CAMBRIDGE SYSTEMATICS

Massachusetts Asset Management Plan

final report

prepared for

Massachusetts Executive Office of Transportation and Public Works

prepared by

Cambridge Systematics, Inc.

with

Hyun-A Park

October 19, 2007

www.camsys.com

report

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1.0 Introduction

1.1 Background

The Commonwealth of Massachusetts faces a significant set of challenges with respect to determining what investments to make in its transportation system. The Commonwealth's transportation network is extensive and well-developed. The road network consists of 35,000 centerline miles of roads, and over 4,500 bridges. The Commonwealth's transportation assets, including its roads, bridges, and other elements of its transportation infrastructure, are in widely varying condition, and have a vast range of maintenance needs. The available funds for transportation are not sufficient for supporting all of the maintenance needs that have been identified for preserving and improving the transportation network. Thus, the Commonwealth emphasizes system preservation, and a carefully-chosen set of system enhancements to gain the greatest benefit from available funds. The Executive Office of Transportation and Public Works' (EOT) recently-drafted long-term transportation plan details the Commonwealth's objectives for its transportation system, the current state of the transportation system, and plans for the future.[1]

Transportation asset management provides a framework that enables the Commonwealth to manage its transportation network more effectively. To support the implementation of asset management, EOT and the Massachusetts Highway Department (MassHighway) have created an Asset Management Steering Committee. This Committee is charged with using transportation asset management to improve resource allocation in Massachusetts. **The first objective of this project is to develop a work plan that supports the activities of the Steering Committee as it moves forward.** The Asset Management Work Plan identifies critical issues that could impact the implementation of asset management practices for management of MassHighway-owned assets, and provides recommendations on specific steps that can be taken.

An area of particular concern for EOT/MassHighway is the management of assets on the interstate highway system (IHS), the most heavily used and visible component of Massachusetts' road network. **The second objective of this project is to develop an asset management plan for the Interstate System** that contributes to efficient and effective management of the Interstate. The Interstate Asset Management plan demonstrates the practical application of asset management techniques.

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[1] Executive Office of Transportation and Public Works, *Transportation in the Commonwealth of Massachusetts: A Framework for Thinking – A Plan for Action (Draft)*, March 2005.

1.2 APPROACH

The findings and recommendations presented in this report are based on a review of existing MassHighway resource materials and a series of interviews with over 20 individuals from EOT, MassHighway headquarters and the five MassHighway districts. Table 1.1 lists the interview participants. These interviews were used to explore stakeholder perceptions of existing practices and opportunities for improvement.

Table 1.1 Staff Interviewed for the Study

Staff	Title
Alex Bardow	Bridge Engineer
Mark Berger	Data Resource Manager
John Blundo	Former Chief Engineer
Neil Boudreau	Acting Traffic Engineer
Bonnie Polin	Chief Safety Analyst
Ross Dindio	District 1 Director
Mike Ecmecian	Pavement Management Engineer
John Gendall	Maintenance Engineer
Patricia Leavenworth	District 4 Director
Thomas Loughlin	Director of Highway Operations
Michelle Maffeo	Director, ITS Programs Unit
Bernard McCourt	District 5 Director
Ken Miller	Director of Asset Management (Former Deputy Secretary of Transportation Planning)
Charles Mistretta	Acting District 3 Director
Luisa Paiewonsky	Commissioner
Gregory Prendergast	Director of Environmental Section
Dave Rock	Deputy Director of Highway Operations
Jim Silveria	Chief Information Officer
Albert Stegemann	District 2 Director
Matt Turo	Pavement Management Engineer

Following this internal assessment, national guidance and relevant best practices by peer agencies in other states were reviewed. Combing the findings from the peer review with the gaps identified during the internal assessment, the project team then identified a set of recommended activities for improving implementation of asset management concepts in the Asset Management Work Plan. The asset management concepts and best practices described in the work plan were then applied to the IHS, resulting in the Interstate Asset Management Plan.

1.3 REPORT ORGANIZATION

The remainder of this report is organized as follows:

- Section 2, Asset Management Vision, provides background information on transportation asset management and establishes a vision for asset management implementation in Massachusetts.
- Section 3, State-of-the-Practice in Other States, documents examples by other agencies in three areas that are highly relevant to this study – asset management systems and data, maintenance management, and performance-based resource allocation.
- Section 4, Asset Management Work Plan, summarizes the findings of the internal assessment and presents a plan for improving asset management in Massachusetts.
- Section 5, Interstate Asset Management Plan, illustrates the application of asset management tools and techniques to the Interstate Highway System.

2.0 Asset Management Vision

Transportation asset management is a set of principles and practices for improving transportation resource allocation decisions. It requires a shift from a traditional tactical project management approach to a strategic, comprehensive systems management concept.

Asset management is concerned with the entire life cycle of transportation decisions, including planning, programming, construction, maintenance, and operations. It emphasizes integration across these functions, reinforcing the fact that actions taken across this life cycle are interrelated. It also recognizes that investments in transportation assets must be decided considering a broad set of objectives, including physical preservation, congestion relief, safety, security, economic productivity, and environmental stewardship.

2.1 Asset Management Principles

Across the U.S there is growing consensus on the following core principles of asset management:

- **Policy-Driven –** Resource allocation decisions are based on a well-defined and explicitly stated set of policy goals and objectives. These objectives reflect desired system condition, level of service, and safety provided to customers, and typically are tied to economic, community and environmental goals as well;
- **Performance-Based –** Policy objectives are translated into system performance measures that are used for both day-to-day and strategic management;
- **Analysis of Options and Tradeoffs –** Decisions on how to allocate resources within and across different types of investments (e.g., preventive maintenance, rehabilitation, pavements, bridges, capacity expansion, operations, different modal mixes, safety, etc.) are based on an analysis of how different allocations will impact achievement of relevant policy objectives. Alternative methods for achieving a desired set of objectives are examined and evaluated. These options are not constrained by established organizational unit boundaries – for example solving a congestion problem could involve a capacity expansion or an operational improvement (e.g., signal coordination). The best method is selected considering the cost (both initial and long-term) and likely impacts on established performance measures. The limitations posed by realistic funding constraints must be reflected in the range of options and tradeoffs considered;
- **Decisions Based on Quality Information –** The merits of different options with respect to an agency's policy goals are evaluated using credible and

current data. These data may apply to specific functions (e.g., pavement and bridge management, traffic monitoring) or reflect a more integrated, corporate view.[2] Where appropriate, decision support tools are used to provide easy access to needed information, to assist with performance tracking and predictions, and to perform specialized analysis (e.g., optimization, real-time simulation, scenario analysis, life-cycle cost analysis, benefit/cost analysis); and

- **Monitoring to Provide Clear Accountability and Feedback –** Performance results are monitored and reported for both impacts and effectiveness. Feedback on actual performance may influence agency goals and objectives, as well as resource allocation and utilization decisions.

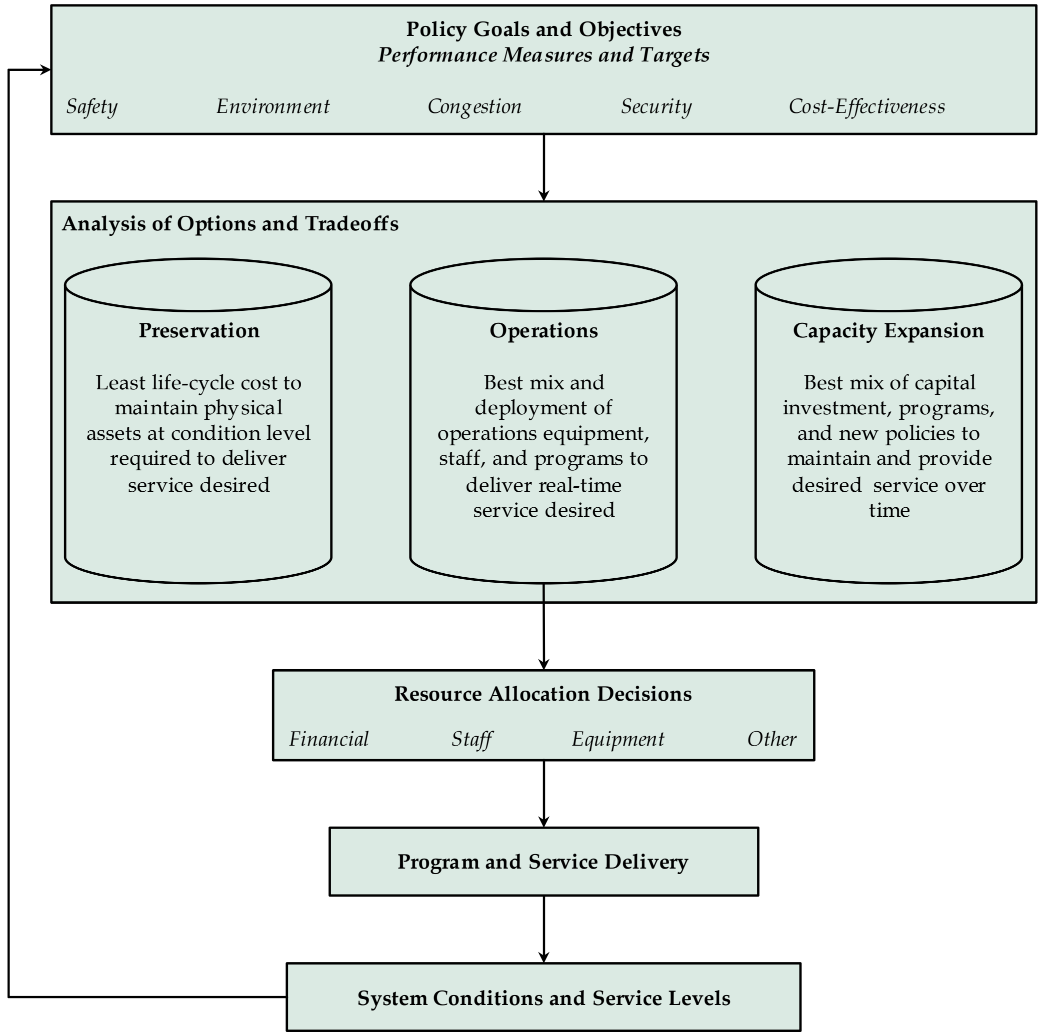
These principles are not unfamiliar, nor are they radical. Most transportation practitioners would agree that investment decisions should be based on weighing costs against likely outcomes, that a variety of options should be considered and evaluated, and that quality information is needed for decision-making. Many agencies are now pursuing performance-based approaches to planning and programming, monitoring system performance, and developing more integrated data and analysis tools to evaluate tradeoffs among capital expansion, operations, and preservation activities. Most agencies recognize that application of asset management principles is critical in times of constrained resources, when all investment and budget decisions are subject to increased public scrutiny.

2.2 ASSET MANAGEMENT PRACTICE

Figure 2.1 illustrates the strategic resource allocation process that embodies the asset management principles presented above.

[2] The FHWA plays a key role in standardizing the content and format of data that are mandated by federal law: e.g., through establishing the Highway Performance Monitoring System (HPMS) and National Bridge Inventory (NBI) data that are reported by state DOTs.

Figure 2.1 Strategic Resource Allocation Process



The diagram includes the following elements:

- **Policy Goals and Objectives,** supported by performance measures are established through the policy and system planning process and used to guide the overall resource allocation process.
- **Analysis of Options and Tradeoffs** includes examination of options *within* each investment area, as well as tradeoffs *across* different investment areas. The definition of investment areas is flexible and can be tailored to how an individual agency does business. For example, an agency may have a separate safety investment area and also incorporate consideration of safety within system preservation, operations, and capacity expansion expenditures. Each option and tradeoff is evaluated with respect to established agency goals and performance objectives.

- **Resource Allocation Decisions** are based on the results of tradeoff analyses These decisions involve allocations of financial, staff, equipment, and other resources to the different investment areas and/or to different strategies, programs, projects, or asset classes within an individual investment area.
- **Program and Service Delivery** is accomplished in the most cost-effective manner which again involves consideration of different delivery options (e.g., use of contractors, interagency agreements), as well as a delivery tracking process involving recording of actions taken, costs, effectiveness, and lessons learned to guide future activity.
- **System Conditions and Service Levels** are tracked to see the extent to which established performance objectives are being addressed. This information is used to refine policy goals and priorities (e.g., put more emphasis on safety in response to an increase in crash rates).

A common reaction to the broad description of asset management is "how is this different from the overall planning and programming process in an agency?" The response is that asset management is not a new kind of business process that replaces planning and programming. Rather, it should be viewed as a set of best practices to be employed within the established planning and programming framework. In addition to planning and programming, asset management principles can also be applied to design, construction, routine and preventive maintenance and operations activities. For example:

- Application of life-cycle cost analysis in the facility design process;
- Analysis of alternative construction materials and methods;
- Tradeoffs across different maintenance activities based on level of service and extended facility life provided to customers;
- Developing an appropriate mix of operations expenditures on technology upgrades, hardware/infrastructure maintenance and replacement, and skilled personnel;
- Evaluation of delivery options (e.g., design-build, use of private contractors for maintenance and operations, inter-agency agreements, etc.).

2.3 Vision of Asset Management in Massachusetts

Asset Management Vision Statement

The vision for transportation asset management in Massachusetts is consistent with definition recently adopted by the American Association of State Highway and Transportation Officials (AASHTO):

Asset management is a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their lifecycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based upon quality information and well defined objectives.

Asset Management Goals

The goal of asset management in Massachusetts is to make the best possible use of available transportation funding, in support of the Commonwealth's objectives:

- Focus primarily on preservation;
- Increase average pavement condition;
- Reduce number of bridges in poor condition; and
- Minimize impact of asset conditions on congestion.

Benefits of Asset Management

Developing a comprehensive transportation asset management system in Massachusetts will lead to the following benefits:

- Lower long-term preservation costs;
- Improved service to customers;
- Improved cost effectiveness;
- Improved communication with elected officials and the public; and
- Improved credibility and accountability for decision making.

3.0 State-of-the-Practice in Asset Management

This section summarizes the state-of-the-practice in other agencies in three areas relevant to the EOT and MassHighway's efforts - asset management systems and data, maintenance management, and performance-based resource allocation. Recent research sponsored by the Federal Highway Administration (FHWA) and AASHTO through the National Cooperative Highway Research Program (NCHRP) has resulted in a number of publications that are highly relevant to efforts in Massachusetts. This section presents a synthesis of these national research efforts. For more detailed information on a particular topic, refer directly to the cited publications. Examples of best practices by other transportation agencies in each area are also provided.

Asset Management Systems and Data

National Guidance

The AASHTO *Transportation Asset Management Guide* identifies the data requirements for a comprehensive asset management program. The fundamental data elements include[3]:

- Asset inventory – for what assets is an agency responsible?
- Current condition and performance – what condition is it in?
- Cost data – how much money is spent?
- Program delivery information – what projects have been completed?

The guide also documents the following system requirements that rely on the information described above:

- Summarize asset condition and performance based on raw condition data;
- Project future asset condition and performance;
- Provide cost estimates for key activities;
- Identify needs and recommend work;

[3] Cambridge Systematics Inc., Parsons Brinkerhoff Quade & Douglas, Inc., Roy Jorgenson Associates, Inc., and Paul D. Thompson, *Transportation Asset Management Guide,* AASHTO, November 2002.

- Evaluate the impact of proposed projects on system condition and performance; and
- Track program delivery information and incorporate it into the above analysis.

The FHWA is currently developing a guide that provides more detailed guidance on collecting data for a wide variety of transportation assets in support of an asset management program. The guide defines core data requirements for pavements, roadside features, drainage structures, traffic control devices, structures and bridges, and special facilities (e.g., rest areas and tunnels). It also presents an approach for prioritizing which assets should be included in the data collection effort. The approach focuses on the following questions:[4]

- Are there established data collection protocols for the asset? If so, are they used?
- What is the relative quantity and value of the asset compared to the entire asset population?
- What is the importance of the asset to the agency and to the traveling public?
- How easy is it to collect data for the asset?
- Can automated tools be used for data collection?
- How frequently should the data be collected?
- How important is the accuracy of the data for the asset?

Another important aspect of asset management systems and data is data integration. A recent study sponsored by the FHWA Office of Asset Management Reviewed the data integration practices of 27 transportation agencies.[5] The study report finds that asset management is a priority for many of these agencies, but it is not always the primary motivating force for integrating transportation data. However, it is generally understood that data integration is an essential requirement for asset management.

Most of the agencies reviewed are dealing with multiple data sets stored in isolated mainframe flat files, redundant data, stovepipe management systems, and functional area barriers. Most recognized a need for data integration in the

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[4] Bryant, J.W., Larson, C.D., *Asset Management Data Collection Guide*, edited version: final draft document.

5 Cambridge Systematics Inc., *Review of Data Integration Practices and their Applications to Transportation Asset Management,* final report, Federal Highway Administration, July 2003.

mid to late 1990s, and some have developed Geographic Information System (GIS) Strategic Plans. Others do not have formal GIS plans but are using GIS to integrate spatial data with business data. The availability and widespread use of GIS has significantly advanced opportunities for data integration.

The report also found that transportation agencies generally choose their integrated data architecture based on the following considerations:

- Phased implementation can be the most practical approach to data integration. Manageable increments with well-defined products enable an agency to minimize technical risks and quickly illustrate practical benefits;
- The architecture should be open and flexible enough to accommodate both changing data requirements and future technologies. Several agencies have found that adherence to Federal guidance and industry protocols have provided this flexibility; and
- The approach to system development should strike a balance between the realization of strategic objectives, the ability to develop practical applications, and the resources required for future maintenance and operations of the system.

Finally, the report provides some guidance on the make vs. buy decision. In most data integration efforts, a key decision appears to be whether to develop an application from scratch or to purchase an off-the-shelf product. Given the broad range of asset management activities in a state department of transportation (DOT), it is difficult for any one product to provide a comprehensive solution. Typically, a mix of off-the-shelf and custom applications are used.

State Experience

The first building block of a comprehensive asset management system is inventory and condition data. State-of-the-art pavement, bridge, and maintenance management systems often provide inventory management functionality. However, several systems have been developed that extend the functionality of these management systems. These inventory management systems are used for ad-hoc reporting and for performing geo-spatial queries and analyses that are helpful for supporting asset management decisions. Because they do not have the advanced predictive functionality of a complete management system, inventory management systems do not represent comprehensive asset management solutions. However, they are a core component of one. An example of an inventory management system is Exor Highways. This tool helps agencies manage data on a variety of assets, provides widespread access to the information via ad-hoc queries and/or a web-based interface, and displays spatially referenced data with a mapping interface.

The next building block is analysis capability. State DOT's often use a mixture of management systems and analytical tools that support their asset management efforts. Management systems have inventory and condition data for a particular asset, and provide functionality for analyzing needs and predicting future costs and conditions. Massachusetts' pavement management system (PMS) and bridge management system (BMS) represent the state-of-the-art in terms of management systems. Many states augment the capabilities of their management systems with analytical tools designed to provide a specific analytic function. For example, a number of agencies use specialized tools for benefit/cost analysis, life-cycle cost analysis and investment performance analysis.

A third component and final component of an asset management system is the integration of data and results from multiple systems. One approach is to develop a central data repository. Decision makers, management systems, and analytical tools can then import data from a single location, perform additional analysis, and export results back to the repository for use by other users and systems. One example of this approach is the Alaska Department of Transportation and Public Facilities' geodatabase. This geodatabase will store location and attribute data for the following features:

- Bridges;
- Culverts;
- Guardrails;
- Maintenance facilities;
- Paved shoulders;
- Rest areas;
- Rumble strips;
- Turn outs; and
- Signs.

It also will integrate with the agency's maintenance management system (MMS), BMS, statewide transportation improvement plan (STIP) database, statewide GIS, and the Highway Analysis System (HAS). HAS contains road network data, highway features, and other transportation data such as traffic counts, vehicle crashes, and pavement conditions. As illustrated in Figure 3.1, the user will access the data though a GIS interface designed to support the agency's asset management functions.[6] For example, users will be able to record maintenance activities by selecting a feature and entering an offset. The geodatabase will then assign an appropriate route and milepost and store the information.

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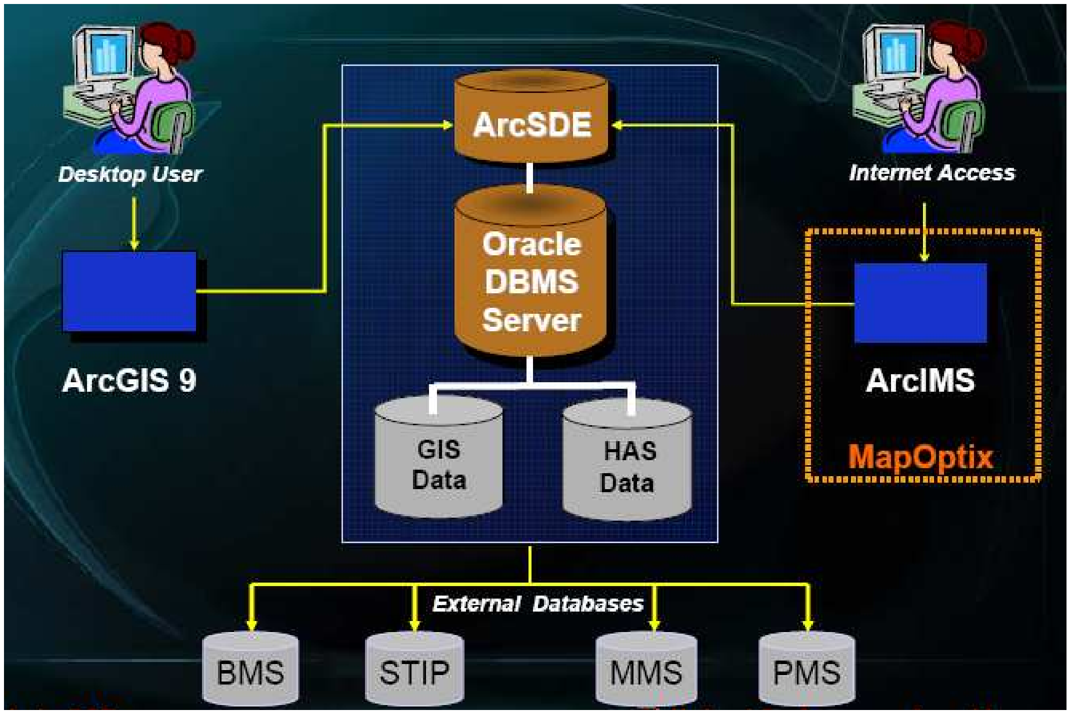
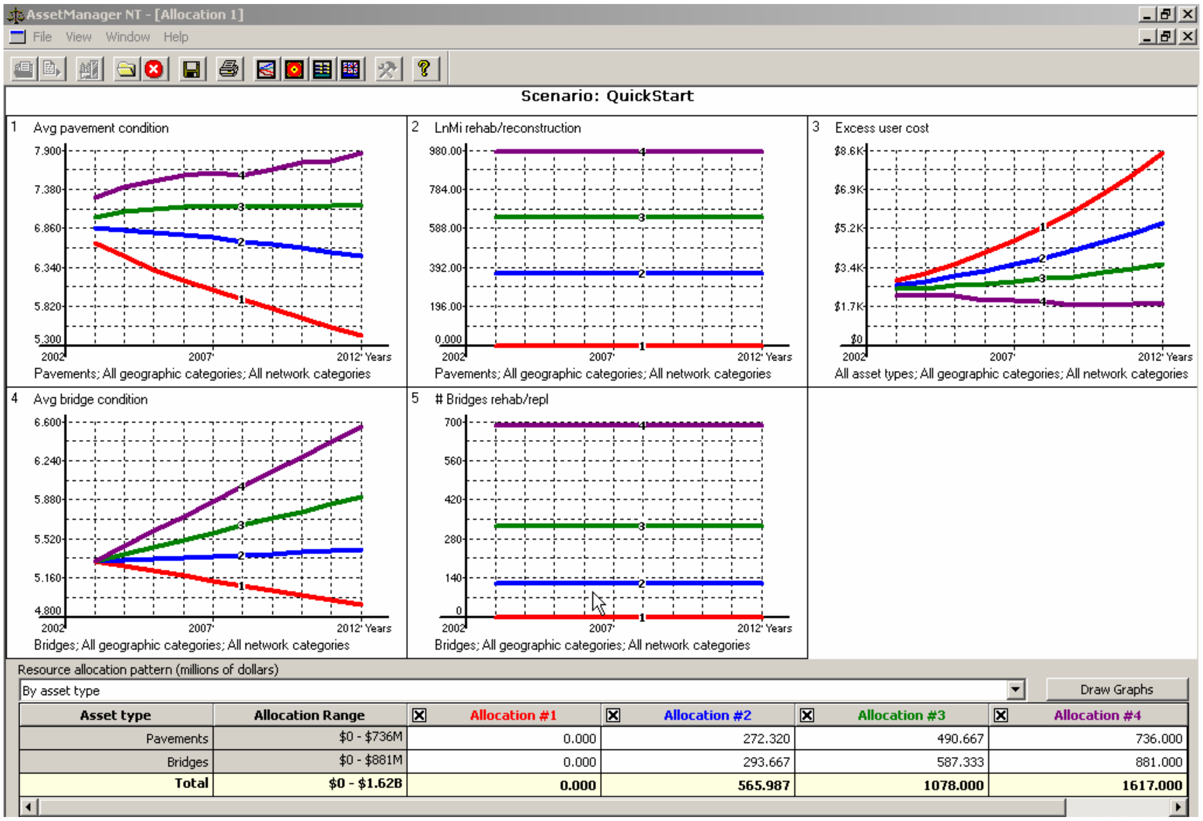
[6] Stickel, J., "Location Referencing for an Asset Management System – A State DOT Approach", presented at the 6th national Conference on Transportation Asset Management, November 2005.

Figure 3.1 Alaska Geodatabase Architecture



Another option for integrating results from various management systems is to pull them into a network level tradeoff tool. AASHTO's AssetManager NT is one example of this type of tool. This system was developed as part of NCHRP 20-57, Analytical Tools to Support Asset Management. AssetManager NT is a visualization tool that allows agencies to explore the performance implications of varying resource allocations – across different asset types and across different portions of the transportation system. The system brings together analysis results from existing management systems and provides "what-if" analysis tool for testing different investment options. Figure 3.2 presents a sample screen shot from AssetManager NT. Each graph shows a different condition measure over time for the four allocation scenarios defined at the bottom of the screen. Using this screen, users can analyze future pavement and bridge performance simultaneously. The District of Columbia, Idaho, Kansas, Michigan, New York, Oregon, Pennsylvania, South Carolina, Vermont, and Wisconsin DOT's are now working to implement this system.

Figure 3.2 AssetManagerNT Example



Maintenance Management

National Guidance

AASHTO recently published guidelines for comprehensive maintenance management systems.[7] The guide finds that there is considerable variation between state DOTs on the functionality of their MMS. It identifies the components of a comprehensive MMS that agencies should consider in terms of their approach to maintenance management and their operating environment. These components are summarized in Table 3.1.

[7] AASHTO, *Guidelines for Maintenance Management Systems*, 2005.

Table 3.1 MMS Models and Elements

Maintenance Function	Data and Information Needs
Planning	Asset inventory Maintenance activity guidelines Customer input Performance targets Condition assessment
Programming and budgeting	Performance-based budget analysis based on levels of service Annual work program Annual budget
Resource management	Resource needs analysis Staffing allocation Equipment management Private contracting
Scheduling	Work needs identification Customer service program Short-term work scheduling
Monitoring and evaluation	Performance measures Work reporting Management analysis
Maintenance support and administration	Permit processing and tracking Adopt-a-highway program Risk management Stockpile management

Guidance on one component of this overall framework (the programming and budgeting piece) were originally developed through NCHRP Project 14-12. This research effort introduced the concept of maintenance quality assurance as "planned and systematic actions needed to provide adequate confidence that highway facilities meet specified requirements. Such requirements are usually defined by the highway agency but are intended to reflect the needs and expectations of the user."[8] While the NCHRP project report reviewed a number of management practices that support this objective, the QA approach that it developed centers on the concept of maintenance "levels of service," or LOS. A QA approach based on LOS can accomplish a number of purposes:

- To determine the LOS expectations the traveling public supports and is willing to pay for;
- To communicate to the public how the agency is meeting these expectations;
- To seek levels of funding needed to achieve the desired LOS;
- To develop a "priority strategy" to focus on key maintenance activities when funding is less than requested; and
- To achieve a more uniform LOS throughout the agency (for highways of a particular class and traffic usage) by identifying locations of excessively high or low maintenance.

State Experience

States DOTs use a number of different tools to support their maintenance management functions. Maintenance management systems can generally be organized into the following five categories:

- **Legacy highway maintenance management systems**. Several states use MMS that were developed in the 1970s and 80s. These systems are often mainframe or client/server systems that field crews use to enter labor, equipment and materials usage by activity type. These systems enable maintenance managers to develop maintenance budgets and plans based largely on what work was accomplished in previous years. In the legacy systems, the inventory data are either non-existent or very rudimentary. As these legacy systems have been upgraded, many have evolved into inventory-based systems, as described below.
- **Inventory-based highway maintenance management systems.** These systems provide many of the features of the legacy systems described above, and add more sophisticated approaches for tracking inventory data. A number of commercially-available asset management systems fall in this category, including AgileAssets' Maintenance Manager, Infor's (formerly Hansen) Asset Management Suite, CartêGraph's Management Suite, Exor's Highways Suite, and the Maintenance Activity Tracking System (MATS) jointly developed by the Maine DOT, New Hampshire DOT.

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[8] M.L. Stivers, K.L. Smith, T.E. Hoerner, and A.R. Romine, *Maintenance QA Program Implementation Manual*, NCHRP Report 422, National Academy Press, Washington, D.C., 1999.

The Maintenance Activity Tracking System (MATS) is an example of an inventory-based management system. MATS was jointly developed by the Maine DOT, New Hampshire DOT and Vermont Agency of Transportation. One of the benefits of including inventory data in an MMS is that work crews can tie their time, materials, and equipment usage to specific highway features. This enables maintenance managers to investigate the work history for a specific asset and to locate highway segments with abnormally high maintenance costs. Another benefit of having inventory data available is that it can be used as the basis for maintenance budgets. For example, Table 3.2 summarizes the inventory information stored by VTrans in MATS. According to the table, VTrans owned nearly 65,000 traffic signs in 2002. If the policy was to replace these signs on a ten year cycle, VTrans' maintenance budget would need to include the resources required to replace 6,500 signs each year. Since MATS is also capable of calculating unit costs, VTrans could use the system to explore the implications of different replacement cycles. This type of analysis could be expanded to each of the items in Table 3.2.

Table 3.2 Summary Inventory Data from MATS

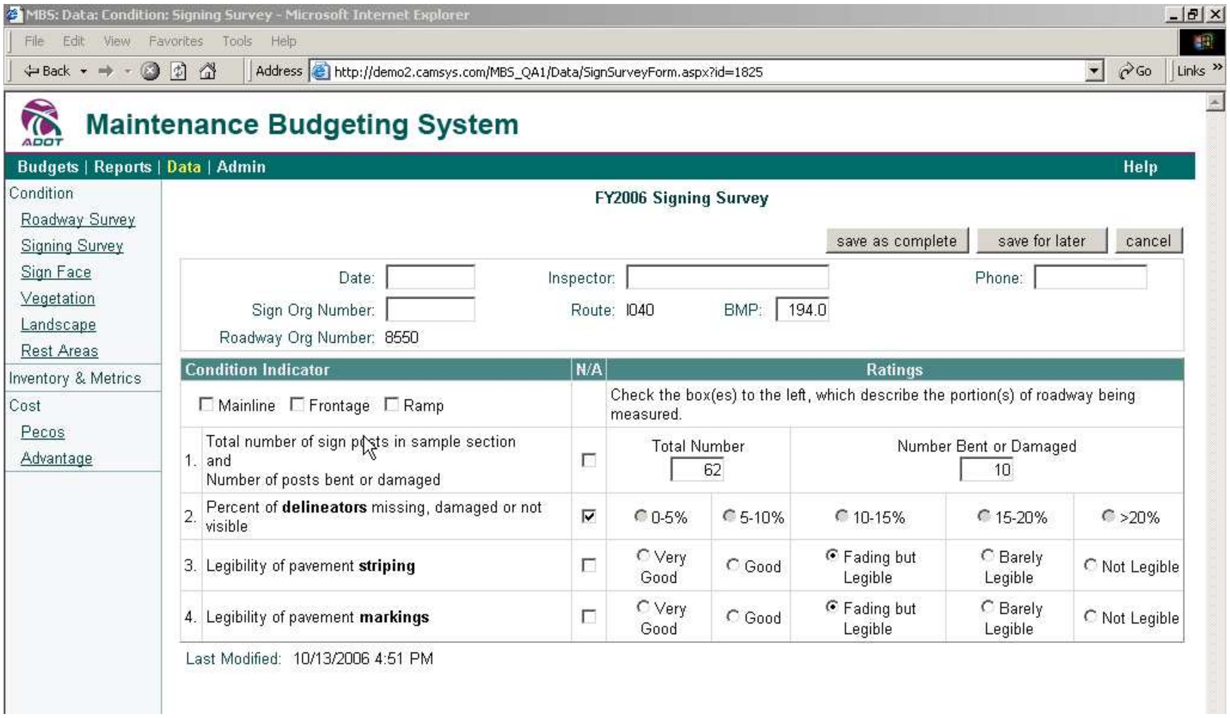
Item	Unit of Measure	Quantity
Traffic Signs	Each	64,873
Travel Directional Signs	Each	404
Paved Shoulders	Mile	4,329
Gravel Shoulders	Mile	3,075
Signals	Each	235
Fence	Mile	1,314
Snow Fence	Linear Foot	53,590
Roadway Lights	Each	981
Delineators/Mile Marker Plaques	Each	64,077
Guardrail	Linear Foot	5,608,792
Ditches	Mile	3,228
Culverts	Each	40,192
Mowable Roadside Area	Acre	11,172

Source: VTrans Maintenance and Aviation Division, November 2002.

- **Non-transportation work management systems.** Many large private sector firms that are responsible for some type of asset maintenance use work order systems to plan, schedule and track maintenance activities. One example of this type of system is IBM's (formerly MRO) Maximo. Work orders can be generated by Maximo automatically based on preventive maintenance schedules, or specified by maintenance mangers based on local knowledge. Information associated with work orders can include location, date, activity, personnel, materials and equipment usage (both planned and actual). Although these systems are not designed specifically to support the public transportation sector, they can be used by transportation agencies wishing to track maintenance work orders.

- **Enterprise resource planning (ERP) systems.** ERP systems are enterprise-oriented products that offer a suite of integrated modules covering financial and operations management. A common ERP system is SAP. SAP has several financial modules including General Ledger, Payables and Receivables, Controlling (budgeting), and Asset Accounting. Its also includes four modules that may be applicable to the maintenance management function: Plant Maintenance, Service Management, Materials Management and the Project System. A cross-application timesheet module (CAT) is also available through SAP, which interfaces to the financial, logistics, and human resource families of products. In addition, a business information warehouse product provides data warehouse capabilities, allowing linkages between SAP and external data. While a number of state DOT's, including Pennsylvania, Idaho and Colorado are now implementing ERP systems, there is not yet a track record of SAP use to support the maintenance management function in a DOT.
- **Performance-based budgeting systems.** Building off NCHRP Report 422 described above, several state DOTs are working towards the development of performance-based maintenance budgets. This approach requires agencies to conduct physical inspections on a sample of the network and model the relationship between expenditures and resulting condition. The analytical functionality required to support this type of budgeting is not widely available in the types of systems described above. Therefore, agencies pursing this approach often develop standalone tools that draw information from their MMS. For example, the Arizona DOT inspects roughly 350, ½-mile segments of highway each year. Figure 3.3 illustrates the traffic component of this survey. The survey also includes a highway and roadside component. Results are entered into the Maintenance Budget System (MBS) and translated to a level-of-service (LOS) scale. The LOS scale is based on letter grades – from A+ to F-. ADOT then uses the MBS to summarize current conditions, explore tradeoffs between maintenance categories (e.g., roadside vs. traffic features), develop a maintenance budget request, and set target LOS values based on this budget.

Figure 3.3 Arizona DOT Maintenance Budget System



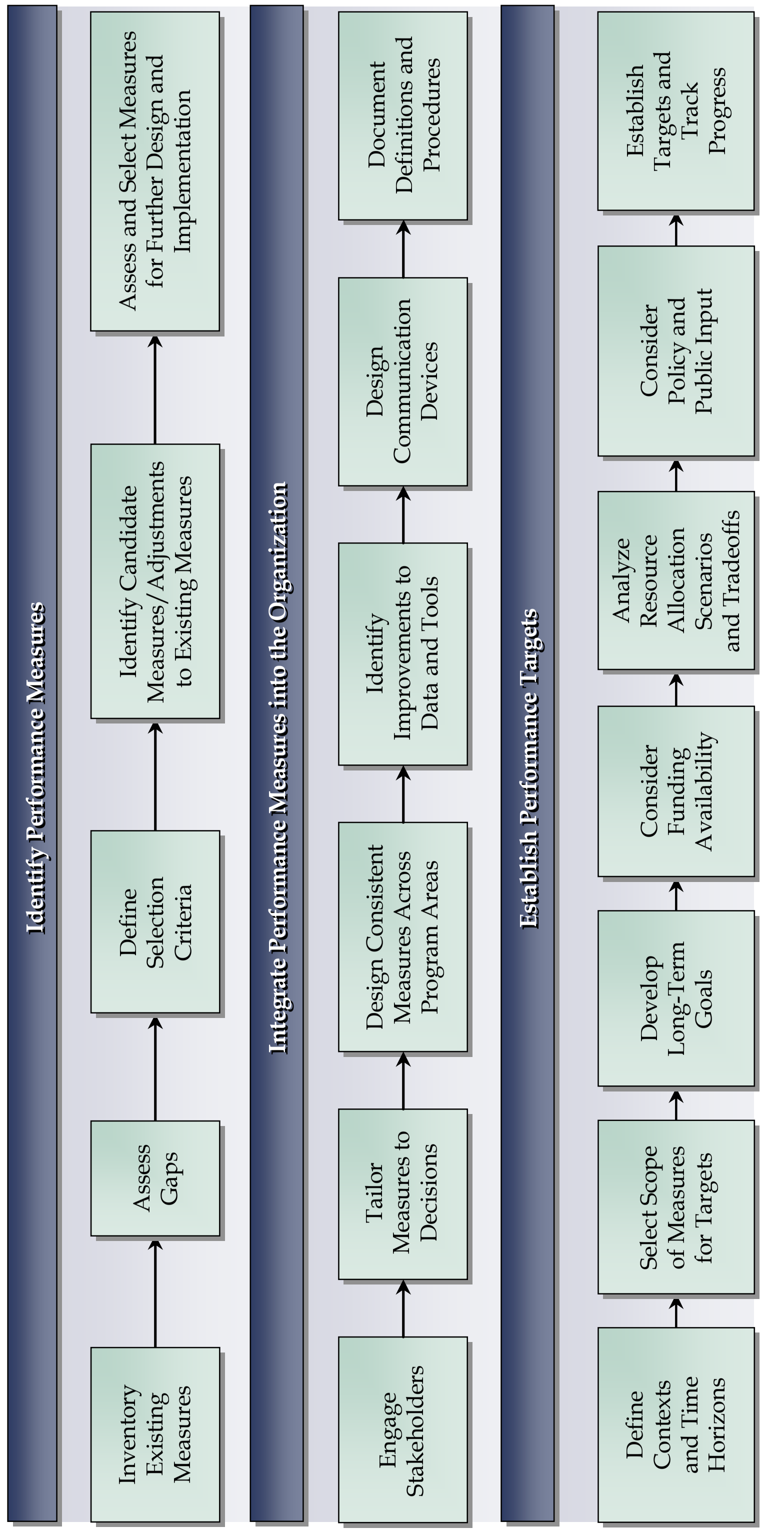
Performance-Based Resource Allocation

National Guidance

At the heart of asset management is a performance-based approach to making decision on how best to allocate resources. The basic building blocks of a performance-based approach are performance measures and targets. NCHRP recently published a guide on performance measures and targets for asset management. The report presents a framework for identifying performance measures that best suite an agencies asset management efforts, integrating the measures into the organization and establishing appropriate performance targets. This framework is illustrated in Figure 3.4.[9] The guide presents detailed guidance on each step in the process.

[9] Cambridge Systematics Inc., PB Consult Inc., and Texas Transportation Institute, *Performance Measures and Targets for Transportation Asset Management*, NCHRP Report 551, National Academy Press, Washington, D.C., 2006.

Figure 3.4 Guidance for Performance Measure and Targets



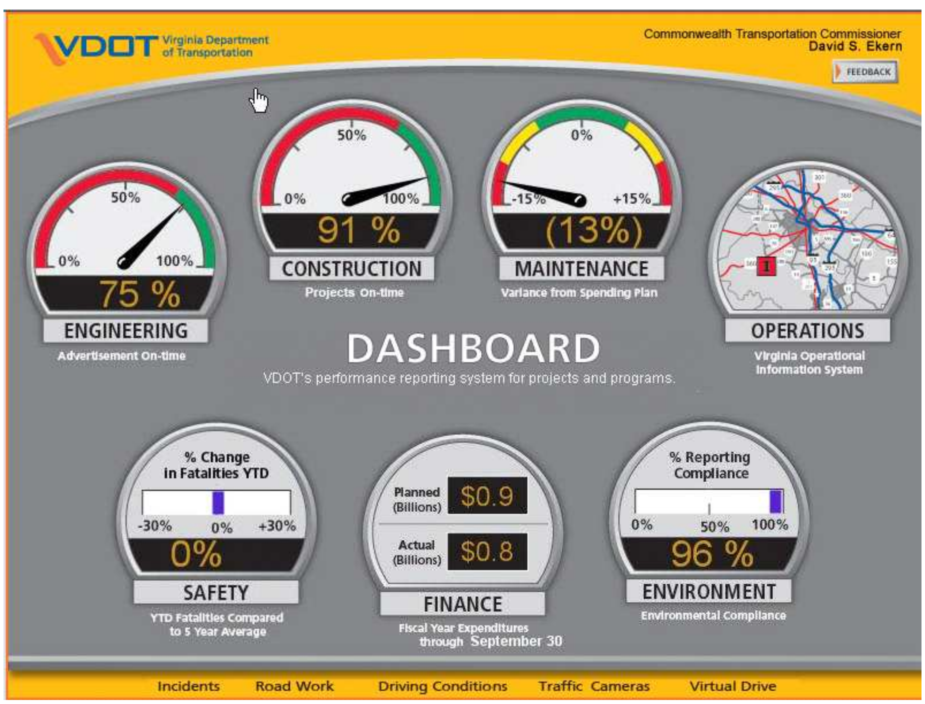
State Experience

During interviews conducted as part of a recent domestic scan on best practices in transportation asset management, the Minnesota DOT described their organization of performance measurement in the following three phases:

- Institutional phase – determining what to measure, selecting measures, and getting buy-in from agency staff on the measures and the process.
- Data phase – collecting data, improving data quality, developing data repositories, and communicating results.
- Decision-support phase – using performance measure results to drive business decisions.

Several agencies are currently focused on the first two phases. For example, the Virginia DOT has established measures in several key functional areas and makes the results available through an on-line dashboard.[10] This dashboard, illustrated in Figure 3.5 provides a snapshot of current performance, indicates the degree to which current performance varies from target values using a green, yellow, and red scale, and enables users to drill down for further details. For example, users can click on the construction gauge and view detailed cost and scheduled information for individual construction projects.

Figure 3.5 Virginia DOT Dashboard



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[10] http://dashboard.virginiadot.org/default.aspx.

Figure 3.6 illustrates another dashboard approach used by the Minnesota DOT. Similar to the Virginia dashboard, current performance is categorized using a green, yellow, and red scale. In addition, smaller arrows indicate trend information. For example, the up arrow next to "Bridges in Poor Condition" indicates that this measure has improved since the previous reporting period.

Fewer agencies have fully evolved to the third phase of performance management – the use of measures to drive decisions. However, several are actively working to get there, such as the Ohio DOT. In 1999 the Ohio DOT implemented a new needs-based approach for allocating funds to its districts. In this case, "needs" were driven by existing system conditions. This new process replaced an approach that was based on what the districts had received in the past. The new process required the following steps:

- Collect existing pavement and bridge conditions;
- Calculate current expenditures for bridges and pavements by district;
- Reallocate between districts and between the pavement and bridge program based on these condition and expenditure data;
- Establish policies and set performance targets at headquarters, but give the districts flexibility to select projects to meet these goals;
- Track results and meet quarterly to discuss and make adjustments.

Figures 3.6 and 3.7 illustrate the results of this new approach.[11] First, there was dramatic improvement in pavement and bridge condition over the course of eight years. Secondly, conditions were much more consistent across districts in 2005. For example, in 1997 the percent of pavement with a pavement condition rating (PCR) less than 65 (their threshold for poor condition) ranged from over 50% to less than 5%, where PCR is measured on a scale of 0 to 100 with 100 representing the best possible condition. In 2005, all districts were below 10%.

[11] Proctor, G. "Asset Management from Strategy to Reality – The Experience of the Ohio Department of Transportation", presentation to the NCHRP 20-68 Domestic Scan on Best Practices in Transportation Asset Management, August 2006.

Figure 3.6 Minnesota DOT Performance Dashboard

Revised
Feb 27, 2006

DEPARTMENT RESULTS

Minnesota Department of Transportation

DATA TREND FROM 3 YRS AGO
STATUS
DEPARTMENT RESULTS SCORECARD

↑ Trend – Improved results
→ Trend – No significant change
↓ Trend - Poorer results

SAFEGUARD WHAT EXISTS

- ↓ **Pavement Condition – Customer Ride Quality –** Principal Arterials [2005]
  Future: Mixed. Both % Good and % Poor projected to increase to 2008. Non-PA also worse.
- ↑ **Bridges in Poor Condition –** Structurally deficient, on Principal Arterials [2005]
  Future: Stable or slight improvement to 2010 based on scheduled construction program.
- ↓ **Snow and Ice Removal –** Annual average hours to bare lanes [2004-05 winter]
- ↑ **Customer Satisfaction with Mn/DOT Maintenance of Roadways** [2006]
- ↓ **Clearance Time for Urban Freeway Incidents** [2005]
  Future: Long-term trend continues worse

MAKE THE TRANSPORTATION NETWORK OPERATE BETTER

- ↓ **Twin Cities Urban Freeway System Congestion –**
  % of miles congested during weekday peak periods [2005]
  Future: Potential small improvement in 2006 if projects completed by October.
- ↑ **Interregional Corridors Miles Meeting Speed Targets** [2003]
  Future: Projected to improve 2007-14 based on scheduled construction program
- ↑ **Bond-Accelerated Construction Projects Put Out for Bid on Schedule** [Feb 2006]
  Future: Expect to continue on schedule
- ↑ **Fatalities – All State and Local Roads** [2005]
- ↑ **Miles of New Bus-Shoulders Established in the Twin Cities Area** [2005]
  Future: Reduced funding and reduced new miles to 2009. Transition to preservation.
- ↑ **Greater Minnesota Bus Service Hours** [2004]
  Future: Projected to remain flat through 2006, then increase 2007 and 2008

MAKE Mn/DOT WORK BETTER

- ↑ **Construction Projects Put Out for Bid on Schedule –** 1st year STIP [2005]
- ↑ **E-Gov't Services –** Percent of desired services delivered electronically [2005] *[updated measure]*

MEASUREMENT GUIDE
GOOD SATISFACTORY POOR

2-Dept Results Scorecard PRINT 2-27-06.doc

Figure 3.7 Ohio DOT Pavement Conditions

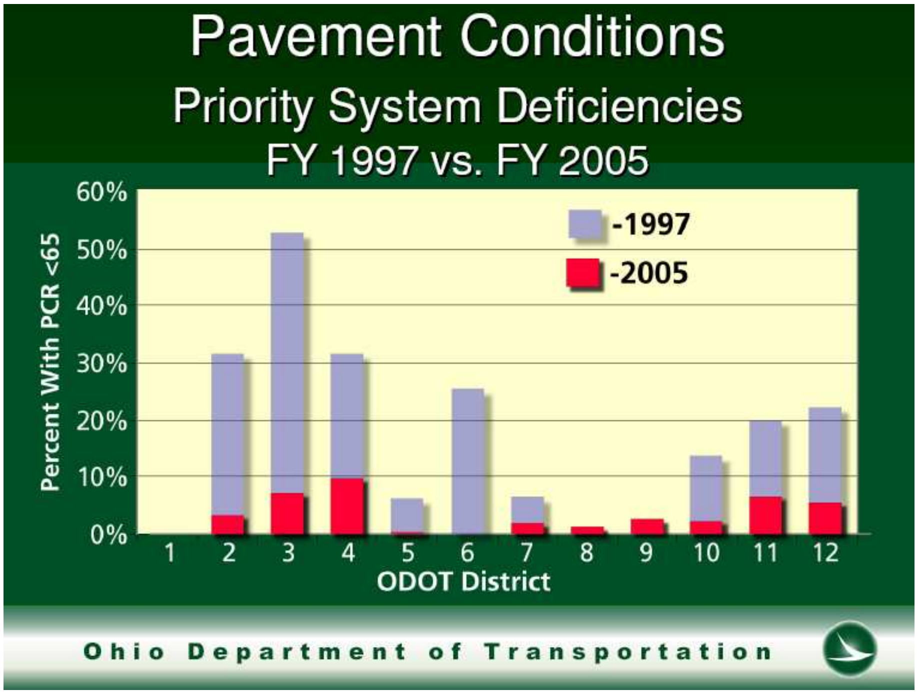
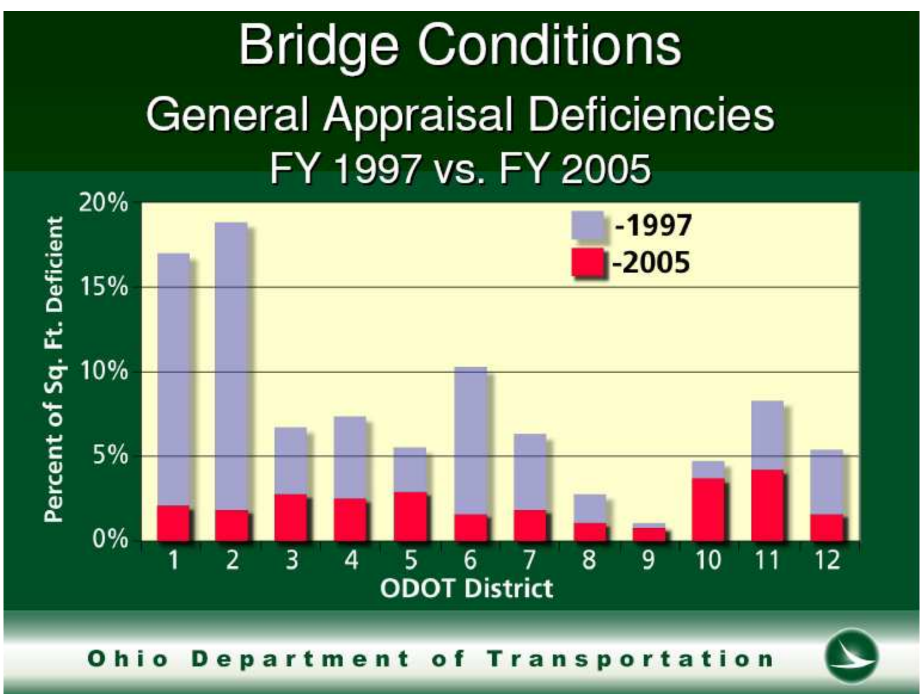


Figure 3.8 Ohio DOT Bridge Conditions



4.0 Asset Management Work Plan

This section presents an asset management work plan for managing Massachusetts highway transportation assets. The plan includes an assessment of current asset management practices by the Executive Office of Transportation and Public Works and Massachusetts Highway Department (EOT/MassHighway). It also documents potential initiatives that support the vision and goals defined in Section 2. For each initiative the plan provides a discussion, work steps, recommended timetable, and a preliminary cost estimate.

Implementing the work plan will require a mixture of indirect and direct costs. Indirect costs cover the resources required for current EOT/MassHighway staff to perform work and to bring their current processes into alignment with the asset management principles presented in Section 2. Direct costs cover the resources required to engage consultants. Consultants may be brought in to add expertise or to address workload constraints. Determining the appropriate mix of in-house and contracted work will be the responsibility of the Asset Management Steering Committee. This work plan represents one implementation scenario, which combines both internal and outsourced work. The final cost of implementing the work plan will decrease if EOT/MassHighway performs more work in-house and increase if consultants are relied upon more heavily relative to what is assumed.

The work plan makes no presumption of the relative priority of this initiative with respect to other EOT/MassHighway initiatives. Rather, the plan presents activities, timeframes, and budgets for steps of high priority in implementing an asset management approach, assuming there are no barriers to proceeding with implementing the recommended steps.

4.1 Current EOT/MassHighway Practices

Tables 4.1 through 4.4 present the state of the practice at EOT/MassHighway as compared to the state-of-the-art in asset management documented in NCHRP 20-24(11). The benchmarks in the table were developed through the NCHRP 20-24(11) effort based on the results of asset management surveys and workshops, a review of current literature, visits to several state DOTs, and a synthesis of industry best practices. The tables represent four matrices that organize key concepts, principles, and state-of-the-art techniques. These matrices lay out a range of options in improved asset management and identify ideal practices to which EOT/MassHighway can strive. They address the full range of DOT infrastructure management activities, and are described by the following questions:

- **Policy Goals and Objectives –** Does policy guidance encourage and provide incentives for good asset management?

- **Planning and Programming –** Do resource allocation decisions reflect good practice in asset management?
- **Program Delivery –** Do oversight techniques and follow-through reflect industry good practice?
- **Information and Analysis –** Do information resources effectively support asset management policy and decisions?

The information in each matrix has been organized in four columns:

- The first column identifies the most important basic characteristics of good asset management practice applicable to U.S. transportation agencies. These have been kept to a small number in each matrix to focus on the most important.
- The second column lists specific evaluation criteria by which these characteristics can be evaluated. They identify the likely places to look in determining whether the policy guidance, management procedures, and decision culture that drive investment choices conform to the characteristics of good asset management.
- The third column describes the current state-of-the-art for each criterion.
- The fourth column describes the situation at EOT/MassHighway in each of the key areas of asset management. These descriptions have been derived from interviews with key personnel and a review of selected EOT/MassHighway documents.

Table 4.1 Policy Goals and Objectives Assessment
Does Policy Guidance Encourage Good Asset Management?

Characteristics	Criteria	Benchmark – State-of-the-Art	EOT/MassHighway State of Practice
1. Policy goals and objectives reflect a holistic, long-term view of asset performance and cost.	Defined goals and objectives	Goals and objectives are comprehensive, integrated with other statewide policy objectives, and supported by quantitative and measurable performance measures or criteria.	EOT/MassHighway publishes *Massachusetts Transportation Facts* with basic information on current conditions and performance. The EOT's long-term plan, *Transportation in the Commonwealth of Massachusetts: A Framework for Thinking – A Plan for Action*, details EOT/MassHighway goals and objectives for transportation. Chapter 1 of the document lists eight guiding principles for transportation planning in Massachusetts, including asset preservation, and relates these to other statewide objectives. The *Objective Evaluation Criteria* provided on the EOT/MassHighway web site provide criteria for evaluating potential projects based on EOT/MassHighway goals.
	Asset Management is a key catalyst for decision and action	Principles of good asset management are articulated in an agency business plan and clearly recognized throughout the agency as the driving force for resource allocation and utilization.	
	Life-cycle perspective	Goals and objectives embody the perspective of life-cycle economic analyses of asset performance and cost, and encourage strategies with long-term benefits.	

Characteristics	Criteria	Benchmark – State-of-the-Art	EOT/MassHighway State of Practice
2. Goals and objectives embody the public interest in good stewardship of transportation assets.	Recognition of asset condition, performance, and public acceptance in policy formulation	This recognition entails the following characteristics: • Policy goals and objectives encourage a business-model, customer-oriented approach to asset management. • Reliable information on asset condition and public perceptions thereof is accounted for in updating policy objectives.	*Transportation Facts* details current conditions. The long-term plan reports predicted pavement conditions (for interstates only) and predicted number of bridges classified as Structurally Deficient. Limited data are available on historic performance of Massachusetts transportation assets. No public reports were identified measuring performance against policy goals and objective, or detailing conditions of assets besides interstate pavements and bridges.
	Public reporting and accountability	Reported system performance is measured against policy goals and objectives.	
3. Policy formulation allows the agency latitude in arriving at performance-driven decisions on resource allocation.	Political process	Political decisions on resource allocation among modes or programs are strongly influenced by objective information on expected performance.	EOT establishes MassHighway's budget based on consideration of available funds, pre-existing commitments (e.g., to funding the Central Artery/Tunnel Project) and a negotiated set of regional targets. MassHighway has flexibility for determining how to allocate its funds among different programs. The allocation is based on a combination of project evaluation, and analysis of predicted pavement and bridge conditions. Historical splits are used for allocating maintenance funds between districts.
	Agency decision-making	The agency makes resource allocation decisions among programs and across geographic regions based on expected performance rather than by historical splits or formulas that do not correlate with an objective indication of system condition.	

<table>
<tr><th>Characteristics</th><th>Criteria</th><th>Benchmark – State-of-the-Art</th><th>EOT/MassHighway State of Practice</th></tr>
<tr><td rowspan="2">4. The agency proactively helps to formulate effective asset management policy.</td><td>Engagement with policy-makers</td><td>The agency actively engages with political leaders and other policy-makers to define expectations of system performance, frame alternative approaches, and outline the consequences of decisions and courses of action relative to these expectations.</td><td rowspan="2">EOT/MassHighway has provided data on predicted pavement condition (for interstates only) and number of bridges Structurally Deficient generated through management systems in the draft long-term plan. This document has been used to facilitate discussions with political leaders and other policy-makers. MassHighway uses its pavement and bridge management systems to provide meaningful analysis of funding choices and consequences.</td></tr>
<tr><td>Provision of information</td><td>The agency’s asset management systems are designed and applied to yield meaningful information on policy choices and consequences.</td></tr>
</table>

Table 4.2 Planning and Programming Assessment
Do Resource Allocation Decisions Reflect Good Practice in Asset Management?

Characteristics	Criteria	Benchmark – State-of-the-Art	EOT/MassHighway State of Practice
1. Planning and programming procedures and criteria are consistent and reinforce policy goals and objectives.	Fiscally responsible planning	Development of statewide long-range plans can be demonstrated to be consistent with policy goals and objectives and with realistic projections of future revenue.	The long-range plan is consistent with policy goals and contains a thorough analysis of revenue trends and projections. Updated revenue projections are prepared annually for the STIP.
	Program prioritization	Funding allocation and project prioritization criteria are consistent with and support the state's and the agency's policy goals and objectives.	EOT/MassHighway is developing improved procedures for program prioritization. The long-term plan presents evaluation criteria for different project types. Criteria for highway projects include analysis of effects including air quality, service quality, environmental justice, and land use and economic development. A combination of management systems and expert judgment are used to prioritize pavement and bridge projects with similar characteristics.
	Updates and revisions	Updates and revisions to the planning and program development process are performed regularly to reflect changes affecting asset management priorities in the arenas of: • Policy (e.g., preserving existing investments, economic development), • Technology (e.g., new design procedures or materials), or • Emerging issues (e.g., updated environmental regulations; identification of potentially catastrophic risks to asset condition or performance).	There is no formal revision schedule for updating the long-term plan or programming process.

Characteristics	Criteria	Benchmark – State-of-the-Art	EOT/MassHighway State of Practice
2. Planning and program development consider a range of alternatives in addressing system deficiencies.	Planning alternatives	Long-range planning identifies and evaluates a range of program alternatives and, as appropriate, modal alternatives to meet present and future deficiencies.	EOT's long-range plan evaluates program alternatives at a general level. Expected bridge conditions are shown for different budget levels. EOT/MassHighway's program development procedures involve consideration of project scope, costs, benefits and impact on performance. For preservation projects (e.g., for pavement and bridge preservation), analysis of project scope is performed between central office and district staff.
	Project scope, cost, benefits, impact on performance	Program development, guided by adopted plans, formulates projects of appropriate scope and develops realistic estimates of their costs, benefits and impacts on system performance.	
3. Performance-based concepts guide planning, program development, and system monitoring.	Performance-based budgeting	Recommended programs and budgets are tied to performance budgeting concepts entailing: • Structuring of costs by activity, and • Relationships of costs to levels of service or performance measures	EOT/MassHighway budgets using categories more analogous to federal funding categories than activities. However, the program structure includes categories specifically for capital maintenance of the Interstate system, and bridge work. Regarding pavement and bridge work, analysis is performed periodically using EOT/MassHighway's management systems to analyze performance, predict future conditions, determine the budget needed to achieve specified target condition levels, and recommend work. EOT/MassHighway uses dTIMS to analyze conditions of interstate and NHS pavements, and uses Pontis to analyze bridge conditions. For signs EOT/MassHighway has determined a replacement interval and monitors performance of its sign replacement program. For other maintenance, budget allocations are made based on historical splits. Analysis of performance is performed on an ad-hoc basis.
	Benchmark achievement	The planning and programming process indicates (or "defines") the resources required to maintain existing assets at target performance levels and at least life-cycle cost.	
	System monitoring	Performance measures or levels of service are defined and regularly applied to quantify the impacts of program decisions and actions and to provide feedback for future planning and program priorities.	
	Reporting	Progress toward stated programmatic system performance targets is measured and reported regularly.	

Characteristics	Criteria	Benchmark – State-of-the-Art	EOT/MassHighway State of Practice
4. Resource allocations and program tradeoffs are based on relative merit and an understanding of comparative costs and consequences.	Program building	Organization of projects within programs (program building) results from statewide competition among projects based on objective criteria.	Evaluation criteria have been defined to assist in selecting projects. EOT/MassHighway regularly reviews candidate projects. Within program areas, EOT/MassHighway managers have worked to formalize the process of building the program. Formal, quantitative tradeoff analysis across program categories is not currently done. Performance measures are available for decision-makers, but information on the implications of more or less resources available to different categories is not generally estimated or communicated.
	Consistency	Projects being designed and built respond to, and are consistent with, overall policy guidance for system performance.	
	Program tradeoffs	Tradeoffs between programs (e.g., Preservation versus Improvement) are based upon analyses of life-cycle benefits and costs, rather than arbitrary formulas or historical splits	
	Communication	The implications of more or less resources allocated to each program are clearly communicated in terms of selected performance measures.	

Table 4.3 Program Delivery Assessment

Do Oversight Techniques and Follow-Through Reflect Good Industry Practices?

Characteristics	Criteria	Benchmark – State-of-the-Art	EOT/MassHighway State of Practice
1. The agency considers all available methods of program delivery.	Cost tracking	The agency knows its costs for delivering its programs and services (e.g., by activity, bid item, or resource class).	EOT/MassHighway tracks project costs and construction bid tabs. Costs by construction project are well-documented. However EOT/MassHighway lacks systematic, ready access to data on costs for maintenance activities, where these are performed by internal forces, or by contract forces through districtwide contracts. There is a heavy reliance on individual managers' experience for knowledge of maintenance costs.
	Options for delivery	The agency periodically evaluates its options for delivering programs and services: e.g., agency employees, intergovernmental agreements, partnering, outsourcing, managed competition.	EOT/MassHighway uses several approaches for program delivery, including internal forces, contract work, and privatization of maintenance work. However, little information is available for comparing the costs of different delivery alternatives.
2. The agency tracks program outputs and outcomes.	Feedback mechanism	The agency has the ability to easily track actual project and service delivery against the program plan so that adjustments can be made.	EOT/MassHighway has well-established procedures for tracking project-level delivery. These procedures are supported by the PROJINFO system.
	Change process	A formal program change process exists to make needed adjustments in cost, schedule, and scope; document causes; and reallocate funds.	Procedures for tracking district-level maintenance work are typically well-defined, but vary between district. Maintenance Standard Operating Procedures (SOPs) and the Maintenance Manual are generally out-of-date, with the notable exception of procedures for snow and ice removal. EOT/MassHighway lacks a maintenance management system for tracking maintenance work, though two districts still use the old MassHighway system.

Characteristics	Criteria	Benchmark – State-of-the-Art	EOT/MassHighway State of Practice
3. Reports on program delivery accomplishments are communicated and applied.	Internal	Department executives and program managers are regularly informed of progress; a well-understood mechanism exists to make needed adjustments.	EOT/MassHighway routinely tracks program and project status. Detailed project information is available internally through PROJINFO. Also, EOT/MassHighway makes project and program information available externally through the EOT/MassHighway web site.
	External	Policy-makers and key stakeholders are kept informed of program status and adjustments.	
4. The approved program is delivered efficiently and effectively.	Delivery measures	Measures are defined and tracked to gauge successful program delivery in terms of schedule, cost, and scope.	The Chief Engineer's Office monitors delivery of preservation work in the program, in coordination with district staff. Central and district-level staff are keenly aware of project schedule, scope and cost issues. Recently improvements have been made in streamlining project delivery.

Table 4.4 Information and Analysis Assessment

Do Information Resources Effectively Support Asset Management Policies and Decisions?

Characteristics	Criteria	Benchmark – State-of-the-Art	EOT/MassHighway State of Practice
1. The agency maintains high-quality information needed to support asset management.	Asset Inventory	The agency maintains an inventory of assets that is a complete, accurate, and current description of infrastructure for which the agency is responsible.	GIS: EOT/MassHighway maintains the Massachusetts Highway Inventory (the Road Inventory File) and related data in its GIS. EOT/MassHighway has state-of-the-art systems for maintaining the inventory. However, improved procedures are needed for updating inventory data. Pavement data: EOT/MassHighway maintains detailed data on pavement conditions, and has state-of-the art systems for this purpose. Pavement data for interstates, other numbered routes, and principal arterials are updated on a three-year cycle. The actual interval update interval may vary due to the availability of trained staff. Bridge data: EOT/MassHighway maintains detailed data on bridge conditions, and has state-of-the art systems for this purpose. Maintenance data: EOT/MassHighway has or is assembling detailed data for selected roadside assets, including ITS-related assets, intersections, memorial signs, and outfall locations. Individual districts have assembled spreadsheets with additional asset inventory data, such as for stop signs at intersections with EOT/MassHighway-owned roads. Also, detailed data on roadside assets are available through video log data. However, EOT/MassHighway lacks an integrated inventory of roadside assets. Also, EOT/MassHighway has no department-wide maintenance management system for tracking maintenance costs. Data on customer perceptions comes from email and telephone complaints. Project data: EOT/MassHighway uses the state-of-the-art PROJINFO system for tracking project data, as discussed above.
	Asset Condition	Asset condition data are updated on a periodic schedule sufficient to meet regulatory requirements (e.g., bridge inspection data) and to provide timely and accurate information on status and performance.	
	Customer Perceptions	Information on customer perceptions is updated regularly through surveys, focus groups, complaint tracking, or other means, to gauge public perception of asset condition and agency performance, and to respond thereto.	
	Program outputs	Information on actual costs and accomplishments by project, asset category, work type, and location are maintained in a form that can be utilized to track actual cost versus performance and improve cost estimation techniques.	

Characteristics	Criteria	Benchmark – State-of-the-Art	EOT/MassHighway State of Practice
2. Agency collects and updates asset management data in a cost effective manner.	Data collection technology	The agency applies the appropriate mix of data collection technology (e.g., visual, automated, remote sensing) to provide cost-effective coverage needed to maintain the quality information base discussed above.	EOT/MassHighway uses an efficient combination of methods to collect asset inventory and condition data for pavements and bridges, including manual inspections, video logging, and the Automatic Road Analyzer (ARAN) vehicle. Data collection is performed in accordance with federal guidelines, such as HPMS and NBI standards. Data are generally lacking on roadside assets, except in the case of selected types of assets noted. To the extent that district staff are collecting asset data, these activities are uncoordinated with the central office or other districts.
	Sampling methodology	The sampling methodology is demonstrated to be appropriate in terms of network coverage, sample size, and frequency, and in the training and team assignments needed to ensure objectivity, consistency, and repeatability.	

Characteristics	Criteria	Benchmark – State-of-the-Art	EOT/MassHighway State of Practice
3. Information is automated and on platforms accessible to those needing it – relates to both databases and systems.	System technology and integration	The agency's single-asset management systems and databases have been updated and integrated to enable consistent information on all asset categories to be accessible to multiple applications, and to provide managers at various organizational levels the information and tools needed for effective asset management.	EOT/MassHighway's pavement and bridge management systems operate largely in a standalone fashion. No standards have been developed for determining what asset data are needed, and/or how development efforts should be coordinated. EOT/MassHighway's referencing standards are well developed. The agency has state-of-the-art capabilities for analysis, display and reporting of GIS data, with the exception of its procedures for updating data.
	Data administration	Information requirements and/or standards for asset management are in place to ensure that future system and database development efforts within the agency will integrate with existing systems and meet asset management information and analysis improvement needs.	
	Geo-referencing	Systems and information are based upon a common geographic referencing system and a common map-based interface for analysis, display, and reporting.	

Characteristics	Criteria	Benchmark – State-of-the-Art	EOT/MassHighway State of Practice
4. Effective Decision-Support Tools are available for Asset Management	Strategy Analysis	The agency has decision-support tools that facilitate exploration of capital versus maintenance tradeoffs for different asset classes.	EOT/MassHighway has state-of-the-art tools for strategy, project and program analysis for pavement and bridge preservation needs. No tools are in use for analysis of needs for other assets besides pavements and bridges. Also, no tools are available for summarizing needs across different program categories or assets types, or for performing analysis of tradeoffs between program categories. No tools exist to perform tradeoffs across program categories.
	Project Analysis	The agency has tools that support consistent analysis of project costs and impacts, using a life-cycle cost perspective.	
	Program Analysis	The agency has tools, which provide an understanding of the system performance implications of a proposed program of projects.	
	Program Tradeoff Analysis	The agency has tools to help explore the system performance implications of different levels or mixes of investments across program categories or subcategories.	
5. Financial value of assets.	Conformity with Government Accounting Standards Board (GASB) Statement 34	The agency reports the value and condition of its transportation capital assets in a manner that conforms to the modified approach specified in GASB standards.	EOT/MassHighway is conforming with the GASB standards, but is not using the modified approach. However, data are available through dTIMS and Pontis for determining the level of expenditure needed to meet target condition levels for MassHighway-owned pavements and bridges.
	Information support for condition and financial reporting	Information on asset condition and the level of expenditure needed to meet target condition is available from the agency's asset management systems.	

4.2 Recommended Asset Management Initiatives

Initiative 1. Implement an Asset/Maintenance Management System

Discussion. As detailed in Section 4.1 EOT/MassHighway maintains its road inventory using the agency GIS, and has state-of-the-art systems for pavement and bridge management. In addition to these systems, EOT/MassHighway staff are engaged in supporting or developing a number of other initiatives for collecting asset data. These include:

- Individual districts have collected data on signs, signals and other assets in spreadsheets;
- Collecting data on all state-owned traffic signals;
- Detailing the location and characteristics of all point source discharges (out fall locations) for compliance with the National Pollutant Discharge Elimination System (NPDES);
- Maintaining a database with service and memorial signs; and
- Maintaining a system with details on ITS assets, including variable messages signs, loop controllers, and other equipment.

Although EOT/MassHighway collects a large amount of data on its assets, asset data are stored in separate systems, and EOT/MassHighway has no department wide maintenance management system (MMS).

As discussed in Section 3, most states rely on an MMS for scheduling resources, tracking maintenance accomplishments, detailing costs, and other critical functions. Most state-of-the-practice systems support a features inventory for tracking inventory and condition data for roadside assets, combining traditional maintenance management processes with additional asset management functionality.

In the absence of a statewide MMS, each district uses a somewhat different approach for managing its day-to-day maintenance operations. Districts 1 and 2 still use the MMS that previously was used statewide. Other districts use a combination of written logs and spreadsheets for managing work orders. Tracking the inventory of roadside assets historically was performed using paper logs. In some cases district staff are continuing to maintain the paper logs (e.g., filling out sign cards when replacing signs). In other cases, districts are using spreadsheets for tracking selected roadside assets, or are simply not tracking them at all. All but one of the districts report on their activities to the central office on a bi-weekly basis, using varying reporting formats. All use the established EOT/MassHighway systems such as PROJINFO for construction and contract management, but these systems lack details on specific maintenance activities and locations.

The existing approach to maintenance management is heavily reliant upon individuals' experience and knowledge. Fortunately, the district staff in place at MassHighway have the experience and knowledge they need for their roles, and excel in operating in a very challenging environment. However, the current approach to maintenance management appears at best inefficient, and at worst unsustainable, considering the reliance on individuals' knowledge, and the fact there is a very limited influx of new staff to take over as existing staff retire. Further, with the current approach it is difficult to obtain objective data for even the most basic kinds of questions one might ask about maintenance activities at a statewide level (e.g., how much is being spent on routine maintenance of the Interstate System?).

There is a clear need for some form of asset/maintenance management system at EOT/MassHighway. At a minimum, EOT/MassHighway should implement a system for tracking work that provides MassHighway managers with access to details concerning what type of work has been performed, who performed it, on what assets it was performed, and what it cost. Ultimately, EOT/MassHighway should move towards implementation of a comprehensive asset/maintenance management system that supports all of the functionality outlined in Table 3.1 and supports the asset management vision described in Section 2.

Appendix A summarizes the set of asset/maintenance management systems in use in the U.S. reviewed as part of this effort. The appendix provides a brief overview of each system, compares the functionality of each, and provides a preliminary estimate of level of expenditure needed to license each based on information obtained for current system users and/or obtained from system vendors. Note that the review focused on systems used by other state DOTs that have some degree of support for maintenance management. Pavement and bridge management systems (e.g., the dTIMS and Pontis systems currently in use by EOT/MassHighway) not designed to support maintenance business processes were excluded from the review. Also, note that implementing any of these systems will require additional resources for data migration, training, and other activities beyond initial licensing and customization costs.

Several of the systems in the review both support basic work reporting functionality needed by EOT/MassHighway, and are used for this purpose by one or more other U.S. state transportation agencies. These include AgileAssets' Maintenance Manager, CartêGraph's Management Suite, Infor's Asset Management Suite, IBM's Maximo, SAP, and the Maintenance Tracking System (MATS) described in the previous section. Exor's system was included in the review as it has been used for inventory management at the DOT level and offers additional functionality for maintenance management.

Of the systems currently in use for maintenance management, MATS is of particular interest for two reasons. This system is jointly owned by the Maine

DOT, New Hampshire DOT and Vermont Agency of Transportation. As it is already in production in other New England states, adopting this system for maintenance management in Massachusetts represents a relatively low-risk strategy. Further, though the states that own the system have not established what it would cost for EOT/MassHighway to procure the system, it is feasible that EOT/MassHighway could negotiate an arrangement with minimal initial licensing costs, provided EOT/MassHighway shares the future costs of maintaining and enhancing the system. Thus, adopting MATS has the potential to be a very low-risk and cost-effective strategy for implementing an asset/maintenance management system for EOT/MassHighway.

If further investigation by EOT/MassHighway staff indicates the system is not suitable for implementation by EOT/MassHighway, or if the licensing arrangement is unfavorable, then we recommend EOT/MassHighway pursue testing of the AgileAssets, CartêGraph, Infor and IBM systems currently used for maintenance management in other U.S. transportation agencies.

We expect that once an MMS is implemented, it will save MassHighway managers time by helping automate tasks now being performed through a combination of antiquated systems and manual steps.

Work Steps

- Contact Paul Corti at the Vermont Agency of Transportation (802-828-2798) to express formal interest and negotiate terms for becoming a MATS partner.
- Review the degree to which MATS supports EOT/MassHighway business processes and goals.
- If the licensing terms for MATS are unfavorable, and/or if the system offers poor support for EOT/MassHighway business processes, perform testing of other system currently in use for maintenance management in other U.S. state transportation agencies, including AgileAsset's Maintenance Manager, CartêGraph's Management Suite, Infor's Asset Management Suite, and IBM's Maximo.
- Develop a detailed asset/management management system implementation plan.
- Implement the selected asset/maintenance management system.

Timing. Review of MATS and/or other systems, and implementation of one of the available systems, could require up to 24 months, pending details of the implementation plan, in addition to the time required for any contract negotiations.

Preliminary Cost Estimate. Initial costs to implement an asset/maintenance management system would be at least $500K, including licensing, data migration, implementation and training costs.

Initiative 2. Integrate EOT/MassHighway Asset Inventory Data

Discussion. A critical principle of transportation asset management is to have quality information on asset inventory and condition to support decision-making. Although it is not strictly required to support an asset management approach, there is often great value to integrating asset data, at least at a summary level, to facilitate analysis of needs, reporting, and other functions.

An agency's asset inventory may take a variety of different forms. In many agencies, the system used for HPMS reporting has evolved into the agency's asset inventory system. Agencies following this trend typically rely on pavement, bridge, and maintenance management systems for collecting data and performing detailed analyses of conditions and needs, using the asset inventory system to integrate the management systems and summary data across asset categories. In other cases, an agency's maintenance management system, supplemented with asset inventory functionality, may serve as the inventory system for roadside assets. However, where such systems have been implemented, there typically remains a need for storing additional asset inventory and condition data in other agency systems, such as the agency's pavement and bridge management systems.

EOT/MassHighway has a state-of-the-art GIS used to manage the official highway inventory for Massachusetts, the Road Inventory File. The GIS has a number of additional data layers of use to EOT and MassHighway staff, such as bridges and numerous environmental features. Further, as described above in the discussion of Initiative 1, EOT/MassHighway has state-of-the-art systems for pavement and bridge management, and has a number of efforts underway to collect additional asset data. However, there is relatively little coordination between the different system owners within EOT/MassHighway, beyond development of general IT standards and monitoring performed by EOT/MassHighway IT staff. Left unaddressed, the current approach is most likely to result in a situation in which data continue to be collected in a fragmented manner, with relatively little integration between different data sources.

We recommend using EOT/MassHighway's GIS as the basis for integrating EOT/MassHighway asset inventory data. Existing data on EOT/MassHighway assets, where available, should be integrated in the asset inventory. Where EOT/MassHighway is collecting additional asset inventory and condition data, these efforts should be coordinated, and the data should be incorporated in the inventory to the extent this supports decision-making.

As the GIS is not a good tool for data entry, and not a substitute for comprehensive asset-specific management systems, we recommend continuing to use existing management systems for data collection and storing detailed condition data. The existing pavement and bridge management systems are generally sufficient for this purpose, but these systems should be supplemented with an additional system for supporting maintenance and data on roadside assets, as described in Initiative 1. With this model, asset-specific management systems would be the primary tool for collecting asset data, and the GIS would be the repository for integrated reporting across assets.

Work Steps

- Establish the Road Inventory File as the Massachusetts Transportation Asset Inventory System.
- Establish a basic taxonomy of EOT/MassHighway asset categories, including a description of what each category includes, and the metadata collected for each category. The taxonomy might include, but is not limited to:
  - Pavement
  - Structures
    - Bridges
    - Culverts
    - Tunnels
  - Interchanges
  - Signals
  - Signs
  - Outfall locations
  - Facilities
  - ITS equipment
- Add available asset inventory and condition data to the Asset Management System, where this data may help facilitate decision-making, such as the signal data recently collected for District 4.
- Establish an Asset Management Steering Committee headed by EOT, with representatives from all EOT agencies. This group should coordinate efforts to integrate asset inventory data, establish protocols for updating asset management data, and oversee plans for maintaining and enhancing the existing management systems.
- Defer further new initiatives for collecting additional asset inventory data pending selection of the EOT/MassHighway asset/maintenance management system as part of Initiative 1.

Timing. Establishing the Asset Inventory and forming the Steering Committee could be accomplished within one month. Developing the basic asset taxonomy and adding available data to the system is expected to require six months.

Preliminary Cost Estimate. Indirect costs only are assumed for this initiative.

Initiative 3. Enhance Asset Condition Monitoring

Discussion: As described in Section 3, many agencies have developed report cards to use for summarizing conditions of transportation assets. The section provides several examples of report cards in use in other states.

EOT/MassHighway reports on overall pavement and bridge conditions in their draft long-term plan. In addition, a monthly report is used to compile data on construction spending totals, length of the construction contracting process, number of Structurally Deficient bridges, and other measures. The *Transportation Facts* document published periodically summarizes overall conditions of the network. We recommend extending these approaches to report a selected set of measures on a regular basis through a report card mechanism, and making them available to a wider audience.

As a starting point, Table 4.5 presents a list of recommended measures, with an indication of which are currently used, the degree to which data required to calculate them are currently available, and recommended reporting frequencies. The table represents a mix of leading and lagging indicators. Lagging indicators are reported annually and reflect actual outcomes. They can be used to assess whether efforts to improve condition and performance have been successful. Leading indicators are reported monthly and represent outputs necessary for achievement of the desired outcomes. They are intended to provide information that helps managers take corrective action. It is recommended that EOT/MassHighway begin with the measures that can be calculated with existing data, and over time expand their data collection efforts so that it is possible to calculate additional measures.

Table 4.5 Recommended Asset Condition Measures

Category	Measure	Currently In Use?	Can be Calculated with Existing Data?	Reporting Frequency
Pavement	% of lane miles in fair or poor condition (PSI <3)	Yes	All numbered routes	Annual
	% of VMT in fair or poor condition (PSI <3)	No	Interstate only	Annual
Bridges	# of structurally deficiency bridges or index (ratio of # in current year to # in a base year)	Yes	Yes	Annual
	Average health index	No	Yes	Annual

Category	Measure	Currently In Use?	Can be Calculated with Existing Data?	Reporting Frequency
Other features	Traffic features (lights, signs, striping, etc.) level of surface	No	No	Annual
	Roadside (mowing, guardrail, drainage, litter, etc.) level of surface	No	No	Annual
	Vegetation (erosion, clear zone, noxious weeds, ground cover, etc.) level of surface	No	No	Annual
Delivery	Cumulative % of planned annual construction budget spent	Yes	Yes	Monthly
	% of total expenditures associated with fix it first projects	Yes	Yes	Monthly
	% of construction projects requiring time extension	Yes	Yes	Monthly
	Cumulative % of planned annual maintenance budget spent by category – e.g., traffic, roadside, and vegetation.	No	No	Monthly

In terms of presentation, it is recommended that EOT/MassHighway develop a report card similar to the example from the Minnesota DOT in Figure 3.6. This format uses a red/yellow/green scale to communicate how each measure compares to the target value. It also includes trend information – has each measure gone up or down since the last reporting period? It also is recommended that the measures be reported at the state level and by district. District-level information will enable managers make adjustments to current practices and provides additional context for resource allocation decisions.

Key Steps

- Finalize the set of measures for use in reporting asset conditions.
- Establish targets for each measure. Refer to NCHRP Report 551 for recommendations on establishing measures and targets. Section 5 provides an example of this process for the Interstate System.
- Produce an Annual Report Card for Asset Conditions. The report card should be distributed online and used when working with planning partners or the legislature in characterizing transportation needs.

Timing. Establishing the set of measures and report card is expected to require six months.

Preliminary Cost Estimate. Indirect costs only are assumed for this initiative.

Initiative 4. Implement Business Process Improvements in Support of Asset Management

Discussion. A series of business process improvements are recommended to provide better support for asset management objectives at EOT/MassHighway. Most of the following leverage existing systems and data, or build upon Initiatives 1 to 3.

Work Steps

- **Improve the analysis of pavement needs.** MassHighway's dTIMS PMS represents a well-established tool for pavement analysis. For lack of staff and current data, MassHighway typically uses the system only for analysis of the Interstate System. Periodically MassHighway evaluates National Highway System (NHS) needs. Limited analyses are performed of pavement conditions of pavement off of the NHS. Ideally, allocation of resources between MassHighway and locally-owned pavement would be informed by analysis across road systems and owners. We recommend that MassHighway analyze pavement needs for the following types of roads on annual basis:

  - MassHighway-owned;
  - Principal arterials;
  - Numbered routes; and
  - Any other roads on the federal aid system.

  Further, we recommend EOT/MassHighway analyze pavement needs for other roads not included in the above list on a periodic basis. Because detailed data are not available for most locally-owned roads, we recommend using a combination of dTIMS and the FHWA Highway Economics Requirements System (HERS-ST) to facilitate coordinated analysis of all Massachusetts pavement needs.

- **Clarify the program structure.** To make the case for its asset investments, EOT/MassHighway needs to be able to characterize how money is being spent. We recommend that EOT/MassHighway summarize for its annual program the amount of money spent by asset category, and for different categories of work. While any such breakdown of transportation investments would require some amount of estimation, as many projects involve work on multiple assets, and serve multiple needs, the resulting summary of the program would serve as a valuable tool for communicating planned transportation investments.

- **Document the formula for allocating maintenance funds between districts.** Allocation of maintenance funds between districts is based on a historical split established through a formula developed at some point in the past. We recommend documenting the basis for this split. In the future, if the split is to be based upon a formula, the formula should be recalculated annually.
- **Analyze interchange investment needs.** Consideration of interchange needs is critical in Massachusetts. Interchanges represent both expensive collections of assets that must be maintained, and opportunities for making improvements to alleviate traffic congestions. Examples of interchanges for which major projects are planned (typically with both preservation and service enhancement implications) include I-93/I-95, Route 24/140, and Route 146/I-290. To analyze its interchange needs, EOT/MassHighway can leverage its existing systems and data, and/or investigate the feasibility of implementing an Interchange Management System, such as the South Carolina DOT Interactive Interchange Management System (IIMS).

Timing. The steps described above could be performed in parallel, and completed within a twelve month period. Implementing an interchange management system (rather than analyzing interchange needs with existing systems and data) would require an additional eight months.

Preliminary Cost Estimate. Indirect costs only are assumed for this initiative. Implementing the existing IIMS would cost approximately $250,000, not including costs for any additional data collection.

5.0 Interstate Asset Management Plan

The Interstate Highway System (IHS) is the centerpiece of the highway system in Massachusetts. Even though interstate highways represent less than 2% of the road miles in Massachusetts, they carry almost 30% of the vehicle miles, and much of the regional freight traffic.

The IHS in Massachusetts consists of major highways, as well as spurs and beltways to those highways. Table 5.1 lists the interstates in Massachusetts. Major interstates in Massachusetts include I-84, I-90, I-91, I-93 and I-95. Interstate spurs are designated by an odd number prefix (in Massachusetts, a 1 or 3) before the two-digit number of the interstate which they serve. Interstate beltways connect two sections of interstate and are designated with a three-digit route number with an even number prefix (in Massachusetts, a 2 or 4) before the two-digit number of the interstate which they serve.

Table 5.1 Massachusetts Interstates

Interstate	Length (miles)	Type
I-84	7	Major
I-90	138	Major
I-91	55	Major
I-93	46	Major
I-95	89	Major
I-190	20	Spur
I-195	36	Spur
I-290	20	Beltway
I-291	5	Beltway
I-295	4	Beltway
I-391	5	Spur
I-395	12	Spur
I-495	121	Beltway

As the interstate system is a central element of the MassHighway-owned road network, it is appropriate that any application of asset management approaches begin with the IHS. Further, there has been increased focus on the IHS in the past year, as the U.S. has recently celebrated the fiftieth anniversary of the HIS.

This milestone provides a fitting point to assess the IHS and the challenges of moving toward a generally accepted asset management framework. A number of efforts are now underway focusing on different aspects of the future of the IHS. For instance, the American Association of State Highway and Transportation Officials (AASHTO) is currently working to develop a vision for the future of the IHS, addressing future interstate demand, investment requirements for the current system, the potential for additional corridors, management and operations, financing, and alternative future program structures. In parallel to this effort, the National Surface Transportation Policy and Revenue Study Commission is evaluating the future of the IHS, supported by staff from the Federal Highway Administration (FHWA). In parallel with these national efforts, a number of states are developing strategies for managing their portion of the IHS.

Part of the challenge of managing the IHS lies in developing cost-effective investment strategies for managing each of the asset types on the system. The challenges will only grow greater as the system ages, and there are further increases in passenger and freight traffic. Each of the individual segments of the IHS is composed of a number of distinct types of infrastructure assets, potentially including pavement, bridges, tunnels, and numerous types of roadside appurtenances, such as signs, sign structures, guardrails, lighting, pavement markings, high mast lights, drainage structures, and traffic management equipment. A hallmark of the IHS is that it was initially constructed to conform to consistent design standards. However, individual segments of the system now face very different realities resulting from factors such as varying physical condition, traffic characteristics, operating environments, weather, and the approaches for operating and maintaining the system that have been employed at the state level.

This Interstate Asset Management Plan is intended to both provide an analysis of the investment needs for MassHighway-owned interstates, and demonstrate applications of the concepts described in the prior sections of this report. The following sections provide an overview of the plan, summarize existing conditions, recommend a set of performance goals, detail a sample analysis performed of the system, identify potential future project locations, and provide a series of recommendations.

5.1 Overview

The purpose of the Interstate Asset Management Plan is to:

- Document the existing physical condition of the Interstate system;
- Recommend performance measure and goals;
- Develop an approach for allocating resources among different types of assets and other needs on the Interstate Highway System.

The Interstate Plan is intended to examine all roads currently designated as Interstate Highways. This designation makes them eligible for certain funding categories of Federal highway programs. It does not include other grade-separated, access-controlled roads such as Routes 2, 3, and 24. It includes only those roads that are owned and maintained by MassHighway. It does not include I-90, the Massachusetts Turnpike, nor does it include the Central Artery section of I-93 that is part of the Metropolitan Highway System. It includes all of the assets on the Interstate System: pavements; bridges on and over interstate highways; guardrails; signs; lighting, drainage systems; and other roadside assets. The only assets not included are those maintenance facilities from which service is provided to the interstates and other MassHighway roads.

Federal guidelines were previously established for Interstate Maintenance Plans in 23 CFR 635 Subpart E. While the requirement to submit an Interstate Maintenance Plan in compliance with these regulations was abolished by the TEA-21 legislation in 1991 and this subpart was subsequently deleted, the activities in previously described in 23 CFR 635.501a are still relevant for the purposes of identifying Interstate Maintenance activities, as cited in the former regulations:

(1) Roadway surfaces. Preservation of the structural integrity of the roadway and the safety and comfort of the user. This includes a safe, smooth, skid-resistant surface, as close as practical to the original, or subsequently improved, grade and cross section.

(2) Shoulders. Preservation of a safe, smooth surface which is free of obstruction, contiguous with the adjacent roadway surface, and as close as practical to the original, or subsequently improved, grade and cross section.

(3) Roadside. Preservation of the roadside in a safe, pleasant, and forgiving manner through vegetation management, erosion control, and litter pick-up.

(4) Drainage. Preservation of hydraulic capacity for which originally designed.

(5) Bridges and tunnels. Preservation of the structural and operational characteristics for which originally designed. These include safe, smooth, skid-resistant surfaces; proper surface drainage; and adequate functioning bearing devices and substructural elements. Replacement or repair of structural railing and approach guardrail should be done without unreasonable delay. Tunnels should be cleaned, properly lighted, and adequately ventilated.

(6) Snow and ice control. Preservation of the roadway safety, efficiency, and environment during winter driving conditions.

(7) Traffic control devices. Preservation of clean, legible, visible, and properly functioning traffic control devices. This includes pavement markings, signing, delineators, signals, etc.

(8) Safety appurtenances. Replacement of damaged, defective, and/or inoperable devices without unreasonable delay. This includes guardrails, impact attenuators, breakaway supports, barriers, etc.

(9) Safety rest areas. Preservation and operation of facilities reasonably necessary for the convenience, relaxation, and informational needs of the user.

(10) Access control. Preservation of the originally designed access control, elimination of unauthorized traffic movement, and prevention of improper or unauthorized use of the highway rights-of-way.

(11) Traffic safety in maintenance and utility work zones. Procedures that will aid the safety of motorists and maintenance workers. The procedures shall be consistent with the provisions of 23 CFR Part 630, Subpart J, and Part VI of the Manual on Uniform Traffic Control Devices.

Of the activities listed above, those that resurface, restore, rehabilitate and reconstruct are also known as capital maintenance. Capital maintenance activities are eligible for funding under the 23.USC.119 Interstate Maintenance (IM) and 23.USC.144 Highway Bridge Replacement and Rehabilitation (HBRR) programs.

While capital maintenance activities generally exclude road widening for the sake of expanding the capacity of the roads, minor road widenings to address roadway design deficiencies are included in this plan. This is consistent with the IM program, which allows for the construction of high-occupancy and auxiliary lanes, but does not include the costs of any "expansion of the capacity of any interstate highway or bridge, where such new capacity consists of one or more new travel lanes." Rehabilitation activities under 23 USC 144 (q) means "major work necessary to restore the structural integrity of a bridge as well as work necessary to correct a major safety defect."

5.2 Existing Conditions

MassHighway continually monitors the performance of the IHS. The subject of this analysis is the physical condition of the IHS. Safety and mobility also are monitored by MassHighway, but are analyzed here only insofar as changes to the physical condition of the IHS should not have an adverse effect on safety or mobility.

The physical components for which the most information is available are the pavements and bridges. Pavement conditions are monitored by MassHighway as part of its comprehensive Pavement Management System (PMS), and conditions are reported annually to the FHWA as part of the Highway Performance Monitoring System (HPMS). Performance on the Interstate System is reported in units of International Roughness Index (IRI). MassHighway also records the Pavement Serviceability Index (PSI) in its dTIMS[12] system.

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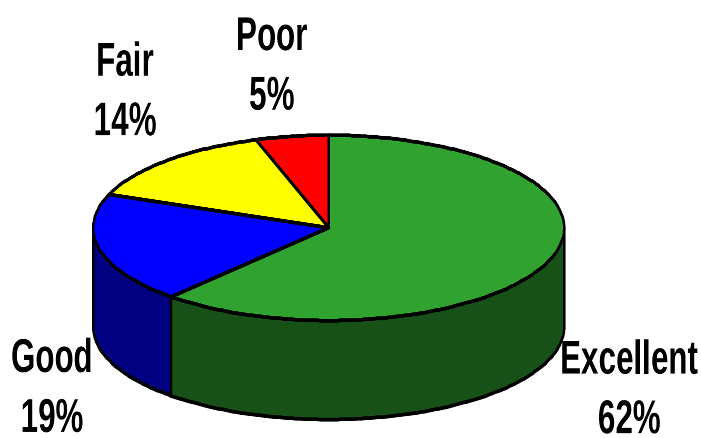
[12] dTIMS software is a tool that uses pavement condition information as the basis for determining and prioritizing roadway maintenance and rehabilitation needs.

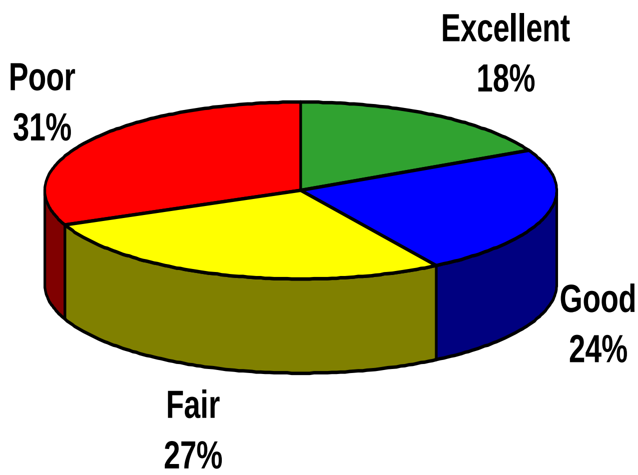
PSI measures pavement condition on a scale from 0 to 5, with 0 being the worst and 5 being the best. MassHighway further uses PSI to characterize pavement condition as Excellent (PSI 3.5 to 5.); Good (3.0 to 3.49); Fair (PSI 2.5 to 2.99); and Poor (PSI <2.5). The current pavement condition on the IHS based on data from dTIMS is shown in Figure 5.1. As shown, the overwhelming majority, 79%, of the interstate pavements are in Excellent or Good condition. The average pavement condition on interstate highways is a PSI of 3.47, which is only just slightly below the threshold between Excellent and Good.

Figure 5.1 Existing Pavement Conditions – Interstate Highways



MassHighway monitors bridge conditions in compliance with National Bridge Inventory (NBI) guidelines. Bridge inspection data are stored in the MassHighway Bridge Management System (BMS), and imported into the Pontis BMS licensed by MassHighway from the American Association of State Highway and Transportation Officials (AASHTO) for analysis. Pontis reports on Structurally Deficient bridges as well as Health Index (HI). The Health Index has been used to set performance thresholds of the bridges as: Excellent, HI greater than 98%; Good, HI 90 to 97.99%; Fair, HI 75 to 89.99%; and Poor, HI less than 75%. Based on these standards the current bridges conditions, as reported by Pontis, are shown in Figure 5.2. From the existing conditions it can be seen that a large number of bridges are in Poor Condition and in need of rehabilitation or replacement work (31% with a Health Index less than 75%).

Figure 5.2 Bridge Condition – On and Over the Interstate Highways



Source: Cambridge Systematics from MassHighway Pontis data

In addition to the Health Index, another useful measure of bridge conditions is the number of bridges classified as Structurally Deficient (SD). A structurally deficient bridge is one that has experienced deterioration significant enough to potentially reduce its load-carrying capacity. However, this rating does not directly correlate to a weight-restricted bridge or an unsafe structure. The percentage of Structurally Deficient bridges by system is shown in Table 5.2, based on information provided by MassHighway. Note that the percentage of Massachusetts bridges that are classified as SD (11.0%) compares favorably to the national average (12.6%).

Table 5.3 Structurally Deficient Bridges in Massachusetts by System

System	Number SD	% SD by Count
All bridges	557	11.0%
National Highway System (NHS) Only	422	10.7%
IHS Only (excluding I-90)	34	2.9%

Section 4 describes the systems available for managing other assets besides pavement and bridges. To summarize, EOT/MassHighway have established a comprehensive mile posting system for use in locating all MassHighway-owned assets. Further, the conditions of all assets can be viewed in the comprehensive record available on the Roadware video log maintained by MassHighway, though no systematic review of the video logs for other asset data has been performed. In addition, data have been compiled for selected assets, such as memorial signs and Intelligent Transportation System (ITS) equipment. However, limited data are available on asset conditions (besides that on pavement and conditions), and MassHighway has no system available for predicting future conditions of other maintainable assets. Thus, the analysis of other maintainable assets was based on anecdotal information.

5.3 GOALS

Goals, as used in performance based planning, are desired outcomes expressed as policy. For example a goal of an asset management plan might be to improve pavement conditions. In order to provide the means to determine how that goal is being met, it is necessary to first establish performance measures or indicators of work performed or results achieved. For example, a performance measure that might accompany the goal of improving pavement condition might be the average PSI on all roads. An asset management plan should establish targets for each of these performance measures which are specific values for performance measures that an agency hopes to achieve. Continuing the pavement example, the target might be the existing pavement condition (which on interstates in Massachusetts is 3.47).

In order to set performance measures and targets for the Interstate Asset Management Plan, the goals established in the EOT long range transportation plan were first examined. In the EOT plan the goals that are pertinent to this Interstate Asset Management Plan are:

- Focus primarily on preservation;
- Improve pavement conditions; and
- Improve bridge conditions.

Based on these goals, the following performance measures were selected for use in a analysis of the interstate system:

- Percentage of lane miles in fair or poor condition (PSI < 3);
- Structurally Deficient (SD) Index, where the current index value is 100 to facilitate representation of the predicted percentage change in SD bridges; and
- Bridge Health Index (HI).

The setting of realistic short- to mid-term targets for these measures is critical for helping decision-makers make performance-based resource allocation decisions. It is a fundamental part of good asset management practice. Setting targets requires a mix of considerations, including:

- Financial – targets should be based on a realistic projection of future funds. The establishment of targets that require resources that are far more than can be expected is not particularly useful;

- Policy – targets should reflect current policies, as established official documents of the agency; and
- Technical – targets should be realistic based on current practices. Establishing targets that require unreasonable advance in technology or practices is not useful.

To support the development of realistic performance targets, the following section contains a sample analysis of projected performance over time for various funding levels. Note that the analysis was performed with planned funding levels based on data provided by MassHighway staff and analysis of the Statewide Transportation Improvement Plan (STIP). This information suggests that the planned budget interstate pavements (paid for with the Interstate Maintenance fund) is approximately $50M per year, and the planned budget for interstate bridges (based on projected costs for interstate bridge projects in the STIP) is $59M per year. Actual expenditures for pavements and bridges depend upon a number of factors not explicitly included in the analysis, such as actual construction costs (versus projected costs in the STIP), the actual scope of the projects performed, and many other factors. Thus, the analysis should be used for demonstrative purpose and cannot be seen as an authoritative prediction of future conditions or projection of actual expenditures. Nonetheless, even with these qualifications, the analysis can serve to help set performance goals and inform the decision-making process.

5.4 Sample Analysis of Predicted Asset Conditions

Tools Used

MassHighway uses the dTIMS pavement management system for pavement analysis. HERS-ST was used with default models and costs for the analysis described here. HERS-ST is the state version of the highway investment analysis software tool used by FHWA in preparing the biennial Conditions and Performance Report. It can be used to identify deficiencies, provide performance prediction, and conduct trade-off analysis. It provides an independent verification and enhancement of the results generated using dTIMS. In order to use HERS-ST in this analysis, a special subset of the Massachusetts HPMS data was prepared containing only the interstate highways included in this Asset Management Plan. Additionally, since the PSI attribute was not consistently updated in the data set provided for analysis, the IRI pavement conditions in HPMS were converted to PSI using procedures included in HERS-ST. These converted values do not correspond to the PSI values in dTIMS; for this reason, the dTIMS values were used as the starting point for the analysis.

In selecting projects, HERS-ST uses a set of deterioration curves to calculate the pavement conditions under given budgets, assuming that funding will be devoted to the most cost effective projects. Pavement work on any road segment is considered in HERS-ST only when pavement conditions fall below a PSI of 3.2, based on the settings used for the analysis.

Pontis was used for the bridge analysis performed for this study. A special subset of the Pontis database consisting of only the bridges on or over the interstates included in this plan was prepared.

In making project recommendations, Pontis distinguishes between functional improvement and preservation projects. Improvement projects alter functional aspects of a bridge. These projects are intended to address functional shortcomings. To develop improvement projects, Pontis identifies instances where adequate standards are not met, develops strategies to meet them, and prioritizes the candidate improvements. Example improvement projects include widening a deck, raising a bridge to increase its vertical clearance, or strengthening a bridge so it can carry heavier loads. Replacement of the structure is also an improvement action, which is considered in the project programming models in a manner that integrates improvement considerations with preservation considerations. Preservation projects consist of bridge maintenance, repair, and rehabilitation (MR&R) actions performed on individual bridge elements. Pontis models show how MR&R actions improve element condition, as well as how bridge elements deteriorate over time in the absence of MR&R actions. The overall objective of preservation projects is to maintain bridges at minimum long-term discounted cost, without altering the bridges' functional aspects. Example preservation projects include replacing a bridge deck, or repainting a bridge's painted steel elements.

Only as a means to ensure that the analysis did not result in a worsening of mobility, as discussed previously, the delay outputs from HERS-ST were examined. AssetManager NT was used to integrate the results of the various HERS-ST and Pontis analyses**.**

Cost Increases

The costs models in HERS-ST and Pontis are based on 2004 dollars. In recognition of the dramatic increase in construction costs that have been experienced by MassHighway, the FHWA's Bid Price Index (BPI) was reviewed as part of the analysis. The BPI is a record of construction bid prices reported by state DOTs to the FHWA. Based on an examination of the Composite Bid Price Index from 2004 to the present it was determined that a 24% adjustment to the 2004 unit prices in HERS-ST and Pontis would adequately reflect changes to 2006 conditions. While some elements of construction have experienced even greater increases, the composite increase from 2004 to 2006 was 19%. While prices for individual elements and by quarter vary even more dramatically, as prices go up, substitutions of material, changes of design will also take place. This seasonal variation and substitution can not be considered in HERS. For that reason, the 24% was chosen as a reasonable adjustment of 2004 unit prices.

For the period beyond 2006, it is assumed that inflation will increase by 4 percent per year. This level has been established in recent guidance issued by FHWA.[13] Further, as shown in Figure 5.3, over the period from 1984 to 2004 (the most recent year for which BPI data are available), the Bid Price Index has generally tracked the inflation rate of the Consumer Price Index (CPI).

Figure 5.3 Comparison of CPI and BPI

Source: Cambridge Systematics from FHWA BPI and BLS CPI data

Analysis Scenarios

Adjusted for inflation, HERS-ST and Pontis produce outputs in 2006 dollars. These outputs implicitly assume that budgets for funding will also increase with inflation. To provide a sensitivity analysis for the situation where funding levels do not increase and where the purchasing power of those budgets would be eroded by inflation, two scenarios were analyzed. In Scenario 1 it is assumed that annual budget will be increased to keep pace with inflation. For example, if the budget in Year 1 is $50M, then in Year 2 the budget would be budget $52M, the Year 1 budget increased by the four percent for inflation. In Scenario 2 it is assumed that the annual budget remains constant over time and that inflation

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[13] email From: Shepherd, Gloria Director, Office of Planning, FHWA, Sent: Friday, August 18, 2006 1:39 PM, Subject: INFORMATION: Use of Inflation Rates for Developing Future Cost Estimates as Part of Fiscal Constraint

effectively erodes the purchasing power of that budget. For example, if the Year 1 budget is $50M, the Year 2 budget would also be $50M. With inflation eroding the purchasing power, this Year 2 budget would in fact be $48 million as measured in 2006 dollars.

Pavement Analysis

The HERS-ST analysis for pavements was conducted in five-year increments from 2006 to 2016. Data provided in June 2006 by MassHighway were used for this analysis. These data represent conditions in 2004 and do not reflect subsequent and ongoing projects. Therefore, prior to running the analysis, the condition of pavement segments that underwent the following types of work were manually reset to reflect the condition of new pavement:

- Resurfacing and related work;
- Resurfacing;
- Resurfacing and traffic sign replacement;
- Roadway construction; and/or
- Widening.

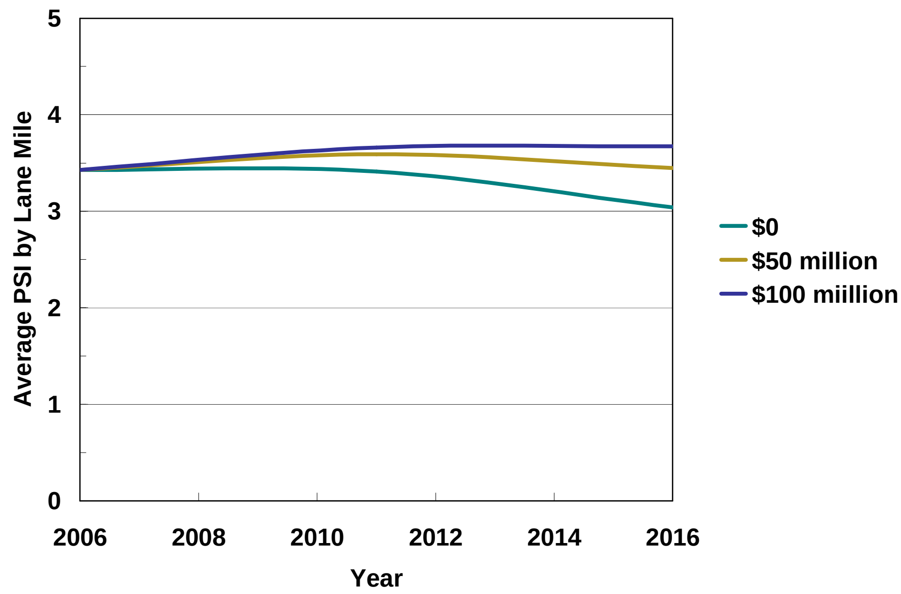
The annual budget for 2006 to 2016 was varied for the different runs to evaluate the impact of different budget levels on predicted pavement conditions. Specifically, runs were performed with annual budgets in $25M increments from $0 to $100M. The work types included in the analysis include resurfacing, reconstruction, and minor widening. Emergencies repairs, maintenance and operations activities were not considered.

Figure 5.4 shows the results for Scenario 1. If the budget for pavements on the interstates is zero, average PSI on the IHS will decrease from the current level of 3.43 to an average of 3.04, a decline of 12%. If the budget for pavement repair is $50M per year, the average PSI will increase slightly to 3.45, an improvement of less than 1%. If the budget for pavement repair is increased to $100 M per year, the average PSI will increase from the current level of 3.43 to an average of 3.67, a 7% increase.

Figure 5.5 shows the results of Scenario 2. In this scenario, the budget remains constant in 2006 dollars but has less buying power as a result of inflation. The impact of a budget of zero is exactly the same as in Scenario 1. The end result for all other budget levels is a lower average PSI. If the budget for pavement repair is $50M, the average condition will decrease slightly from 3.43 to 3.38. If the budget for pavement repair is increased to $100M per year, the average PSI will increase to 3.58, a 4% increase.

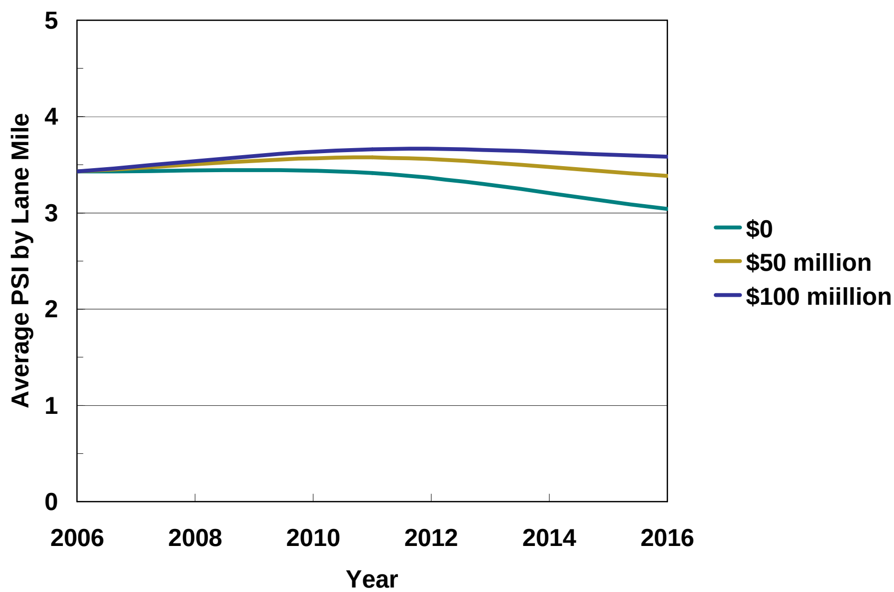
Figure 5.6 combines the information from Figures 5.4 and 5.5 to show pavement conditions in 2016 under different budget levels for each scenario. The yellow line in Figure 5.6 shows that maintaining current conditions requires $50M annually under Scenario 1 and $59M annually under Scenario 2.

Figure 5.4 Interstate Pavement Condition Over Time by Annual Funding Level – Scenario 1



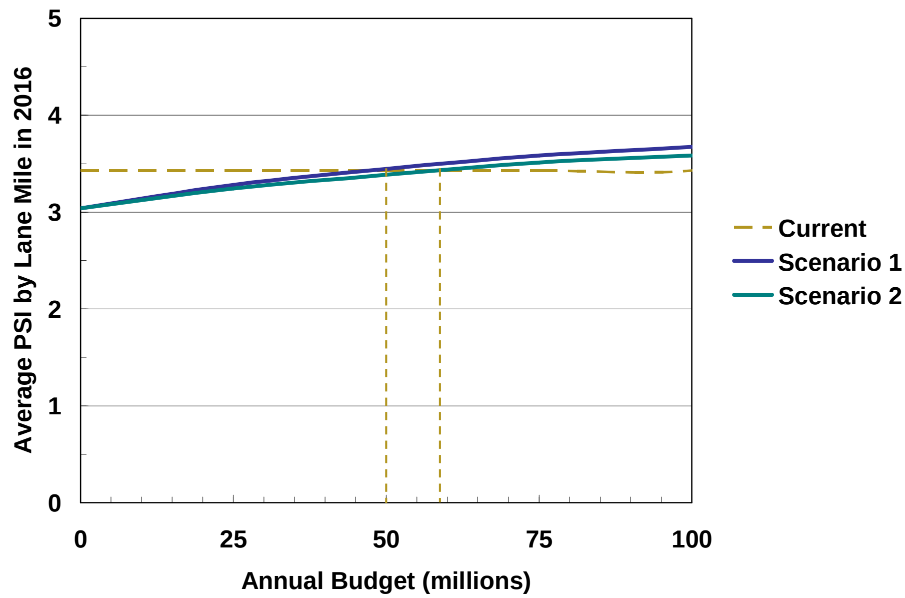
Source: Cambridge Systematics from HERS-ST

Figure 5.5 Interstate Pavement Condition Over Time by Annual Funding Level – Scenario 2



Source: Cambridge Systematics from HERS-ST

Figure 5.6 Interstate Pavement Condition in 2016 versus Annual Budget



Source: Cambridge Systematics from HERS-ST and AssetManager NT

Bridge Analysis

The bridge analysis was conducted with the Pontis software, using a subset of MassHighway's Pontis database consisting of only bridges on or over the interstate highways. The time period fro the analysis was five years, a period long enough to determine bridge investment decisions without the distortions of low budget levels in the initial years.

Data provided by MassHighway in June 2006 was used for this analysis. These data do not account for recent projects or deterioration. Therefore, prior to performing the simulations, structures removed or replaced as part of the Big Dig were removed from the data base, and bridge projects for fiscal years 2003 to 2006 were entered into the system. The scenario treatment for these ongoing and planned projects was set to "assume done" in Pontis. This ensured that in the first year of the program simulations performed using Pontis (2006), all of these projects were scheduled to occur, regardless of the budget or plans for future years, and additional work was not recommended for the bridges handled through these projects.

The simulation was set to run from 2006 to 2011. The budget for the first year was set to $1. This ensured that all planned projects described above were simulated as being performed in 2006, but no additional work was simulated in 2006. The annual budget for 2007 to 2011 was varied for the different runs to evaluate the impact of different budget levels on predicted bridge conditions. Specifically, runs were performed with annual budgets in $25M increments from

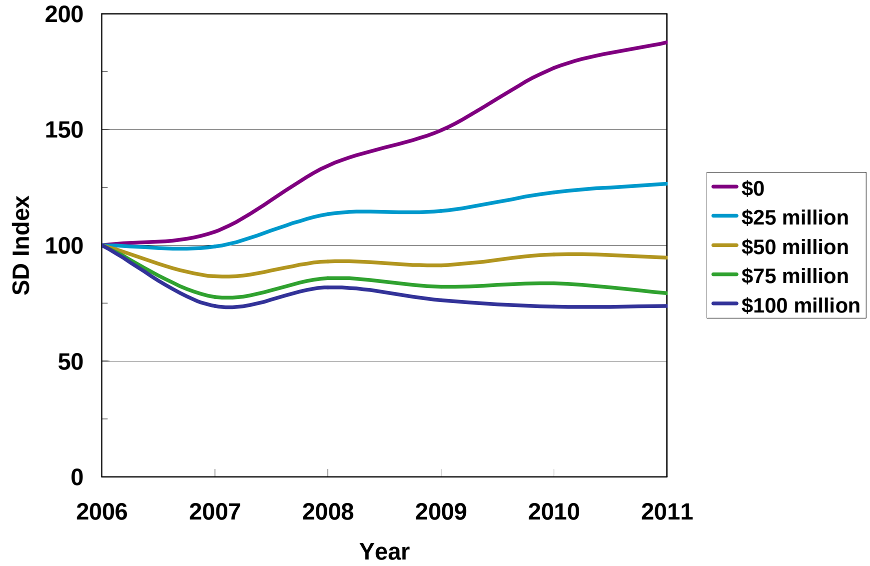
$0 to $150M. Not included in the budget are emergency repairs, work on approach roadways, or other work performed on other assets besides bridges using bridge funds.

Figure 5.7 shows the results of Scenario 1. If the budget for replacing or rehabilitating interstate bridges is zero, the number of SD bridges would increase by 88% by 2011. If the budget for bridges is $50M per year, the number of SD bridges would decrease by 5%. If the budget for bridges is $75M per year in constant dollars, the number of SD bridges would decrease by 20%. If the budget for bridges is $100M per year in constant dollars, the number of SD bridges would decrease by 26%.

Figure 5.8 illustrates the results for Scenario 2. In this scenario, the budget remains constant in 2006 dollars but has less buying power as a result of inflation. The impact of a budget of zero is exactly the same as in Scenario 1. The end result for all other budget levels is a higher number of SD bridges. If the budget for bridges is $50M per year, the number of SD bridges would stay roughly the same. If the budget for bridges is $75M per year in current year dollars, the number of SD bridges would decrease by 15%. Finally, if the budget for bridges is $100M per year in current dollars, the number of SD bridges would decrease by 23%.

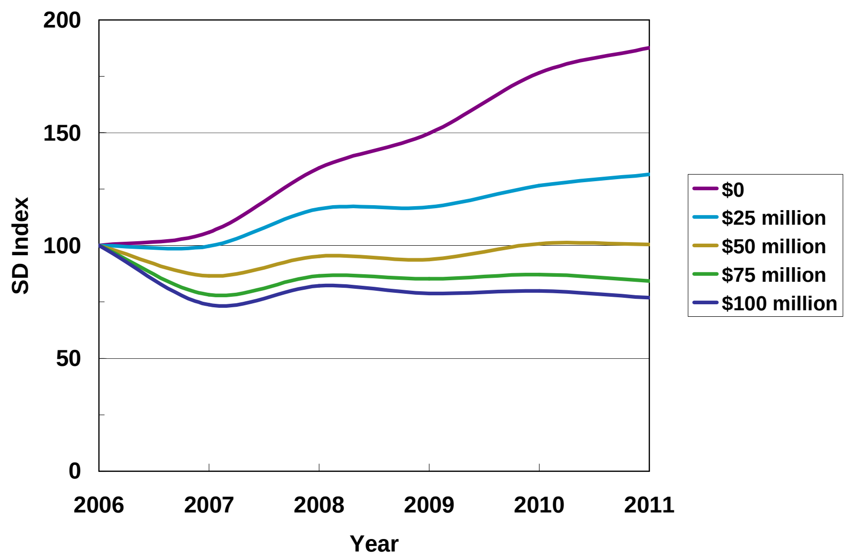
Figure 5.9 combines the information from Figures 5.7 and 5.8 to show bridge conditions in 2011 under different budget levels for each scenario. The yellow line in Figure 5.9 shows that maintaining the current percentage of SD bridges on the IHS would require $48M annually under Scenario 1 and $51M annually under Scenario 2. As shown by the red lines in Figure 5.9, the current budget of $59M would result in a decrease in SD bridges of 13% in Scenario 1 and a decrease in 5% in Scenario 2.

Figure 5.7 Interstate Bridge SD Index Over Time by Annual Funding Level – Scenario 1



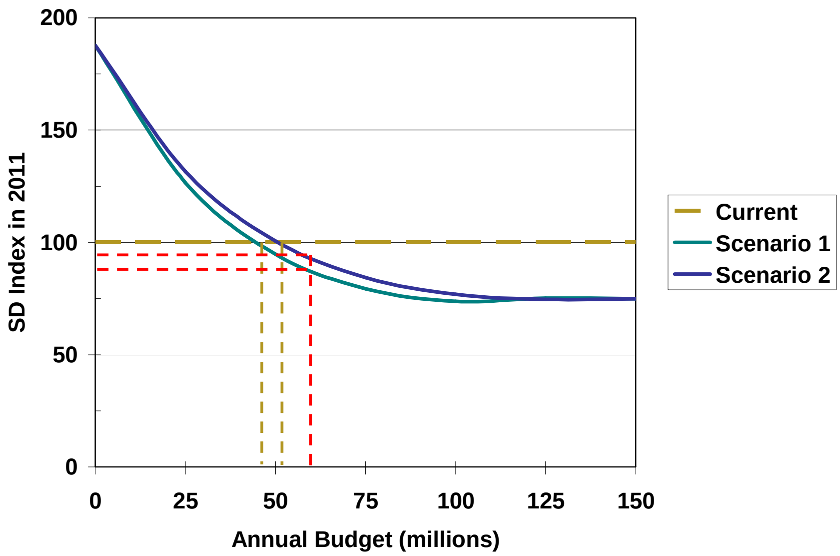
Source: Cambridge Systematics from Pontis

Figure 5.8 Interstate Bridge SD Index Over Time by Annual Funding Level – Scenario 2



Source: Cambridge Systematics from Pontis

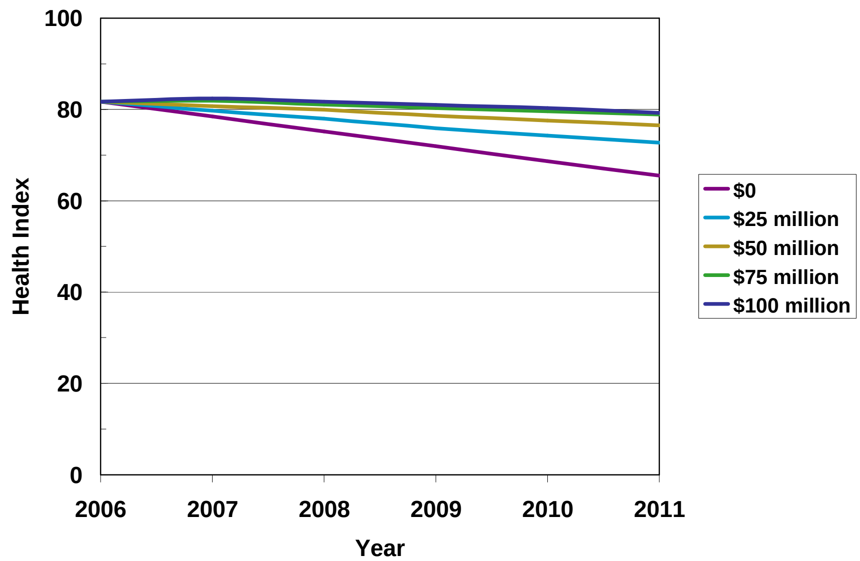
Figure 5.9 Interstate Bridge Condition in 2011 versus Annual Budget



Source: Cambridge Systematics from Pontis and Asset Manger NT

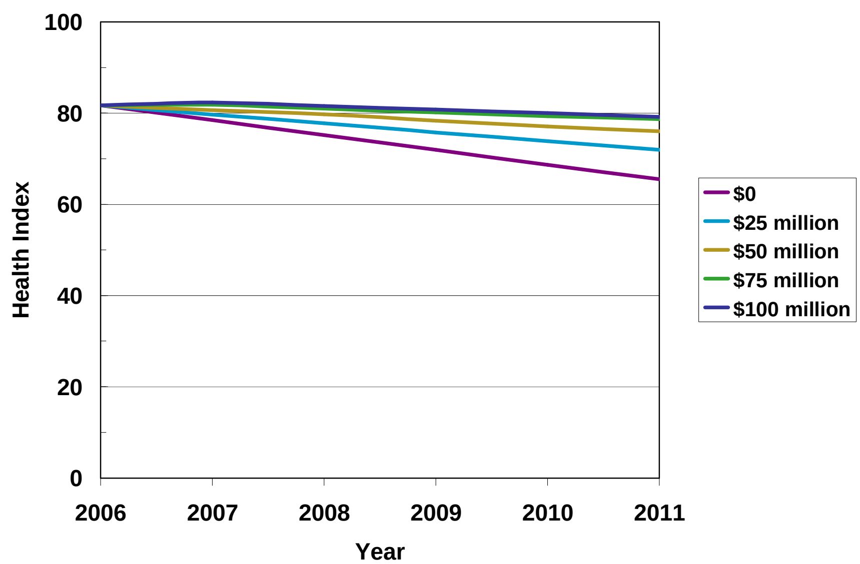
Figures 5.10 through 5.12 illustrate the results of the bridge analysis in terms HI. Based on these results, it appears that HI is less sensitive to the impact of inflation. Figures 5.10 and 5.11 appear nearly the same, as do the two lines representing Scenarios 1 and 2 in Figure 5.12. As shown by the red lines in Figure 5.12, under both scenarios the current budget of $59M dollars would result in a decrease in the average HI from 82% to 77%. As shown by the yellow line, the average HI will decrease over the next five years even if the annual budget is increased to $150M. This result is largely a reflection of the fact of two factors: 1) regardless of the level of investment, most bridges on or over the IHS will deteriorate over time; and 2) once economically-justified needs are satisfied, Pontis will leave money unspent rather than changing the criteria for what work to perform.

Figure 5.10 Bridge Health Index Over Time by Annual Funding Level – Scenario 1



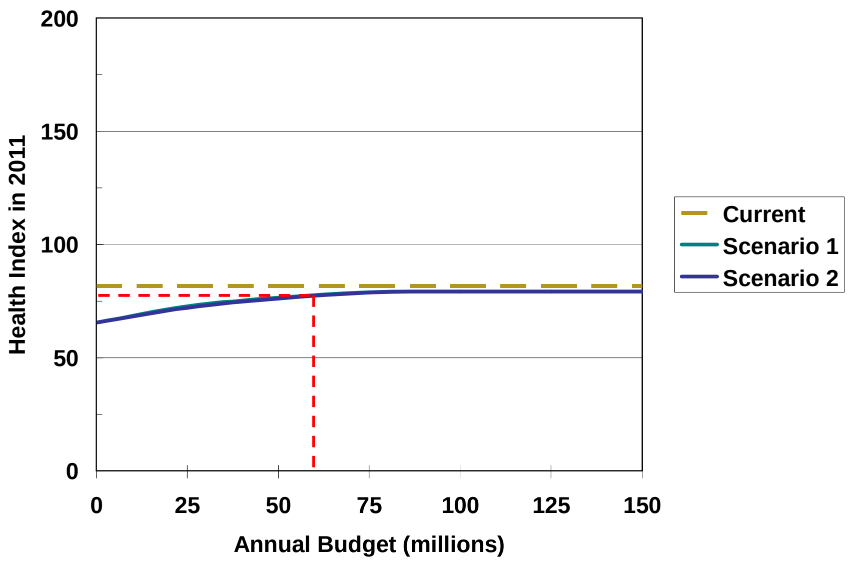
Source: Cambridge Systematics from Pontis

Figure 5.11 Bridge Health Index Over Time by Annual Funding Level – Scenario 2



Source: Cambridge Systematics from Pontis

Figure 5.12 Bridge Health Index in 2011 versus Annual Budget



Source: Cambridge Systematics from Pontis and Asset Manger NT

Other Maintainable Assets

As discussed previously, while there is a comprehensive Roadware video log for the IHS that could be used to examine other maintainable assets, the log has not been reviewed in any systematic fashion. There is limited data available on condition of maintainable assets other than pavement and bridges. Anecdotal evidence suggests that current expenditures are at best sufficient for maintaining current conditions.

As discussed in Section 2, a number of agencies use a maintenance level-of-service (LOS) approach to analyze the relationship between maintenance expenditures and conditions. Following is an example of how this approach could be applied to the IHS based on signs.

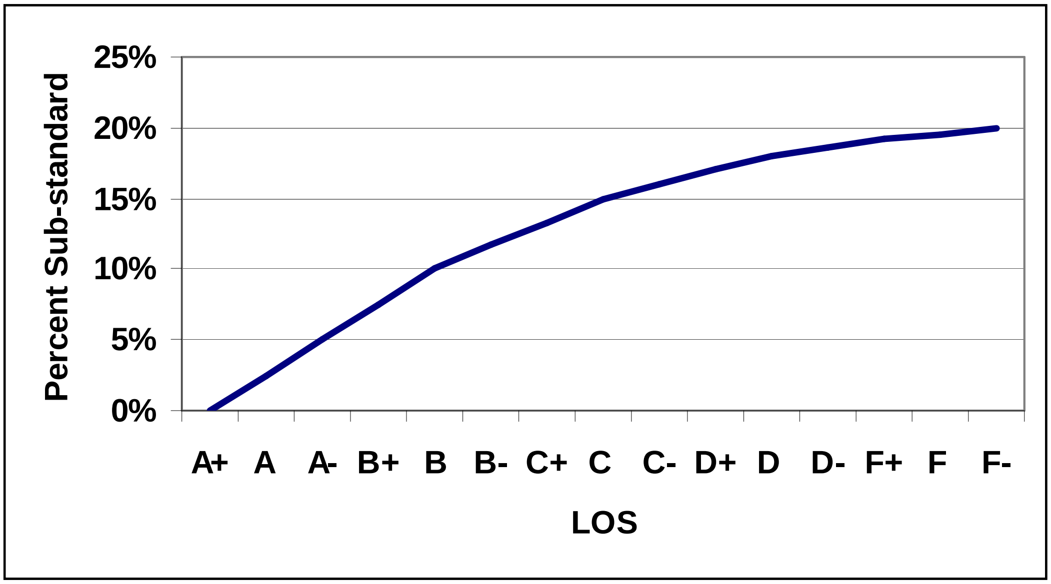
The first step in developing an LOS program is to compile condition information. In the case of signs, the frequency in which they are replaced can serve as a condition indicator. MassHighway's goal is to replace signs every ten years. In this example, it is assumed that this goal has been followed for several years so that a steady-state has been achieved – each year, 10% of interstate signs need to be replaced.

The second step is to compile cost information. MassHighway has estimated that it costs an average of $182,000 to changes all signs on an interchange and that there are on average six signs per interchange.

The next step is to develop an LOS model that maps condition to a letter grade. In this example, the condition is based on percent of signs that are sub standard.

"Sub-standard" is defined as being older than ten years. Figure 5.13 shows a sample LOS model for interstate signs. Not that if the current standard is being met, i.e., 10% of the signs are sub-standard, the result is an LOS of B. If this percent doubles to 20%, the result is an LOS of F-.

Figure 5.13 Example LOS Model for Interstate Signs



The final step is to determine the relationship between cost and resulting LOS. Based on the current condition and the current cost estimates for replacing signs, Figure 5.14 illustrates the LOS that can be expected next year for a given budget. For example, $4.8M would be required to maintain an LOS of B. Moving to LOS A would require approximately $8.5M. Conversely, if $2.5M were allocated to sign replacement, the LOS would deteriorate to a C.

Figure 5.14 Example LOS Model for Interstate Signs

Routine Maintenance

In addition to capital maintenance activities, MassHighway undertakes routine maintenance activities on the interstates. These activities are undertaken by MassHighway district personnel or by contractors under the direction of the districts. Interviews were conducted with staff from four of the five MassHighway districts to determine maintenance expenditures on the interstates. (MassHighway District 1 has no Interstate mileage other than I-90, the MassPike, which is not included in this Plan). The review attempted to identify expenditure on interstates in each district. The interviews demonstrated that there was no consistent approach for tracking maintenance expenditures used by all districts. Instead, each district uses its own approaches for tracking work performed, as discussed in Section 4. Little data are available for supporting analysis of expenditures by system, much less the condition of the asset being addressed before of after the maintenance.

Based on the information provided the initial estimate of current expenditures is $15 to 21M per year. This estimate includes most roadside maintenance activity, but excludes mowing, sweeping, incident response and snow and ice removal. As mentioned previously, there are limited data available on condition of maintainable assets. However, anecdotal evidence suggest current expenditures are at best sufficient for maintaining current conditions.

5.5 Recommended Capital Project Locations

Tables 5.3 and 5.4 present tentative recommended locations for capital pavement and bridge projects over the next five years based on the analysis described above. (The locations are presented graphically in Figures 5.15 and 5.16.) These projects were recommended by HERS-ST and Pontis for an annual budget of $75M each for pavements and bridges. These locations should be considered a starting point for the planning and programming process. Engineering judgment and a more detailed analysis of actual available funding levels are required to finalize these locations and develop specific projects.

Table 5.3 Recommended Locations for Capital Pavement Projects

Route	Beginning Milepost	Ending Milepost	Length (Miles)
91	0.0	3.3	3.3
91	12.3	24.8	12.5
91	25.8	27.4	1.6
91	35.0	43.2	8.2
91	45.6	45.9	0.3
93	7.4	10.9	3.5
93	12.0	15.5	3.5
93	18.0	18.5	0.5
93	19.3	21.0	1.7
93	21.5	22.5	1
93	23.3	26.5	3.2
93	26.8	27.1	0.3
95	24.1	27.1	3
95	27.6	28.2	0.6
95	38.0	39.4	1.4
95	41.1	41.8	0.7
95	45.0	45.4	0.4
95	51.1	52.3	1.2
190	-0.4	0.4	0.8
195	11.8	12.2	0.4
290	0.0	0.3	0.3
290	4.7	6.9	2.2
295	4.2	4.5	0.3
495	7.7	12.2	4.5

Route	Beginning Milepost	Ending Milepost	Length (Miles)
495	14.4	19.2	4.8
495	31.0	33.6	2.6
495	48.2	48.5	0.3
495	58.9	62.6	3.7
495	75.6	78.0	2.4
495	78.0	81.8	3.8
495	106.8	108.6	1.8
495	110.2	111.8	1.6
495	114.0	118.5	4.5
		Total	80.9

Figure 5.15 Recommended Locations for Capital Pavement Projects

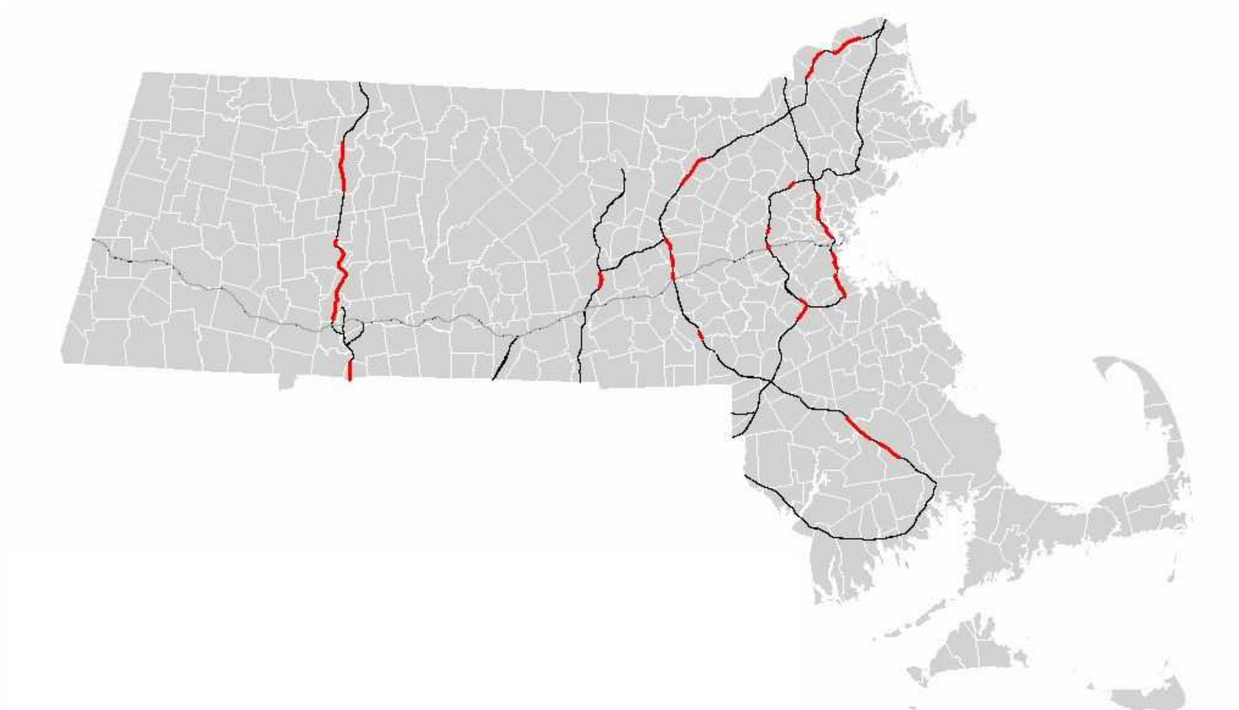


Table 5.4 Recommended Locations for Capital Bridge

Bridge ID	Facility Carried	Feature Intersected
3Y5	ALLEN AVE	I 295
3Y6	BARNEY AVE	I 195
3F7	BOSTON ST	I 93 /US1/ST3
137	BURKE FLAT	I 91
215	BURNCOAT	I 290
2LV	CARLISLE ST	I 495
1KA	CEDAR ST	I 395
2Y2	CENTRAL ST	I 95
2YY	CHANDLER RD	I 93
13H	CHESTNUT ST	I 291 CONN A, B, C, D & RMP F
11X	COLRAIN RD	I 91
3YH	DAVIS RD	I 195
2Y4	ENDICOTT RD	I 95
3EP	FELLSWAY WST	I 93
3XJ	FOURTH ST	I 195
21B	FRUIT ST	I 495
28W	HARWOOD AVE	I 495
2YX	HIGH PLN RD	I 495
1PX	HOLBROOK ST	I 395
2MF	HOPKINS ST	I 95 /ST 128
1PY	HUGUENOT RD	I 395
1VV	J APPLSD LN	I 190
31R	JEWETT ST	I 95
1X9	LAUREL ST	I 190
3YA	LEES RIV AVE	I 195
12Y	LEYDEN RD	I 91
30B	LOCKWOOD LN	I 95
1VJ	MALDEN ST	I 190
216	MARSH AVE	I 290
13C	MOUNTAIN DR	I 91

Bridge ID	Facility Carried	Feature Intersected
11G	ROOSEVELT AV	I 291/US 20
297	RUSSELL ST	I 495
2ME	SALEM ST	I 93
11D	ST JAMES AVE	I 291/US 20
1Q2	SUTTON AVE	I 395
31W	TENNEY ST	I 95
3VJ	TONER BLVD	I 95
2M6	TRULL RD	I 495
4AY	VERNON ST	I 495
2AQ	WASHNGTON ST	I 495
3XU	WEST ST	I 495
2LQ	WESTFORD ST	I 495
1PJ	I 84 EB	ST 15 MASHAPAUG RD
0WU	I 90	I 391
1QT	I 90 EB	I 290
1QU	I 90 WB	I 290
0X1	I 91	COMB CT R, BMRR & ST116
10K	I 91	COMB STS & BMRR & GARGE
10J	I 91	HWY CITY STS&GARAGE
10T	I 91	HWY NOBLE ST
0X2	I 91	HWY WN RAMP
10Q	I 91	OTHER BUILDING
10R	I 91	ST116 MAIN ST (N END)
10W	I 91	US 5 RIVERDALE ST
10L	I 91 & RMPS L & M	I 291 & CITY STS
0X3	I 91 NB	COMB STLWTR RD & DFLD R
0XR	I 91 NB	RR BMRR
0WX	I 91 NB	WATER FALLS RIVER
0X4	I 91 SB	COMB STLWTR RD & DFLD R
100	I 91 SB	COMB US 5 & BMRR
0X5	I 91 SB	HWY W DEERFLD LOWER RD
0XT	I 91 SB	RR BMRR

Bridge ID	Facility Carried	Feature Intersected
0WY	I 91 SB	WATER FALLS RIVER
0YH	I 91 SB ON RAMP	ST141 EB
2HN	I 93	BORDER RD ACCESS
2HW	I 93	CONCORD ST
2J3	I 93	MONTVALE AVE
3B5	I 93	RIVERSIDE AVE
3BN	I 93	SHORE DR
2HK	I 93	I 95 /ST128
2HM	I 93	RR SPUR (abandoned)
3B3	I 93	ST 16 MYST VAL PKY
3BH	I 93	ST 28 & ST38 & TEMPLE ST
3B7	I 93	ST 60 WB/SALEM ST
2V0	I 93	WATER MERRIMACK RIVER
3B4	I 93	WATER MYSTIC RIVER
3EC	I 93 /US 1/ST 3	COMB MBTA & COLUMBIA RD
3D6	I 93 /US 1/ST 3	COMB MBTA & RED LN SSH
3D5	I 93 /US 1/ST 3	CITY STS
3B2	I 93 /US 1/ST 3	GRANITE AVE
3BE	I 93 /US 1/ST 3	WEST ST
3D1	I 93 /US 1/ST 3	WATER NEPONSET RIVER
3FC	I 93 RP TO I 93 NB	I 93
2V1	I 95	WATER MERRIMACK RIVER
2FC	I 95 /ST 128	MBTA/BMRR
2FL	I 95 /ST 128	ST129 WB MAIN ST
3R8	I 95 NB	OLD POST RD
3Q6	I 95 NB	ST 1 A/NEWPORT AVE
3Q4	I 95 NB	US 1 WASHINGTON ST
2ER	I 95 NB/ST 128 NB	S BEDFORD ST
3R9	I 95 SB	OLD POST RD
3Q7	I 95 SB	ST 1 A/NEWPORT AVE
2VH	I 95 SB	ST 62 MAPLE ST
3Q5	I 95 SB	US 1 WASHINGTON ST

Bridge ID	Facility Carried	Feature Intersected
2EV	I 95 SB/ST128 SB	ST 3 A/CAMBRIDGE ST
1XF	I 190 NB	ST 12 & RAMP B
1VU	I 190 NB	N NASHUA RIVER
1XB	I 190 SB	PWRR
1XG	I 190 SB	ST 12 NB & RAMP B
1VR	I 190 SB	ST117 N MAIN ST
1VT	I 190 SB	N NASHUA RIVER
1NV	I 190 SB & ST 2 EB	NASHUA ST
3TY	I 195	CSX & PURCHASE ST
3TK	I 195	ST79 & TAUNTON RIV
3U0	I 195	COUNTY&STATE STS
3U1	I 195	ST 18 ASHLEY BLVD
3TQ	I 195	ST 81 PLYMOUTH AVE
3TV	I 195 EB RAMP F	WELD ST & RELIEF
3U3	I 195 WB	ST 140
3TU	I 195 WB RAMP C	RELIEF
1T7	I 290 EB	4 CITY STS & CSX
1R9	I 290 EB	MDC AQUEDUCT & CSX
1RR	I 290 EB	STHBRG ST & MDL R
1TX	I 290 EB	I 495
1RL	I 290 EB	PWRR
1TC	I 290 EB	ST 70 LNCLN ST & ON RAMP
1T3	I 290 EB	ST146 MILLBURY ST
1TR	I 290 GRFTN ST ONR	KEESE ST
1KH	I 290 RAMP A	I 290 RMP C & MILLBRK ST
1TT	I 290 SHWBY ST OFR	MBTA PKNG ACCSS
1T8	I 290 WB	4 CITY STS & CSX
1R8	I 290 WB	MDC AQUEDUCT & CSX
1RT	I 290 WB	STHBRG ST & MDL R
1R4	I 290 WB	CHURCH ST
1TY	I 290 WB	I 495
1RM	I 290 WB	PWRR

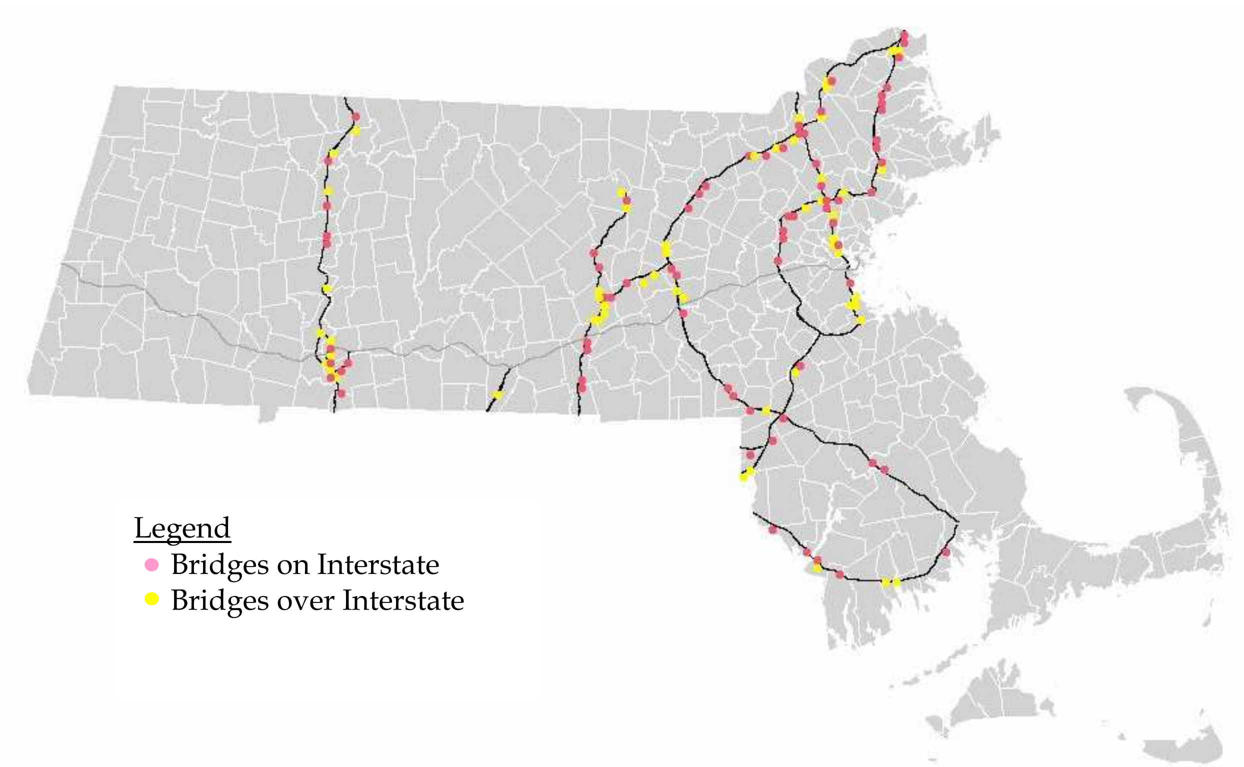
Bridge ID	Facility Carried	Feature Intersected
1T4	I 290 WB	ST 146 MILLBURY ST
1T5	I 290 WB 0N RAMP	CAMBRIDGE ST
119	I 291 CONN B & C	DWIGHT ST
114	I 291 LINE K	I 91
0WL	I 391	CHIC R, STS & RLF
0WR	I 391	ST 116 CHICOPEE ST
0WF	I 391	CONNECTICUT RIVER
0WQ	I 391 & OFF RAMP	BMRR
0WT	I 391 & RAMPS ABCD	MAIN ST & PVRR
0WM	I 391 NB SB RAMPS	N BR CHICOPEE RIV
0WH	I 391 SB	I 91
2XJ	I 495	MASSACHUSETTS AVE
1U9	I 495 NB	MDC AQUEDUCT & CSX
2JB	I 495 NB	GOLDEN COVE RD
1UV	I 495 NB	I 90
2XQ	I 495 NB	I 93
2XL	I 495 NB	I 95
2WJ	I 495 NB	BMRR (ABANDONED)
1U5	I 495 NB	ST 9 TURNPIKE RD
1UX	I 495 NB	ST 62 CENTRAL ST
2XH	I 495 NB	ST 110 /ST 113/MERRIMACK
3RU	I 495 NB	US 1 WASHINGTON ST
2WM	I 495 NB	MERRIMACK RIVER
2WL	I 495 NB	MERRIMACK RIVER
2XC	I 495 RAMP L	MERRIMAC ST & MBTA
2XK	I 495 RAMP N	SUTTON ST & MBTA
1UA	I 495 SB	MDC AQUEDUCT & CSX
1V3	I 495 SB	S BOLTON RD
1UP	I 495 SB	I 90
2XR	I 495 SB	I 93
2WK	I 495 SB	BMRR (ABANDONED)
27N	I 495 SB	MBTA/BMRR

Bridge ID	Facility Carried	Feature Intersected
2JT	I 495 SB	ST 38 MAIN ST
2XG	I 495 SB	ST 110 /ST 113/MERRIMACK
2JA	I 495 SB	ST 110 CHELMSFORD ST
2JV	I 495 SB	ST 133 ANDOVER ST
3RT	I 495 SB	US 1 WASHINGTON ST
2WN	I 495 SB	MERRIMACK RIVER
2X1	I 495 SB	MERRIMACK RIVER
2XD	I 495 UPPER LEVEL	I 495 LOWER LEVEL
2JX	ST 2 A/MARRETT RD	I 95 /ST 128
26M	ST 2 A/ST 110/KING	I 495
2E2	ST 2 EB	I 95 /ST 128
2E1	ST 2 WB	I 95 /ST 128
2DH	ST 3 A/GORHAM ST	I 495
2KB	ST 4 BEDFORD ST	I 95 /ST 128
3VQ	ST 27 HIGH PLN ST	I 95 NB
2L2	ST 28 FELLSWAY W	I 93
120	ST 83 NB RAMP Z	I 91 & ST 83 SB
3WB	ST 88 NB	I 195
30G	ST 97 BROADWAY	I 495 NB
3PD	ST 103 WILBUR AVE	I 195
47X	ST 105 FRONT ST	I 195
28L	ST 111 MASS AVE	I 495
30W	ST 113 STOREY AVE	I 95
128	ST 116 CONWAY RD	I 91
3VL	ST 121 WEST ST	I 495
2E8	ST 125 BALLRDVLE ST	I 93
2RU	ST 125 CONN WB	I 495
2KV	ST 129 LOWELL ST	I 93
2YT	ST 133 E MAIN ST	I 95
1YH	ST 140 BOYLSTON ST	I 290
2AK	ST 140 W CENTRAL ST	I 495
123	ST 141 GRATTAN ST	I 391

Bridge ID	Facility Carried	Feature Intersected
31P	ST 286 MAIN ST	I 95
31N	ST 286 SB RAMP	I 95
2VN	US 1 CONN RPS A&B	I 95 /ST 128
3PQ	US 1 NB/GL EDWRDS	I 95
2T8	US 1 NB/NEWBRY ST	I 95
2T9	US 1 SB/NEWBRY ST	I 95
2G2	US 3 SB	I 95 /ST 128 & CD
0UA	US 5 /ST10/STATE	I 91
0WE	US 5 NB RAMP A	I 91
1L5	US 20 WB/BSTN PST	I 495
2E3	US 20 WB/WESTON ST	I 95 /ST 128
1M9	US 20 WB/WSHNGTN	I 395
45D	US 44 HARDING ST	I 495

Source: Cambridge Systematics from Pontis

Figure 5.16 Recommended Locations for Capital Bridge Projects



5.6 INTERSTATE FUNDING RECOMMENDATIONS

Based on the analysis in this section it is recommended that:

Pavement

- EOT and MassHighway should continue to spend at least $50M annually on interstate pavements. If this budget increases annually to account for inflation (Scenario 1) the average PSI will remain roughly the same. If the budget remains at a constant $50M (Scenario 2), the average PSI will decrease slightly. Note that this estimate is based on planned expenditures, and actual expenditures may vary significantly from planned expenditures due to a variety of factors.
- Analysis suggests that spending $50M annually in constant dollars would be required to maintain current pavement conditions, or $59M in current dollars.

Bridge

- EOT and MassHighway should continue to spend at least $59M annually on interstate bridges. If this budget increases annually to account for inflation (Scenario 1) the number of SD bridges will decrease over the next five years by 13%. If the bridge budget remains at a constant $59M (Scenario 2), the number of SD bridges will decrease by 5%. In both cases, the average health index will decrease from approximately 82 to 77% due to deterioration of bridges not targeted for work. Note that this estimate is based on planned expenditures, and actual expenditures may vary significantly from planned expenditures due to a variety of factors.
- Analysis suggests that spending $48M annually in constant dollars would be required to maintain the current number of SD bridges, or $51M per year in current dollars.

Maintenance

- Available data do not provide sufficient information on current condition or expenditures of other assets besides pavement and bridges.
- MassHighway should standardize reporting of costs and collect at least summary information on inventory of maintainable assets to support a maintenance budgeting approach, as discussed in Section 4. The analysis presents a sample analysis for sign needs.
- Anecdotal evidence suggests it would be unwise to reduce maintenance expenditures below current levels, estimated to be $15 to 21M annually

Tradeoffs Between Assets

- It is recommended that management systems be used to determine overall budget levels for pavement and bridge assets using an approach similar to that demonstrated here for interstate assets, considering performance goals and funding constraints.
- It is recommended that the PMS and BMS be used to identify specific treatments and project locations. Section 5.6 presents tentative project locations recommended by HERS-ST and Pontis for a given budget level. These should be considered as a starting point, but must be tempered by engineering judgment and logistical considerations.
- It is recommended that the overall maintenance budgets should be established using a maintenance budgeting approach that considers the maintenance funds needed to maintain a given level of service by category of maintenance, but that specific activities and locations of work should be determined by the districts.
- Additional analysis would be needed to establish the best split between interstate and non-interstate assets.

Appendix A. MMS Review

This appendix summarizes maintenance management systems used by state departments of transportation. It provides a brief overview of each system, compares the functionality of each, and provides a preliminary estimate of level of expenditure needed to license each. The review focused on systems that have some degree of support for maintenance management. Pavement and bridge management systems (e.g., the dTIMS and Pontis systems currently in use by EOT/MassHighway) not designed to support maintenance business processes were excluded from the review.

A.1 SYSTEM OVERVIEWS

AgileAssets Maintenance Manager

Developer: AgileAssets, Inc.
Available from: AgileAssets Inc.
Software platform: Web-based application
DOT users: Indiana, Kentucky, North Carolina, Wyoming
Description: Supports the tracking of labor, equipment and materials expenditures, annual maintenance planning, work order management and asset inventory management.
Relevance to MassHighway: This system is a viable option for MassHighway. It appears to provide all of the MMS functionality MassHighway would likely require.

CartêGraph Management Suite

Developer: CartêGraph
Available from: CartêGraph
Software platform: Web-based application
DOT users: New York, Wisconsin
Description: Suite of systems for supporting inventory and maintenance management for pavement, signs, sewers, bridges, etc… Also includes support for work order support and call management. CartêGraph provides tools for customizing the system and database to tailor it to agency needs
Relevance to MassHighway: Historically, CartêGraph has focused on developing tools for municipalities. However, recently two DOTs have implemented the system at a state level. The system appears to be a viable option for MassHighway and to provide all of the MMS functionality MassHighway would likely require.

Hansen 8 Transportation Solution

Developer: Hansen Information Technology
Available from: INFOR
Software Platform: web-based application
DOT users: California, New Brunswick
Description: Represents highway inventory as straight-line diagrams, includes an integrated pavement management system, enables asset condition tracking, and supports work order management.
Relevance to MassHighway: This tool provides the core MMS functionality required by MassHighway. Its main disadvantage is the lack of a significant track record of state DOTs using the system. One exception is the California DOT, which uses the system extensively. Also, New Brunswick DOT is currently implementing the system in conjunction with Highways by Exor (described below). The DOT plans to use the Hansen system to support maintenance management and the Exor system to support inventory management.

Highways by EXOR

Developer: EXOR Corporation
Available from: EXOR Corporation
Software Platform: Service oriented architecture using Oracle technology.
DOT users: Indiana, Kansas, Virginia, New Brunswick
Description: Enables the integration of asset inventory and condition data through a common linear referencing system. Can be integrated with another EXOR module that supports work order management.
Relevance to MassHighway: The strength of Highways by EXOR is in the management of linear asset inventory and the integration of data. Although EXOR offers work order management functionality, DOTs use this system mainly for inventory management. In some cases, the DOTs have implemented another system to support the maintenance management function. For example, the Indiana DOT uses EXOR and AgileAssets. New Brunswick uses EXOR and the Hansen system.

Maintenance Activity Tracking System (MATS)

Developer: Booz Allen Hamilton
Available from: Current users through multi-state partnership
Software platform: Powerbuilder front end connected to Oracle or SQL Server database
DOT Users: Maine, New Hampshire, Vermont
Description: Provides the following maintenance management functionality - material management, equipment tracking, personnel, payroll, daily work report generation, GIS linkage, asset inventory, work order tracking and incident management.
Relevance to MassHighway: MATS meets all of the MMS functionality required by MassHighway. The system was developed jointly by the Maine, New

Hampshire and Vermont DOTs. MassHighway could join this tri-state partnership and use MATS for a relatively small investment. The exact terms of the agreement would have to be negotiated with the current MATS users, but costs would mainly be associated with future upgrades to the system, which presumably would benefit MassHighway and the consortium as a whole.

MaintStar Municipalities Suite

Developer: Bender Engineering Inc.
Available from: Bender Engineering Inc
Software platform: Not available.
DOT users: Michigan (fleet module)
Description: Series of modules that supports maintenance budgeting, resource management, and work order management.
Relevance to MassHighway: This tool provides the general work order management and maintenance budgeting functionality required by MassHighway. However, it is used mostly be cities and counties to manage infrastructure assets other than highways (e.g., facilities, waste water, and storm water). One exception is that the Michigan DOT uses it as a fleet management system.

Maximo

Developer: MRO Software
Available from: PSDI (IBM)
Software platform: Windows/web-based system with SQL Server database
DOT users: Maryland
Description: Provides extensive work order management functionality – e.g., maintenance notification, scheduling, cost planning and tracking, resource availability planning, work order tracking, and materials management.
Relevance to MassHighway: This tool provides the general work order management and maintenance budgeting functionality required by MassHighway. Maximo supports specification of asset inventories, but is not specifically designed to support a road network, and thus would be of limited value for road inventory management.

SAP

Developer: SAP
Available from: SAP
Software platform: Service oriented architecture
DOT users: Colorado, Pennsylvania, Idaho
Description: Enterprise-oriented product covering financial and operations management. The R/3 Plant Maintenance module provides the following maintenance management functionality - maintenance notification, scheduling, cost planning and tracking, resource availability planning, work order tracking, and automation of work order generation.

Relevance to MassHighway: SAP is designed for agencies that need a single enterprise system to support all core business processes (e.g., financials, payroll, human resources, materials management, maintenance). If an agency is not already using an ERP system, the time and cost associated with implementing SAP may outweigh the potential benefits.

A.2 SUMMARY

Table A.1 presents a summary of the systems described above. For each system, the table identifies the developer, lists DOT users, categories the type of system (inventory-based, non-transportation work order management, or enterprise resource planning), lists the functionality required by MassHighway that it supports, and provides an initial cost estimate. (Implementing any of these systems will require additional resources for data migration, training, and other activities beyond initial licensing and customization costs.) Estimates are based on information obtained from current system users and a literature review. The cost estimates are presented in the following ranges:

- Low – less then $200K.
- Medium - $200K - $500K.
- High – greater than $500K.

Table A.1 MMS Comparison

System	Developer	DOT Users	MMS Type	Functionality: Highway Inventory Management	Functionality: Maintenance Budgeting	Functionality: Resource Management	Functionality: Work Order Management	Estimated Initial Cost
AgileAssets Maintenance Manager ™	AgileAssets	IN, KY, NC, WY	Inventory-based	√	√	√	√	Medium[1]
CartêGraph Management Suite	CartêGraph	NY, WI	Inventory-based	√	√	√	√	Medium[1]
Hansen	INFOR (formerly Hansen)	CA, New Brunswick (NB)	Inventory-based	√	√	√	√	High[2]
Highways by EXOR	EXOR Corporation	IN, KS, VA, NB	Inventory-based	√			√	Medium[2]
MaintStar	Bender Engineering	MI	Non-transportation work management		√	√	√	Medium[1]
MATS	Booz Allen Hamilton	ME, NH, VT	Inventory-based	√	√	√	√	Low[3]
Maximo ®	IBM (formerly MRO)	MD	Non-transportation work management		√	√	√	Medium[1]
SAP R/3 Plant Maintenance	SAP	CO, ID, PA	Enterprise resource planning		√	√	√	High[4]

[1] Based on cost data from review of agency purchase orders available on-line.
[2] Based on discussion with the New Brunswick DOT.
[3] Based on discussion with Vermont DOT.
[4] Based on discussion with an SAP implementation consultant.