows:

- Unit Price.
- Lump Sum.
- Cost Plus Fee.
- Hybrid of Unit Price and Lump Sum.

Award

The specific contract terms included under award are as follows:

- Low Bid.
- Best Value.

SELECTING PERFORMANCE MEASURES

Once TxDOT refines the list of objectives for the asset being managed, they must identify appropriate performance measures on the selected objectives. The performance measures fall into nine categories that are detailed below: preservation, mobility/accessibility, operations and maintenance, safety, economic development, environmental impacts, social impacts, security, and project delivery.

Preservation

The specific performance measures included under preservation are as follows:

- Pavement Condition/Ride Quality.
- Asset Condition (General).
- Remaining Life/Structural Capacity.
- Asset Value.
- Backlog or Need.
- Agency Financial Impacts.
- Customer Benefit or Disbenefit (or Surrogates).
- Customer Perception.

Mobility/Accessibility

The specific performance measures included under mobility/accessibility are as follows:

- Congestion.
- Speed.
- Travel Time.
- Travel Time Reliability.
- Delay.
- Travel Cost.
- Accessibility to Destinations.
- Accessibility to Facilities and Services.
- Accessibility to Different Modes.
- Backlog or Need.
- Customer Perceptions.

Operations and Maintenance

The specific performance measures included under operations and maintenance are as follows:

- System Operations Efficiency.
- Incident Response.
- Winter Operations.
- Emergency Operations.
- Capacity and Availability.
- Maintenance Level of Service.
- Cost Efficiency
- Occupancy.
- Fuel Efficiency.
- Backlog or Need.
- Customer Perceptions.

Safety

The specific performance measures included under safety are as follows:

- Crashes.
- Transportation Infrastructure.
- Backlog or Need.
- Customer Perception.

Economic Development

The specific performance measures included under economic development are as follows:

- Economic Costs and Benefits.
- Direct User Costs.
- Transportation Infrastructure Support for Freight Movement.
- Support Improved Service to Existing Urbanized Area.
- Support of Brownfield or Infill Sites.
- Customer Perceptions.

Environmental Impacts

The specific performance measures included under environmental impacts are as follows:

- Vehicle Emissions.
- Air Quality Standard Attainment.
- Length or Extent of Air Quality Problem.
- Water Quality, Wetlands, Aquatic Life.
- Hazmat Impacts.
- Energy Impacts.
- Noise Impacts.
- Recycling.
- Completion of Mitigation Steps.
- Customer Perceptions.

Social Impacts

The specific performance measures included under social impacts are as follows:

- Social, Cultural, Neighborhood, Community Quality of Life.
- Customer Perceptions.

Security

The specific performance measures included under security are as follows:

- Incident Rates.
- Prevention Activity.
- Customer Perceptions.

Project Delivery

The specific performance measures included under project delivery are as follows:

- Accomplishment.
- Quality.
- Efficiency.
- Schedule and Budget Adherence.
- Responsiveness.
- Backlog.
- Customer Impact and Safety (Work Zone).

Selection of Performance Measures Based on Assets to Be Managed

After determining the performance measures based on the selected objectives, TxDOT must define specific needs for the assets being managed and what measures are relevant and critical for agency success. This step allows the agency to consider any unique circumstances that may dictate which measures are more important or relevant than others.

Tool Generates Specific Performance Measures Based on General Measures

Once TxDOT refines the list of performance measures for the asset being managed, the *Asset Management Screening Tool* identifies more specific or more detailed performance measures based on the selected measures. This list of specific performance measures is based on an internal matrix that identifies the specific relationships between the two.

CHAPTER 5: MATRIX OF STRATEGIES/ASSET MANAGEMENT PRACTICES

Building upon the information gathered through the review of published and electronic literature, and the assessment of practices across the United States in the area of asset management, the researchers developed a matrix of best asset management strategies that can most benefit TxDOT. This matrix matches viable and proven strategies of management with specific asset components. As determined through numerous discussions with the project oversight committee, the matrix has a three-tiered format that mirrors the three-tiered approach to asset management that TxDOT desired:

- Total asset management for large urban areas encompassing multiple counties.
- Asset management of critical functions on a smaller regional scale—such as maintenance of roadside components excluding the pavement.
- Asset management for specific types of assets—such as pavement markings or LED signal indications—that may be based on warranty specifications.

The matrix identifies the various types of practices that are appropriate for these levels of asset management. Furthermore, it notes which specifications, pricing structures, and award selection criteria fit within this three-tiered structure. This matrix, which Figure 4 illustrates, provided the general framework for the *Asset Management Guidebook*. As the research team developed the guidebook, the information in this matrix was matched with critical information related to those activities and processes for the asset management program, such as asset inventory, asset valuation, quantitative condition and performance measures, performance prediction, qualitative issues, and feedback procedures. These best practices and their detailed relationships were further refined within the guidebook once results from Task 5 (Technology Assessment) and Task 6 (Impediments to Implementation/Institutional Issues) were completed. They were then interfaced with critical questions and constraints that TxDOT needs to answer to help identify the most appropriate asset management strategy based on designated goals, objectives, needs, and constraints. Additional details and components of this framework are provided in Appendix A.

	Specifications			Pricing					Awards		
Asset Management Category	Method-based specifications	Performance-based specifications	Warranty Specifications	Lump Sum	Unit Price	Cost Plus Fee	Hybrid of Lump Sum and Unit Price	Cost Reimbursement	Low Bid	Best Value	Qualification Based
Comprehensive Transportation Asset Management											
Routine Maintenance	X	X	X	X	X	X			X	X	
Total Asset Management	X	X		X	X		X		X	X	
Integrated	X	X		X	X	X			X	X	
Alliance	X	X		X	X	X					X
Critical Functions - Regional Scale											
Moderately Bundled / Activity-Based	X	X	X	X	X	X			X	X	
Significantly Bundled	X			X	X	X			X	X	
Partial Competitive	X	X	X	X	X				X	X	
Jointly Performed	X	X	X	X	X	X			X	X	
Routine Maintenance	X	X	X	X	X	X			X	X	
Kilometer (or mile) per month		X			X				X	X	
Integrated	X	X	X	X	X	X			X	X	
Framework	X	X	X	X	X	X				X	
CREMA (Combined Rehabilitation and Maintenance)		X			X			X	X	X	
Specific Assets											
Individual Activity	X	X	X	X	X	X			X	X	
Long-Term Separate	X	X	X	X	X				X	X	
Framework	X	X		X	X	X				X	
CREMA (Combined Rehabilitation and Maintenance)		X			X			X	X	X	

Figure 4. Matrix of Asset Management Practices.

DEVELOPMENT OF ASSET INVENTORY/DATABASE

In order to successfully utilize any asset management program, decisions must be based on accurate information regarding the agency's assets. Items that are typically included in a transportation agency's inventory may include roadway features such as pavement and pavement markings, signs, signals, lighting, bridges, guardrails, barriers, and drainage features. Integrated asset inventory systems, such as those using GIS-based platforms, are often used to consolidate asset information from different systems using a common theme. The value and condition of each item in the inventory should be documented.

Valuation of Assets

An accurate valuation of assets is critical for calculating life-cycle costs. Life-cycle costs are subsequently used to analyze maintenance options and develop maintenance programs. An agency's ability to properly maintain assets can be severely hindered if the agency lacks the ability to estimate values for various assets.

Quantification of Asset Condition

Asset condition information can be collected using a variety of methods. Many states utilize GPS-enabled mobile data collection systems to document asset conditions (i.e., pavement roughness, rutting, and distress). In some cases, statistical sampling of a particular data item can provide managerial information with the same or equivalent level of confidence with less effort than sampling every single item. The data can be uploaded to the agency's asset inventory and used to determine which assets may need to have a higher maintenance priority or ranking. For example, pavement management systems may have decision rules (which are often implemented as condition-based triggers) to identify locations where specific treatments should be performed. In addition, methods for projecting future conditions are based largely on accurate depictions of existing conditions.

METHOD-BASED SPECIFICATIONS

Method-based contracts are the traditional means of contracting maintenance activities. The can occur in one of two forms: directed and specification based (*23*).

Directed

In directed contracts, the contracting agency is responsible for verifying that the quantities of work claimed by the contractor match the agency's estimate of work complete. These contracts use method-based specifications, which typically describe how, when, and where the work is to be performed, and require significant involvement from the agency in terms of risk, control, and administration of the work. Consequently, the contractor's risk and control is low. Directed contracts are based upon unit prices and contractor selection has historically been based on low bid. The unit price serves as the payment method for the contractor's work. However, selection of the best unit of work for the pricing structure is important. For example, the preferred work units for crack sealing should be based on length of cracks sealed instead of quantity of sealant used. This would deter a contractor from unnecessarily over-applying sealant.

Specification-Based

Specification-based contracts put a greater responsibility on the contracting agency to ensure that the contractor is performing the work according to the required specification. These specifications impose quality standards on the work being performed. Although the contractor may be required to have a quality control program in place, the agency has the ultimate responsibility for quality control and must carefully inspect the contractor's work for compliance. This type of contract shifts some of the risk and control from the agency to the contractor, although the agency's administrative involvement still remains high.

PERFORMANCE-BASED SPECIFICATIONS

In performance-based contracts, the agency establishes outcome-based performance standards before the work is awarded. A performance-based specification will clearly describe the agency's expectations of the contractor for each asset in the contract document and must

have clearly defined performance measures. Deciding how, when, and where to perform maintenance work is the contractor's responsibility. The agency then periodically checks the contractor's performance. Performance-based contracts shift more of the risk and control to the contractor and significantly reduce the agency's administrative involvement.

Development of Performance Measures

Performance measures are a means of monitoring progress toward a result or goal. They have been used by transportation agencies for many years to "help track and forecast the impacts of transportation system investments, monitor the condition of highway features, and gauge the quality of services delivered by an agency." Although performance measures are typically technical in nature, many non-traditional issues, such as security, social, environmental, and economic development issues, may also need to have performance measures established (*24*). NCHRP Report 551 (Volume 2) *Guide for Performance Measure Identification and Target Setting* introduces a framework for identifying performance measures and setting target values. A summary of the steps for identify performance measures is given below. However, the authors refer the readers to NCHRP Report 551 for more details.

1. Inventory existing performance measures and identify how they are being used.
2. Identify gaps to be addressed based on coverage of critical outcome areas for agency goals and objectives and support for the asset management best practices.
3. Define criteria for selecting new measures (the guidance suggests a set of criteria but presumes that agencies will tailor criteria based on their needs and priorities).
4. Identify additional candidate measures.
5. Select a set of measures from the list of candidates for further design and implementation.

Warranties

Warranties provide an added layer of protection for contracting agencies against early contractor failure, construction problems, or other performance issues. A warranty assures that the contractor's work is performed in a sound manners and that it will remain in an acceptable condition for a specific period of time (*23*).

Qualitative Issues

While performance measures for preservation, mobility, and safety can be found throughout the literature, performance measures that address security, social, environmental, and economic development impacts are less prevalent. These impacts are not generally measured in quantitative terms but are, instead, more qualitative in nature. For example, security may be measured in terms of protection of travelers, freight, vehicles, and system infrastructure from criminal and terrorist actions, while social impacts include effects on broader society (such as neighborhoods located near transportation facilities) or on population groups (such as the disadvantaged). Environmental impacts may include air quality, groundwater, protected species, noise and natural vistas, while economic development are focused on the both direct and indirect impacts of transportation on the economy (*24*).

Feedback/Process Improvement

Performance measures should provide managers with sufficient information to understand problems and find solutions. As performance measures are monitored, feedback is used to assess the effectiveness of the agency's transportation system investments and services, work accomplished, and program and service delivery. In addition, the feedback/process improvement is critical for prompting the agency to respond to changing conditions, demands and priorities as needed. Feedback should help agencies understand the impacts of past and future actions and make adjustments to policy goals and objectives along the way (*24*).

CHAPTER 6: TOOLS FOR ASSET MANAGEMENT FOR SAFETY AND OPERATIONS

CURRENT TOOLS AND TECHNOLOGIES FOR PROCESSING AND MONITORING CONTRACTS

After analyzing all 25 TxDOT districts, the research team selected and visited several districts based on their location, size, rural or urban, and asset management contract methods, in order to collect data and information in the following areas:

- What type(s) of contacts the district uses (traditional, performance-based, or warranty-based).
- What type(s) of contract pricing the district uses (unit pricing, lump sum, or cost and fee).
- What asset management methods and software (tools) the district uses for contract preparing, bidding, letting, and monitoring.
- How the contract-related payment system works in the district.
- How the district communicates/exchanges asset management data/information with TxDOT Headquarters, including the use of software/tools.
- How the district collects daily operation data related to the asset maintenance management.

Based on the data and information the team collected, the current tools and technologies used within TxDOT for processing and monitoring asset maintenance contracts are discussed in detail. While TxDOT uses Microsoft® Excel, Access, and other small commercially available software/tools for facilitating the daily asset maintenance management, the major software/systems used statewide are listed in Table 1 below.

Table 1. Major Software/Systems Used for Strategy-144 Routine Maintenance.

System	Description
CMCS	Construction and Maintenance Contracting (CMCS) System—An information system used to track routine maintenance contracts, including letting and contract payment processing (developed in the 1980s; currently used by district and headquarters).
FIMS	Financial Information Management System (FIMS)—Used by the Finance Division (FIN) to track and manage the federal, state, and local funds expenditures in support of the Texas Traffic Safety Program.
MCIS	Miscellaneous Contract Information System (MCIS)—A computerized management information system used to monitor and control miscellaneous contracts for expenditures that are not construction/maintenance or purchase of service contracts that get entered into CIS/CMCS or automated purchasing system (APS).
MMIS	Maintenance Management Information System (MMIS)—An online system designed to provide data for planning and scheduling maintenance activities.
PMIS	An automated system for storing, retrieving, analyzing, and reporting information needed to support pavement-related decision making.
PONTIS	A Bridge Management System that AASHTO sanctioned in 2001. TxDOT has created a customized PONTIS application called PonTex. The integration of PonTex with PONTIS analytical tools will occur in the future.
TxMAP	A condition survey that documents the overall maintenance condition of the state highway system. This assessment provides documentation to TxDOT districts on maintenance functions that need additional attention and allows maintenance managers to monitor the condition for determining resource needs.

Construction and Maintenance Contracting System (CMCS)

CMCS is central to the project management and financial control of TxDOT's construction and maintenance programs (*25*). It is the primary system used to control maintenance and construction contracts from the planning phase through close out, keep track of progress for each individual contract and the highway improvement process, and handle the payment (*26*). Here are the functions of CMCS:

- Helps track the progress of a contract from design to close out.
- Prints required contract documents.
- Records the status of contract requirements like contractor insurance and bonding.
- Provides management reports for contract administration including payments and material quality control.

In addition:

- CMCS can also automate most <u>maintenance contract</u> activities including:
  - Plans, Specifications, and Estimates.
  - Public Notices.

- Bid Proposal Documents.
- Letting.
- Post-Letting.
- Contractor Payment.
- Monitoring of Insurance, Bonding, etc.

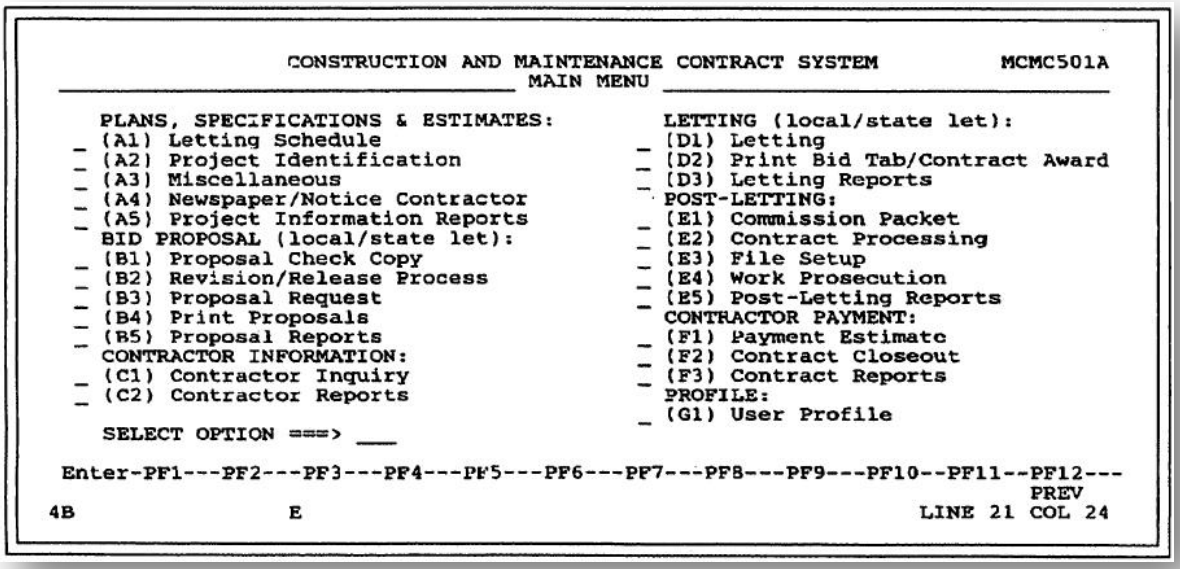
- CMCS can provide support to construction contract processing for:
  - Contractor Qualification Status.
  - Public Notices.
  - Bid Proposal Documents.
  - Post-Letting Activities including Award.
  - Monitoring of Insurance, Bonding, etc.
  - Option for Payments/Materials Processing.

- CMCS is like an umbrella. The user only needs to hold the CMCS handle to get the job done without noticing that CMCS automatically communicates with other TxDOT computer systems operating behind the scene.

Moreover, the CMCS provides statewide, online automated support for highway improvement contract activities that includes:

- Project Specification (PS&E).
- Proposal Preparation and Distribution.
- Letting and Award.
- Payment and Quality Control Procedures.
- Public Notices.
- Bonds and Insurance Status.
- Contractor information.
- Contract Close Out.

The CMCS functions can be categorized into seven groups, as shown in the CMCS main menu. The user interface of CMCS, as shown in Figure 5, is text-based and not a graphical user interface (GUI) that is widely used today.



```
                    CONSTRUCTION AND MAINTENANCE CONTRACT SYSTEM          MCMC501A
                                      MAIN MENU

   PLANS, SPECIFICATIONS & ESTIMATES:          LETTING (local/state let):
_  (A1) Letting Schedule                      _ (D1) Letting
_  (A2) Project Identification                _ (D2) Print Bid Tab/Contract Award
_  (A3) Miscellaneous                         _ (D3) Letting Reports
_  (A4) Newspaper/Notice Contractor            POST-LETTING:
_  (A5) Project Information Reports           _ (E1) Commission Packet
   BID PROPOSAL (local/state let):            _ (E2) Contract Processing
_  (B1) Proposal Check Copy                   _ (E3) File Setup
_  (B2) Revision/Release Process              _ (E4) Work Prosecution
_  (B3) Proposal Request                      _ (E5) Post-Letting Reports
_  (B4) Print Proposals                        CONTRACTOR PAYMENT:
_  (B5) Proposal Reports                      _ (F1) Payment Estimate
   CONTRACTOR INFORMATION:                    _ (F2) Contract Closeout
_  (C1) Contractor Inquiry                    _ (F3) Contract Reports
_  (C2) Contractor Reports                     PROFILE:
                                              _ (G1) User Profile
   SELECT OPTION ===> ___

 Enter-PF1---PF2---PF3---PF4---PF5---PF6---PF7---PF8---PF9---PF10--PF11--PF12---
                                                                        PREV
4B                E                                                LINE 21 COL 24
```

Figure 5. CMCS Main Menu.

SiteManager™ is used by TxDOT's Construction Division. The system adopts an Oracle® database management system and is designed to capture the daily contract management data and report from on-site inspectors and contractors. (Currently, the daily contract/project data/report from the contractors and inspectors are kept as a hardcopy diary and are not entered into the CMCS system.) TxDOT has implemented SiteManager statewide in all districts, and in 2007 the production system was upgraded to SiteManager 3.7b. Version 3.7b includes several upgrades for materials management and to improve performance. The 3.7b upgrade requires an upgrade to Oracle 10g Release 2.

Financial Information Management System (FIMS)

TxDOT's Finance Division uses FIMS to track and manage the federal, state, and local funds expenditures. The system uses alpha-numeric designators to track sub-grantee expenditures by task and sub-task, as listed in the Highway Safety Performance Plan (HSPP). FIMS is made up of approximately 35 segments and 700 programs.

Miscellaneous Contract Information System (MCIS)

MCIS is a computerized management information system used to monitor and control miscellaneous contracts for expenditures that are not construction/maintenance or purchase of service contracts that get entered into CIS/CMCS or APS.

Maintenance Management Information System (MMIS)

MMIS is a mainframe information system primarily used to provide data for planning and scheduling maintenance activities. It helps gather and analyze data for various purposes. The Single Entry Screen System (SES) and CMCS input data into MMIS. MMIS is designed to:

- Collect data on selected routine maintenance functions, which together account for the majority of maintenance expenditures.
- Draw data from other computer systems to generate reports relating maintenance costs to specific roadway segments.
- Maintain an inventory by county of the reference limits of every state-maintained highway in Texas.

The MMIS interacts with other computer systems within TxDOT to achieve its intended objectives. The details of the major systems that interact with MMIS are presented below and their interrelation depicted on Figure 6:

- Construction and Maintenance Contracting System (CMCS).
- Financial Information Management System (FIMS).
- Material and Supply Management System (MSMS)—an online system used to order and track material usage.
- Salary Labor and Distribution (SLD)—TxDOT uses this system to perform salary and labor distributions.
- Equipment Operating System (EOS)—used to order and track equipment usage.
- Single Entry Screen—TxDOT uses this system to input roadway maintenance data into MMIS, SLD, EOS, and MSMS.

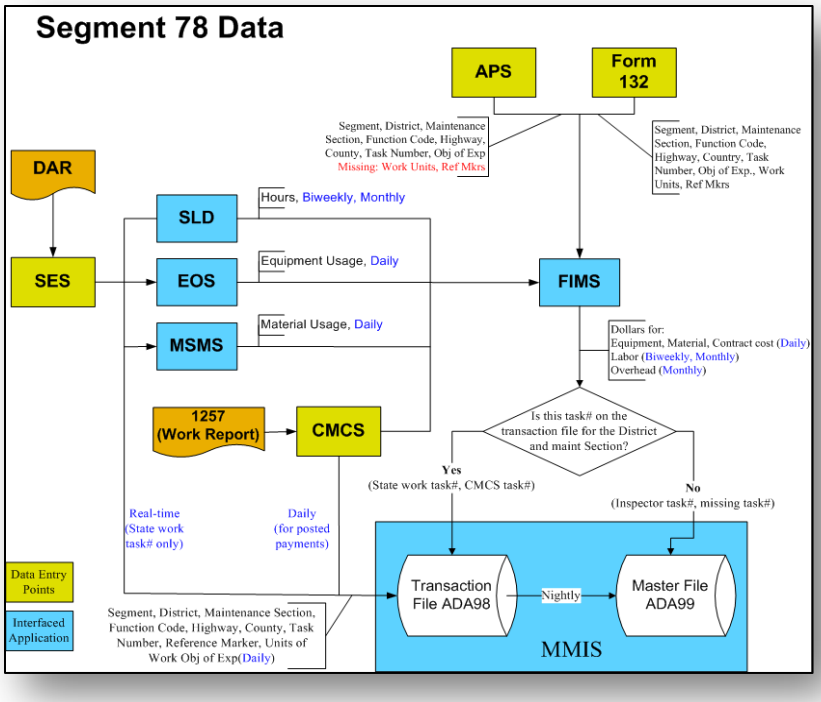


Figure 6. Maintenance Management Information System.
(Source: TxDOT Maintenance Division)

Pavement Management Information System (PMIS)

The PMIS is an automated system for storing, retrieving, analyzing, and reporting pavement condition information. Like MMIS, the PMIS provides standard reports used for evaluating and planning. It is used to retrieve and analyze pavement information to compare maintenance and rehabilitation treatment alternatives, monitor current pavement conditions, and estimate total pavement needs (*27*).

PMIS collects data such as pavement evaluation data on all major pavement types used in Texas, including asphalt surfaced pavement, continuously reinforced concrete pavement, and jointed concrete pavement. These types of data include the following:

- Distress Data—describes surface defects.
- Ride Quality Data—measures pavement roughness.
- Deflection Data—measures the structural strength of the pavement section.
- Skid Resistance Data—measures surface friction using the TxDOT Skid Truck.

Pontis

Pontis is TxDOT's comprehensive bridge management system developed as a tool to assist in the challenging task of bridge management. It does the following tasks:

- Stores bridge inventory and inspection data.
- Formulates network-wide preservation and improvement policies for use in evaluating the needs of each bridge in a network.
- Makes recommendations for what projects to include in an agency's capital plan for deriving the maximum benefit from limited funds (*28*).

Pontis supports the entire bridge management cycle, allowing user input at every stage of the process. The system stores bridge inventories and records inspection data. Once inspection data have been entered, Pontis can be used for maintenance tracking and federal reporting. Pontis integrates the objectives of public safety and risk reduction, user convenience, and preservation of investment to produce budgetary, maintenance, and program policies. Additionally, it provides a systematic procedure for the allocation of resources to the preservation and improvement of the bridges in a network. Pontis accomplishes this by considering both the costs and benefits of maintenance policies versus investments in improvements or replacements.

Pontis has been developed to provide the user with a well-organized and intuitive graphical user interface. The system consists of a set of modules, each of which has been designed to provide the user with the informational display, options, and actions relevant to the module's particular function. Each site license of Pontis includes a copy of the Pontis application, a single workstation license for the Infomaker © application required for customizing the Pontis database and Pontis reports, access to the Pontis Support Center, and unlimited support for a designated user for one year. Pontis supports the Sybase Adaptive Server Anywhere and Oracle databases, and soon it will support the SQL server. Licensees should confirm support for specific versions or releases for these vendors with the contractor.

Texas Maintenance Assessment Program

TxDOT solely uses TxMAP in its headquarters office. The list of data that TxMAP collected includes Raised Pavement Markers; Striping, Pavement Graphics; Attenuators; Delineators; Shoulder Texturing; Edges; Shoulders; Vegetation Management; Litter; Sweeping; Trees and Brush; Drainage; Encroachments; Guardrails; Guardrail End Treatments; Mailboxes; and General Public Rating.

Single Entry Screen System

TxDOT uses SES to input roadway maintenance data into the following four systems (see Table 2).

Table 2. SES Data Feeds.

SES Feeds Data to System	Tracks
Maintenance Management Information System	Work performed
Salary and Labor Distribution System	Employee time
Equipment Operations System	Equipment use
Material Supply Management System	Material use

Additional TxDOT Systems

Budget Information System (BIS)

TxDOT purchased COGNOS, a commercial-off-the-shelf (COTS) software to develop a BIS, which includes both budget preparation and budget monitoring. Financial expenditures from a mainframe ADABAS database are sent on a daily basis to update a client/server database that allows end users in the districts and divisions to view five years' worth of budget reports. Budget adjustments, additional funding requests, and additional budget requests, along with the corresponding approval of these requests, are automated components of this system.

Electronic Project Records System (EPRS)

EPRS will allow contractors and sub-contractors to securely submit payrolls over the internet to a TxDOT database. The TxDOT database will be used to provide discrepancy reports, to build the wage rate surveys, and to comply with FHWA reporting requirements. TxDOT will begin implementing Phase I, contractor payrolls, soon and will partner with the Associated General Contractors of Texas to schedule regional training in several locations throughout Texas over the spring and summer of 2007.

Decision Support System (DSS)

DSS 6.6b is currently being tested while existing DSS 5 data are being converted from SAS to Oracle. TxDOT has more than 20 years' worth of construction contract data that it needs to convert and store in the DSS 6.6b database. The new version of DSS will have a direct interface from SiteManager 3.7b and will serve as a data warehouse for TxDOT construction information.

FUTURE TOOLS AND TECHNOLOGIES FOR PROCESSING AND MONITORING CONTRACTS

As described in the previous section, TxDOT uses several major software/systems to facilitate asset maintenance management contracts. However, not all of these software programs/systems are linked to talk to each other and share the data/information they collect. Some data/information is stored repeatedly and at multiple locations, which creates very challenging data sharing and maintenance.

In an effort to address some of the historical technology issues, in FY 2013 TxDOT will implement the COMPASS Project that entails a new system called the Maintenance Management System (MMS). MMS will have more functions and will integrate with other systems more intensively than MMIS. MMS is comprised of 16 different systems with 24 system interfaces. The details of the MMS system are depicted in Figure 8 below.

Because the COMPASS Project is still in the development stage, only a few of the modules will be described, as listed below:

- Budget Information System—the automated system for both budget preparation and budget monitoring.
- Customer Relations and Feedback Tracking (CRAFT)—allows Texas road users to report road issues and receive updates regarding the problem or complaint.
- Design and Construction Information System (DCIS)—an automated information system used for planning, programming, and developing projects. DCIS is essential for preparing construction projects for contract letting.
- Fleet Management System (FMS)—will replace *FleetFocus* and will be used to report vehicle data on a monthly basis.
- Pavement Management Information System—the automated system used for storing, retrieving, analyzing, and reporting information needed to support pavement-related decision-making and a four-year plan import from MMS pavement management plan data.
- Pontis—an AASHTO-sanctioned Bridge Management System in 2001 that will be customized into an application called PonTex. The integration of PonTex with the Pontis analytical tools will occur in FY 2010.
- Texas Reference Marker (TRM)—the automated system that documents the past, present, and future state-maintained highway network.
- Human Resources (HR)—will process employee data inputs, whereas the Time and Labor module will import/export labor hours and the associated costs into MMS.
- Project Costing System—inputs and exports PeopleSoft project costing data by district, maintenance section, county or function into and from MMS, and validation tables and the PeopleSoft codes.
- Accounts Payable and Stock Balances—interface with MMS on material purchase, costs and material inventory balances, respectively. Material catalog system inputs material inventory data into MMS.
- SiteManager replaced CMCS. TxDOT has implemented SiteManager statewide in all districts; in 2007, the production system was upgraded to SiteManager 3.7b. Version 3.7b includes several upgrades for materials management and to improve performance. The 3.7b upgrade requires an upgrade to Oracle 10g Release 2.

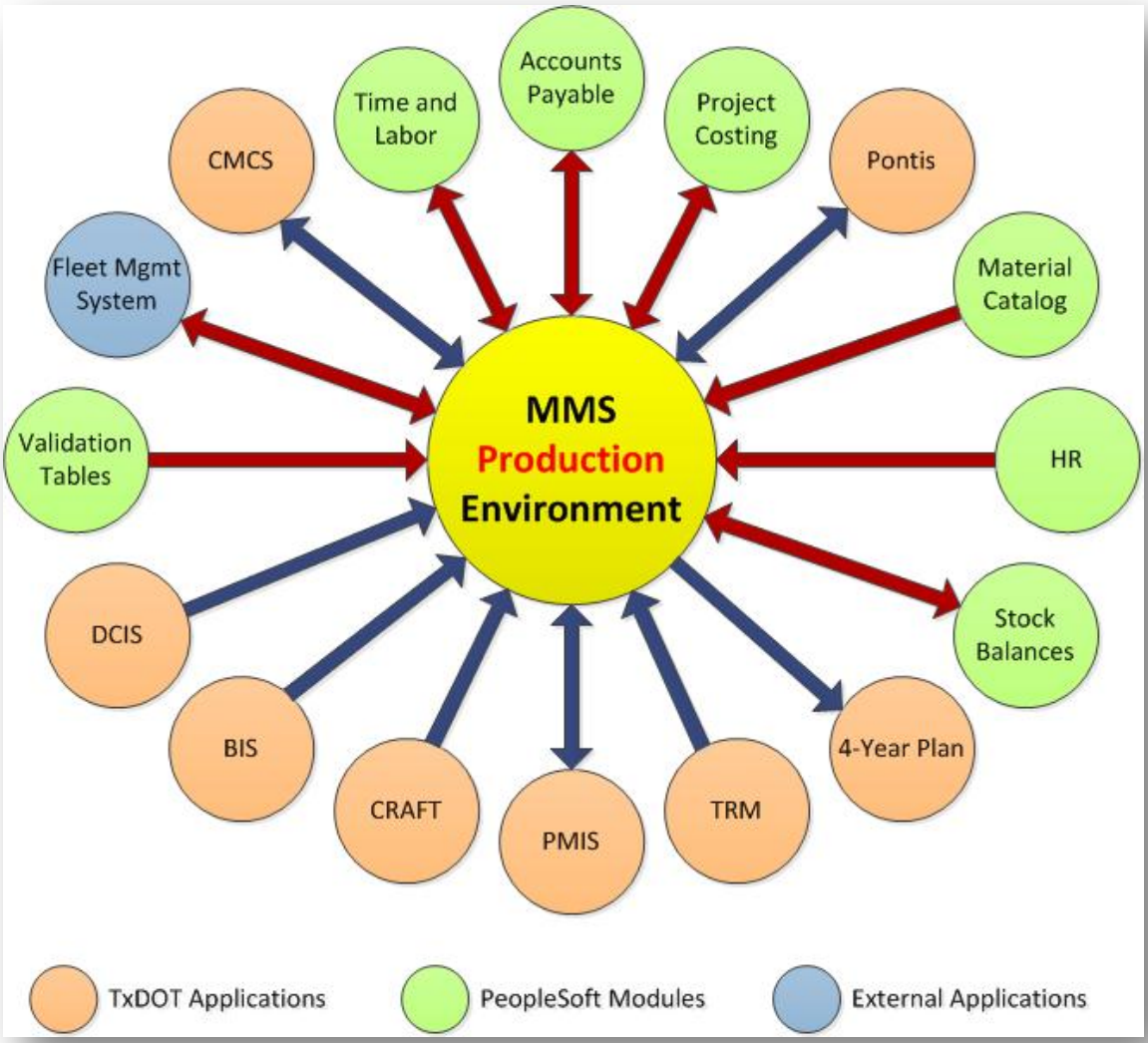


Figure 7. COMPASS Project—Maintenance Management System.
(Source: TxDOT Maintenance Division)

MIGRATION PLAN

Through the COMPASS Project, TxDOT has moved toward instituting a statewide, united, and comprehensive asset maintenance management system that is going to be available to a variety of administration levels. This unique system is expected to cover the entire life cycle of asset maintenance contracts, including planning, programming (bidding and awarding), budgeting and payment, work scheduling, monitoring and inspection, and support decision making at different levels. The challenge now is to develop a strategy for migrating the system with the proposed three-tiered structure to fully maximize TxDOT's management of its assets.

CHAPTER 7: IMPEDIMENTS TO IMPLEMENTATION/INSTITUTIONAL ISSUES

INTRODUCTION

Institutions that are at the threshold of implementing change will need to prepare for numerous challenges and opportunities that may impact their business philosophies, processes, and practices. To this end, TxDOT may soon embrace several proposed recommendations to its current asset management practices. As these recommendations are identified and eventually implemented, it is imperative to have as much insight as possible to some of the institutional issues that may occur. Therefore, the remaining sections of this document present a brief overview of TxDOT's current asset management practices, discuss recommendations that will promote establishing a comprehensive asset management program for TxDOT, and outline a few of the common institutional impediments and issues that TxDOT should consider if proposed recommendations are integrated with its current asset management practices.

TXDOT CURRENT ASSET MANAGEMENT PRACTICES

TxDOT manages a wide range of transportation safety and operations assets. These assets include, but are not limited to, pavements, pavement markings, raised pavement markers, structures, roadside signs, traffic signals, roadway illumination, traffic barriers, guard fences, attenuators, maintenance equipment, vehicles, ITS equipment, traffic detection equipment, real estate, corporate data, and materials. In an effort to implement asset management, TxDOT uses a variety of maintenance contracts to meet the needs of the agency.

In a 2010 study, the Center for Transportation Research concluded that there are three components to a maintenance contracting strategy: delivery method, type of contract specification, and pricing strategy. The 13 delivery methods for maintenance contracts implemented within TxDOT and the rest of the United States include:

- Individual Activity Contract Method—single maintenance activity is outsourced (19 districts).
- Activity Based Maintenance Contract Method—a specific activity or activities that are often similar or sequential in nature are outsourced (18 districts).
- Moderately Bundled Activities Contract Method—maintenance activities that are unrelated are let together in a single outsourced contract (10 districts).
- Significantly Bundled Activities Contract Method—nearly all maintenance activities, with the exception of a few special activities, are bundled and outsourced in a single contract (two districts).
- Partial Competitive Maintenance Contract Method—TxDOT personnel perform a certain percentage of the maintenance and the rest is outsourced (one district).
- Jointly Performed Maintenance Contract Method—a portion of a specific activity is performed by TxDOT personnel and the remainder of the activity is outsourced (eight districts).
- Routine Maintenance Contract Method—all routine maintenance activities are bundled into one contract and outsourced (two districts).

- Total Asset Management Contract Method—operations, maintenance, upgrades, and expansion of a road asset are outsourced in a single contract (also called Total Maintenance Contracting) (one district).
- Integrated Maintenance Contract Method—a combination of routine and preventive maintenance activities is bundled and outsourced in one contract (two districts).
- CREMA Contract Method—Combined Rehabilitation and Maintenance contract requires contractors to rehabilitate and subsequently maintain a sub-network of roads under a lump sum contract for a total period of five years (0 district).
- Long-term Separate Maintenance Contract Method—a single activity is outsourced for a long-term period (five or more years) and may span a large area (one district).
- Framework Contract Method—several contractors are pre-approved and receive nominal contracts that make them eligible for maintenance projects (one district).
- Kilometer (Mile) Per Month Contract Method – outsourcing that applies to a sub-network of paved roads that is in good to fair condition and is expected to remain in that condition over the next few years through routing maintenance activities alone, without any major strengthening or rehabilitation (0 districts).
- Alliance Contract Method—a contractor is selected based entirely on qualifications and has the opportunity to gain or lose 15 percent of the contract value depending on performance (0 district) (*21*).

The study also found that there were three types of contract specifications, three pricing strategies, and two contract award strategies. The contract specification identified were method-based, performance-based, and warranty specification (*21*).

The method-based contract specification allows the contracting agency to specify the methods, materials, and quantities that a contractor can use to perform a special maintenance activity, and payment is based on the amount of work the contractor has completed. The performance-based contract enables the contracting agency to define a set of measurable outcomes, allowing the contractor to decide which methods and materials to use for achieving those outcomes. The contracting agency must establish a set of minimum performance standards or targets, and payment is based on the performance, typically with options for penalties and rewards. Finally, the warranty specification requires the contractor to warrant the work for a specified length of time (*21*).

The three pricing strategies were unit price, fixed price or lump sum, and cost plus fee. The unit price enables the contracting agency to pay the contractor for the number of units completed based on the unit price for each maintenance activity or line item. The fixed price allows the contracting agency to pay the contractor on a monthly basis over the contract period based on a lump-sum amount. Reductions or increases in payments may occur if the contract includes disincentives or incentives, respectively, for falling short or exceeding the performance standard or target. The cost plus fee enables the contracting agency to pay the contractor in accordance with the cost it incurs for performing the maintenance work plus a fee for profit (*21*).

The award strategies were low bid and best value. Low bid selects contractors solely on price, where the lowest bidding contractor is selected. On the other hand, best value is based on a combination of factors including experience, bid price, and work plan (*21*).

In a subsequent survey, the CTR study team found that TxDOT widely used the method-based contract specifications for maintenance contracting as opposed to performance-based or warranty contract specifications. The team also found that: (1) TxDOT used unit price more commonly as the pricing strategy for maintenance contracting, as opposed to lump sum or cost plus fee and (2) nearly all districts indicated that the delivery methods they use are performed successfully. However, one district indicated a Significantly Bundled Activities Contract was not performed successfully (*21*).

Regardless of the components to a maintenance contracting strategy, each maintenance contract will follow a sequence of chronological events (see Figure 9). TxDOT uses the Construction and Maintenance Contracting System to control maintenance and construction contracts from the planning phase through close out, keep track of progress for each individual contract and the highway improvement process, and handle the payment. Specifically, CMCS:

- Helps track the progress of a contract from design to close out.
- Can print required contract documents.
- Records the status of contract requirements like contractor insurance and bonding.
- Can provide management reports for contract administration including payments and material quality control.

CMCS can also automate most maintenance contract activities including:

- Plans, Specifications and Estimates.
- Public Notices.
- Bid Proposal Documents.
- Letting.
- Post-Letting.
- Contractor Payment.
- Monitoring of Insurance, Bonding, etc. (*25*).

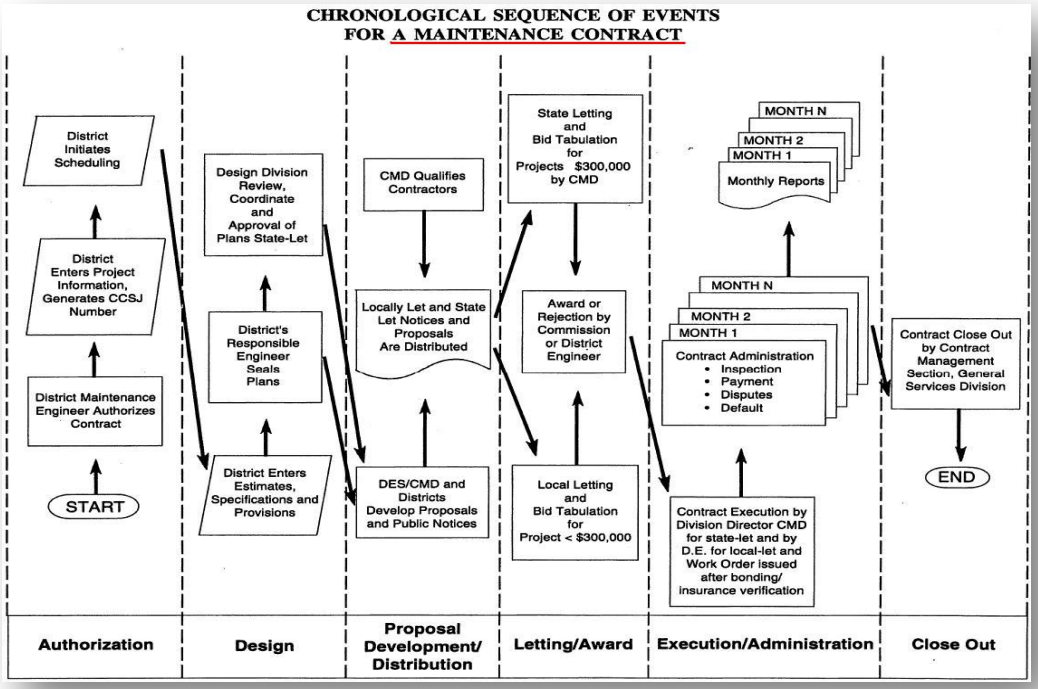


Figure 8. Maintenance Contract Flowchart (*25*).

PROPOSED RECOMMENDATIONS TO TXDOT ASSET MANAGEMENT PRACTICES

From the literature, asset management is generally defined as a process used in the business world to allow the owners or corporate leaders of that business to make decisions and set goals based on the company's assets. Asset management uses a decision-making framework that covers an extended time horizon and the asset management approach draws from best practices in economics, engineering, and business. In 2001, Madeline Bloom, then the Director of the Federal Highway Administration (FHWA) Office of Asset Management, remarked that the bottom line goal of asset management is cost-effective resource allocation and programming decisions (*29*).

In 1999, the Office of Asset Management for the Federal Highway Administration published a "Primer" for asset management (*6*). In that document, the following 12 key elements of an asset management program were defined:

- Strategic goals.
- Inventory of assets.
- Valuation of those assets.
- Quantitative condition and performance measures.
- Measurement of how well strategic goals are being met.
- Performance prediction capabilities.

- Relational databases to integrate individual management systems.
- Qualitative issues considerations.
- Linkage to the budget process.
- Engineering and economic analysis tools.
- Useful outputs.
- Continuous feedback procedures (*6*).

By integrating the information regarding the general definitions of asset management and the key elements of an asset management program, three major recommendations have been identified. It is anticipated that these recommendations collectively, if implemented, will serve as viable alternatives to expand TxDOT's asset management practices. The recommendations consist of the following:

- Formulate a Comprehensive Policy—Develop an overarching comprehensive policy to guide the Department in establishing and implementing a formal asset management program that incorporates the 12 key elements previously mentioned. Additionally, by using a team approach and embracing a willingness to change, TxDOT can then strategically provide the most cost-effective investment decisions in an environment enriched with significant aging infrastructure facilities, limited resources, and funding shortfalls.

- Execute a Three-Tiered Approach—A three-tiered approach is expected to capture evolving management strategies that TxDOT considers critical to guiding future asset management contractual activities. The approach consists of:
  - Total asset management for large urban areas encompassing multiple counties.
  - Asset management of critical functions on a smaller regional scale, such as maintenance of roadside components excluding the pavement.
  - Asset management for specific types of assets—such as pavement markings or LED signal indications—that may be based on warranty specifications.

  As described previously in Chapter 4, the information was matched with critical information related to the 12 key elements of an asset management program, interfaced with critical questions and constraints that will assist TxDOT in identifying the most appropriate asset management contract strategy based on designated goals, objectives, needs, and constraints.

- COMPASS Project—In FY 2013, TxDOT will implement the COMPASS Project that entails a new comprehensive system called the Maintenance Management System. MMS will have more functions and will integrate with other systems more intensively than the Maintenance Management Information System. MMS is comprised of 16 different systems with 24 system interfaces. The details of the MMS system are depicted in Figure 7 in Chapter 5. Some of the models included are:
  - Budget Information System is the automated system for both budget preparation and budget monitoring.
  - Customer Relations and Feedback Tracking (CRAFT) allows Texas road users to report road issues and receive updates regarding the problem or complaint.

- Design and Construction Information System (DCIS) is an automated information system used for planning, programming, and developing projects. It is essential for preparing construction projects for contract letting.
- Fleet Management System will replace *FleetFocus* and be used to report vehicle data on a monthly basis.
- Pavement Management Information System is the automated system used for storing, retrieving, analyzing, and reporting information needed to support pavement-related decision making and a four-year plan import from MMS pavement management plan data.
- PONTIS, an AASHTO-sanctioned Bridge Management System in 2001, will be customized into an application called PonTex. The integration of PonTex with the PONTIS analytical tools will occur in FY 2010.
- Texas Reference Marker is the automated system that documents the past, present, and future state-maintained highway network.
- Human Resources (HR) will process employee data inputs, whereas the Time and Labor module will import/export labor hours and the associated costs into MMS.
- Project Costing System inputs and exports PeopleSoft project costing data by district, maintenance section, county, or function into and from MMS and validation tables and the PeopleSoft codes.
- Accounts Payable and Stock Balances interface with MMS on material purchase, costs, and material inventory balances, respectively. Material catalog system inputs material inventory data into MMS.
- SiteManager will replace CMCS. TxDOT has implemented SiteManager statewide in all districts and in 2007 the production system has been upgraded to SiteManager 3.7b. Version 3.7b includes several upgrades for materials management and to improve performance. The 3.7b upgrade requires an upgrade to Oracle 10g Release.

INSTITUTIONAL ISSUES AND IMPEDIMENTS

With the inception of the above recommendations, there are several institutional issues and obstacles that may need to be considered, given the impact they can have on the implementation of an asset management program for TxDOT. While the array of issues and obstacles presented in Table 3 are not inclusive, the intent is to raise some level of awareness and capture lessons learned from the strategic and operational perspective of other DOTs that have institutionalized an asset management program.

Table 3. Institutional Issues and Impediments.

	Issues	Impediments
Formulate Comprehensive Policy	• Secure internal and external buy-in • Centralize (Headquarter level) versus Decentralize (division and district levels) • Legislative support and approval • Consider COMPASS Project output	• Legal limitations associated with developing a comprehensive asset management policy for the state of Texas • Resource limitations • Managing expectations
Three-Tiered Approach		
Comprehensive Transportation Asset Management • *Large urban areas encompassing multiple counties*	• Identify tangible/intangible benefits • Identify decision criteria • Performance indicators to help TxDOT define and evaluate business practice improvements as a result of using the new approach • Determine performance measures	• Budgetary constraints • Redefining scope of the maintenance office and administrative staff • Managing momentum through implementation • Agree on performance measures acceptable by the organization levels that will have to evaluate them
Critical Functions – Regional Level • *Smaller regional scale*	• Identify tangible/intangible benefits • Identify decision criteria • Performance indicators to help TxDOT define and evaluate business practice improvements as a result of using the new approach • Determine performance measures	• Budgetary constraints • Redefining scope of the maintenance office and administrative staff • Managing momentum through implementation • Agree on performance measures acceptable by the organization levels that will have to evaluate them
Specific Assets	• Identify tangible/intangible benefits • Identify decision criteria • Performance indicators to help TxDOT define and evaluate business practice improvements as a result of using the new approach • Determine performance measures	• Budgetary constraints • Redefining scope of the maintenance office and administrative staff • Managing momentum through implementation • Agree on performance measures acceptable by the organization levels that will have to evaluate them
COMPASS Project	• TxDOT user accessibility levels • Contractor access • Automate maintenance contracting strategies to accommodate each level defined in the three-tiered approach • Defining a relationship between the products (guidebook and screening tool) of this research and the COMPASS Project output	• End user training duration • May have to rework integration points to accommodate the three-tiered approach • Possibly adding customized capabilities to align with each level defined in the three-tiered approach

Moreover, the information in Table 3 can also be beneficial in providing a deeper understanding to developing a successful asset management program that meets TxDOT's short-range and long-range planning needs.

ATTRIBUTES FOR SUCCESS

In an earlier section of this report, the following 12 key elements of an asset management program were introduced:

- Strategic goals.
- Inventory of assets.
- Valuation of those assets.
- Quantitative condition and performance measures.
- Measurement of how well strategic goals are being met.
- Performance prediction capabilities.
- Relational databases to integrate individual management systems.
- Qualitative issues considerations.
- Linkage to the budget process.
- Engineering and economic analysis tools.
- Useful outputs.
- Continuous feedback procedures (*6*).

Also, it was mentioned that once the following core questions can be answered, an asset management plan/program can be developed and applied to the transportation infrastructure with greater success than those that fail to do so.

- What is the current state of my assets?
- What is the required level of service?
- Which assets are critical to sustained performance?
- What are my best investment strategies for operations and maintenance and for capital improvement?
- What is my best long-term funding strategy? (*22*).

As TxDOT continues to critically review the lessons learned from other DOTs that have implemented a transportation asset management program, one major observation is that the 12 key elements and core questions are significantly interrelated. Moreover, this interrelationship provides a unique opportunity to influence successful institutional change.

CLOSING THE LOOP FOR CONTINUOUS IMPROVEMENT

Continuous improvement is a key component to ensuring that any asset management plan/program achieves its intended goals and objectives. While there are various techniques and tools that can be used to assess an asset management plan/program at different stages, an assessment plan should be developed in parallel to the plan/program itself. Doing so helps to better define the assessment procedure, appropriate levels of data to collect, expected outcomes,

performance criteria and indicators, and critical milestones and checkpoints. Also, it is important to develop a feedback loop that generates documentation periodically and takes into account performances related to the asset management plan/program as well as internal (e.g., maintenance office personnel) and external (e.g., contractors) user evaluations, to name a few.

Next, it is important to review what management does with the feedback they receive. Note that the data collected were transformed into actionable and timely results; thus demonstrating a continuous improvement accruing. Any improvements that are approved should be done so by a governing body that management has established to ensure that there is a viable check-and-balance system in place.

Last, the responsibility for closing the loop for continuous improvement falls directly on the shoulders of the institution. All institutions, regardless of its mission, should always make a concerted effort to blend its people, processes, and technology to drive an assessment process that is iterative, systematic, and revolving.

CHAPTER 8: FINAL REMARKS

As noted previously, asset management is a business process. It uses a decision-making framework that covers an extended time horizon. The asset management approach draws from best practices in economics, engineering, and business and allows transportation agencies to focus on strategic goals and consider assets comprehensively. In other words, it allows decision makers to "see the big picture" and make decisions in that context.

Today, growing congestion, limited resources, funding shortfalls, aging infrastructure, and an increasing focus on system performance impact transportation. If the current trends continue, state DOTs, as well as other public sector transportation agencies, will face increased system and budget needs with limited resources. At the same time, states will have to deal with increasing system complexity and increased public demands for accountability and levels of service. The application of asset management to transportation will allow agencies to meet these demands, and an effective asset management framework as a balance of (a) goals, policies, and budgets, (b) technical information, and (c) integration—all connected via technology in the form of powerful computer systems capable of managing the breadth and depth of state DOT-managed infrastructure information.

The information gathered when answering these questions can be utilized to develop an initial set of goals. These goals can then be incorporated into the transportation improvement plan, which is a short-range planning document, and the statewide transportation improvement program (STIP), which is a longer range plan. Transportation agencies can also use data gathered through asset management in decision making for operations, preservation, and maintenance of assets, as well as performance measurement and evaluation. Therefore, a well-designed asset management system should be a critical component of a DOT's plan for providing for the mobility of its customers, preserving the infrastructure already in place, planning for future improvements of that infrastructure, and being responsive and accountable to the public regarding the investment of their tax dollars.

It is clear that state DOTs have a significant investment in their infrastructure that they need to manage efficiently and effectively. Various approaches exist for the management of assets that may include pavements, pavement markings, raised pavement markers, structures, roadside signs, traffic signals, roadway illumination, traffic barriers, guard fences, attenuators, maintenance equipment, vehicles, ITS equipment, traffic detection equipment, real estate, corporate data, and materials. A well-designed asset management system should be a critical component of TxDOT's plan for providing for the mobility of its customers, preserving the infrastructure already in place, planning for future improvements of that infrastructure, and being responsive and accountable to the public regarding the investment of their tax dollars. In short, asset management provides the best strategy for future preparedness in ensuring that TxDOT can meet its goals of reducing congestion, enhancing safety, expanding economic opportunity, improving air quality, and increasing the value of transportation assets. The *Asset Management Guidebook* and *Asset Management Screening Tool*, generated out of this research project, have the potential to help TxDOT meet those goals through effective management of its assets on a continuous and comprehensive basis.

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APPENDIX: ASSET MANAGEMENT TOOL FRAMEWORK

Asset Management Goals	Asset Management Objectives																						
	System Performance Objectives									Financial Objectives					Analysis Objectives								
	Meet present system demands	Meet future system demands	Identify current system deficiencies	Identify future system deficiencies	Ensure specified percentage of assets meet agency performance levels	Maintain acceptable levels of service	Minimize motorist delay during work activities	Establish performance measures to ensure that goals are being met	Perform condition assessments at useful intervals	Establish accurate valuation of assets	Improve resource allocation	Estimate the backlog of investment requirements	Enable cost-effective solutions	Accurately project future requirements	Develop decision framework	Provide continuous feedback procedures	Establish means to eliminate or mitigate impacts of constraints	Establish accurate inventory of assets	Utilize advanced technology where appropriate	Utilize appropriate data collection processes	Utilize appropriate data evaluation system	Support network level analysis (b/c for entire system)	Support project level analysis (specific to project
Build a more cost-effective infrastructure	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Preserve existing infrastructure	X	X	X		X	X	X	X	X		X		X					X		X	X		X
Operate existing infrastructure more cost-effectively	X	X	X	X	X	X	X	X	X		X	X	X	X	X			X		X	X	X	X
Improve safety		X	X	X	X	X	X	X	X		X				X	X			X	X	X	X	X
Improve asset performance	X	X	X	X	X	X	X	X	X		X				X	X				X	X	X	X
Enhance agency credibility	X	X	X	X				X	X		X	X	X		X	X	X	X	X	X	X	X	X
Enhance agency accountability								X	X		X	X	X		X	X	X	X	X	X	X	X	X
Support smart long-term decision making								X		X	X	X	X	X	X	X	X	X	X	X	X	X	
Enhance system sustainability	X	X	X	X	X	X	X	X			X			X	X	X	X	X	X	X	X	X	X
Improve agency agility	X							X			X			X		X	X	X	X	X	X	X	
Ensure equitability/objectivity		X						X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Enhance agency transparency								X	X		X	X	X		X	X	X	X	X	X	X	X	X

Figure A-1. Asset Management Goals vs. Objectives.

Asset Management Contracting Strategies		Asset Management Objectives																						
		System Performance Objectives									Financial Objectives					Analysis Objectives								
		Meet present system demands	Meet future system demands	Identify current system deficiencies	Identify future system deficiencies	Ensure specified percentage of assets meet agency performance levels	Maintain acceptable levels of service	Minimize motorist delay during work activities	Establish performance measures to ensure that goals are being met	Perform condition assessments at useful intervals	Establish accurate valuation of assets	Improve resource allocation	Estimate the backlog of investment requirements	Enable cost-effective solutions	Accurately project future requirements	Develop decision framework	Provide continuous feedback procedures	Establish means to eliminate or mitigate impacts of constraints	Establish accurate inventory of assets	Utilize advanced technology where appropriate	Utilize appropriate data collection processes	Utilize appropriate data evaluation system	Support network level analysis (b/c for entire system)	Support project level analysis (specific to project
Comprehensive Transportation Asset Management	Routine Maintenance	X		X	X	X	X	X	X	X		X		X			X	X	X	X	X	X	X	X
	Total Asset Management	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Integrated	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Critical Functions - Regional Scale	Moderately Bundled / Activity-Based	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Significantly Bundled	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Partial Competitive*	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X
	Jointly Performed	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Routine Maintenance	X		X	X	X	X	X	X	X		X		X			X	X	X	X	X	X	X	X
	Integrated	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Framework	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Specific Assets	Individual Activity	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
	Long-Term Separate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Framework	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X

* - Currently Not Used by TxDOT

Figure A-2. Asset Management Objectives vs. Strategies.

Asset Management Contracting Strategies		Organizational Conditions															
		In-House Contract Administration & Purchasing Processes											In-House Personnel				
		Need to increase bid competition	Need to meet state mandated 105/144 budget distributions	Need to reduce contract administration overhead costs	Need to reduce the number of bid packages and RFPs issued	Work can be assigned by a simple purchase of services	Work is awarded to multiple contractors awaiting work orders	Must be willing to pay awardees even if no work orders are issued against contract	Agency has a good method for evaluating contractors	A well-defined set of maintenance specifications has been developed	Outsourcing experience is limited	Outsourcing experience is plentiful	Need for additional labor is only temporary	Qualified staff is available to perform inspections	Lack of qualified staff to manage contracts	Lack of in-house expertise	Lack of qualified staff to perform maintenance work in-house
Comprehensive Transportation Asset Management	Routine Maintenance		X	X	X					X		X		X		X	X
	Total Asset Management		X	X	X				X			X				X	X
	Integrated		X	X	X					X		X		X		X	X
Critical Functions - Regional Scale	Moderately Bundled / Activity-Based		X	X	X					X		X		X		X	X
	Significantly Bundled		X	X	X					X		X		X		X	X
	Partial Competitive*	X	X								X						
	Jointly Performed		X			X							X				
	Routine Maintenance		X		X	X				X		X		X		X	X
	Integrated		X							X		X		X		X	X
	Framework		X	X	X		X	X								X	X
Specific Assets	Individual Activity	X	X			X				X	X	X	X	X	X	X	X
	Long-Term Separate		X													X	X
	Framework		X	X	X		X	X								X	X

* - Currently Not Used by TxDOT

Figure A-3. Asset Management Strategies vs. Conditions.

Asset Management Contracting Strategies		Organizational Conditions									
		In-House Equipment			Work Location	Time Constraint				Contractor	
		Lack of in-house equipment	Need to reduce equipment costs	Work requires specialized equipment that is expensive to acquire	Work is too spread out (i.e., statewide rest area maintenance)	Must make a quick selection	Severe weather	Seasonal work	Emergency work	Unable to perform all work in an activity bundle	Few contractors are qualified & willing to bid
Comprehensive Transportation Asset Management	Routine Maintenance	X									
	Total Asset Management	X									
	Integrated	X									
Critical Functions - Regional Scale	Moderately Bundled / Activity-Based	X	X					X			
	Significantly Bundled	X									
	Partial Competitive*										
	Jointly Performed	X	X	X		X	X	X	X		
	Routine Maintenance	X									
	Integrated	X									
	Framework	X				X					X
Specific Assets	Individual Activity	X	X	X			X	X	X	X	X
	Long-Term Separate	X	X	X	X						X
	Framework	X				X					X

* - Currently Not Used by TxDOT

Figure A-4. Asset Management Strategies vs. Conditions (continued).

Asset Management Strategies		Asset Management Contract Terms								
		Specification			Pricing				Award	
		Method-Based	Performance-Based	Warranty-Based	Unit Price	Lump Sum	Cost Plus Fee	Hybrid of Unit Price and Lump Sum	Low Bid	Best Value
Comprehensive Transportation Asset Management	Routine Maintenance	X	X	X	X	X	X		X	
	Total Asset Management		X			X		X	X	X
	Integrated	X	X	X	X	X	X		X	
Critical Functions - Regional Scale	Moderately Bundled / Activity-Based	X	X	X	X		X	X	X	
	Significantly Bundled	X			X				X	X
	Partial Competitive*	X	X	X	X		X		X	
	Jointly Performed	X	X		X		X		X	
	Routine Maintenance	X	X	X	X		X		X	
	Integrated	X	X	X	X		X		X	
	Framework	X	X	X	X		X			
Specific Assets	Individual Activity	X	X		X		X		X	
	Long-Term Separate	X	X		X		X		X	
	Framework	X	X	X	X		X			

* - Currently Not Used by TxDOT

Figure A-5. Asset Management Strategies vs. Contract Terms.

Asset Management General Performance Measures		Asset Management Objectives																						
		System Performance Objectives									Financial Objectives					Analysis Objectives								
		Meet present system demands	Meet future system demands	Identify current system deficiencies	Identify future system deficiencies	Ensure X% of assets meet agency performance levels	Maintain acceptable levels of service	Minimize motorist delay during work activities	Establish performance measures to ensure that goals are being met	Perform condition assessments at useful intervals	Establish accurate valuation of assets	Improve resource allocation	Estimate the backlog of investment requirements	Enable cost-effective solutions	Accurately project future requirements	Develop decision framework	Provide continuous feedback procedures	Establish means to eliminate or mitigate impacts of constraints	Establish accurate inventory of assets	Utilize advanced technology where appropriate	Utilize appropriate data collection processes	Utilize appropriate data evaluation system	Support network level analysis (b/c for entire system)	Support project level analysis (specific to project)
Preservation	Pavement Condition / Ride Quality	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Asset Condition (General)	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Remaining Life / Structural Capacity	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Asset Value			X		X			X	X	X	X	X		X			X	X		X	X	X	X
	Backlog or Need		X		X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X
	Agency Financial Impacts	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Customer Benefit or Disbenefit (or Surrogates)	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X		X	X	X	X	X
	Customer Perception	X		X		X	X	X	X	X		X		X	X		X	X		X	X	X	X	X
Mobility / Accessibility	Congestion	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
	Speed	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
	Travel Time	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
	Travel Time Reliability	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
	Delay	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
	Travel Cost	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X		X	X	X	X	X
	Accessibility to Destinations	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Accessibility to Facilities and Services	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X
	Accessibility to Different Modes	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Backlog or Need		X		X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X
	Customer Perceptions	X		X		X	X	X	X	X		X		X	X		X	X		X	X	X	X	X

Figure A-6. Asset Management Objectives vs. Performance Measures.

Asset Management General Performance Measures		Asset Management Objectives																						
		System Performance Objectives									Financial Objectives					Analysis Objectives								
		Meet present system demands	Meet future system demands	Identify current system deficiencies	Identify future system deficiencies	Ensure X% of assets meet agency performance levels	Maintain acceptable levels of service	Minimize motorist delay during work activities	Establish performance measures to ensure that goals are being met	Perform condition assessments at useful intervals	Establish accurate valuation of assets	Improve resource allocation	Estimate the backlog of investment requirements	Enable cost-effective solutions	Accurately project future requirements	Develop decision framework	Provide continuous feedback procedures	Establish means to eliminate or mitigate impacts of constraints	Establish accurate inventory of assets	Utilize advanced technology where appropriate	Utilize appropriate data collection processes	Utilize appropriate data evaluation system	Support network level analysis (b/c for entire system)	Support project level analysis (specific to project)
Operations and Maintenance	System Operations Efficiency	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Incident Response	X		X		X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X
	Winter Operations	X				X	X	X	X	X		X		X			X	X		X	X	X		
	Emergency Operations	X		X		X	X	X	X			X		X		X	X	X		X	X	X		
	Capacity and Availability	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Maintenance Level of Service	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Cost Efficiency	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Occupancy					X		X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Fuel Efficiency	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Backlog or Need		X		X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X
	Customer Perceptions	X		X		X	X	X	X	X		X		X	X		X	X		X	X	X	X	X
Safety	Crashes	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Transportation Infrastructure	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Backlog or Need		X		X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X
	Customer Perception	X		X		X	X	X	X	X		X		X	X		X	X		X	X	X	X	X

Figure A-7. Asset Management Objectives vs. Performance Measures (continued).

Asset Management General Performance Measures		Asset Management Objectives																						
		System Performance Objectives									Financial Objectives					Analysis Objectives								
		Meet present system demands	Meet future system demands	Identify current system deficiencies	Identify future system deficiencies	Ensure X% of assets meet agency performance levels	Maintain acceptable levels of service	Minimize motorist delay during work activities	Establish performance measures to ensure that goals are being met	Perform condition assessments at useful intervals	Establish accurate valuation of assets	Improve resource allocation	Estimate the backlog of investment requirements	Enable cost-effective solutions	Accurately project future requirements	Develop decision framework	Provide continuous feedback procedures	Establish means to eliminate or mitigate impacts of constraints	Establish accurate inventory of assets	Utilize advanced technology where appropriate	Utilize appropriate data collection processes	Utilize appropriate data evaluation system	Support network level analysis (b/c for entire system)	Support project level analysis (specific to project)
Economic Development	Economic Costs and Benefits	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X		X	X	X	X	X
	Direct User Costs	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Transportation Infrastructure Support for Freight Movement	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
	Support Improved Service to Existing Urbanized Area		X		X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Support of Brownfield or Infill Sites		X		X	X			X	X	X	X		X	X			X	X	X	X	X	X	X
	Customer Perceptions	X	X	X	X	X	X	X	X	X		X		X	X		X	X		X	X	X	X	X
Environmental Impacts	Vehicle Emissions	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Air Quality Standard Attainment	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Length or Extent of Air Quality Problem	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Water Quality, Wetlands, Acquatic Life	X	X	X	X	X	X		X	X	X	X		X	X			X		X	X	X	X	X
	Hazmat Impacts	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Energy Impacts	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Noise Impacts	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Recycling	X	X	X	X	X			X					X				X	X	X			X	X
	Completion of Mitigation Steps	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Customer Perceptions	X		X		X	X	X	X	X		X		X	X		X	X		X	X	X	X	X

Figure A-8. Asset Management Objectives vs. Performance Measures (continued).

Asset Management General Performance Measures		Asset Management Objectives																						
		System Performance Objectives									Financial Objectives					Analysis Objectives								
		Meet present system demands	Meet future system demands	Identify current system deficiencies	Identify future system deficiencies	Ensure X% of assets meet agency performance levels	Maintain acceptable levels of service	Minimize motorist delay during work activities	Establish performance measures to ensure that goals are being met	Perform condition assessments at useful intervals	Establish accurate valuation of assets	Improve resource allocation	Estimate the backlog of investment requirements	Enable cost-effective solutions	Accurately project future requirements	Develop decision framework	Provide continuous feedback procedures	Establish means to eliminate or mitigate impacts of constraints	Establish accurate inventory of assets	Utilize advanced technology where appropriate	Utilize appropriate data collection processes	Utilize appropriate data evaluation system	Support network level analysis (b/c for entire system)	Support project level analysis (specific to project)
Social Impacts	Social, Cultural, Neighborhood, Community Quality of Life	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X		X	X	X	X	X
	Customer Perceptions	X	X	X	X	X	X	X	X	X		X		X	X		X	X		X	X	X	X	X
Security	Incident Rates	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Prevention Activity	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Customer Perceptions	X		X		X	X	X	X	X		X		X	X		X	X		X	X	X	X	X
Project Delivery	Accomplishment	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X	X
	Quality	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Efficiency	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Schedule and Budget Adherence	X	X	X	X	X	X	X	X	X	X	X		X	X			X		X	X	X	X	X
	Responsiveness	X	X	X	X	X	X	X	X	X								X		X	X	X	X	X
	Backlog		X		X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X
	Customer Impact and Safety (Work Zone)	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X		X	X	X	X	X

Figure A-9. Asset Management Objectives vs. Performance Measures (continued).