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16. Abstract

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 systems (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 during the process to assist TxDOT in making cost-effective investment decisions. This project provided TxDOT with guidance on developing a well-designed asset management system as a critical component of the agency's approach to 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. This guidance is in the form of a comprehensive Guidebook and a Screening Tool to help TxDOT quickly identify the best approach for managing assets. Such a system will be an integral part of TxDOT's ability to meet its goals of reducing congestion, enhancing safety, expanding economic opportunity, improving air quality, and increasing the value of transportation assets.

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT.

This report does not constitute a standard, specification, or regulation. This report is not intended for construction, bidding, or permit purposes. The engineer (researcher) in charge of the project was Beverly T. Kuhn, Ph.D., P.E. #80308.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

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 reflects 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 is often looked upon as being of limited value by the transportation planning community. 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.

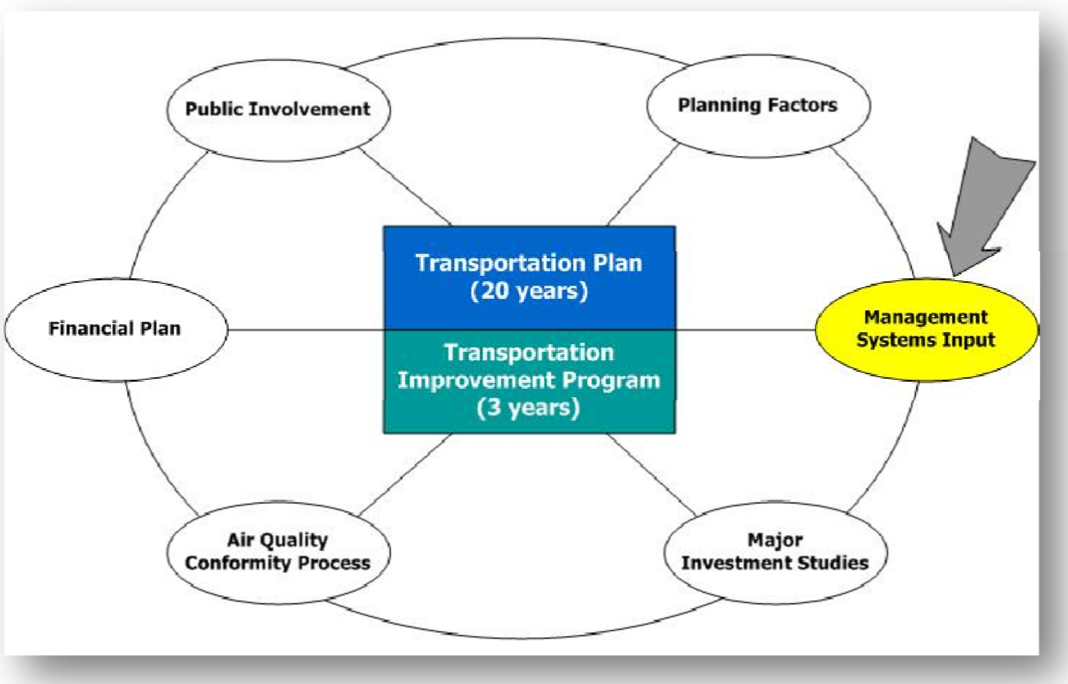


Figure 1. Metropolitan Transportation Planning Process.

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*). An effective asset management framework, as depicted in Figure 2, is 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 infrastructure information managed by a state DOT.

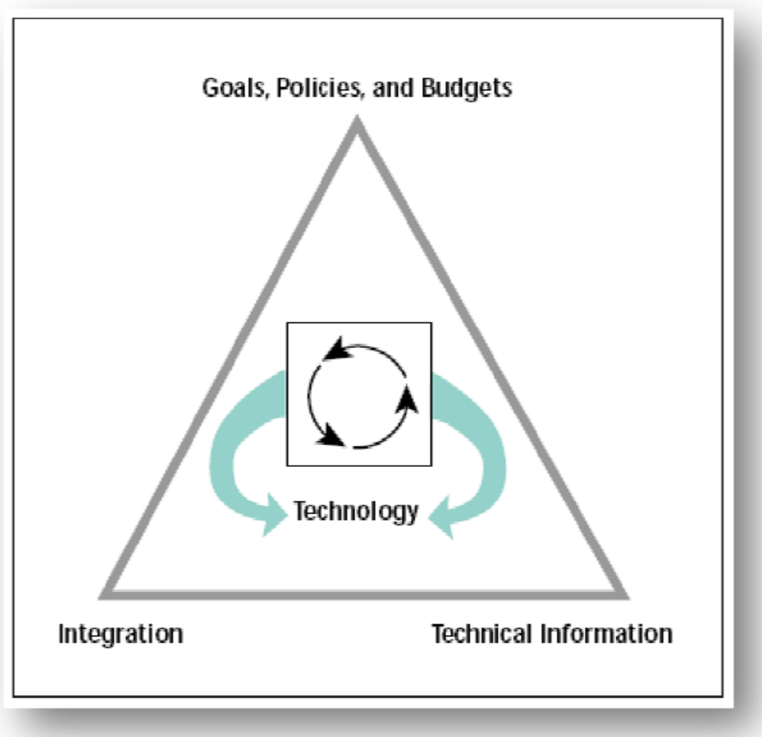


Figure 2. Asset Management Framework (6).

As noted in *Asset Management Overview*, published by the FHWA 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*)

Once researchers answer these questions, engineers can develop and apply asset management systems to the transportation infrastructure. The information gathered 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.

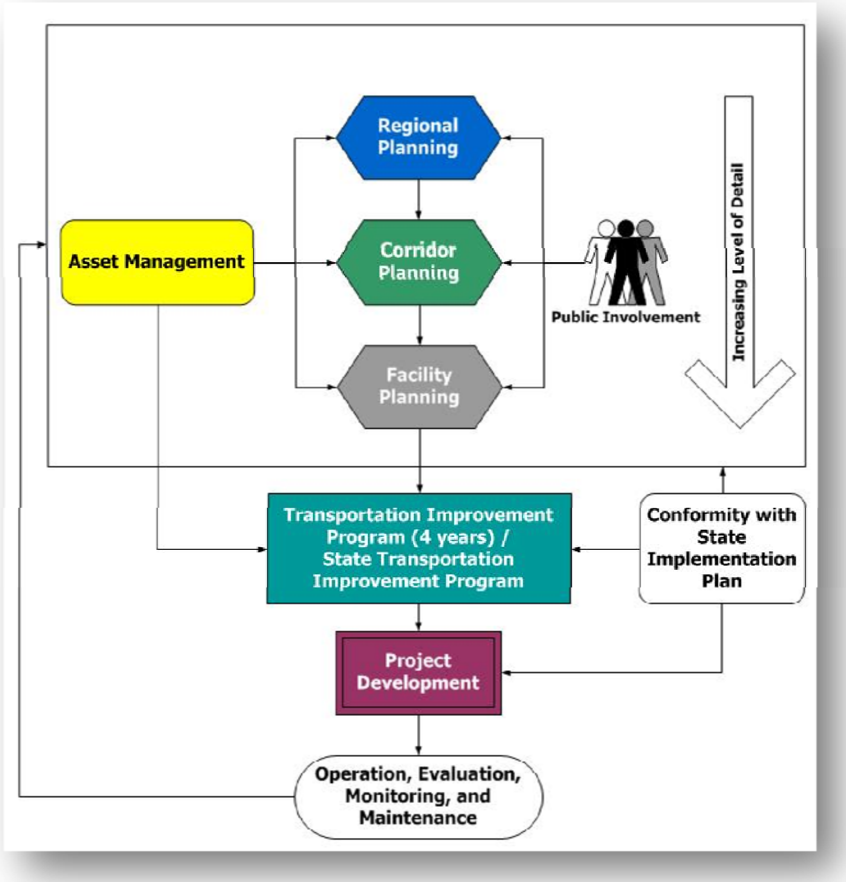


Figure 3. Regional Planning Process and Asset Management.

FACETS OF ASSET MANAGEMENT

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 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.

Pavement and Bridge Management Programs

Currently the most prevalent types of asset management used by transportation agencies are pavement and bridge management programs. The assets these programs manage are road miles and bridges. The most common type of asset management used in these programs is documenting performance measures as they 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.

Pavement and bridge management systems, in their simplest forms, 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 conduct reconstruction on 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.

RESEARCH OBJECTIVES

The objectives of this research project were to:

- Identify strategies for defining asset management for safety and operations.
- Determine the best practices for applying asset management for safety and operations.
- Develop recommendations for implementing asset management and establishing associated performance measures for safety and operations within TxDOT.
- Develop a decision screening tool that TxDOT can use in its asset management efforts.

Researchers developed a two-year research approach to satisfy the stated objectives. The research approach consisted of nine tasks that represented a logical sequence of needs assessment, research, evaluation, and product development. The main products of this research include:

- Asset Management Guidebook.
- Asset Management Screening Tool.

Implementation

The research team recognizes that the findings from this study will have near-term, if not immediate applicability for TxDOT staff across the state as they grapple with managing the valuable assets of the agency in an era of limited resources and increasing use of infrastructure. TxDOT will have a keen interest in the results and could use information on the best practices for asset management at all levels of the organization.

The research team's implementation approach was to balance the need and expectation for user-friendly products with the importance of completing a thorough, scientific review of the subject. As such, the Texas Transportation Institute (TTI)/Prairie View A&M University (PVAMU) team identified the following products as elemental to a successful project and successful deployment within TxDOT.

Asset Management Guidebook

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.

Asset Management Screening Tool

The research examined the best practices and approaches to asset management for safety and operations. It also assessed various tools used by agencies 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. Using the results of the various tasks within the project, the research team developed an *Asset Management Screening Tool* in the form of software capable of operation on any typical desktop computer without the need for server interface. The team based the screening tool on information in the *Asset Management Guidebook* to facilitate its implementation by TxDOT staff members in an easy-to-use format. The remaining chapters in this report document the research progress and the research results.

CHAPTER 2: LITERATURE REVIEW

OVERVIEW

The Texas Department of Transportation 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, 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.

Asset Management Defined

As generally defined, asset management is a process used in the business world that allows 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. The asset management approach draws from best practices in economics, engineering, and business. In 2001, Madeline Bloom, then the Director of the 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.

In today's world, transportation is impacted by growing congestion, limited resources, funding shortfalls, aging infrastructure, and an increasing focus on system performance. If the current trends continue in the future, 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 manage 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 (*13*).

As noted in *Asset Management Overview*, published by the FHWA in 2007 (*14*), 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 Asset Management Plan

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? (*15*)

Once an agency answers these questions, they can develop and apply asset management strategies to the transportation infrastructure. They can utilize the information gathered to develop an initial set of goals and then incorporate these goals into the TIP, which is a short-range planning document, and the STIP, which is a longer range plan. They can use the data gathered through asset management in decision making for operations, preservation, and maintenance of assets, as well as performance measurement and evaluation (*15*).

In 1999, the Office of Asset Management for the Federal Highway Administration published a "Primer" for asset management (*13*). In that document, 12 key elements of an asset management program were defined. These elements included:

- Strategic goals.
- Inventory of assets.
- Valuation of those assets.
- Quantitative condition and performance measures.
- Measurement of how well an agency is meeting strategic goals.
- 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 (*13*).

As noted in that publication, many of the state DOTs had—and continue to have—many of these elements in place, even if they have not implemented a formal asset management program.

APPLICATIONS OF ASSET MANAGEMENT IN TRANSPORTATION IN THE UNITED STATES

In recent years, numerous states have implemented either comprehensive or limited asset management plans. Limited plans are most often in the form of pavement or bridge management plans. More complex or comprehensive forms of asset management expand the practice to other aspects of transportation and allow states to use good quality management practices. 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.

The Office of Asset Management for FHWA conducted a series of case studies beginning in 2002. This series of case studies examines the various aspects of asset management, including:

- Bridge management (*16*).
- Culvert management (*17*).
- Comprehensive transportation asset management (*18*, *19*, *20*).
- Data integration (*21*, *22*, *23*, *24*, *25*).
- Economics (*26*, *27*, *28*).
- Highway economic requirements systems-State (HERS-ST) (*29*, *30*, *31*).
- Life cycle cost analysis (*32*, *33*, *34*).
- Management systems (*35*).
- Pavement management systems (*36)*.

The publication format for each case study is an executive briefing in booklet. The states examined in these studies furnish details regarding their experiences and successes with asset management. By dividing experiences by topics and using the case study to examine a single segment of asset management, the series provides valuable insight, ideas, and documented experiences on asset management.

Washington

The Washington State Department of Transportation (WSDOT) began a pavement condition survey program in the 1960s that surveyed the condition of the entire state highway system every two years. This program evolved into a Pavement Management System in the late 1970s and since 1988, WSDOT has surveyed pavement conditions annually (*36*). The focus of the program is pavement preservation, and WSDOT uses the information gathered to identify candidate pavement projects. WSDOT also uses the survey data to conduct engineering and economic analysis for the purpose of improving performance of pavements, maximizing investments, and prioritizing projects. One example of the use of the data was an investigation of the performance of concrete pavements on I-5 in the Seattle area. This study attempts to determine when the concrete pavements on I-5 will fail and how much time WSDOT has to plan and develop projects before the deterioration reaches unacceptable levels (*14)*.

Virginia

The Virginia Department of Transportation (VDOT) is responsible for the third-largest, state-maintained highway system in the United States; only North Carolina and Texas maintain larger systems. VDOT is legislatively mandated to maintain existing transportation assets before funding capital improvements (*25*). In 1995, VDOT initiated a comprehensive maintenance and operations business process reengineering effort known as BPR. This review reflected asset management principles that evolved into VDOTs Asset Management model, which projected a

15 percent return on investments by 2006. In the late 1990s, Virginia signed the first performance-based turnkey asset management maintenance contract in the United States (*37)*. This concept awarded one contract from fence-line to fence-line and was all inclusive for maintenance services for the contracted segment. The first contract was for 250 miles of various segments of Virginia's Interstate System. The estimated savings for this turnkey approach to maintenance was 15 to 20 percent by various studies (*37*).

Florida

Florida implemented asset management through a planning process called "program and policy planning." The Florida asset management program has evolved into a strategy of creating a performance driven method of contracting for routine maintenance and management of highway infrastructure. This program, known as Asset Maintenance (AM), uses contracts with durations ranging from 6 to 10 years for inspection and routine maintenance of highway infrastructures. These contracts encompass four general types of asset management:

- Roadway corridor contracts, which center around a specific roadway such as a limited access facility.
- Geographic contracts that contain multiple types of transportation facilities within a specified region.
- Facility contracts, which focus on rest areas, welcome centers, and weigh stations.
- Fixed and movable bridge contracts (*38*).

These maintenance contracts allow for bundling of maintenance costs for each of these general contracts. The contracts, known as AM contracts, typically include the traditional maintenance activities such as mowing, sign and guardrail maintenance, pavement striping, raised pavement marker replacement, fence repair, shoulder maintenance, and drainage system cleaning. Additionally, they also include:

- Compliance with environmental requirements, incident response, natural disaster preparedness, and damage repair.
- Permit application review and evaluation.
- Highway lighting and call box maintenance.
- Customer service complaint resolution.
- Formal inspection of bridges and safety features.
- Motorist aid service patrols.

As previously noted, the duration of the contracts range from 6 to 10 years, and the payments are monthly fixed sum amounts (*38*). The estimated savings for Florida by 2005 was about 17 percent for the life of the contract (*37*).

Colorado

The Colorado Department of Transportation (CDOT) began using life-cycle cost analysis (LCCA) in the late 1970s as a response to inflation, and in 1981 CDOT mandated that an LCCA be completed in the design phase for all major projects (*32*). LCCA as defined by CDOT is an engineering analysis tool that is useful in comparing the relative merit of competing project alternatives (*39*). By using LCCA as a tool for considering all aspects of cost during the life of an asset, CDOT can analyze the costs and select the lowest cost option. It also allows the agency to balance the construction, rehabilitation, and preservation of an asset with the needs of the agency and the roadway user. Continual use of the process allows CDOT to alter initial plans during all stages to meet the needs of the agency and user. These alterations may include such things as design changes, work zone criteria, and altered traffic plans (*39*).

In the more than 30 years since CDOT implemented LCCA, it has reported a number of valuable lessons learned including:

- A vocal advocate within leadership for a process such as LCCA is useful for both a clear vision and facilitation of the process.
- Involvement of contractors and industry in the process helps to clarify issues and promote buy-in.
- Involving all transportation-related offices in training deepens the use of the practice across the organization.
- LCCA gives the agency some control over escalating costs because it creates a venue for examining competing options.
- LCCA predicts pavement performance better than subjective surveys (*32*).

North Carolina

North Carolina has the second largest state-maintained highway system in the nation. Traditionally, the North Carolina Department of Transportation (NCDOT) committed a large portion of its transportation funding to new construction (*19*). In 2000, NCDOT began the asset management process through the establishment of a multimodal steering committee. This committee was charged with guiding the development of a Long Range Statewide Transportation Plan. Once the plan was developed, NCDOT began a 30-month public involvement process, where the public was asked to provide input on general direction for the department. Simply put, the public was asked where they would like to see the transportation department go and how they would like to see their tax dollars spent. This input was then incorporated into the long range plan (*19*).

In addition to the development of the Long Range Statewide Transportation Plan, NCDOT established an Asset Management Office under the Chief Engineer-Operations in 2003. The implementation of asset management brought about numerous changes to how NCDOT operated. Those changes included the addition of a system preservation line item in the legislative budget, changing secondary roads legislation from a program that focused solely on paving dirt roads to a program that also included improvement projects, and finally the development of several management systems including pavement management, maintenance management, traffic signal maintenance management, bridge management, and geographic information systems (*19)*. Currently, the Asset Management Office has the responsibility of recommending to the Board of Transportation the distribution of maintenance and resurfacing funds for the 14 divisions and 100 counties. The office also supports the bridge management unit, equipment and inventory control unit, pavement management unit, secondary roads unit, and the state road maintenance unit (*40*).

APPLICATIONS OF ASSET MANAGEMENT IN TRANSPORTATION INTERNATIONALLY

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 (*41*) 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 dollar" of limited investment resources (*41*).

New Zealand—in conjunction with Australia—began reporting the financial value of their road infrastructure assets in the late 1980s, and since 1997 all major road agencies in the two countries have recognized road assets in annual financial statements (*14*). Working in conjunction, the two countries have collaborated to advance their respective programs in asset management. Both countries utilize long-term (10 year), performance-based contracts for maintenance of roads. One contract in Australia for 450 km (280 miles) of urban roads improved road conditions by an estimated 15 percent while saving an estimated 35 percent in costs *(37*).

Transit New Zealand, the national highway agency in New Zealand, now uses a National Asset Management Plan to guide planning related to transportation assets and resource allocations decisions. The agency uses performance measures and indicators at all levels of planning and decision making (*14).*

CONTRACTING FOR ASSET MANAGEMENT

One unique application of asset management is performance-based maintenance contracts. As previously noted, Virginia, Florida, Colorado, New Zealand, and Australia have successfully used these contracts. Generally, the contracts are long-term and are fixed price. The most frequently used range for the term of the contracts is 5 to 10 years (*37, 38*). Florida requires contractors to post a performance bond for the amount of the annual contract, and an asset management evaluation committee that has a minimum of five contract evaluators select all contracts (*42*).

Another important aspect of contract management for long-term maintenance contracts is quality assurance of the maintenance performed. Florida has implemented a maintenance rating program that it uses for asset management contracts. When a long-term contract is executed, the State Maintenance Office provides the district with sample sites that are used for evaluating contract performance (*42*). The samples are used to rate the contractors' maintenance efforts, and the results are entered into a maintenance rating for the contractor. These ratings are used in quality assurance reviews for the contract (*42*).

DATA FOR ASSET MANAGEMENT

As previously noted, state DOTs currently have and maintain many databases used for asset management and inventory control. However, various sections or divisions of the DOT often maintain these databases. Asset management requires taking this knowledge and combining or integrating it into one system or program. The Colorado DOT created a system centering on geographic information system (GIS) technology to manage four major systems of asset management: bridges, pavement, maintenance, and budget/financial management (*22*). In an effort to ensure that all applications and components of CDOT's information technology support data integration goals, a team was formed to provide input and guidance regarding integrated information technology planning (*22*).

Analysis of the available data also requires the use of various analytical tools. A team led by Cambridge Systematics examined this subject in a National Cooperative Highway Research Program (NCHRP) study in 2009 (*43*). The study found that there are a large number of analytical tools that support asset management, including tools for investment analysis, management systems, needs and project evaluation, risk management, and results monitoring. For example, one investment analysis tool utilized by a number of states is FHWA's Highway Economic Requirements System – State (HERS-ST). HERS-ST is the state version for the Federal HERS program. This program uses Highway Performance Monitoring System (HPMS) data to predict highway investment needs and measures. Other investment analysis tools utilized include:

- Highway Development and Management (HDM)-4 from the World Road Association – a system used to evaluate road projects, budget scenarios, and policy options.
- National Bridge Investment Analysis System (NBIAS) – a system that models national-level bridge investment.
- The Multi-Objective Optimization System (MOOS) – a spreadsheet tool for bridge investment and analysis.
- AssetManager NT – an investment analysis tool that integrates data from other tools such as HERS-ST, NBIAS, etc.
- Executive Support System (ESS) – a cross asset analysis system developed by the Ministry of Transportation of Ontario (*43*).

The New Mexico Department of Transportation (NMDOT) began using the HERS-ST system in 2001. Like many states, NMDOT used HERS to develop its list of needs and design a long range plan. Early on in using HERS-ST, NMDOT identified three areas of concern with the program: it is DOS driven, it only processes HPMS data, and it does not provide concise summary reports (*30*). As a result of input from NMDOT, FHWA's Office of Asset Management made changes to the HERS-ST software to make it more user-friendly. As a result, NMDOT planners were able to manipulate the data and generate more customized reports that met their needs (*30*). It is important to understand that when utilizing the various data integration and data management tools, the tools selected must be flexible in order to provide the desired outcome.

CHAPTER 3: UNITED STATES PRACTICES IN ASSET MANAGEMENT

The research team built upon the information gathered through the review of published and electronic literature to conduct an assessment of United States' practices in and/or future plans for asset management. This information is intended to assist in identifying best practices for defining, developing, and implementing asset management for safety and operations and subsequently formulating recommended general guidelines. In addition, this information will help to identify potential impediments to implementation of these practices.

This chapter first provides a brief introductory overview of safety and operations asset management, then summarizes asset management practices in the United States and in Texas, and identifies key recommendations for and impediments to effective safety and operations asset management.

BACKGROUND

State transportation agencies generally consider three types of investment categories—preservation, operations, and capacity expansion—that are defined as follows:

- **Preservation** encompasses work to extend the life of existing facilities (and associated hardware and equipment), or to repair damage that impedes mobility or safety. The purpose of system preservation is to retain the existing value of an asset and its ability to perform as designed. 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 (*44*, *45*).

- **Operations** focus on the real-time service and operational efficiency provided by the transportation system 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 (*44*, *45*).

- **Capacity expansion** focuses on the actions needed to expand the service provided by the existing system 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 (*44*, *45*).

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. As significant portions of the system aged, competition for resources increased and 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 (*45*).

- **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; and deployment of guardrails, impact attenuators, lighting, signs, signals, and pavement markings (*45*).

- **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 in order to improve safety and operational efficiency (*45*).

- **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 also may 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 (*45*).

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 a variety of 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 a number of 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 (*46*). 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 (*47*). 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 (*48*). *NCHRP Synthesis Report 322: Safety Management Systems* describes current agency practices and reviews two model state SMS initiatives (*49*). 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 (*44*). 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.

UNITED STATES ASSET MANAGEMENT PRACTICES

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 life-cycle cost analyses. Select states have also developed asset management systems focused on data integration and sharing. Table 1 lists a sampling of states observed to have the various asset management systems in place. The following summarizes each state's asset management experiences.

Consistent with earlier statements, asset management systems that focused on safety and/or operations were observed to be limited among state transportation agencies in the United States. Safety asset management systems—that focus on safety-related assets rather than outcomes—are challenged by the breadth of potential strategies, resources, and agency involvement. Asset management systems focused on operations present a similar challenge. Given the dearth of safety and operations focused asset management systems and because safety, operations, preservation, and capital expansion decision making are interrelated, this review considered the broader range of asset management systems.

Table 1. Sampling of State Asset Management Systems.

States	Comprehensive Transportation Asset Management	Focused Asset Management Systems							
		Pavement Management	Bridge Management	Culvert Management	Life-Cycle Cost Analysis	HERS-ST	Economics	Data Integration	Safety Management
Alabama				X					
Arizona								X	
California	X		X						
Colorado					X			X	
Florida			X				X		
Georgia		X			X				
Indiana						X			
Iowa									X
Maryland				X					
Michigan		X						X	
Minnesota				X					
New Mexico						X			
New York		X					X		
North Carolina	X								
Ohio	X						X		
Oregon						X			
Pennsylvania					X			X	
South Dakota			X						
Texas		X							
Virginia								X	
Washington	X	X							X

Comprehensive Transportation Asset Management

The following sections highlight success stories in the United States related to comprehensive transportation asset management.

California

Motivated by an unfavorable review of its business processes—which found duplication in data entry, inaccurate "cost" information, inaccurate and outdated inventory reports, and limited tools for planning or scheduling future work—the California Department of Transportation (Caltrans) initiated development of a comprehensive transportation asset management system—Integrated Maintenance Management System (IMMS)—intended to:

- Forecast work to be performed on assets.
- Perform activity-based costing on all assets.

- Provide decision-making tools to managers.
- Create an inventory of assets.
- Track associated service calls.
- Track assets' condition.
- Perform "what-if" deterioration analysis.
- Track work performed and associated costs (*50*).

The IMMS brings together four previously distinct systems:

- Pavement Management System—containing information related to current pavement condition, identification and prioritization of future projects, and estimates of fiscal resources required to make pavement repairs.
- Levels of Service (LOS)—containing information related to level of service rating summaries and attribute summary analysis.
- Bridge Management System—containing information related to the bridge inventory, bridge inspection results, and a record of completed and upcoming bridge work needed.
- Asset Management System—containing information related to the asset inventory; planned, scheduled and completed work; and costs based on asset or activity performed.

The umbrella IMMS—containing information related to maintenance needs profiles and overall needs index analysis—provides a mechanism for managers to forecast and track work, make informed decisions, and evaluate the condition of assets.

Maintenance Program managers identified a series of factors that led to the success of the IMMS system including, but not limited to, the following:

- Developing an implementation strategy at project's inception.
- Obtaining buy-in from key decision makers for implementation schedule.
- Marketing the benefits of changing the agency's way of doing business.
- Identifying Caltrans staff to work throughout the life of project.
- Obtaining stakeholder buy-in, including control agencies, Caltrans executives, district and field end-users, and other system owners.
- Conducting proof-of-concept pilot and adjusting accordingly prior to statewide rollout.
- Providing sufficient training and support/help desk services for ongoing assistance.
- Working as an integrated team comprising technical, functional, testing, training, and external participants.
- Ensuring quality assurance through an issues resolution procedure, rigorous cross-functional testing processes, technical review meetings, contingency plans, back-up and recovery procedures, and feedback surveys.

North Carolina

North Carolina has the second largest state-maintained highway system in the nation. Traditionally, NCDOT committed a large portion of its transportation funding to new construction (*51*). In 2000, NCDOT began the asset management process through the establishment of a multimodal steering committee. This committee was charged with guiding the development of a Long Range Statewide Transportation Plan. Once the plan was developed, NCDOT began a 30-month public involvement process, where the public was asked to provide input on general direction for the department. Simply put, the public was asked where they would like to see the transportation department go and how they would like to see their tax dollars spent. This input was then incorporated into the long range plan (*51*).

In addition to the development of the Long Range Statewide Transportation Plan, NCDOT established an Asset Management Office under the Chief Engineer-Operations in 2003. The implementation of asset management brought about numerous changes to how NCDOT operated. Those changes included the development of several management systems—including pavement management, maintenance management, traffic signal maintenance management, bridge management, and geographic information systems—as part of a broader transportation asset management program for the agency *(51)*.

The Asset Management Office has garnered several lessons from NCDOT's development of a comprehensive transportation asset management program:

- First, state transportation agencies should start with something it is already doing (e.g., pavement preservation), and expand over time. NCDOT has been working on its transportation asset management program for eight years, and the program is still evolving.

- Second, transportation asset management must have buy-in at all levels—from the chief executive to the frontline manager; implementing a comprehensive transportation asset management program requires a team approach and a willingness to change from a "firefighting" approach to a planning mode. Involving the public is also a vital component of a successful transportation asset management effort.

- Third, a state transportation agency needs to give field personnel the tools they need in order to make intelligent decisions regarding system conditions and maintenance priorities. By establishing performance measures, a measurement methodology and robust management systems, the department is poised to provide the highest possible return on investment dollars.

Ohio

By the mid-1990s, the Ohio Department of Transportation (ODOT) had 7,800 employees; agency operating costs rising at an average rate of 5.7 percent; and 24.68 percent of its multi-lane pavement in need of immediate rehabilitation (*52*). The agency's primary pavement preservation tool was a pavement condition rating (PCR) system. The PCR ratings were helpful to pavement engineers, but ODOT was not using the information as an effective planning and budgeting trigger. Further, the organization's centralized structure was not conducive to asset management (*52*).

After a thorough self-assessment, ODOT began a reengineering process—VISION 2000—that promoted the philosophy that an agency must continually reexamine itself in order to achieve excellence and meet the demands of its customers. Agency management wanted to: (1) decentralize the department by reengineering the organization from top to bottom, and (2) develop a more accurate transportation asset management system. To accomplish this, ODOT needed to revamp its system preservation and project-delivery processes and develop an effective performance measurement tool (*52*).

The agency decentralized, organizing all operations under three core functions; giving the districts authority over their own project budgets; and making the Central Office responsible for policy and guidance. It worked with the Ohio General Assembly to establish the Transportation Review Advisory Council (TRAC) and provide a more objective means for selecting new capacity projects. With this framework in place, ODOT turned its focus to its project-delivery and data warehousing systems, developing cutting-edge programs for managing system assets more effectively. Finally, ODOT developed an Organizational Performance Index (OPI) that tied accountability to performance at all levels of the organization, empowering employees, making asset management a team effort, and establishing ODOT as a nationally recognized leader in the field of innovation (*52*).

With these changes in place, ODOT was able to focus on its next major task—developing system preservation and project-delivery processes that would become the hallmark of the department's asset management program and enable ODOT to achieve a steady state condition. The department had a number of data reference systems in place for pavements, bridges, and so forth, but the databases were not compatible, and things were slipping through the cracks. ODOT addressed this concern by developing a GIS-based program, the Base Transportation Referencing System (BTRS). The BTRS provides an official log of all highway latitude and longitude locations at a hundredth of a mile and consolidates the department's various referencing systems using a 14-digit naming convention for each route in the state. The BTRS uses a logpoints file to integrate various information systems for pavements, bridges, and safety as well as project development and road inventory. It allows data warehouses to combine data within and among the agency's various information systems (*52*).

The district multi-year work plan has also proven to be a vital part of ODOT's asset management process. This district-driven document uses the GIS system to show multiple years of pavement and bridge preservation efforts. Pavement histories and degradation formulas predict upcoming needs. Agencies identify projects on up to a 10-year planning horizon with the goal of maintaining all assets at acceptable levels into perpetuity (*52*).

Another key component to developing a more efficient project-delivery system was tying engineering functions to financial management and performance. It took ODOT three years to develop its project management system, but the results were worth it. The web-based program not only helps the districts manage their work plan project lists based on funding needs and current allocations, but it allows project managers to track the projects from the time the study area is defined to when construction is complete, benchmarking key milestones and tracking performance throughout the process. By identifying trends and revisiting project planning triggers, ODOT has been able to utilize quantifiable targets such as PCR thresholds to blend pavement management concepts into the project selection process (*52*).

ODOT has made significant advances in asset management since the unveiling of VISION 2000 twelve years ago. Overall, since 1995 ODOT has reduced system condition deficiencies by 66 percent for roads and 80 percent for bridges (*52*).

Washington

The Washington State Department of Transportation has long utilized data collection and analysis to help manage its transportation assets. Beginning in 1990, a series of legislative efforts helped WSDOT enhance its programming process and refine its data collection efforts (*53*).

Even as the agency became more adept at maximizing system performance, a rapidly increasing population, mounting system needs, funding shortages, and WSDOT's lack of regular communication with state leaders and residents was leading to additional change. In 1998, WSDOT appointed a 47-member Blue Ribbon Committee on Transportation (BRCT). Within 18 months the committee identified a $50 billion project backlog and possible funding scenarios, along with 11 system benchmarks it considered key to the effective management of transportation assets. The situation climaxed two years later, when the legislature requested that WSDOT demonstrate how it was achieving lowest life-cycle costs on transportation infrastructure in order to consider additional funding (*53*).

In response to the legislature's request, the agency made optimization of the entire network its mantra when programming projects, implementing tiered solutions wherever possible. Oftentimes this meant looking at low-cost options such as the addition of new ITS technologies, the use of auxiliary lanes between interchanges, and/or the addition of storage capacity on urban ramps. The goal is to reach the point where the system cannot handle any more traffic. Because congestion is a major factor for travelers, WSDOT is moving away from level of service as its measure. The agency sees enhancing system reliability and maximizing throughput, which it defines as traffic moving at 70 to 85 percent of the posted speed, as a more appropriate means of benchmarking and measuring system performance (*53*).

Second, it demolished internal silos and adopted what agency planners term a transparency mode. Prior to 2000, the various sections of the agency tended to view their areas as isolated "silos" rather than interdependent units and simply did not talk to one another. In order to move forward with effective asset management, staff needed to understand that everyone was equally responsible for the success of the department. It took time, but eventually staff acclimated to the notion that, if one succeeds, all succeed and, if one fails, all fail. The idea that the agency was "transparent"—that nothing should or would be hidden—assisted greatly with that process (*53*).

Third, the department dedicated additional resources to developing programs that could consolidate transportation asset data. The first generation of data accessibility was via Excel spreadsheets, which were distributed manually from office to office. By the late 1990s, WSDOT had developed the Priority Array Tracking System (PATS), a mainframe system that cross-referenced fields via various data sorts in order to generate the desired reports. Not content with such a laborious system, the program development division volunteered in 2000 to work with the GIS unit on moving to a GIS-based program. The idea of the GIS Workbench is to plot the whole state utilizing a 1,000-foot view that provides multiple layers of data. To accomplish this goal, WSDOT needs to establish a linear reference system that could provide a crosswalk between databases (*53*).

Finally, the department developed a comprehensive performance report, "The Gray Notebook," as its central reporting tool; adopted a series of performance measures and benchmarks; and began reporting its progress in detail to legislators and the public each quarter (*53*).

Unlike many other DOTs with centralized transportation asset management programs, WSDOT relies on a distributed method where everyone in the agency is responsible for the effective management of transportation assets. Supporting asset management systems include a pavement management system, a bridge management system, life-cycle cost models for the ferry construction program, and a performance measures/level of service based maintenance accountability process to maintain its highway system assets (*53*).

WSDOT's enhanced efforts to assess and communicate system and agency performance helped support two recent funding increases: a five-cent gas tax increase in 2003 and a nine-cent gas tax increase in 2005. This makes continued performance communication and system evaluation even more paramount. WSDOT's annual, detailed asset management reports demonstrate the state's commitment to show taxpayers the return on their investments. Plus, the agency continues to expand its analysis and asset management capabilities through a variety of department-wide efforts (*53*).

Focus Transportation Asset Management Systems

The following sections summarize successful application of focused transportation asset management systems in the United States.

Alabama

To support culvert repair and replacement decision making, the Alabama Department of Transportation (AlDOT) has a computerized inventory and maintenance management system. Developed in the 1970s, the maintenance management system can schedule future maintenance activities, but it cannot predict deterioration, estimate costs, or prioritize replacements. The agency is committed to changing and updating the system and has expressed interest in a future version of the FHWA Culvert Management System software that formalizes and automates functions already performed by many agencies responsible for culverts, including but not limited to the following:

- Recording the number and location of culverts for which the agency is responsible.
- Tracking the condition of the culverts.
- Determining what repairs are necessary to fix the culverts.

- Developing a long-term plan for repairs over the next five years.
- Formulating a schedule of work to be performed during the next year (*54*).

Arizona

In response to a rapid population growth and an ever-increasing demand for transportation infrastructure and services, the Arizona Department of Transportation (ADOT) undertook several initiatives to improve its business practices. ADOT knew that an integrated information system would be critical to fully implement the necessary system improvements (*55*).

The agency's data integration initiative—ADOT Information Data Warehouse (AIDW)—was viewed as the fastest and least expensive way to integrate data from its existing systems. Existing management systems and databases will continue to be the agency's official data sources. However, the data in these systems will be extracted periodically, referenced using a common geographic referencing system, and stored in the AIDW. Users will access the integrated data using online tools (*55*).

The data integration effort has faced technical, cultural, and business process challenges. Pulling data from many sources into one repository exposes quality issues that agencies must resolve and data disconnects that they must fix at the source. To solve these problems, ADOT's overall approach addresses cultural and process issues concurrently with technological change (*55*).

The data warehouse is critical to future infrastructure management practices: improving the availability of timely and accurate information will help ADOT offset the loss of experienced transportation personnel that they predict to occur over the next few years. As less experienced staff are tasked with meeting the demands of a growing population, information and technology will replace experience and precedent as the basis for important decisions (*55*).

ADOT has already added several types of data to the AIDW, including pavement and bridge data, project expenditures, photo logs, accident data, and as-built engineering drawings. Over the next several years, ADOT plans to add new data sources. This incremental approach will enable ADOT to produce results and benefits quickly and often (*55*).

California

California is responsible for the inspection and preservation of approximately 24,500 bridges. The Caltrans Division of Maintenance Office performs periodic inspections and maintenance for all of California's 12 districts (*56*).

Caltrans personnel enter all information from statewide inspections into the centralized bridge management database. Bridge inspectors use SMART, a custom inspection collection and report generation software, which has a thin-client (Web-based) interface that allows inspectors to access the database from a remote location. The bridge information entered into the database through the inspection process is ultimately presented in a bridge inspection report. The inspection team is responsible for the inspection report and for making recommendations for preservation actions based on their findings in the field. The bridge inspection report documents the current condition of the bridge and all recommended work for that structure. This inspection report is the primary means of conveying the results of the inspection to the bridge owners (*56*).

In addition to the bridge report, agencies use the bridge management database to generate various lists and reports for district maintenance crews, project planners, Caltrans management, and the California Transportation Commission (*56*).

A single database contains all the information necessary to manage the integrity of California's bridge infrastructure with sharing features achieved using the Pontis® Bridge Management System. This interoperable database supports various activities such as project tracking, maintenance recommendations, detailed fracture critical, scour and load rating information, and post-earthquake inspection activities. The bridge management staff uses the Pontis Bridge Management System to perform deterioration modeling and project prioritization. Bridge projects generated are manually coordinated with pavement management system projects, which are done through data extraction of projects from the bridge management database (*56*).

California maintains a complete image archive of all bridge "as-built" plans, bridge reports, photos, and other significant correspondence in the bridge database. Staff specifically trained for this task scan and index this information into the database. Individuals can use BIRIS to read access data archived in the database, a web application product developed specifically for Caltrans (*56*).

Colorado

The Colorado Department of Transportation has undertaken several important initiatives designed to improve transportation planning, decision making, and resource allocation. CDOT approached the issue of data integration to support Asset Management from both the policy and information technology perspectives (*57*).

On a policy level, CDOT has been reorganizing its business planning processes since the early 1990s by defining investment categories and associated performance measures. The department developed an Investment Category Structure, a framework that enabled it and the Commission to relate statewide programs to goals and objectives, monitor progress, and provide accountability through defined performance measures. The Investment Category Structure was unique in the following ways:

- It integrated several elements critical to Asset Management within a coherent, overarching framework.
- It structured investments based on policy objectives and impacts on performance rather than on funding sources.
- It facilitated the analysis of tradeoffs among capital, maintenance, and operations program categories (*57*).

The department complemented the Investment Category approach by updating the statewide planning process and the program prioritization process, establishing maintenance program levels of service, instituting the use of customer surveys, and updating relevant information technology (IT) applications. CDOT also began to focus on Asset Management, by forming an Asset Management Task Force in 2001 (*57*).

As CDOT undertook these policy changes, staff realized that many business processes were not directly supported by advanced IT. For example, several departmental systems, including database systems, existed in "stovepipes" with little or no automatic transfer of data between them. Many of the systems were outdated and existed on mainframe or PC platforms that made integration of major data systems such as bridge and pavement management systems nearly impossible. Each of the systems was generating its own reports for customers, including the Transportation Commission and FHWA. This structure made it difficult to obtain critical information needed for decision making (*57*).

CDOT is moving quickly toward a completely integrated data system, supported by the rapid development of its GIS services, the implementation of a Strategic IT plan, and the migration of stovepipe/desktop applications to an enterprise environment. The Strategic IT Plan, created in 2001, halted development of all IT systems and consequently attracted the attention of the entire department. The plan required the justification of the business case for all new applications and approval of the Information Technology Management Team (ITMT) to ensure its consistency with the overall strategy (*57*).

CDOT uses several management systems that support Asset Management:

- **Pontis Bridge Management System.** CDOT now uses AASHTO's Pontis as a database repository for inventory and condition information on state-owned (on-system) and local (off-system) bridges. Part of the information collected is shared with maintenance management for performance-based budgeting, as described below.
- **Pavement Management System.** The PMS assists the department in tracking current pavement condition and estimating future needs to maintain the pavement network according to specified performance goals. The PMS recommends the most cost-effective pavement surface treatments and maintenance activities. It also serves as a planning tool to support funding and allocation decisions on the network and project levels. Seventy percent of the construction and maintenance surface treatment projects the CDOT regions select are based on the recommendations made by its PMS.
- **Maintenance Management.** CDOT's Maintenance Management System (MMS) tracks expenditures and accomplishments by activity in nine maintenance program areas. This system has been supplemented with a performance-based budgeting tool that incorporates explicit levels of service related to the condition of highway maintainable items and to levels of activity performance or responsiveness.
- **Budget and Financial Management.** CDOT's financial management systems provide information on the funding and expenditure components of Asset Management (e.g., the "true" costs of Asset Management activities that include indirect cost components and other adjustments that are not accounted for in infrastructure management systems) (*57*).

Broadened application of these systems, additional improvements in systems features and capabilities, and integration of systems logic or data will advance CDOT's Asset Management practice (*57*).

As an alternate transportation asset management approach, CDOT also began using life-cycle cost analysis in the late 1970s as a response to inflation, and in 1981 CDOT mandated that an LCCA be completed in the design phase for all major projects (*58*). LCCA as defined by CDOT is an engineering analysis tool that is useful in comparing the relative merit of competing project alternatives (*59*). By using LCCA as a tool for considering all aspects of cost during the life of an asset, CDOT can analyze the costs and select the lowest cost option. It also allows the agency to balance the construction, rehabilitation, and preservation of an asset with the needs of the agency and the roadway user. Continual use of the process allows CDOT to alter initial plans during all stages to meet the needs of the agency and user. These alterations may include such things as design changes, work zone criteria, and altered traffic plans (*59*).

In the more than 30 years since CDOT implemented LCCA, it has reported a number of valuable lessons learned including:

- A vocal advocate within leadership for a process such as LCCA is useful for both a clear vision and facilitation of the process.
- Involvement of contractors and industry in the process helps to clarify issues and promote buy-in.
- Involving all transportation-related offices in training deepens the use of the practice across the organization.
- LCCA gives the agency some control over escalating costs because it creates a venue for examining competing options.
- LCCA predicts pavement performance better than subjective surveys (*59*).

Florida

To support bridge repair and replacement decision making in Florida, agencies enter inspections in Pontis through Citrix MetaFrame, a Web tool for bridge inspections that efficiently provides users a single point of access from any location, for any number of people, using many devices, over any connection. A Feasible Action Review Committee (FARC) in each district office is responsible for reviewing and prioritizing the needs identified by the inspectors. FARC uses the Project-Level Analysis Tool (PLAT), an integrated software customized for the Florida Department of Transportation (FDOT). PLAT is a decisions support system tool that makes routine policy, programming, and budgeting decisions regarding preservation and improvement of the state's bridges (*56*).

Engineers use PLAT to determine the economic health of a structure, and they use it as a design tool for candidate projects to program into the management process. When the engineer modifies a candidate by changing the element action selections, quantities, or various cost factors, PLAT responds, immediately updating its predictive results. This new project-level decision support framework complements and builds on the existing network-level analysis in Pontis. Florida is one of the few states integrating Pontis to do network-level analysis applications (*56*).

Work orders are created in Pontis and uploaded to FDOT's customized mainframe Maintenance Management System. Work orders are given priority ratings from 1 to 4, priority 1 being an emergency situation requiring completion of work within 60 days; priority 2, an urgent situation with a 180-day limitation; priority 3, routine work to be done within one year; and priority 4, no immediate deadline but information is provided. One of FDOT's performance measures is to monitor delinquency of work orders. Districts or an independent asset management contractor schedule and perform all work orders (*56*).

In a broader effort, Florida implemented asset management through a planning process called "program and policy planning." The Florida asset management program has evolved into a strategy of creating a performance driven method of contracting for routine maintenance and management of highway infrastructure. This program, known as Asset Maintenance, uses contracts with durations ranging from 6 to 10 years for inspection and routine maintenance of highway infrastructures. These contracts encompass four general types of asset management:

- Roadway corridor contracts, which center around a specific roadway such as a limited access facility.
- Geographic contracts that contain multiple types of transportation facilities within a specified region.
- Facility contracts that focus on rest areas, welcome centers, and weigh stations.
- Fixed and movable bridge contracts (*60*).

These maintenance contracts allow for bundling of maintenance costs for each of these general contracts. The contracts, known as AM contracts, typically include the traditional maintenance activities such as mowing, sign and guardrail maintenance, pavement striping, raised pavement marker replacement, fence repair, shoulder maintenance, and drainage system cleaning. Additionally, they also include compliance with environmental requirements, incident response, natural disaster preparedness and damage repair, permit application review and evaluation, highway lighting and call box maintenance, customer service complaint resolution, formal inspection of bridges and safety features, and motorist aid service patrols. As previously noted, the duration of the contracts ranges from 6 to 10 years, and the payments are monthly fixed sum amounts (*60*). The estimated savings for Florida by 2005 was about 17 percent for the life of the contract (*60*).

Another important aspect of contract management for long-term maintenance contracts is quality assurance of the maintenance performed. Florida has implemented a maintenance rating program that is used for asset management contracts. When a long-term contract is executed, the State Maintenance Office provides the district with sample sites that are used for evaluating contract performance (*61*). The samples are used to rate the contractors' maintenance efforts, and the results are entered into a maintenance rating for the contractor. These ratings are used in quality assurance reviews for the contract (*61*). Florida requires contractors to post a performance bond for the amount of the annual contract, and all contracts are selected by an asset management evaluation committee that has a minimum of five contract evaluators (*61*). Florida's aggressive maintenance contracting program resulted from a government mandate in which they were directed to increase their outsourcing to 60 percent while reducing personnel 25 percent (*62*). Ultimately, they reported cost savings of nearly

20 percent, demonstrating that contracting out maintenance activities was generally cost-beneficial (*63*).

Georgia

Like other state transportation agencies, the Georgia Department of Transportation (GDOT) wanted to facilitate consistency throughout the agency and expand its transportation asset management program, including the use of life-cycle cost analysis. Specifically, GDOT wished to compare multiple alternatives for a project and evaluate the relative economic merit of each option by analyzing initial and discounted future expenditures for rehabilitation and preservation activities. The pavement design committee adopted GDOT's first LCCA guidelines in 1994, incorporating user costs into the equation.

In 2002, GDOT staff participated in FHWA training for the agency's RealCost software, a Microsoft Excel-based LCCA spreadsheet program that states can utilize at no charge. During efforts to use RealCost, GDOT staff encountered a challenge: RealCost could compare only two project alternatives at a time, and GDOT wished to compare 10 or more alternatives simultaneously. GDOT continues to refine its LCCA process. This effort includes accounting for risk by developing procedures for a probabilistic analysis where a range of possible inputs can be evaluated.

In 2006, GDOT's Office of Transportation Data and Office of Materials and Research formed an asset management task group composed of senior managers from the various offices. This task group brought asset management to higher levels of the organization. It was also GDOT's desire to better coordinate the timing of the LCCA in the project development process, as the LCCA now takes place after preliminary plans are complete. Scheduling it to occur during the concept stage of the project development process would increase opportunities for incorporating recommendations. Earlier consideration of the LCCA results would help GDOT meet its primary goal of delivering Georgia's transportation program.

Indiana

The stated focus for the Indiana Department of Transportation (INDOT) is mobility and connecting major activity centers to enhance the movement of people and goods. In order to facilitate this goal, INDOT began exploring the use of needs analysis models for statewide planning. In 1988, the agency selected a customized version of HERS that became known as HERS-IN (*64*). This customized version of the software contained features and capabilities including override that allows analyst-specified improvements, map production, evaluation of expansion projects, and estimation of individual capacity improvement elements on traffic system-wide. Indiana has utilized HERS-IN, along with a suite of tools it developed, to build a comprehensive asset management program. One tangible outcome is the May 2006 release of the first fully funded 10-year production/construction plan in the agency's history (*64*).

INDOT still uses its customized version of the software, HERS-IN, but is moving toward use of the standard HERS-ST software. The agency has totally re-engineered its organizational structure, creating a dedicated staff of technicians responsible for the use of HERS-ST. INDOT also strives to increase the interest in HERS-ST at MPO and local levels (*64*).

Maryland

Similar to the approach taken by the Alabama Department of Transportation, the Maryland State Highway Administration (MDSHA) opted to develop an in-house management system to support culvert repair and replacement rather than utilize FHWA's CMS. Within the MDSHA, the responsibility for culvert management and inspection is divided between the Bridge Inspection and Remedial Engineering Division (BIRED) and the Highway Hydraulics Division (HHD). The BIRED tracks culverts that meet the size and fill requirements in an in-house Access database, referred to as a Structure Management System, which is also used for National Bridge Inspection Standards (NBIS)-length bridges. The SMS does not predict culvert service life as a function of existing or anticipated deterioration (*54*).

Similarly, HHD developed an in-house, Access-based GIS for inventory. Because of the large amount of data stored in the inventory, HHD will eventually convert to an Oracle-based GIS. This database is separate from the BIRED bridge database, although there may be some small overlaps with culverts in the 60 to 72 inch range (*54*).

Michigan

In the early 1990s, the Michigan Department of Transportation (MDOT) began a data integration effort through the implementation of a Transportation Management System (TMS). MDOT envisioned an Asset Management approach to managing the transportation system that was a comprehensive, long-term view depending upon quality data, the initial condition, service levels of the system, and the performance of the investments made to address system needs (*65*).

In order to support decision making, the agency utilized TMS to migrate key planning, programming, and project-delivery data from a mainframe to five major databases (*65*). Initial efforts to develop the TMS focused on the existing software and on processes supporting project and program development. MDOT discovered that four large data files contained essentially the same information but were stored and accessed in different ways. Reconciling these different storage methods and definitions allowed MDOT to eliminate several legacy applications and reduce multiple procedures to two major applications and one database. This integration also significantly improved data quality and allowed the organization to function as a single entity with common data requirements (*65*).

Minnesota

To support culvert repair and replacement decision making in Minnesota, the Minnesota Department of Transportation (MnDOT) utilizes two different computerized management systems: Pontis and HYDraulic INFRAstructure (HYDINFRA).

For inventory and management of the larger structures, MnDOT's Bridge Inspection Unit uses the Pontis Bridge Management System. Although intended primarily for bridges, a state transportation agency can use the software to also manage its inventory of culverts. Pontis has the capability to predict deterioration and remaining service life and to make repair and rehabilitation recommendations (*54*).

The HYDINFRA system manages both inventory and inspection data for each hydraulic feature. The impetus for the development of HYDINFRA came from the district hydraulics engineer's decision to create a management system for the hydraulic infrastructure on a statewide level. Development of HYDINFRA began in 1996 and was completed a year later. Prior to this, each district either did not collect data for small culverts, nor had its own way of inventorying and collecting data from paper records to simple databases. Fortunately, there was no catastrophic failure or event that prompted the Mn/DOT to manage these structures. Although Mn/DOT does not differentiate culverts from storm drains, there are approximately 50,000 pipes in the inventory. Mn/DOT estimates that they have inventoried 75 percent of the state-owned pipes. HYDINFRA data are used primarily for construction project scoping and to plan maintenance and repairs. Survey crews have used HYDINFRA data to locate culverts for more detailed mapping work. Beginning in 2006, HYDINFRA was used to find features requiring maintenance under the new water quality requirements. Inspection and maintenance activities are logged by date so that the history of problems or repairs is available for each feature. Field inspectors collect data with global positioning system (GPS) receivers, and the data are then uploaded to an Oracle database. Geographic information tools allow users to query the database for specific information and create maps for use in various projects. Users can query by condition, need for repair, or need for cleaning (*54*).

New Mexico

The New Mexico Department of Transportation began using the HERS-ST system in 2001. Like many states, NMDOT used HERS to develop its list of needs and design a long-range plan. Early on in using HERS-ST, NMDOT identified three areas of concern with the program: it was DOS driven, it only processed HPMS data, and it did not provide concise summary reports (*66*). As a result of input from NMDOT, FHWA's Office of Asset Management made changes to the HERS-ST software to make it more user-friendly.

NMDOT planners used the HERS-ST software to manipulate the data and generate more customized reports that met their needs (*66*). New Mexico has used HERS-ST to develop the need projections for its long-range plan since the program's inception. By 2003, NMDOT had fully integrated HERS-ST into its long-range-planning process. NMDOT utilizes HERS-ST in a number of ways, including the aforementioned long-range-planning process, calculating benefit-cost ratios for all Governor Richardson's Investment Partnership (GRIP) projects, generating system condition summaries, estimating maintenance and operational costs, calculating the impacts on highway users at different funding levels, and providing user interface for accessing and viewing highway data. New Mexico is looking to expand its use of HERS-ST in a variety of ways. The planning office sees the DOT utilizing the program to establish impacts to user benefits at certain funding levels, a tool that will become increasingly valuable as dollars for transportation improvements become more limited (*66*).

New York

The New York Department of Transportation (NYDOT) has been committed to sound management practice and in the 1960s began to develop automated systems for processing data for pavement, bridges, and safety (*67*). Provisions contained in the Intermodal Surface Transportation Efficiency Act of 1991 (*1*) reinforced NYDOT's efforts to refine network-level management systems for individual classes of assets such as pavements and bridges. At the individual project level, NYDOT improved its economic analysis methods for project scoping and evaluating alternative solutions to identified problems. For example, NYDOT now evaluates alternative pavement treatments using life-cycle cost analysis. By 2001, NYDOT began to develop a tool that provides a technical platform for making tradeoffs at program level. Four pre-existing management systems support the department's goal areas—pavements, bridges, safety, and mobility—and provide input to this new tool, the Transportation Asset Management (TAM) Tradeoff Model. In May 2003, five years after the development of its "Blueprint," NYDOT announced the adoption of TAM as the framework for managing all infrastructure investments. Economic methods at both the program and project levels now play an essential and larger role in this framework (*67*).

Oregon

The Oregon Department of Transportation (ODOT) has used computer modeling since the early 1990s to support the department's decision-making processes. ODOT initially relied on the Highway Performance Monitoring System Analytical Process (*68*). In 1997, ODOT needed to produce a long-range, statewide multimodal transportation plan and a short-term, statewide transportation improvement program that would fit within this plan. During their efforts to produce these plans, they came to realize that HPMS was, while successful for many years, lacking when it came to user costs and benefits. ODOT decided to employ a new system, Highway Economic Requirements System. This system was able focus on the impact that the condition and performance of the highway system will have on highway users. With the ability to modify the HERS system to the specific needs of Oregon, ODOT was able to implement HERS-OR. ODOT was immediately able to see the effects of the new HERS-OR system when they used it to help frame the difficult choices that arise from decreases and increases in spending when resources are constrained (*68*).

In Oregon, HERS-OR has proven its value as a transportation planning tool. ODOT has used HERS-OR to support the needs analysis requirements in development of the modal, corridor, and MPO plans leading to the STIP. In each case, HERS-OR was used to analyze the impact of different investment levels on the system and its users. ODOT continues to use HERS-OR to conduct various needs analyses and has applied selected features of the model in producing special studies (*68*).

Pennsylvania

Pennsylvania is a large state in terms of transportation assets, and the Pennsylvania Department of Transportation (PENNDOT) is responsible for the fifth-largest state highway system in the United States. Like many states, Pennsylvania faces an aging roadway system and constrained financial growth. In response to these issues in combination with moderate population growth, PENNDOT adopted a "Maintenance First" philosophy. This philosophy focuses on preserving the functionality of existing assets over strategic expansion of the system (*69*). As a part of the maintenance first philosophy, strategic expansion of the system will still occur, but growth is not the primary focus. In the near term, PENNDOT has established an 80/20 target split between maintenance and expansion expenditures. In the long term, the agency expects to meet the vast majority of expansion needs by 2025 (*69*).

Organizationally, PENNDOT moved to a more decentralized structure. Although the headquarters retains an oversight function, PENNDOT has given districts the flexibility and resources to develop new solutions, adopt success stories as best practices, and disseminate these experiences throughout the state. PENNDOT also shifted toward greater participation by local and regional parties in transportation planning and management activities (*69*).

In order to achieve this philosophy, PENNDOT was required to implement a top-down and bottom-up approach to data integration. The central component of this data integration process is a series of projects to update the department's highway, bridge, and maintenance management practices, and the legacy systems that support them (*69*). Improvement of data integration and asset management systems will lead to improved management decisions for both long-term and short-term expenditures. If better Asset Management decisions can improve the efficiency of PENNDOT's capital program by only 1 percent (such as achieving similar benefits using less resources), the department would save over $28 million annually. Although the details of PENNDOT's enterprise data architecture are still under development, the department continues to make significant progress in several other areas required to make improved decision making a reality (*69*).

South Dakota

Improving upon both the accuracy and efficiency of bridge management, the South Dakota Department of Transportation (SDDOT) saved approximately 900 annual man-hours in labor by customizing the Pontis Bridge Management System check-out/check-in process and abandoning its previous practice of entering inspection data from paper forms (*56*).

During 2002 and 2003, SDDOT used Pontis to begin setting up improvement models based on established policies and standards. Efforts in developing the preservation policy were concentrated on the most common elements in the inventory and the type of preservation work most commonly performed, namely:

- Deck treatments such as epoxy chip seal overlays.
- Low slump dense concrete overlays.
- Membrane and asphalt overlays.
- Waterproofing joints.
- Bridge rail modifications.
- Steel fatigue retrofits.
- Approach slabs and approach modifications (*56*).

SDDOT recognized the efficiency of programming Pontis for the most prevalent elements first, and in time, it plans to continue programming to cover policies for all National Bridge Inventory (NBI) elements. The deterioration calculations were initially based on expert elicitations, and it is expected that as more element-level inspection data are collected, the historical data will supersede the expert elicitations. In other words, Pontis has the capability of "learning" from the inspection information that personnel input every two years (*56*).

Because of efficiencies SDDOT gained using Pontis, it has been able to go to the next level of bridge management, embarking on a project called Concept to Contract (C2C). C2C incorporates all management systems into the new State Transportation Improvement Program. C2C includes the following subsystems:

- *Maintain Candidate* is a consolidated database containing South Dakota's highway system needs.
- *Scoping and Estimating* identifies alternatives for specific work to be done on a project and its cost.
- *Scheduling and Task Management* identifies the tasks to be completed prior to bidding, and by whom.
- *Funding* identifies what funding to use on what projects and when to use it.
- *Bid Letting* allows preparation of bidding documents and electronic interaction with contractors (*56*).

Through the C2C program, SDDOT envisions several computer programs working together as a system to share common information that is part of a highway construction project. They anticipate that the information will follow the life of the construction project from conception to the time it is advertised for construction (*56*).

Virginia

The Virginia Department of Transportation (VDOT) is responsible for the third-largest, state-maintained highway system in the United States. VDOT is legislatively mandated to maintain existing transportation assets before funding capital improvements (*57*). In 1995, VDOT initiated a comprehensive maintenance and operations business process reengineering effort known as BPR. This review reflected asset management principles that evolved into VDOT's Asset Management model, which projected a 15 percent return on investments by 2006. In the late 1990s, Virginia signed the first performance-based turnkey asset management maintenance contract in the United States (*37)*. This concept awarded one contract from fence-line to fence-line and was all inclusive for maintenance services for the contracted segment. The first contract was for 250 miles of various segments of Virginia's Interstate System. The estimated savings for this turnkey approach to maintenance was 15 to 20 percent by various studies (*69*).

In 1996, VDOT established an interstate *Asset Management Contract* as a pilot to prove the soundness of this new contracting technique. The contractor was generally responsible for maintaining all assets between the right-of-way fences on all sections of the interstate highway and was paid a lump sum amount each month. The type of contract specification was a performance-based specification, which required the contractor to meet or exceed specific maintenance performance targets for five asset groups that are located within VDOT's right-of-way: Pavement, Roadside, Drainage, Traffic, and Bridges. Each asset group was subdivided further into a number of individual assets related to the group. For example, the traffic asset group included the subcategories of signs, signals, highway lighting, pavement markings, and guardrails. The contractor was responsible for providing all work, materials, labor, services, and equipment necessary to achieve the established performance targets (Joint Legislative Audit and Review Commission (JLARC) of the Virginia General Assembly Report 2001).

In 1996, VDOT awarded a five-year asset management contract using a performance-based approach. VDOT initially claimed that the contract saved $23 million. A JLARC Report (*70*) identified that the projected cost savings was largely based on estimates and forecasts of its future maintenance costs as compared to the payments it would make to the contractor. However, estimates of planned maintenance expenditures completed in 1996 may have little relationship to the actual maintenance costs in subsequent years. Therefore, the JLARC Report (*70*) stated that VDOT's estimate of savings was not useful in assessing the effectiveness of the contract. In 2000, an independent study performed by Virginia Tech reduced the savings range from $23 million to $16 million (*62*). In terms of this study, the JLARC Report (*70*) stated that "The study approach appears to be a reasonable effort at comparing certain costs for the contractor and VDOT…but because of its narrow scope may not provide conclusive findings on the overall cost effectiveness of the asset management approach."

Washington

The Washington State Department of Transportation began a pavement condition survey program in the 1960s that surveyed the condition of the entire state highway system every two years. This program evolved into a Pavement Management System in the late 1970s and since 1988, WSDOT has surveyed pavement conditions annually (*36*). The focus of the program is pavement preservation, and the information gathered is used to identify candidate pavement projects. The survey data are also used to conduct engineering and economic analysis for the purpose of improving performance of pavements, maximizing investments, and prioritizing projects. One example of the use of the data was an investigation of the performance of concrete pavements on I-5 in the Seattle area. This study attempts to determine when the concrete pavements on I-5 will fail and how much time WSDOT has to plan and develop projects before the deterioration reaches unacceptable levels (*46)*.

TEXAS ASSET MANAGEMENT PRACTICES

In late 1998, TxDOT implemented a *Total Maintenance Contract* for highway maintenance outsourcing. The contract was a performance-based contract, whereby the contractor was required to maintain a prescribed level of service for a lump sum bid. The contractor in effect 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. The contractor determined what work to perform and what materials and methods to use. They 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 (*71*).

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) (*71*), 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 (*71*) 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 (*62*) further noted that "Although 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 by the Center for Transportation Research (CTR) (*72*), three components were identified that make up a maintenance contracting strategy: delivery method, type of contract specification, and pricing strategy. The study identified a list of 13 delivery methods for maintenance contracts that have been implemented within TxDOT. These methods included:

- 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 (2 districts).
- Partial Competitive Maintenance Contract Method – TxDOT personnel perform a certain percentage of the maintenance and outsources the remainder (1 district).
- Jointly Performed Maintenance Contract Method – TxDOT personnel perform a portion of a specific activity and outsource the remainder of the activity (8 districts).
- Routine Maintenance Contract Method – all routine maintenance activities are bundled into one contract and outsourced (2 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) (1 district).
- Integrated Maintenance Contract Method – a combination of routine and preventive maintenance activities are bundled and outsourced in one contract (2 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 districts).
- Long-term Separate Maintenance Contract Method – a single activity is outsourced for a long-term period (5 or more years) and may span a large area (1 district).
- Framework Contract Method – several contractors are pre-approved and receive nominal contracts that make them eligible for maintenance projects (1 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) (*72*).

A subsequent survey by 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 unit price is more commonly used as the pricing strategy by TxDOT 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 (*72*).

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 (*72)*.

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 (*72*).

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 (*72*).

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 (*72*).

CHAPTER 4: DEVELOPING A MATRIX OF BEST 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 desired by TxDOT: (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 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.

	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 Best Asset Management Practices.

CHAPTER 5: TECHNOLOGY ASSESSMENT

INTRODUCTION

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, to improve coordination among the many specialized staff groups responsible for the facilities, and to 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. To this end, the research team reviewed the latest available state-of-the-art tools and technologies that are useful and provide field personnel at TxDOT with an innovative capability to better manage and maintain a wide range of transportation safety and operations assets.

TEXAS DEPARTMENT OF TRANSPORTATION ASSET MANAGEMENT CONTRACT METHODS

The results of the project assessment of United States practices revealed that from a study conducted in 2010 by the Center for Transportation Research, there were 13 delivery methods for maintenance contracts that TxDOT has implemented and that other states across the country have also implemented (*72*). The 13 delivery methods included:

- **Individual Activity Contract Method** – a 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 (2 districts).
- **Partial Competitive Maintenance Contract Method** – TxDOT personnel performs a certain percentage of the maintenance and the agency outsources the rest (1 district).
- **Jointly Performed Maintenance Contract Method** − TxDOT personnel perform a portion of a specific activity and the agency outsources the remainder of the activity (8 districts).
- **Routine Maintenance Contract Method** – TxDOT bundles all routine maintenance activities into one contract and outsourced (2 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) (1 district).
- **Integrated Maintenance Contract Method** – TxDOT bundles a combination of routine and preventive maintenance activities and they are outsourced in one contract (2 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 districts).
- **Long-term Separate Maintenance Contract Method** – TxDOT outsources a single activity for a long-term period (5 or more years) and may span a large area (1 district).
- **Framework Contract Method** – TxDOT pre-approves several contractors and they receive nominal contracts that make them eligible for maintenance projects (1 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).

Moreover, in the development of the matrix of best asset management practices under the guidance of the Project Monitoring Committee, researchers concluded that a three-tiered structure should be used to capture the evolving management strategies that TxDOT considers critical to guiding future asset management contractual activities. TxDOT's proposed three-tiered approach to asset management consists of: (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 LED signal indications—that may be based on warranty specifications.

The research team used these results to identify and review the current and future tools and technologies used by TxDOT to process and monitor asset related contracts. This summarization provides an appropriate view of the technological opportunities and gaps that could be considered for the various contractual methods used to manage and maintain a wide range of transportation safety and operation assets within a three-tiered structure. The following sections discuss the details and results of the work performed by the research team.

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 2 below.

Table 2. 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; will be replaced by "SiteManager" that is currently used in the Construction Division).
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	Automated system for storing, retrieving, analyzing, and reporting information needed to support pavement-related decision making.
PONTIS	A Bridge Management System sanctioned by AASHTO in 2001. TxDOT has created a customized PONTIS application called PonTex. The integration of PonTex with PONTIS analytical tools will occur in FY 2010.
TxCAP	Texas Condition Assessment Program (TxCAP) − measures combined information on pavement condition, roadside conditions, and traffic elements (including work zones and railroad crossings) to assess the overall condition of the state's road inventory.
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

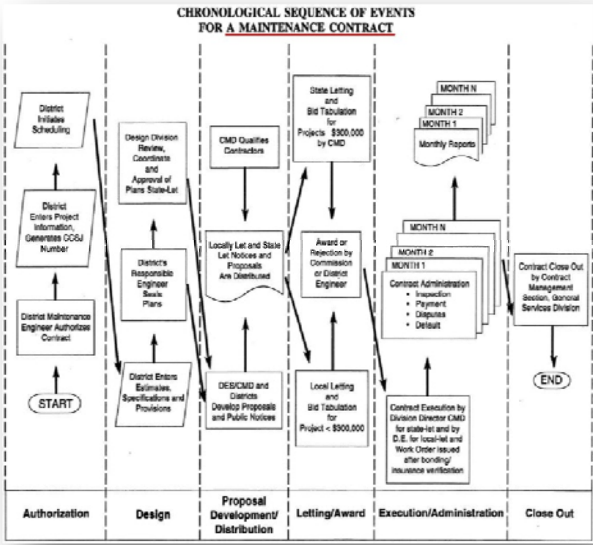
CMCS is central to the project management and financial control of TxDOT's construction and maintenance programs (*73*). It is the primary system used to control maintenance and construction contracts from the planning phase through close out, keep track of progress for each individual contract and the highway improvement process, and handle the payment (as shown in the flowcharts in Figure 4) (*74*). CMCS: (1) helps track the progress of a contract from design to closeout; (2) prints required contract documents; (3) records the status of contract requirements like contractor insurance and bonding; and (4) provides management reports for contract administration including payments and material quality control. In addition:

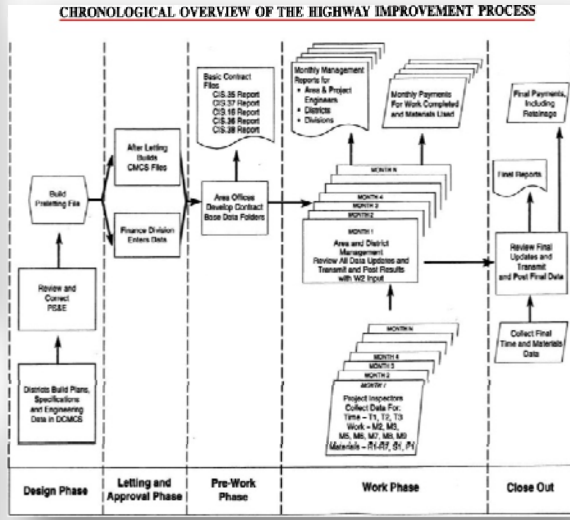
- CMCS can also automate most maintenance contract activities including: (1) Plans, Specifications and Estimates; (2) Public Notices; (3) Bid Proposal Documents; (4) Letting; (5) Post-Letting; (6) Contractor Payment; and (7) Monitoring of Insurance, Bonding, etc.
- CMCS can provide support to construction contract processing for: (1) Contractor Qualification Status; (2) Public Notices; (3) Bid Proposal Documents; (4) Post-Letting Activities including Award; (5) Monitoring of Insurance, Bonding, etc., and (6) 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 Closeout.

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 6, is text-based and not a graphical user interface (GUI) that is widely used today.





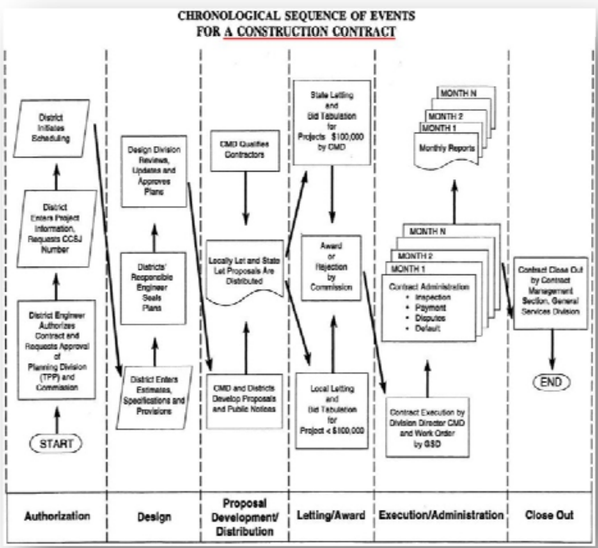


Figure 5. CMCS Contractual Flowcharts.

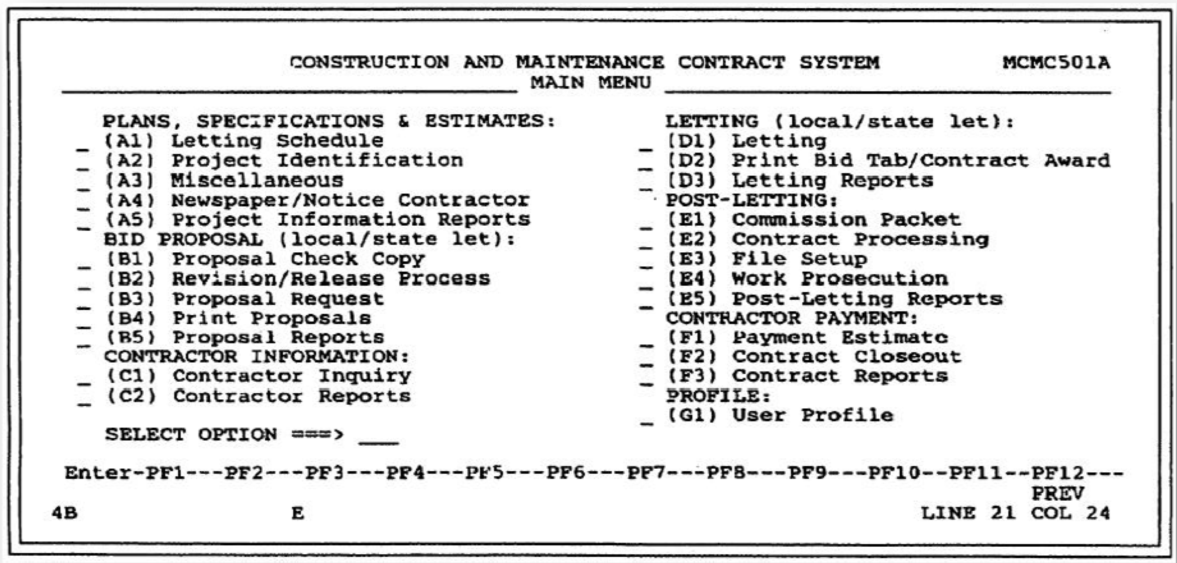


Figure 6. CMCS Main Menu.

"SiteManager" that TxDOT's Construction Division currently uses will replace CMCS. The "SiteManager" 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 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

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 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 is a mainframe information system primarily used to provide data for planning and scheduling maintenance activities. It helps gather and analyze data for a variety of 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 7:

- CMCS.
- FIMS.
- Material and Supply Management System (MSMS) – an online system used to order and track material usage.
- Salary Labor and Distribution (SLD) – used by TxDOT to perform salary and labor distributions.
- Equipment Operating System (EOS) – used to order and track equipment usage.
- SES – used by department to input roadway maintenance data into MMIS, SLD, EOS, and MSMS.

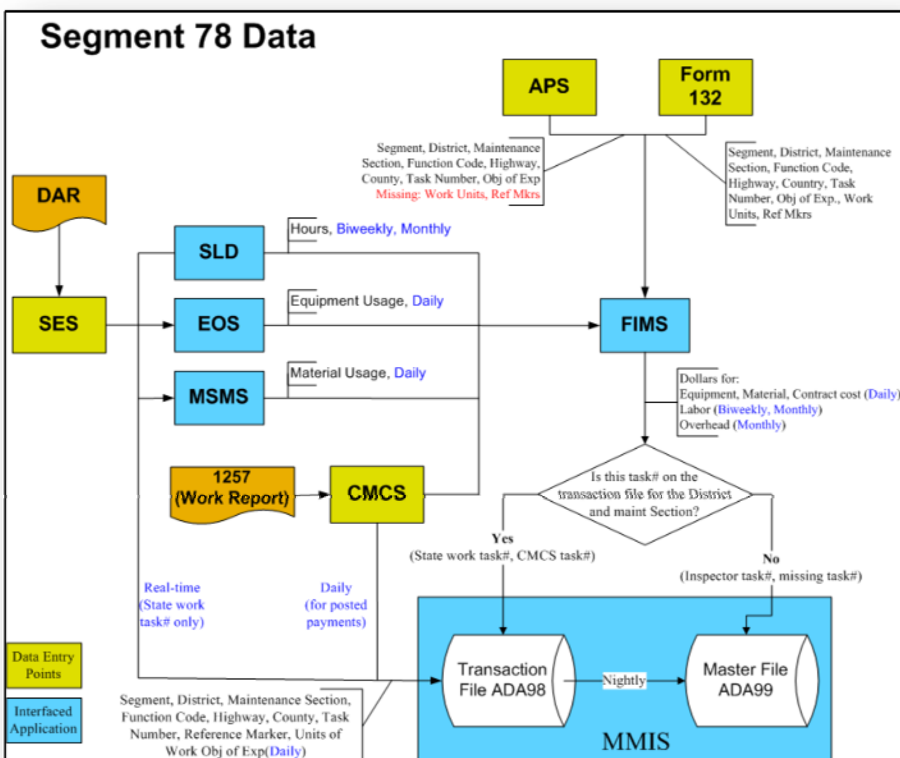


Figure 7. Maintenance Management Information System. (Source: TxDOT Maintenance Division)

Pavement Management Information System

The PMIS is an automated system for storing, retrieving, analyzing, and reporting pavement condition information (*75*). 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.

Data collected by PMIS include 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 bridge management system. Pontis is a comprehensive bridge management system developed as a tool to assist in the challenging task of bridge management. Pontis 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; and makes recommendations for what projects to include in an agency's capital plan for deriving the maximum benefit from limited funds (*76*).

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 SQL server. Licensees should confirm support for specific versions or releases for these vendors with the contractor.

Texas Condition Assessment Program

This system was designed to combine information on pavement condition, roadside conditions, and traffic elements (including work zones and railroad crossings) to assess the overall condition of the state's road inventory. The TxCAP combines data from three different divisions' reporting systems: TxMAP, PMIS, and the Texas Traffic Assessment Program (TxTAP) are used to assess the Turnpike Project's assets. TxCAP eliminates duplication of the three separate scoring systems and provides a simplified and concise scoring scale. This system is now phasing out from TxDOT usage.

Texas Maintenance Assessment Program

TxDOT solely uses TxMAP in its headquarters office. The list of data collected by TxMAP 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; General Public Rating.

Single Entry Screen System

TxDOT uses SES to input roadway maintenance data into the following four systems, as shown in Table 3.

Table 3. 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 which 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 – a Bridge Management System sanctioned by AASHTO 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 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.

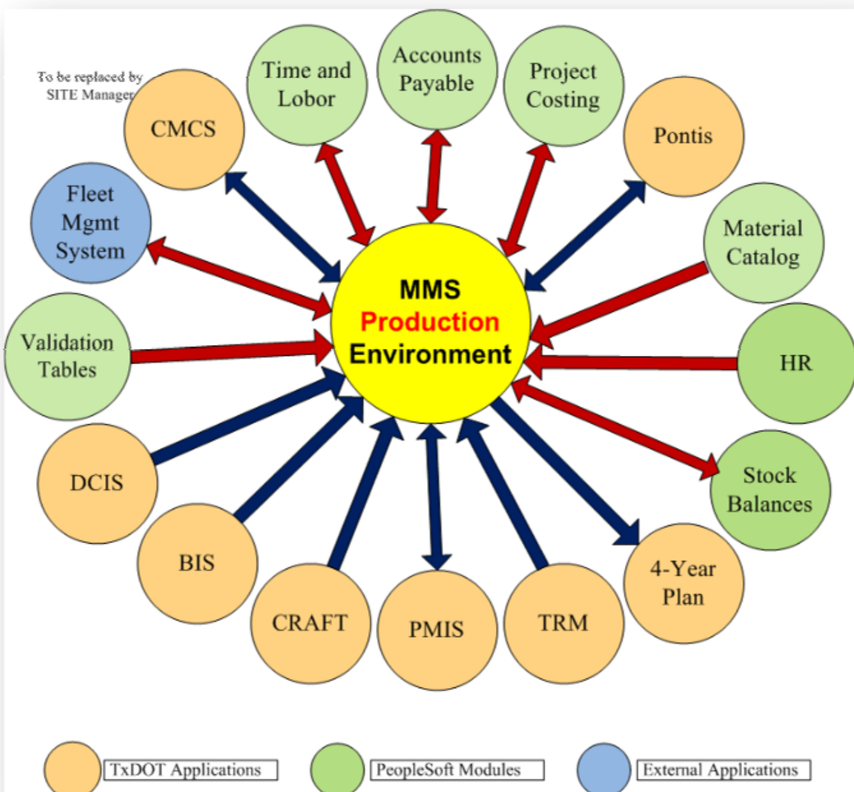


Figure 8. COMPASS Project - Maintenance Management System.
(Source: TxDOT Maintenance Division)

FINAL REMARKS

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 6: 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 2010, a study conducted by 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 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 (2 districts).
- Partial Competitive Maintenance Contract Method – a certain percentage of the maintenance is performed by TxDOT personnel, and the rest is outsourced (1 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 (8 districts).

- Routine Maintenance Contract Method – all routine maintenance activities are bundled into one contract and outsourced (2 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) (1 district).
- Integrated Maintenance Contract Method – a combination of routine and preventive maintenance activities are bundled and outsourced in one contract (2 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 districts).
- Long-term Separate Maintenance Contract Method – a single activity is outsourced for a long-term period (5 or more years) and may span a large area (1 district).
- Framework Contract Method – several contractors are pre-approved and receive nominal contracts that make them eligible for maintenance projects (1 district).
- 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 districts) (*72*).

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 (*72*).

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 (*72)*.

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 (*72*).

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 (*72*).

A subsequent survey by the CTR study team found that method-based contract specifications are widely used by TxDOT for maintenance contracting as opposed to performance-based or warranty contract specifications. The team also found that unit price is more commonly used as the pricing strategy by TxDOT 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 (*72*).

Regardless of the components to a maintenance contracting strategy, each maintenance contract will follow a sequence of chronological events as depicted in Figure 9. TxDOT uses the Construction and Maintenance Contracting System to control maintenance and construction contracts from the planning phase through closeout, keep track of progress for each individual contract and the highway improvement process, and handle the payment. CMCS: (1) helps track the progress of a contract from design to closeout; (2) can print required contract documents; (3) records the status of contract requirements like contractor insurance and bonding; and (4) can provide management reports for contract administration including payments and material quality control. CMCS can also automate most maintenance contract activities including: (1) Plans, Specifications and Estimates; (2) Public Notices; (3) Bid Proposal Documents; (4) Letting; (5) Post-Letting; (6) Contractor Payment; and (7) Monitoring of Insurance, Bonding, etc. (*73*).

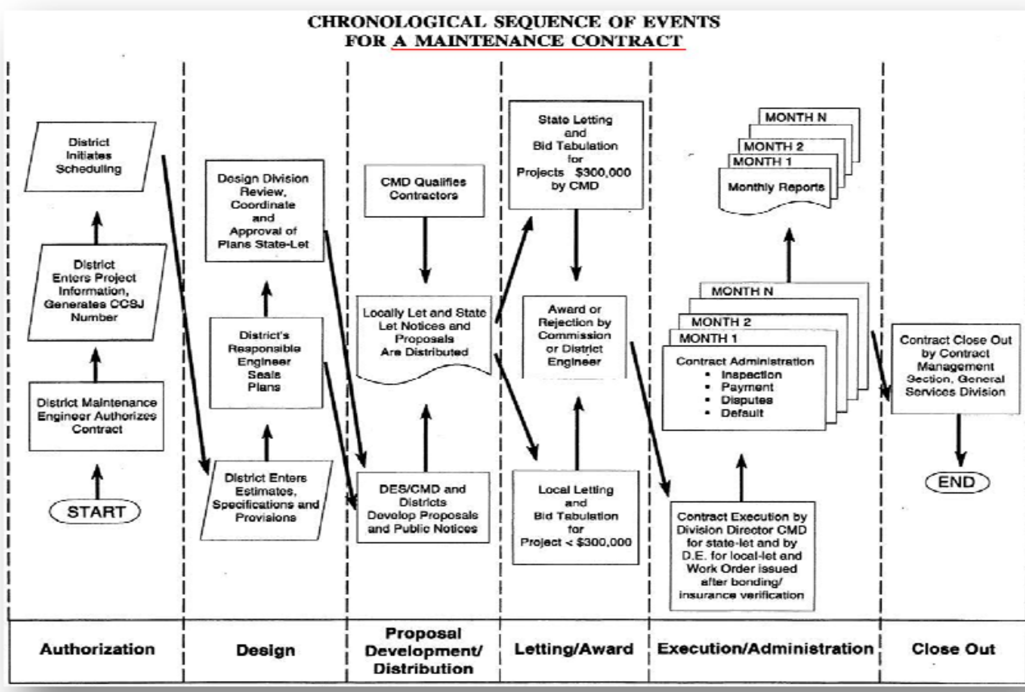


Figure 9. Maintenance Contract Flowchart (*73*).

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 (*77*).

In 1999, the Office of Asset Management for the Federal Highway Administration published a "Primer" for asset management (*14*). In that document, 12 key elements of an asset management program were defined. These elements included:

- 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 (*14*).

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 to be critical to guiding future asset management contractual activities. The approach consists of: (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 LED signal indications—that may be based on warranty specifications. As shown in Figure 4 and 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 are depicted in Figure 8 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 is an automated information system used for planning, programming, and developing projects. DCIS 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, a Bridge Management System sanctioned by AASHTO 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 4 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 4. 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 4 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, 12 key elements of an asset management program were introduced. These elements included:

- 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 (*14*).

Also, it has been cited 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? (*15*).

As TxDOT continues to critically review the lessons learned from other DOTs that have implemented a transportation asset management program, one major observation to note 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, 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. It is of particular interest to 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 established by management 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. Every institution, 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 7: DEVELOPMENT OF GUIDEBOOK

A primary product of this research project 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 (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. The following sections highlight key milestones in the development of the *Guidebook.*

OUTLINE DEVELOPMENT

Building upon the information gathered through the review of published and electronic literature, the assessment of practices across the United States in the area of asset management, the matrix of best asset management practices developed by researchers, the technology assessment, and the investigation of institutional issues and possible impediments to implementation, the researchers prepared a draft outline for a guidebook for asset management. The intent of this outline was to provide a framework for the final guidebook. After vetting the draft outline with the project team and project monitoring committee, the project team prepared a final draft of the guidebook outline, which is presented in

Table 5. Once the outline was completed, the project team developed the guidebook by following the outline and including text for all sections and a glossary of terms.

A THREE-TIERED APPROACH FRAMEWORK

In the development of the guidebook, the research team organized the document around the matrix of best asset management practices. The three-tiered structure established in the matrix was used to capture the evolving management strategies that TxDOT considers critical to guiding future asset management contractual activities. TxDOT's proposed three-tiered approach to asset management consists of: (1) total asset management for large urban areas encompassing multiple counties, (2) asset management of critical functions on a smaller regional scale, and (3) asset management for specific types of assets.

Table 5. Asset Management Guidebook Outline.

Chapter	Title / Description
1	***Introduction (Including Concept and Tenets of Asset Management)***
2	***Background (Status of TxDOT Asset Management Program)***
3	***Asset Management Approach***
	A. Guidance on General Statewide Policy
	B. A Three-tiered Approach Framework 1. Total Asset Management (Large Urban Areas; Multi-county) 2. Asset Management for Critical Functions (Smaller Regional Scale) 3. Asset Management for Specific Assets
4	***Critical Considerations***
	A. Asset Management Goals
	B. Asset Management Objectives
	C. Potential Asset Management Strategies
	D. Organizational Conditions
	E. Performance Measures
5	***Matrix of Strategies/Best Practices***
	A. Development of Asset Inventory/Database 1. Valuation of Assets 2. Quantification of Asset Condition
	B. Method-based Specifications 1. Development of Specifications (Means and Methods)
	C. Performance/Warranty Specifications 1. Development of Performance Measures 2. Performance Prediction
	D. Qualitative Issues
	E. Feedback/Process Improvement
6	***Tools for Asset Management***
	A. Strategy 144 Routine Maintenance
	B. Current Systems for Processing and Monitoring Contracts 1. CMCS a. Contractual Flowcharts 2. MMIS
	C. Additional Systems
	D. Future Systems for Processing and Monitoring Contracts 1. COMPASS Project 2. Integration with Budget Processes
	E. Migration Plan
7	***Impediments to Implementation/Institutional Issues***
	A. TxDOT Current Asset Management Practices
	B. Proposed Recommendations to TxDOT Asset Management Practices
	C. Institutional Issues and Impediments
	D. Attributes for Success
	E. Close the Loop for Continuous Feedback
8	***Recommendations***
9	***Summary/Conclusions***

Total Asset Management

Total asset management, or comprehensive transportation asset management, is focused on large urban areas encompassing multiple counties. The intent is 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 all 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 signal indicators and may be based on warranty specifications.

KEY GUIDEBOOK SECTIONS

The guidebook provides an introduction to the concept of asset management along with background information on the types of investment categories of asset management. It then describes the three-tiered approach to asset management described above. The following sections briefly describe the critical guidebook components that provide detail on asset management from the organizational perspective and in a stepwise approach. These steps are reflected in the screening tool that is a companion to the guidebook.

Asset Management Objectives

When approaching asset management, it is critical that TxDOT identify specific objectives to support each of the goals mentioned in the previous section. These objectives 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.
- 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.

Financial Objectives

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

- Establish accurate valuation of assets.
- Improve resource allocation.
- Estimate the backlog of investment requirements.
- Enable cost-effective solutions.
- Accurately project future requirements.

Analysis Objectives

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

- 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 (benefit/cost for entire system).
- Support project level analysis (specific to project).

Agency Organization Conditions

Once TxDOT's available contracting strategies are considered, 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: in-house contracting administration and purchasing processes, in-house personnel, in-house equipment, work location, time constraint, and contractor.

Contract Terms for Each Strategy

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

Selecting Performance Measures

Once TxDOT personnel refine the list of objectives for the asset being managed, the appropriate performance measures must be identified based 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.

TOOLS FOR ASSET MANAGEMENT FOR SAFETY AND OPERATIONS

Based on data and information the team collected during the project, they identified current tools and technologies used within TxDOT for processing and monitoring asset maintenance contracts. 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 6 below. The guidebook provides detailed descriptions of these tools and provides information on migration of these tools to COMPASS.

Table 6. 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; will be replaced by “SiteManager” that is currently used in the Construction Division).
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	Automated system for storing, retrieving, analyzing, and reporting information needed to support pavement-related decision making.
PONTIS	A Bridge Management System sanctioned by AASHTO in 2001. TxDOT has created a customized PONTIS application called PonTex. The integration of PonTex with PONTIS analytical tools will occur in FY 2010.
TxCAP	Texas Condition Assessment Program (TxCAP) − measures combined information on pavement condition, roadside conditions, and traffic elements (including work zones and railroad crossings) to assess the overall condition of the state’s road inventory.
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.

IMPEDIMENTS TO IMPLEMENTATION/INSTITUTIONAL ISSUES

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. As a wrap-up, the guidebook includes 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.

CHAPTER 8: DEVELOPMENT OF SCREENING TOOL – ASSET MANAGEMENT FOR SAFETY AND OPERATIONS

INTRODUCTION

Haas and Hensing state that since the 1980s, advocates for business standards have called for the application of standard business accounting practices to the oversight of government agencies. The demand for increased financial accountability for publicly owned assets, coupled with the growing need to carefully shepherd scarce government resources, has motivated government agencies to develop more formal asset management programs (*78*).

With this said, new decision support technologies are being developed to assist DOTs with their decision making as well as business processes for resource allocation and utilization. Recognizing its growing importance to transportation agencies, an *Asset Management (AssetMgt) Screening Tool* was developed to represent a unique approach to managing transportation infrastructure based upon quality information and well-defined objectives.

ASSETMGT SCREENING TOOL FOR SAFETY AND OPERATIONS

Based on the information gathered throughout the course of the project, the research team designed a software-based *AssetMgt Screening Tool* based on the *Asset Management Guidebook.* The intent of this tool is for it to be a user-friendly application of the guidebook for use by TxDOT. The purpose of the screening tool is to provide a screening instrument for TxDOT managers and other appropriate staff to use to help assess the best asset management approach or strategy for various assets based on a three-tiered approach. It was designed to facilitate the decision-making process related to asset management and associated performance measures for safety and operations within TxDOT.

This screening tool is a simplified version of the guidebook: essentially an instrument that provides guidance electronically to the end users. A detailed user guide accompanies the tool. The screening tool is a stand-alone, standardized, Windows application that can assist TxDOT in finding the information from the documents being produced in this project. The user interface is the same as that of other typical Windows applications and is designed to run on any Windows-based computer.

ASSETMGT SCREENING TOOL PROCESS

The project team began the screening tool development by developing a process for the *AssetMgt Screening Tool.* The process, as shown in Figure 10, is an illustration of how the user steps through the screening tool to generate specific output. The following sections describe the process and the information included in each step from which the user selects to move through the tool.

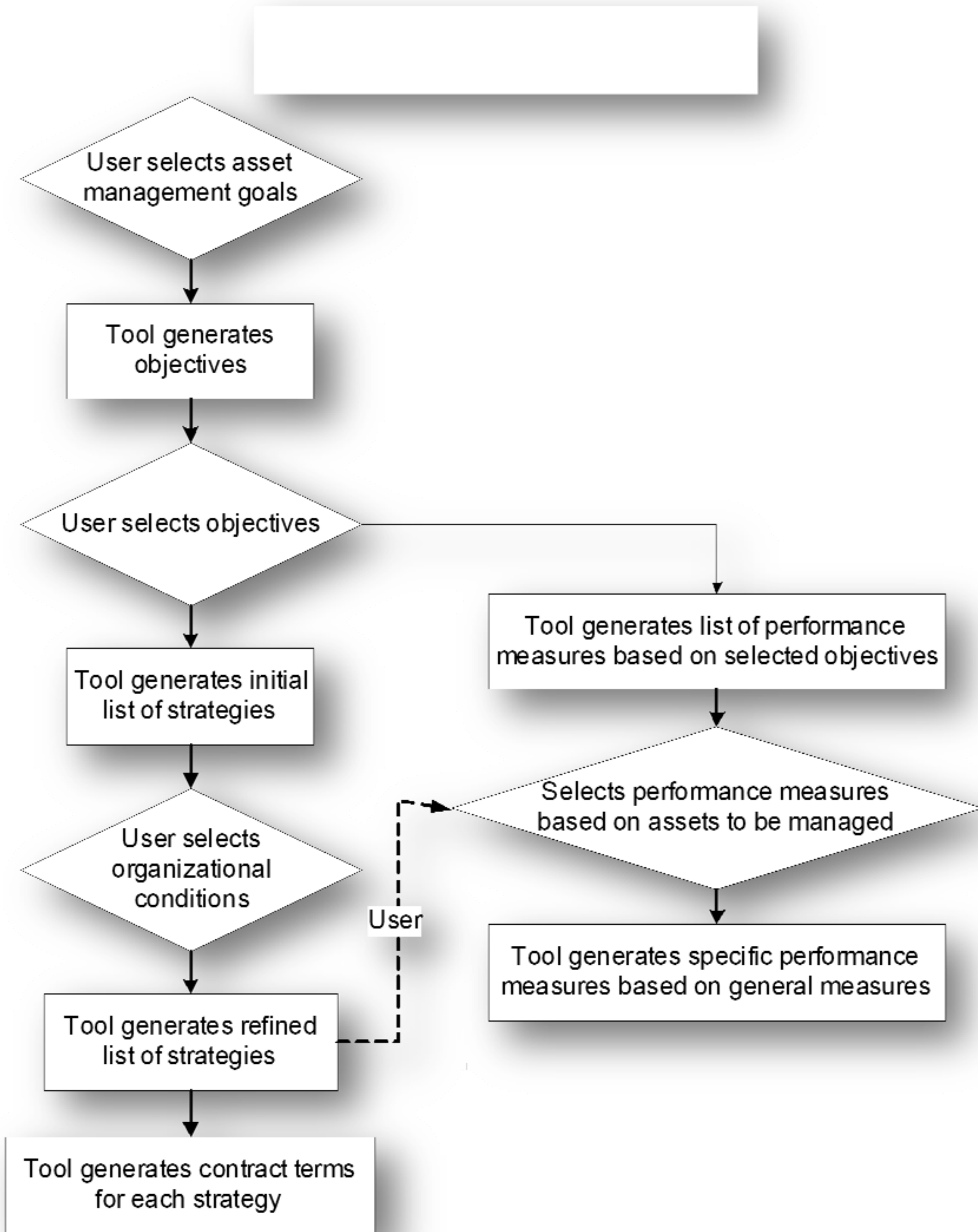


Figure 10. *AssetMgt* Screening Tool Process.

User Selects Asset Management Goals

The first step in the screening tool is for the user to select specific goals that the agency determines are relevant for the asset being managed. The specific goals included in the tool are as follows:

- Build a more cost-effective infrastructure.
- Preserve existing infrastructure.

- Operate existing infrastructure more cost-effectively.
- Improve safety.
- Improve asset performance.
- Enhance agency credibility.
- Enhance agency accountability.
- Support smart long-term decision making.
- Enhance system sustainability.
- Improve agency agility.
- Ensure equitability/objectivity.
- Enhance agency transparency.

Tool Generates Objectives

Once the user selects the appropriate goals, the tool generates a list of appropriate objectives for those goals based on an internal matrix that identifies the specific relationships between goals and objectives. A portion of the matrix is provided in Figure 11. The objectives fall into three categories that are detailed below: system performance, financial, and analysis.

Asset Management Goals	Asset Manageme											
	System Performance Objectives									Financial Ob		
	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
Build a more cost-effective infrastructure	X	X	X	X	X	X	X	X		X	X	X
Preserve existing infrastructure	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
Improve safety		X	X	X	X	X	X	X	X		X	
Improve asset performance	X	X	X	X	X	X	X	X	X		X	
Enhance agency credibility	X	X	X	X				X	X		X	X
Enhance agency accountability								X	X		X	X
Support smart long-term decision making								X		X	X	X
Enhance system sustainability	X	X	X	X	X	X	X	X			X	
Improve agency agility	X							X			X	
Ensure equitability/objectivity		X						X	X	X	X	X
Enhance agency transparency								X	X		X	X

Figure 11. Goals versus Objectives Matrix.

System Performance Objectives

The specific system performance objectives included in the tool are as follows:

- 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.

Financial Objectives

The specific financial objectives included in the tool are as follows:

- Establish accurate valuation of assets.
- Improve resource allocation.
- Estimate the backlog of investment requirements.
- Enable cost-effective solutions.
- Accurately project future requirements.

Analysis Objectives

The specific analysis objectives included in the tool are as follows:

- 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 (benefit/cost for entire system).
- Support project level analysis (specific to project).

User Selects Objectives

After the screening tool generates objectives for specific goals, the user is able to change the objectives that will be considered in the tool to fit the specific needs of the assets being managed. This step allows the user to customize the tool based on any unique circumstances that may dictate which objectives are more important or relevant than others.

Tool Generates Initial List of Strategies

Once the user customizes the objectives, the tool generates a list of appropriate asset management contracting strategies for those objectives based on an internal matrix that identifies the specific relationships between objectives and asset management contracting strategies. A portion of the matrix is provided in Figure 12

The asset management contracting strategies fall into three categories which are detailed below: comprehensive transportation asset management, critical function, and specific assets.

Asset Management Contracting Strategies		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
		Asset I										
		System Performance Objectives									Finar	
Comprehensive Transportation Asset Management	Routine Maintenance	X		X	X	X	X	X	X	X		X
	Total Asset Management	X	X	X	X	X	X	X	X	X	X	X
	Integrated	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
	Significantly Bundled	X	X	X	X	X	X	X	X	X	X	X
	Partial Competitive*	X	X	X	X	X	X	X	X	X	X	X
	Jointly Performed	X	X	X	X	X	X	X	X	X	X	X
	Routine Maintenance	X		X	X	X	X	X	X	X		X
	Integrated	X	X	X	X	X	X	X	X	X	X	X
	Framework	X	X	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	X	X	X	X	X	X	X	X
	Framework	X	X	X	X	X	X		X		X	X

Figure 12. Objectives versus Strategies Matrix.

Comprehensive Transportation Asset Management

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

- 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.

**Partial competitive contracts are not currently used by TxDOT. 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.

User Selects Organization Conditions

The next step in the screening tool is for the user to select organizational conditions that may dictate or eliminate specific asset management contract strategies from consideration. Those 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

The specific organizational conditions that are included under in-house contract administration and purchasing processes are as follows:

- 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 requests for proposals (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.

In-House Personnel

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

- 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.

In-House Equipment

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

- Lack of in-house equipment.
- 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 is 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:

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

Tool Generates Refined List of Strategies

Once the user selects specific organizational conditions, the tool generates a list of appropriate asset management contracting strategies for those conditions based on an internal matrix that identifies the specific relationships between the two. A portion of the matrix is provided in Figure 13.

Asset Management Contracting Strategies		O											
		In-House Contract Administration & Purchasing Processes											
		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
Comprehensive Transportation Asset Management	Routine Maintenance		X	X	X					X		X	
	Total Asset Management		X	X	X				X			X	
	Integrated		X	X	X					X		X	
Critical Functions - Regional Scale	Moderately Bundled / Activity-Based		X	X	X					X		X	
	Significantly Bundled		X	X	X					X		X	
	Partial Competitive*	X	X								X		
	Jointly Performed		X			X							X
	Routine Maintenance		X		X	X				X		X	
	Integrated		X							X		X	
	Framework		X	X	X		X	X					
Specific Assets	Individual Activity	X	X			X				X	X	X	X
	Long-Term Separate		X										
	Framework		X	X	X		X	X					

Figure 13. Organizational Conditions versus Strategies Matrix.

Tool Generates Specific Contract Terms for Each Strategy

Once the tool generates a list of appropriate asset management contracting strategies based on the selected organizational conditions, it also generates specific contract terms for each strategy. This list of contract terms is based on an internal matrix that identifies the specific relationships between the two. Figure 14 provides the matrix. The contract terms fall into three categories—specification, pricing, and award—detailed below.

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			

Figure 14. Contract Terms versus Strategies Matrix.

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.

Tool Generates List of Performance Measures Based on Selected Objectives

Once the user refines the list of objectives for the asset being managed, the tool generates a list of appropriate performance measures based on the selected objectives. This list of general performance measures is based on an internal matrix that identifies the specific relationships between the two. The matrix is provided in Figure 15. 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.

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 15. Performance Measures versus Objectives Matrix.

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).

User Selects Performance Measures Based on Assets to Be Managed

After the screening tool generates performance measures based on the selected objectives, the user is able to change the measures that will be considered in the tool to fit the specific needs of the assets being managed and what measures are relevant and critical for agency success. This step allows the user to customize the tool based on 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 the user refines the list of performance measures for the asset being managed, the tool generates a list of 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. Figure 16 provides this matrix.

Asset Management General Performance Measures		Average condition	No. miles below acceptable threshold condition	Percent in good condition	Percent in fair condition	Percent in poor condition	Percent in "state of good repair"	Average health index (0-100 scale)	Percent structurally deficient (SD)	Percent with sufficency rating less than 50	Percent of bridges that meed department standards	Number of posted or restricted bridges
Preservation	Pavement Condition / Ride Quality	x	x	x	x	x	x					
	Bridge Condition							x	x	x	x	x
	Asset Condition (General)			x	x	x	x					
	Remaining Life / Structural Capacity											
	Asset Value											
	Backlog or Need											
	Agency Financial Impacts											
	Customer Benefit or Disbenefit (or Surrogates)											
	Customer Perception											
Mobility / Accessibility	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											

Figure 16. General Performance Measures versus Specific Performance Measures Matrix.

TOOL DEVELOPMENT

The researchers used Microsoft (MS) Visual C++ to develop the stand-alone system. The developed tool is able to run on any MS Windows-based computer, and its user interface is the same as any other Windows' applications. Standard graphics include buttons, check boxes, radio buttons, combo boxes, list boxes, horizontal and vertical scroll bars, sliders, etc., depending on the requirements. No database or server is needed as all of the aforementioned matrices are embedded in the tool. The tool consists of four separate files that need to reside in a unique folder on the computer in order for the tool to work properly. The impact of the tool on TxDOT's IT resources is minimal.

When the user first launches the screening tool, they see the screen illustrated in Figure 17. This screen introduces the user to the tool and provides a brief explanation as to the purpose of the tool. Once the user clicks the "Continue" button, the overlay window with the title disappears, and the tool is ready to use.

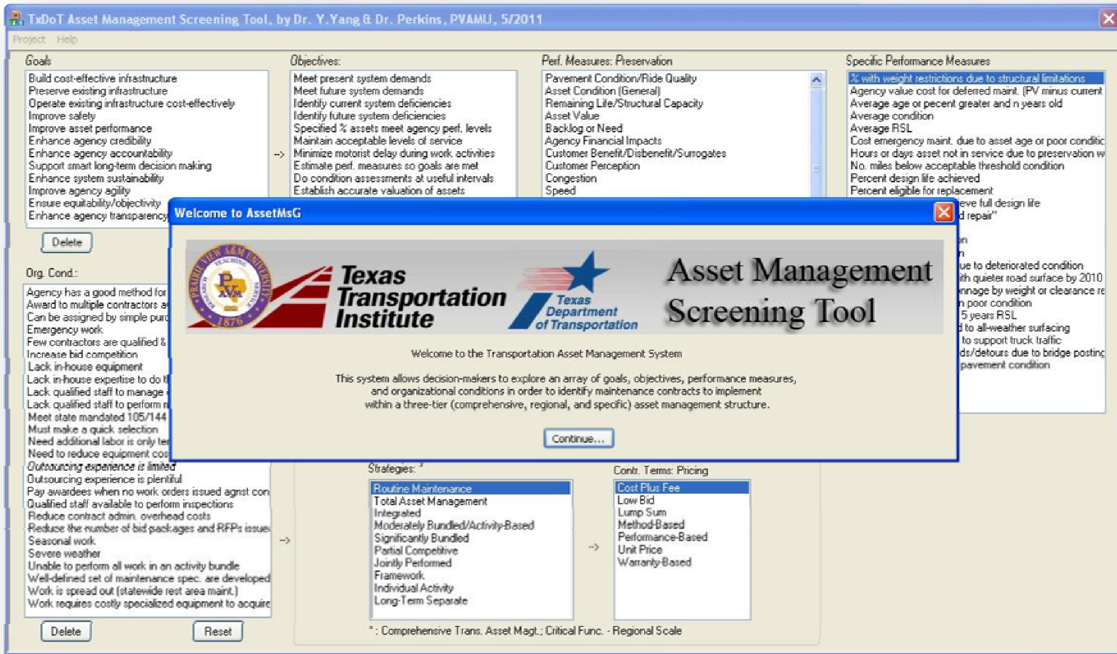


Figure 17. ***AssetMgt* Screening Tool Home Screen.**

Figure 18 displays the input screen for the screening tool. The user works through the steps of the tool from left to right along the top row of boxes and then along the bottom row.

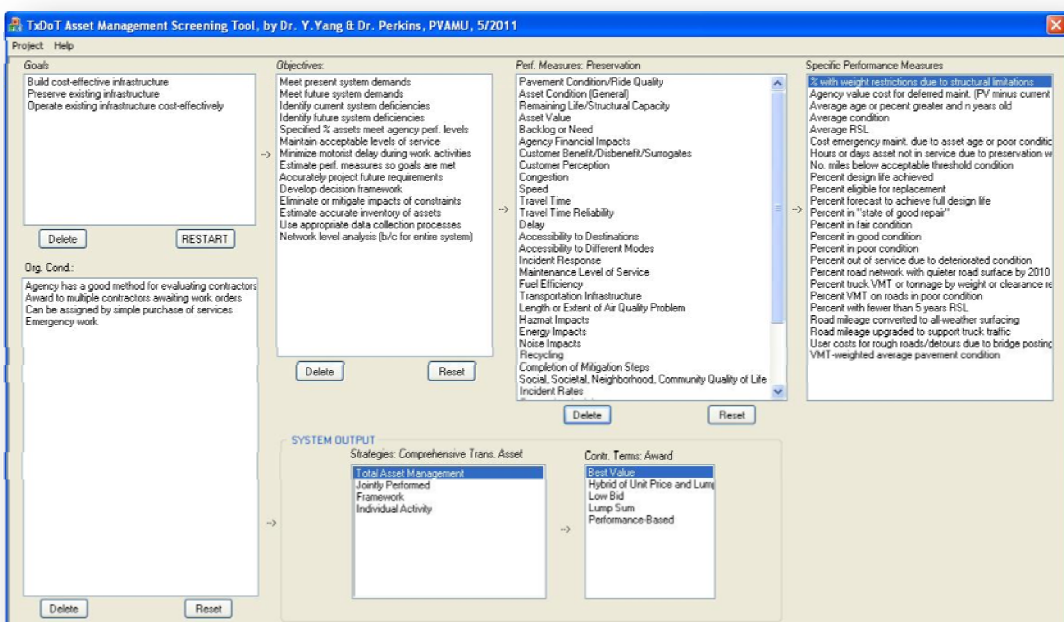


Figure 18. ***AssetMgt* Screening Tool Input Screen.**

The first box shows the potential list of goals for asset management. The default is that all of the goals are selected. To remove a goal from the list, the user highlights that goal and clicks the "Delete" button to eliminate it. If the user is unsatisfied with any changes made, they can click the "RESTART" button to reset the tool to the default setting. Figure 19 shows this initial input box.

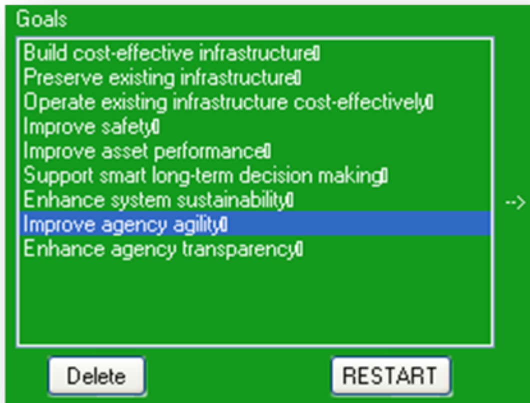


Figure 19. Goals Selection Box.

Once satisfied with the selections, the user moves to the right to address the objectives to ensure those provided are appropriate. For each set of objectives displayed, the user can delete any by highlighting it and clicking the "Delete" button. If the user is unsatisfied with any changes made, they can click the "RESTART" button to reset the tool to the original list. Figure 20 shows this objectives selection box.

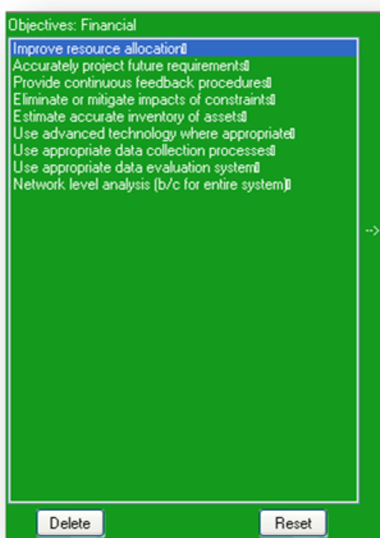


Figure 20. Objectives Selection Box.

As changes are made and refined in the goals and objectives boxes, the strategies box below displays appropriate strategies. The user also has the option to refine the performance measures box on the top row (as shown in Figure 21) as well as the organizational conditions on the bottom row (as shown in Figure 22). Once all of the selections are made, the strategies box shows the identified potential strategies and shows the specific contract terms for each strategy.

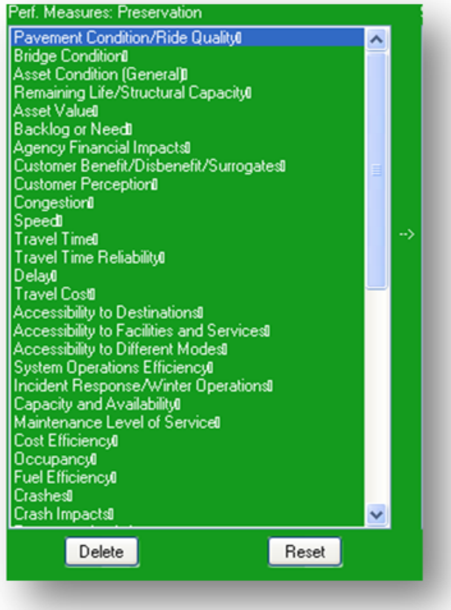


Figure 21. Performance Measures Selection Box.

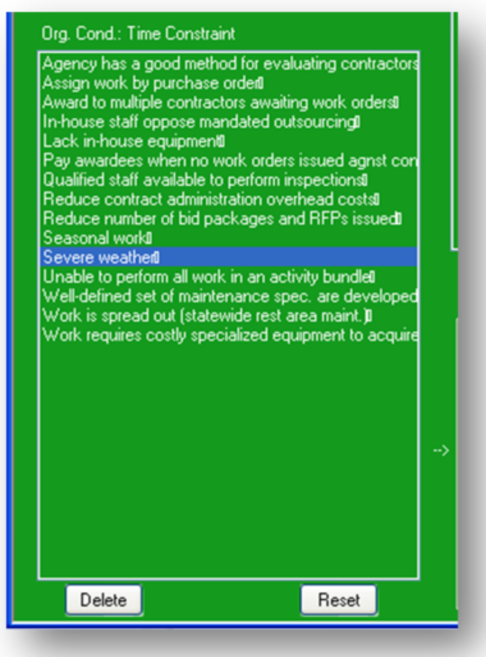


Figure 22. Organizational Conditions Selection Box.

The user can save the file by clicking on the “Project” link on the top left corner of the screen and follow the prompts to save the file. Once the user is finished with the analysis, he or she can also print out a report of the end results. Two output files are possible: Level 1 and Level 2. A Level 1 output, shown in Figure 23, shows an aggregated list of selections and outputs for the various components. This is a high-level report that provides general information on the goals, objectives, strategies, performance measures, organizational conditions, and contract terms. A Level 2 output, shown in

Figure 24, illustrates the specific selections for each option as the user moved through the tool. For example, the specific objectives selected for each goal are listed as a group rather than combined with all of the other objectives for all of the selected goals. These reports are saved in a text file and can be copied into any word processing software for enhancement and printing.

System Report
===
***** User's Inputs & Selections ******

1. All the Goals Selected
   Goal: Build a more cost-effective infrastructure
   Goal: Preserve existing infrastructure
   Goal: Operate existing infrastructure more cost-effectively
   Goal: Improve safety

2. All the Objectives Linked to the Goals
   Objective: Accurately project future requirements
   Objective: Develop decision framework
   Objective: Utilize appropriate data evaluation system
   Objective: Support network level analysis (b/c for entire system)
   Objective: Support project level analysis (specific to project)

3. All the Performance Measures Applicable
   Perf. Measure: Pavement Condition / Ride Quality
   Perf. Measure: Bridge Condition
   ....
   ....
   Perf. Measure: Customer Impact and Safety

4. Complete List of all Specific Performance Measures Applicable
   S. P. M.: Average condition
   S. P. M.: No. miles below acceptable threshold condition
   ....
   ....

   S. P. M.: Vehicle-miles of detour due to work zones

5. All the Organizational Conditions Selected
   Org. Condition: Work can be assigned by a simple purchase order
   Org. Condition: Work requires specialized equipment that is expensive to acquire
   Org. Condition: Severe weather
   Org. Condition: Seasonal work
   Org. Condition: Unable to perform all work in an activity bundle

***** System Output *****

6. All the Strategies Suggested.
   Strategy: Jointly Performed
   Strategy: Individual Activity
   Strategy: Long-Term Separate

7. All the Contract Terms Linked to Suggested Strategies
   Contract Term: Method-Based
   Contract Term: Performance-Based
   ....
   ....
   Contract Term: Low Bid Best Value

End of Report.

Figure 23. Level 1 Output.

```
System Report
==============================================================

***** User's Inputs & Selections ******

1. All the Goals Selected
   Goal: Build a more cost-effective infrastructure
       Obj.: Accurately project future requirements
       Obj.: Support project level analysis (specific to project)
   Goal: Preserve existing infrastructure
       Obj.: Utilize appropriate data evaluation system
       Obj.: Support project level analysis (specific to project)
   Goal: Operate existing infrastructure more cost-effectively
       Obj.: Utilize appropriate data evaluation system
       Obj.: Support network level analysis (b/c for entire system)
       Obj.: Support project level analysis (specific to project)
   Goal: Improve safety
       Obj.: Develop decision framework
       Obj.: Support project level analysis (specific to project)

2. All the Objectives Linked to the Goals
   Objective: Accurately project future requirements
       P. M: Pavement Condition / Ride Quality
       P. M: Bridge Condition
       ...............................
        ...............................
       P. M: Customer Impact and Safety
   Objective: Develop decision framework
       P. M: Backlog or Need
   Objective: Utilize appropriate data evaluation system
       P. M: Pavement Condition / Ride Quality
       P. M: Bridge Condition
       ...............................
       ...............................
       P. M: Customer Impact and Safety
..........................................................................................................................

***** System Output *****

6. All the Strategies Suggested.
   Strategy: Jointly Performed
       Contract Term: Method-Based
       Contract Term: Performance-Based
       Contract Term: Unit Price
       Contract Term: Lump Sum
       Contract Term: Cost Plus Fee
       Contract Term: Price and Lump Sum
       Contract Term: Low Bid Best Value
   Strategy: Individual Activity
       Contract Term: Method-Based
       Contract Term: Performance-Based
       Contract Term: Warranty-Based
       Contract Term: Unit Price
       Contract Term: Lump Sum
       Contract Term: Cost Plus Fee
       Contract Term: Price and Lump Sum
       Contract Term: Low Bid Best Value

End of Report.
```

Figure 24. Sample Level 2 Output.

CHAPTER 9: FINAL REMARKS

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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