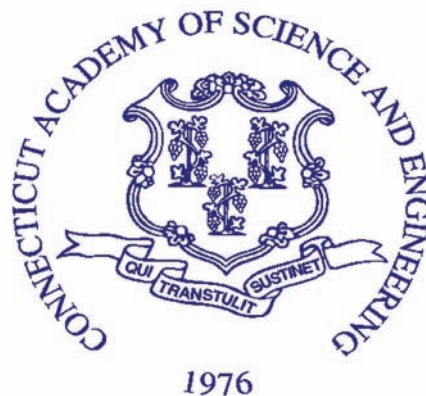# Applying Transportation Asset Management in Connecticut

December 2008

A Report By

The Connecticut Academy of Science and Engineering

For

The Connecticut Department of Transportation

Applying Transportation Asset Management in Connecticut

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The Connecticut Academy of Science and Engineering

ORIGIN OF INQUIRY:	CONNECTICUT DEPARTMENT OF TRANSPORTATION
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This study was initiated at the request of the Connecticut Department of Transportation on November 7, 2007. The project was conducted by an Academy Study Committee with the support of Study Managers Nicholas Lownes, PhD, and Adam Zofka, PhD. The content of this report lies within the province of the Academy's Transportation Systems Technical Board. The report has been reviewed by Academy Members Peter G. Cable, PhD and A. George Foyt, PhD. Martha Sherman, the Academy's Managing Editor, edited the report. The report is hereby released with the approval of the Academy Council.

Richard H. Strauss
Executive Director

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16. Abstract

The study consists primarily of a detailed review of those states that utilize transportation asset management systems that may be applicable for Connecticut's consideration, and includes as well the identification of a comprehensive pavement life-cycle analysis tool. The primary conclusion of this study is that, across the United States, states are finding the shift to Transportation Asset Management Systems worthwhile and productive as they are steadily seeing the condition of their assets improve and their resource allocation decisions galvanizing around an increasingly coherent vision for their transportation infrastructure. The findings indicate that ConnDOT should consider utilizing five concepts (Clarity, Communication, Champion, Consistency, and Comprehensive), the 5Cs, as a strategy for TAM implementation. The 5Cs provide a focus for ConnDOT's development of a sustainable TAM program to guide the state's investment in the acquisition, construction, repair, and preservation of the state's transportation assets.

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GLOSSARY OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
AIMS	Airport Information Management System
BMS	Bridge Management System
BTS	Bureau of Transportation Statistics
CASE	Connecticut Academy of Science and Engineering
CDOT	Colorado Department of Transportation
CMS	Congestion Management System
ConnDOT	Connecticut Department of Transportation
DOT	Department of Transportation
FAA	Federal Aviation Administration
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FRWP	Final Regional Work Program (NY)
FTP	Florida Transportation Plan
GIS	Geographic Information System
HAL	High Accident Location
HPMS	Highway Performance Monitoring System (CT)
ISMS	Information Safety Management System (OR)
ISTEA	Intermodal Surface Transportation Efficiency Act
ITIS	Integrated Transportation Information System (OR)
ITS	Intelligent Transportation Systems
LCCA	Life-Cycle Cost Analysis
MAA	Maryland Aviation Administration
MATS	Maintenance Activity Tracking System (VT)
MdTA	Maryland Transportation Authority
MnDOT	Minnesota Department of Transportation
MoDOT	Missouri Department of Transportation
MPA	Maryland Port Administration
MPO	Metropolitan Planning Organization
MTA	Maryland Transit Authority
MTP	Maryland Transportation Plan
MVA	Motor Vehicle Administration (MD)

NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NHS	National Highway System
NPV	Net Present Value
NYSDOT	New York State Department of Transportation
ODOT	Oregon Department of Transportation
OPM	Office of Policy and Management (CT)
OTC	Oregon Transportation Commission
OTIA	Oregon Transportation Investment Act
OTMS	Oregon Transportation management System
OTP	Oregon Transportation Plan
PHD	Person Hours of Delay
PM	Pavement Management
PMS	Pavement Management System
P/PMIS	Project and Program Management Information System
PSMS	Project Safety Management System (OR)
RCW	Revised Code of Washington
RPA	Regional Planning Agency
RPC	Regional Planning Commission (VT)
RPO	Regional Planning Organization (MD)
SHA	State Highway Administration (MD)
STIP	State Transportation Improvement Program
TAM	Transportation Asset Management
TDD	Transportation Development Division (OR)
TIPM	Transportation Infrastructure Performance Management (CT)
TRB	Transportation Research Board
VMT	Vehicle Miles Traveled
VTrans	Vermont Agency of Transportation
WisDOT	Wisconsin Department of Transportation
WSDOT	Washington Department of Transportation

EXECUTIVE SUMMARY

This study, Applying Transportation Asset Management in Connecticut, was conducted for the Connecticut Department of Transportation (ConnDOT) by the Connecticut Academy of Science and Engineering (CASE). The study consists primarily of a detailed review of those states that utilize transportation asset management systems that may be applicable for Connecticut's consideration, and includes as well the identification of a comprehensive pavement life-cycle analysis tool.

BACKGROUND

The American Association of State Highway and Transportation Officials (AASHTO) adopted the following definition of Transportation Asset Management (TAM) (NCHRP 2002):

> Transportation Asset Management is a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their life cycle. 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.

This definition concisely summarizes some of the key qualities of any TAM system:

1. It is a strategic and systematic process.

2. It incorporates costs and benefits over the entire life cycle of assets.

3. It is concerned with resource allocation.

4. It requires quality data and well defined objectives as necessary components of any system.

Although the report focuses primarily on highway and bridge assets, TAM also can be applied to other transportation assets. It is a multimodal management strategy that provides a systematic approach to making the best transportation system investment decisions to sustain and improve the mobility of goods and people, and improve the quality of life of the public.

SCOPE

The following research was conducted to investigate best TAM practices that might be utilized in Connecticut:

- Existing literature was surveyed to identify the broad principles that guide TAM implementation and use in the United States and other countries. Also, brief summaries of the TAM systems in Colorado, Florida, Missouri, Michigan, Minnesota, Ohio, Washington and Wisconsin were developed to articulate each state's experience and practices.

- The TAM systems from Maryland, New York, North Carolina, Oregon and Vermont were selected for more thorough, in-depth analysis of their practices. These five states

helped place the broad principles in a more concrete context and highlighted their applicability for ConnDOT's consideration in developing a TAM system for the state.

- Focus groups of transportation professionals within ConnDOT, as well as representatives from the General Assembly and the state's executive branch, were conducted to identify current practices that could be included in a Connecticut-based TAM system, as well as other practices that may need revision or substitution.

BRIEF STATEMENT OF PRIMARY CONCLUSION

The primary conclusion of this study is that, across the United States, individual states are finding the shift to Transportation Asset Management Systems worthwhile and productive as they are steadily seeing the condition of their assets improve and their resource allocation decisions galvanizing around an increasingly coherent vision for their transportation infrastructure.

SUMMARY OF FINDINGS AND SUGGESTIONS

The findings of this study indicate that ConnDOT should consider utilizing five concepts, which have been identified as the 5Cs, as a strategy for TAM implementation. The 5Cs organize and provide a structure for five concepts that were consistently identified as critical for achieving success in TAM. The 5Cs embody the principles of TAM that were highlighted in many previous studies and reports and within the focus group discussions conducted as part of this project. The 5Cs of Asset Management provide a focus for ConnDOT's development of a sustainable TAM program to guide the state's investment in the acquisition, construction, repair, and preservation of the state's transportation assets. The 5Cs are briefly described as follows:

Clarity

A clearly stated vision and a process for implementation are necessary for successful implementation of any TAM system. ConnDOT should consider clearly defining its goals, objectives and performance measures to assure that a strong foundation and framework is created for its TAM program. Also, adopting enabling TAM legislation has proven a successful strategy in other states and should be considered as part of the state's TAM implementation strategy.

Communication

TAM tools are novel and useful because they support managing transportation assets from a systems and life-cycle perspective, as opposed to utilizing a class-specific, worst-first asset management philosophy for investment decision making. Communication throughout the organization, both vertically and horizontally and with other agencies and branches of state government, is critical for creating and maintaining a successful TAM system. Consideration should be given to developing clear communication channels between ConnDOT's senior management, the executive branch, and legislators to assure effective coordination, management and unbiased performance reporting. "What if?" analyses are useful means of communicating the performance-based impacts of funding decisions.

Champion

Visible and active ConnDOT champion(s) are needed to guide and support successful TAM implementation and sustainability. It is suggested that strong and consistent support at the leadership level is necessary to implement an effective and comprehensive TAM system. ConnDOT senior management and staff need to be committed to the asset management program and understand the value and benefits of implementing TAM.

Consistency

Consistency on several levels is important: consistency in the message from the state leadership to those in the field; consistency in the priorities across various administrations, and consistency within the data collection and sharing practices among ConnDOT bureaus. It is suggested that

- a TAM steering committee be established that includes key senior ConnDOT management staff with representation from all bureaus;

- the Bureau of Policy and Planning's Transportation Infrastructure Performance Management group provide the administrative support for the committee; and

- inter-bureau information sharing on TAM topics be incorporated into a coordinated system.

Comprehensive

It is necessary to recognize that each asset class of transportation infrastructure is part of an overall transportation system, and that the goal of managing this system is not to "get by" year to year, but to best manage resources and investments over the long term—that is, over the life cycle of the assets. Worst-first management ignores life-cycle costs, as does a philosophy of always selecting the least expensive short-term alternative. In moving away from a worst-first and lowest-cost practice, ConnDOT should consider pursuing a life-cycle cost-effectiveness strategy, while continuing to ensure that safety standards are rigorously maintained.

A shift to a TAM system would be a major change in the way the department and the state approaches investment in transportation assets. This change demands a clear vision, excellent communication, champion(s), and a comprehensive perspective to assure success. Around the country, states are finding this shift worthwhile as they are steadily seeing the condition of their assets improve and their resource allocation decisions galvanizing around an increasingly coherent vision for their transportation infrastructure.

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I. INTRODUCTION

STUDY BACKGROUND

This study, *Applying Transportation Asset Management in Connecticut,* was conducted for the Connecticut Department of Transportation (ConnDOT) by the Connecticut Academy of Science and Engineering (CASE). It includes a review of those states that utilize transportation asset management systems that may be applicable for Connecticut's consideration, as well as the identification of a comprehensive pavement life-cycle analysis tool.

Many of the state's transportation assets require periodic repair, maintenance, rehabilitation and replacement. A statewide transportation asset management system that is continually maintained would be a valuable tool in identifying funding requirements and allocating limited resources for the highest priorities. Additionally, various highway paving/overlay methods are utilized to repair the state's highways. Some methods have higher initial "project" cost and last longer; others are designed for shorter life cycles with lower initial "project" cost. However, other factors such as motorist inconvenience during construction periods, increased maintenance and related motorist delays under certain scenarios, and cost of vehicle repairs due to poor road conditions, affect total economic life-cycle cost of a project. Additionally, these factors may have different impacts in different areas of the state.

PROJECT CONCEPT AND SCOPE

Transportation Asset Management (TAM) has its roots in the private sector in companies that required a large asset base for their operations. While government agencies are not profit driven, it was realized that the concepts of performance and cost-effectiveness in resource allocation were applicable. These roots have taken hold across the United States and the world, prompting TAM principles to be implemented within state DOTs and in transportation strategic plans in varying degrees. While the movement toward TAM has been a consistent one, since transportation organizations are for the most part unique entities and have customized TAM systems to meet their specific needs, the definitions of TAM are as numerous as the organizations purporting to have endorsed its principles.

The American Association of State Highway and Transportation Officials (AASHTO) adopted the following definition of TAM (NCHRP 2002):

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This definition concisely summarizes some of the key qualities of any TAM system:

1. It is a strategic and systematic process.

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3. It is concerned with resource allocation.

4. Quality data and well defined objectives are necessary components of any system.

5. These concepts appear throughout this report in one form or another, though the wording and their specific application may vary. There is a plethora of TAM-related literature available. This study draws upon these resources and provides a representative sampling of material for the possible application of TAM concepts and principles in a Connecticut context and as a tool for managing the state's transportation assets.

This study will also seek answers to the following questions:

What is TAM?
Why consider TAM?
Where has TAM been implemented?
What are the TAM applications for CT?

The report focuses primarily on highway and bridge assets. However, TAM is a multimodal management strategy that provides a systematic approach to making the best transportation system investment decisions to sustain and improve the mobility of goods and people, and improve the quality of life of the public.

II. TRANSPORATION ASSET MANAGEMENT: AN OVERVIEW

TAM provides a transportation agency with the methodology to strategically fulfill its mission. Asset management assists in improving performance by establishing a framework for the systematic execution of many agency duties and responsibilities by

- defining agency policy goals, objectives and performance measures;
- evaluating an agency's investment strategy through program trade-off analysis and its planning and programming priorities;
- establishing efficient program delivery processes; and
- evaluating the effectiveness of an agency's decision by system monitoring and performance reviews.

Two key components of a TAM that help an agency in its decision making process are good quality data and robust decision support systems. Since bridges and pavements are the predominant and most costly asset types an agency has to manage, decision support systems, such as Bridge Management Systems (BMS) and Pavement Management Systems (PMS), have historically provided an optimization analysis within their respective class. However, newer forms of integrated management systems are emerging that go beyond these individual systems (Pagano et al. 2004, 2005). More and more state DOTs and other transportation agencies are adopting TAM to improve their customer-driven strategic plans and to decrease agency costs.

TAM comes at a cost that includes costs relating to data, software development and acquisition, hardware, and staff. TAM practices are incorporated into the strategic plans of many states, suggesting that the concept of asset management is well accepted. All states use some sort of TAM system, though few states have a dedicated asset management organizational unit. TAM is not always mentioned in a strategic plan or mandated by legislation, though in practice its principles govern many of the activities of those states reviewed in this report, and each state has identified broadly defined goals, and objectives and measures that it will strive to achieve.

Some states have legislated or have developed statutes to help implement TAM programs. Others have replaced their "worst-first" prioritization with system preservation and system optimization principles. For example, each paving project in Maryland must support network-level objectives in order to be allocated resources (Pagano et al. 2004, 2005). Maintenance-first and customer focus are two strategic focus areas found in many states with related high-level tools that have direct linkage with TAM.

BARRIERS TO TAM IMPLEMENTATION

Prior to the implementation of TAM, several barriers must be overcome. These barriers can be overcome partially by quantifying and showing that the benefits of TAM exceed the costs of their implementation. Although this appears to be a relatively basic task, in practice it has proven to be a difficult undertaking.

TAM systems provide a holistic approach to strategic decision making. TAM systems assure the best expenditure of funds; they help in building more accurate information, tracking the performance of management strategies and, hence, help improve the transportation infrastructure. However, effective implementation of TAM needs to show that benefits exceed the costs of its implementation and operation (Mizusawa and McNeil 2005).

Several barriers were highlighted by the Transportation Research Board (TRB) asset management peer exchange (Hendren 2005) that brought together 11 practitioners from around the United States to discuss several relevant aspects of TAM. The barriers that were discussed, several of which are listed below, are certainly relevant to Connecticut:

Existing Data System

Existing data are insufficient to support the agencies' decisions regarding capacity expansion programs or the predictive deterioration models that are used in expanding TAM to assets other than highways.

Organizational Issues

Cultural resistance, lack of defined goals and objectives, and lack of communication present formidable organizational issues with respect to TAM implementation. Agencies use TAM systems to predict future performances and in most cases, the information is used to inform budget discussions. However, final budget decisions are based on additional qualitative factors. Implementing TAM across asset classes is a difficult task and is often limited by the organizational structure and existing practices within each asset class, the management of which is commonly segregated within an organization.

Technological Issues

Analysis tools and process, methods to quantify benefits, and tailoring TAM for different agencies all fall under the umbrella of technical issues. Significant technological barriers for TAM implementation include

- lack of tools designed to support cross-asset analysis;

- difficulty of analyzing assets that have very different service lives; and

- application of purely theoretical approaches to cross-asset management.

Costs

Cost is an especially critical issue and barrier. Without showing that benefits of TAM exceed costs for TAM implementation and operation, implementation would be difficult to achieve. In particular, upper-level transportation department managers, as well as legislators and state executive branch leadership, are interested in benefits that can be translated into monetary values, as they need to justify their investment in these tools. Costs are not confined to the purely monetary realm, either. There are political costs of adhering to a TAM system in which capacity expansion projects are sacrificed for the life-cycle benefit of the system. These types of costs are also more difficult to justify to various constituencies, suggesting that broad, strong support from upper management is necessary to enable a shift towards a TAM philosophy.

OPTIMIZATION TOOLS

Many software tools have been applied to TAM. Several of these are reviewed in NCHRP Report 545 (2005).

TAM is a system that is defined with highly uncertain parameters and data, leading to more complex problem formulations, such as those proposed by Li and Kaini (2007). Large and complex formulations require increasing amounts of expertise, computational power and effort for implementation. These tools can help define optimal investment strategies, but they cannot provide the organizational foundation to make such investment strategies a reality. The use of such tools is only one element of a TAM framework.

A relevant example of a software tool is Soft Systems Methodology (SSM). SSM, a methodology developed in 1981 to address large, complex, ill-defined problems, can be used to determine potential strategies to solve TAM implementation problems. SSM is a framework that provides a strategy for integrating social, economic, political, and human elements into the solution, but SSM does not provide an absolute correct solution (Mizusawa and McNeil 2006). It is just one of many optimization-based methodologies for choosing optimum TAM implementation strategies.

To this end, SSM requires that an agency visualize the mechanism (the organizational structure) of successful TAM implementation in their organization (Mizusawa and McNeil 2006). This suggests that aside from the tool's implementation, preparing the model and systematically thinking about TAM is a useful exercise in itself.

PERFORMANCE MEASURES

Performance measures are an essential component of a TAM system. Tying performance to resource allocation is fundamental, and is explicitly required in many of the most successful TAM case studies in the United States. Performance measurement provides benefits such as greater accountability, a better understanding of the impacts of alternative courses of action, and feedback in the ongoing improvement of system management.

Performance measures need to perform four duties well. They should

1. respond to policy objectives;

2. support the "what-if?" analysis of different scenarios'

3. form an integral part of the business and decision processes of an agency; and

4. best support the principles of asset management.

Different types of performance measures are in use are categorized as

1. preservation of assets;

2. mobility and accessibility;

3. operations and maintenance; and

4. safety.

Table 1 lists performance measurement categories and example measures that are commonly used (NCHRP 2006). There is an increased use of performance measurement in transportation policy making, programming, planning and system monitoring, even if it is not part of a formal TAM program. TAM principles are being developed formally through collaborative efforts among different agencies, with more focus being placed upon analytical tools and information technology resources that are needed for performance-based management.

Table 1.   Example Performance Measures for Asset Management

Measure Category	Example Measures	Comments
Preservation of Assets	Pavement condition index Bridge health index Remaining life Debt index (ratio of deterioration or lost value to replacement value)	Condition and remaining life measures can be expressed as averages or distributions (e.g., percent of system length or VMT on roads in good, fair, and poor condition).
Mobility and Accessibility	Amount of congested travel (person-miles or VMT under congested conditions) Travel time index (ratio of peak travel time to free-flow travel time) Average travel time between major origins and destinations, by mode Average shipment cost between selected origins and destinations	Care must be taken to distinguish results of agency actions from changes due to growth patterns, fuel prices and other factors. This can be accomplished through use of modeling tools, supplemental socioeconomic and traffic monitoring data, and well-designed before-after studies.
Operations and Maintenance	Traffic signal malfunction rate Average incident clearance time Time interval after precipitation stops to restore road conditions to defined standard Sign and pavement marking retroreflectivity Customer satisfaction rating for different maintenance elements	Maintenance level of service approaches can be used to relate achievement of different service levels to budget levels by category of work.
Safety	Serious crashes per million VMT Fatalities per 100 million VMT Number of work zone crashes Hazard index (based on crash incidence and severity rates) Backlog ($) of identified cost-effective safety countermeasures to address high-crash locations	Use of the fatality rate measure is recommended for consistency with the U.S. DOT's national performance target to reduce fatalities to 1.0 per million VMT.

VMT = vehicle-miles traveled

Note: VMT = Vehicle Miles Traveled   *(Source: NCHRP 2006)*

TABLE 1: EXAMPLE TAM PERFORMANCE MEASURES

SUMMARY

Many state agencies use TAM to manage their assets in a more systemic and systematic manner. BMS and PMS are management systems that are currently being used extensively. Much effort is being expended by transportation agencies to improve their asset management systems but various political, organizational, and institutional barriers slow the broader implementation of TAM. Most agencies utilizing TAM are emphasizing its use only for the management of highways, as they typically represent the largest single transportation asset class. However, the application of TAM in other modes of transportation is gaining momentum.

Of the four questions to be addressed in this study, the first two: "What is TAM?" and "Why consider TAM?" have been introduced in this chapter. The answers to these questions are related. TAM is a systematic, objective-driven method of managing transportation assets utilizing principles that have been successful in the private sector. The success of these principles in the private sector has been built upon the concepts of performance-based resource allocation and life-cycle cost-effectiveness. These principles tend to lead to a better management policy, a longer view of resource allocation, and for state transportation agencies, a better use of the public's resources over the life cycle of infrastructure investments.

The remainder of this report addresses the latter two questions: "Who has implemented TAM?" and "What are the Applications for Connecticut?" The following chapters are focused on several specific topics, including

- the general organization of transportation management in Connecticut along with the specifics of TAM in Connecticut;

- a summary of focus group sessions that included ConnDOT staff, as well as others involved in the state's transportation infrastructure decision making processes including state legislators, representatives from the Office of Policy and Management, and the Transportation Strategy Board;

- a brief review of many of the case studies around the United States that highlights the extent and variety of TAM implementation;

- a discussion of five detailed case studies and the lessons that each has for Connecticut;

- Pavement Management Systems (PMS) and Life-Cycle Cost Analysis (LCCA)

- Findings and Suggestions most relevant for the state's consideration.

III. TRANSPORTATION ASSET MANAGEMENT IN CONNECTICUT

This chapter presents a brief overview of Connecticut's transportation system and TAM practices. Also included is a summary of focus group sessions administered by the study management team and attended by Connecticut transportation professionals, as well as others from state agencies and the General Assembly.

INTRODUCTION TO CONNECTICUT

Connecticut covers 5,543 square miles total area (4,845 square miles of land area) with a population of 3,405,565 (2006 estimate). It is the fourth most densely populated state in the country behind New Jersey, Rhode Island and Massachusetts. The state capital is Hartford; other major cities include New Haven, New London, Stamford, and Bridgeport. Connecticut has a mix of rural areas in the northeast and northwest corners and highly urban areas in the southwestern part of the state near the New York border. Connecticut's transportation system consists of 20,845 miles of public roads, of which 346 miles are interstate. It also contains 4,177 road bridges; 69 miles of Class I railroad trackage, 177 miles of inland waterways and six state-owned airports.

ConnDOT

ConnDOT manages and maintains the state's transportation system, including highways, transit, airports and a port. ConnDOT employs roughly 3,200 and consists of five bureaus: Finance and Administration, Policy and Planning, Engineering and Highway Operations, Aviation and Ports, and Public Transportation.

A report issued by the governor's commission on the reform of ConnDOT in early 2008 recommended that ConnDOT needs fundamental change, that it should be more responsive and less insular (ConnDOT 2008). Further, recent state budget cuts may impact the nature of the changes to be initiated at ConnDOT. The fluid situation within ConnDOT therefore requires that any specific recommendation be qualified accordingly. However, the fluidity does not negate the relevance of the core principles of TAM.

The commission made several recommendations to reform ConnDOT that were grouped into four areas and for each area, specific recommendations of actions to be taken by ConnDOT were made. The various recommendations do not specifically mention TAM, but it was clear that the principles of TAM were desirable. Specifically, a recommendation to adopt a "Fix-it-First" strategy echoes TAM principles, yet needs a more rigorous treatment to ensure that this strategy is pursued in an optimal manner that considers the full life cycle of the state's transportation assets.

Connecticut TAM Organization Structure

Currently, TAM functions in ConnDOT are based within the Office of Intermodal and Environmental Planning in the Bureau of Policy and Planning. TAM, formally known as Transportation Infrastructure Performance Management (TIPM), is divided into two units: Asset Management, and Performance Measures & Quality Partnerships.

TAM in ConnDOT traces back to its pavement management division, first established in 1986, which shared the responsibilities of condition reporting with the department's maintenance office. Since the 1990s, the division has been performing an annual survey of cracking, rutting and roughness, and a Highway Performance Monitoring System (HPMS) has been in place since 1978. A Pavement Preservation working group was established in 2006, along with the current Asset Management division under which the TIPM unit now resides.

There is no formally established bridge management division in ConnDOT, though the research division of ConnDOT developed a Bridge Information System in the late 1980s which was partially implemented in the Bridge Safety and Evaluation Office. The department also purchased PONTIS, a comprehensive bridge management system software tool developed by AASHTO, and has partially utilized it since the early 1990s. ConnDOT performs bridge inspections based on the requirements of the National Bridge Inspection Standards of the Federal Highway Administration (FHWA). ConnDOT utilizes a Maintenance Management System for scheduling and recording activities, labor and materials.

The Geographic Information System (GIS) Unit under the Bureau of Policy and Planning carries out the system inventory and has digitized and linked the highway network. Some TAM tools for individual asset classes have been developed in-house. A partial sign inventory system was developed using photolog images but has not yet been implemented. A partial guide rail inventory system was also developed by the division using photolog images in the early 2000s, but it is also not yet implemented. Life Cycle Cost Analysis (LCCA) is utilized informally by ConnDOT's pavement management division without considering user costs. A FHWA National Highway Institute life-cycle cost course was held at ConnDOT in 1998.

Future activities for ConnDOT's TAM program include the following:

- Develop mission and vision statements.

- Identify and develop performance measures and target values for roads, bridges and other through group meetings.

- Review existing management systems and encourage enhancements.

- Review software for prioritization/optimization.

- Coordinate TAM development with GIS unit.

- Develop outreach materials to communicate awareness of asset management.

Summary

ConnDOT has been using the pavement and bridge management systems for managing and maintaining its assets. It has also partially developed separate systems for signs and guide rail inventory but has not implemented them. With respect to TAM, ConnDOT appears to have many asset-class specific TAM measures available or actively engaged, though a consistent policy throughout the organization or clear ties to project selection and resource allocation are not apparent. However, ConnDOT is working toward developing a more comprehensive TAM program, as is evident from the department's issuance of a TAM policy statement and its planned activities.

SUMMARY OF FOCUS GROUP DISCUSSIONS

The TAM literature is consistent in asserting that a key step in implementing any TAM program is a thorough self-assessment. This self-assessment includes understanding the organizational structure that a TAM system must operate within, the goals of such a system, the current mechanisms available to build upon, existing performance measures, and other aspects of TAM. Accordingly, to evaluate the best practices gathered from the experiences of other states in this study with regard to their appropriateness for ConnDOT, it is valuable to have a basic understanding of ConnDOT – its structure, goals, and current practices. However, a full, thorough self-assessment of ConnDOT is beyond the scope of this study.

The focus group meetings were designed as guided discussions to gain firsthand knowledge of the workings of ConnDOT relevant to TAM as well as the impressions of TAM from several members of the General Assembly with committee assignments involving transportation operations and funding, and representatives from the Office of Policy and Management, Office of Fiscal Analysis and the Transportation Strategy Board. A discussion guide was used to engage attendees and guide the flow of discussions. The detailed content of each focus group varied considerably depending upon the participants and the threads of conversation that evolved. Copies of the focus group guides used in these discussions are included in Appendices A and B.

Each focus group session lasted approximately one hour and included 6-12 participants. The discussion guide in Appendix A was used for each session with ConnDOT leadership, with the moderator asking the same broad questions of each group. The Appendix B guide was used for the sessions with Connecticut's leadership. Follow–up questions were asked based on the flow of the discussion, along with specific "probe" topics to be explored in further detail if the discussion yielded an appropriate opportunity.

While each focus group resulted in very different threads of conversation, certain topics were common to each group. The results of these focus groups are anonymous and have been summarized to express the general ideas broached during focus groups discussions. The ideas presented are the product of detailed notes taken during the focus group sessions.

ConnDOT Focus Groups: Key Points

The ConnDOT focus groups included participants from each of the department's bureaus, with intentionally diverse representation in each individual focus group session. Within the four ConnDOT focus group sessions there were several common threads that were repeated in each session. There were many points brought up throughout the sessions, but only those that surfaced multiple times have been included in this summary. The four key categories of TAM issues in ConnDOT were identified as

- high-level support;

- inter-bureau communication;

- utilization of existing TAM capabilities; and

- movement away from worst-first mentality.

A discussion of each of these topics follows.

HIGH-LEVEL SUPPORT

In an organization such as ConnDOT, staff responsible for identifying projects, measuring performance, and implementing components of TAM look to the organizational leadership for direction in a governing philosophy of asset management. Specifically, the focus group cited support from the General Assembly (GA) as a key component of shifting to and endorsing this philosophy. Whether this support takes the form of legislation or an active interest was not specified. Support of ConnDOT leadership was cited as a crucial component for TAM implementation. ConnDOT's current operating structure, with inter-bureau TAM discussion taking place primarily at the high levels of the organization, requires a strong commitment to TAM by ConnDOT's leadership.

The focus groups also cited a need for ConnDOT leadership to effectively communicate the governing principles and philosophy of TAM and its support for TAM to ConnDOT staff. It was suggested that many staff are unsure of how projects are selected and how resources are allocated by the department.

COMMUNICATION

Two aspects of communication surfaced throughout the focus groups: inter-bureau communication ("getting out of the silos") and the effective communication of asset data. Much of the TAM communication takes place at the higher levels of ConnDOT's organizational structure. However, focus group attendees felt that it would be useful to develop more communication between bureaus at various staff levels to improve efficiency and consistency, and to reduce redundancy.

Data collection and distribution was identified as a recurring concern that could also be an excellent TAM tool. Several groups at ConnDOT currently collect a wide variety of asset information that would be useful to incorporate in a TAM tool for decision-making purposes. PONTIS is a well established industry software tool that among other things is used to track the condition of bridges in Connecticut. The pavement management group collects extensive pavement condition data and has been using this information to perform various "what if?" funding scenario analyses. The traffic group maintains an inventory of traffic signals, a guardrail inventory database is in development, and development of a roadway signage inventory was recently mandated by the federal government. The transit group maintains an inventory and tracks the condition of their vehicles. The Geographic Information Systems (GIS) group maintains a geo-database of the Connecticut roadway network and some other assets. However this database system is not yet comprehensive in its application for use in TAM.

Data useful for TAM are available, collected and used to make resource allocation decisions. A common statement was that employees outside the group responsible for data collection may not be aware that data are being collected. Others may be aware that such data are being collected, but gaining access to it may be difficult, or in some cases the data may be unreliable. The finance group is seeking to identify ways to incorporate TAM into a current system of asset management, CORE, used by ConnDOT. The focus group discussion suggested that CORE has the capability to serve as a central TAM data warehouse, though assigning responsibility for maintaining such a database needs to be addressed.

The focus group participants generally were not aware of how ConnDOT communicates with the General Assembly.

UTILIZE EXISTING TAM CAPABILITIES

The bridge, pavement, traffic and transit groups all maintain some aspects of TAM in their current operations. However, these aspects are not consistent across the bureaus. TAM is implemented internally, helping those within certain groups allocate resources, but not conforming to an overarching department-wide philosophy of TAM. The bridge group tracks the condition of bridges regularly and uses these condition ratings in allocating maintenance and construction resources. However, the assigned budget limits the maintenance activities actually undertaken to those assets that need immediate attention. Life-cycle costs are not employed in the decision-making process, as the group is in a continual state of "putting out fires."

The pavement management (PM) group uses a pavement condition data collection vehicle and photo data logger to evaluate pavement condition each year. However, the actual activities are generally governed by "fires" to be put out and projects deemed high priority outside of the asset management process. PM has recently taken the additional step of providing department leadership with results of "What if?" analyses each year, using current condition data and a variety of funding scenarios. These analyses using a PM-TAM procedure provide leadership with a view of what projects can be completed in a given year at a particular funding level, as well as a resulting overall pavement condition rating. Reportedly, this type of analysis has been well received by leadership and has proven useful as a tool for securing funds and allocating resources for the PM group.

The traffic and transit groups maintain inventories of assets and, in some cases, track the condition of their assets. However, attendees stated that current funding is inadequate and that resources are allocated to address immediate needs without quantitative consideration of life-cycle costs or cost-effectiveness. Further, attendees believed the current level of funding is adequate to fix what is broken, but not enough for farsighted preventive maintenance or necessary upgrades to help the systems perform optimally.

MOVE AWAY FROM "WORST-FIRST"

Attendees indicated that nearly every group within ConnDOT is currently operating under a "worst-first" policy where the most immediately noticeable defects are addressed each year. This leaves no resources for preventive maintenance, upgrades, or TAM planning, and results in a cycle of ignoring small needs until they become big problems that are addressed only when they are big problems, to the detriment of new, small needs.

Related to this concept of "worst-first" is the idea of always selecting the lowest cost alternative for implementation. Focus group participants indicated that this method of project selection ignores life-cycle costs and results in sacrificing the quality of work for short-term project cost.

Connecticut Leadership Focus Groups: Key Points

Focus groups were also conducted with several members of the General Assembly who have committee assignments involving transportation operations and funding, and representatives from the Office of Policy and Management, Office of Fiscal Analysis and the Transportation Strategy Board. A copy of the focus group discussion guide can be found in Appendix B. Unlike

the ConnDOT focus groups, in which nearly every participant's primary responsibility involved transportation, much of the leadership experiences transportation only as a small portion of the their responsibility. Elected officials, strategy board members and staffers often have a far different background and expertise than those at ConnDOT. As a result of these differences, the responses from this round of focus groups offered less commonality. The responses from the leadership tended to display different opinions about what the transportation system is and should be. Fewer opinions were expressed on what specific mechanisms would be most efficient for TAM. Three ideas can be garnered from the discussions with leadership:

EFFECTIVE COMMUNICATION IS CRITICAL

Not all participants were aware of current communication channels with ConnDOT and of the information currently published each year by ConnDOT. Even if they were aware, many of the publications would require too much of a time investment to digest. These comments appear to offer an opportunity for utilizing "dashboard" or snapshot communication techniques that are part of the TAM toolbox. These tools are designed to give policymakers a quick, layman's version of the critical aspects of the transportation system and how various policy and resource decisions may impact the system's operation.

CONSISTENCY IS KEY

A wide variety of transportation asset management philosophies and procedures exist within the state. Variation is especially common between local transportation authorities. Each town may choose to allocate funding among transportation projects in its own fashion, with limited accountability to the state or region. Creating a consistent procedure for transportation resource allocation, obtaining local buy-in, and making local authorities accountable for adhering to this procedure will be a difficult, but necessary, task if TAM is to be truly systemic.

COMMUNICATION WITH THE PUBLIC IS IMPORTANT

Effectively communicating the benefits and value of TAM to the public and the state's leadership can often be a challenging and difficult task. For example, with its emphasis on life-cycle costs and a divergence from "worst-first" practice, there may be sections of roadway that are allowed to deteriorate significantly prior to rehabilitation while other sections are maintained more regularly. This creates a difficult situation for elected leaders, a situation that can be mitigated through a focused effort to communicate the benefits of TAM to the public concisely and effectively. A principal idea of TAM is that strategic investment of resources will over the long term create a better transportation network that all can benefit from, even if, in the short term, some road segments must endure less than desirable pavement conditions.

Summary

The focus group sessions yielded a considerable amount of information that suggests that ConnDOT and Connecticut leadership see value and benefits in many of the principles of TAM. Aspects of TAM are being implemented in isolation in several groups throughout the department, and this experience provides an opportunity to use lessons learned in the continued implementation of TAM throughout the department and its bureaus. Also, it is expected that support by the state's leadership of a cohesive TAM policy that links resources with the state's transportation investment decisions and TAM principles of performance-based management will be critical for achieving results.

IV. US EXPERIENCE: BRIEF STATE SUMMARIES

The FHWA data bank indicates that each of the 50 states, the District of Columbia, and Puerto Rico have some kind of a pavement management system. Forty-two states reported that their systems included a method of prioritization, and 20 states included a provision for optimization for purposes of budget planning and project programming (Finn 1997).

The following brief summaries provide experiences of several states around the nation. Later in this report, five states are investigated in considerably more detail. The summaries presented in this chapter highlight one or two aspects of a program, and do not represent a comprehensive description. They are influenced substantially by NCHRP (2007), Hendren (2005), and FHWA case study documents provided through their Asset Management website (http://www.fhwa. dot.gov/infrastructure/asstmgmt/casestudies.cfm) that highlight strengths of transportation asset management programs, including: bridge management, culvert management systems, comprehensive TAM, data integration, economics, life-cycle cost analysis, and pavement management systems.

COLORADO (CDOT)

CDOT is managed by the Colorado Transportation Commission which allocates funds according to investment categories and programs consistent with its adopted investment performance objectives. The TAM program within CDOT is implemented by an Asset Management (AM) task force. The task force is chaired by the deputy commissioner and consists of ten members from across the organization. This commitment by the department's leadership to diversity of membership has allowed CDOT to treat TAM simply "as a way of doing business" (FHWA 2004a).

TAM has helped CDOT meet department goals and objectives; it also has helped in developing performance objectives based on quantitative data. Data sharing and policy consultation with planning partners on appropriate trade-offs and collection of data for performance measures and trade-off analysis on a consistent and statewide basis are considered to be major barriers to the use of TAM. Although CDOT does not manage transit, it is working to improve the state's system. Additionally, CDOT is making consistent progress with involving the state's leadership and promoting a consistent message.

FLORIDA (FDOT)

FDOT has a strong tradition of leadership in multimodal transportation planning and decision-making. FDOT has been one of the leading state agencies in developing new approaches and strategies for linking infrastructure decisions with economic, environmental and transportation system performance objectives (NCHRP 2007).

The investment decision making in FDOT is guided by the 20-year Florida Transportation Plan (FTP). Important principles include investing first in projects that enhance safety and system preservation, promoting economic competitiveness, and providing mobility. FDOT explicitly utilizes a "fix-it-first" methodology for project selection, and has not created a separate asset management program or organizational unit. Asset management is simply considered as the

department's entire process of planning, programming, and system monitoring as they relate to preserving the state's transportation system (NCHRP 2007).

Similar to Wisconsin's DOT, FDOT breaks TAM into asset classes: pavement, bridge, and maintenance. Each of these has an extensive inventory-driven, performance-based management system that supports investment decisions in each area independently.

MICHIGAN (MDOT)

MDOT is another leader in the practice of TAM. MDOT has adopted an asset management strategy for a wide range of transportation assets, including airports, park and ride facilities, signs, traffic signals, and other transportation assets (NCHRP 2007). TAM is not simply a program in name only at MDOT. It is a core value that is dictated by state law, first defined in §247.649a of the Michigan Transportation Fund Act in 2002 as "…an ongoing process of maintaining, upgrading, and operating physical assets cost-effectively, based on a continuous physical inventory and condition assessment." This definition was later expanded upon in 2007 by legislation that said: "The Department shall develop and implement a life-cycle cost analysis for each project for which total pavement costs exceed $1,000,000 funded in whole, or in part, with state funds and thus select a project depending on the analysis."

These acts were built upon earlier legislation in the early 1990s to establish a statewide Asset Management Council, of which MDOT is a member. MDOT was one of the first states to develop the six management systems required by the Intermodal Surface Transportation Efficiency Act (ISTEA): pavement, bridge, congestion, intermodal, public transit facilities and equipment, and safety management systems (NCHRP 2007).

MDOT believes that the existence of state legislation requiring asset management has been a strong catalyst for the adoption of TAM principles. MDOT's use of asset management has provided a methodology that shows the benefit of developing bridge and pavement strategies comprising a mix of fixes (preventive maintenance, rehabilitation, and replacement/reconstruction). Also, the support and active engagement of senior management has been helpful in the successful implementation of TAM (NCHRP 2007).

MINNESOTA (MNDOT)

MnDOT's investment decision-making process is driven by performance-based plans and programs, though they do not have a specified TAM process or group devoted to the task of TAM. System preservation is the most important strategic direction for MnDOT. MnDOT requires that each district prepare a project-specific district plan that shows how its program meets statewide policy directions and its system preservation policy (NCHRP 2007).

Minnesota does not mandate TAM by law or statute, although its principles are espoused by MnDOT leadership. Asset preservation measures are reported on MnDOT's department scorecard that provides top management and key stakeholders with some indication of the progress being made in meeting overall performance targets. This type of "at-a-glance" or "dashboard" system has proven successful in many states as a means of short-term management and evaluation of a TAM system. TAM principles have helped MnDOT develop a better decision-making process by establishing a framework for decisions that has helped to improve internal decision making by providing clear priorities (NCHRP 2007).

MISSOURI (MODOT)

TAM in Missouri is used in the allocation of funding to districts, for funding the needs projections, for predicting system conditions, and in tracking MoDOT performance (Hendren 2005). The usage of TAM has made planning at district and central locations more consistent and reliable. The ability to perform "what-if?" scenarios to predict system conditions based on assumed changes in funding levels or distribution factors has been very beneficial to MoDOT.

TAM has been helpful in the automation of operations associated with programming, project selection, needs determination, and prioritization. However, the conversion of historic data into a form that is compatible with the current systems has been a slow and complex process (Hendren 2005). Interagency cooperation is also cited as an obstacle, as there is little motivation to change existing systems unless there is a direct benefit to the other agency.

OHIO (OHIO DOT)

Ohio DOT has one of the most integrated approaches to asset management of any state DOT. Ohio DOT decisions are guided by a set of principles and strategic goals that encompass five strategic areas: transportation safety, economic development and quality of life; efficient and reliable traffic flow; system preservation; and resource management (NCHRP 2007).

Condition and performance measures are an integrated part of all the departmental functions and are not considered as separate asset management processes. Ohio DOT uses a "mix of fixes" to provide as close to a steady state in condition as possible. Ohio DOT developed a project management system to track all capital project scopes, schedules and budgets (NCHRP 2007). Ohio DOT's integrated management system links project and program investment decisions to the pavement and bridge inventory databases.

The system preservation strategy followed by Ohio DOT provides a consistent institutional mission for the organization and also has helped promote coordination among the different units responsible for the state's road network.

WASHINGTON (WSDOT)

The TAM system plans in Washington are based on the policies, priorities and long-term goals dictated by the state transportation plan. In addition, state law and the transportation commission provide guidance. Legislative efforts since 1990 have helped the WSDOT improve its system management and data collection (FHWA 2007c). Specifically, the 1994 passage of the Revised Code of Washington (RCW) 47.05 allowed for more flexibility in project selection. Additionally, the change promoted LCCA as the preferred tool for project evaluation and selection.

WSDOT uses separate management systems for each asset class, and it has found this to be an effective management strategy. Most of these applications are custom built using various software including Microsoft Sequel, Power Builder, Access, and Cold Fusion. Headquarters planning and programming staff work to utilize information from management systems to develop proposed long-range and short-range plans and investment alternatives for presentation to agency executives. The overall system conditions have improved as a result of TAM. Specifically, WSDOT has a seen a 3.6% increase in 2005 alone in the number of roadways rated "good" and an equivalent decrease in the number rated "poor."

WISCONSIN (WISDOT)

The TAM system developed by WisDOT uses inventory data and information on pavements, bridges, safety, and congestion to identify highway deficiencies, provide a range of appropriate responses, and determine the estimated cost for each alternative. Deficiencies are defined on the basis of the goals, policies, and priorities set within financial constraints defined by the legislatively approved budget. The department maintains an ongoing six-year improvement program, and improvements scheduled in the program are accounted for in the needs analysis on a location and time-specific basis (Hendren 2005).

All capacity expansion programs in Wisconsin are approved by the legislature and are funded from a separate appropriation. The main benefits of using TAM in Wisconsin include:

1. budget justification;

2. program management;

3. more emphasis on system optimization;

4. increased program flexibility;

5. prioritization of data collection.

Consistent challenges faced in Wisconsin stem from the integration of activities across internal divisions and asset classes. The movement toward TAM has helped address these issues by instituting a broader view of asset management.

SUMMARY

The US experience offers a wide range of best practices and lessons learned for consideration in Connecticut:

- A TAM task force can be used to effectively create support and utilization of TAM at the leadership level (Colorado)

- A successful TAM system can retain and encourage existing independent asset-class TAM mechanisms (Washington)

- TAM has been very useful for conducting "what if?" analyses for various funding scenarios (Missouri)

- Integrating data collection efforts and ensuring data consistency across internal divisions and asset classes is a challenging task (Wisconsin)

- A 'fix-it-first' mindset is desirable (Florida)

- Legislation further enables a DOT to ensure TAM is not merely a program in name only, but a core value that plays a fundamental role for investment in the state's transportation infrastructure (Michigan)

- A dashboard, or scorecard view, of TAM performance measures is a useful management and accountability tool (Minnesota)

- Ideally, condition and performance measures are an integrated part of all processes and TAM is not considered the function of an isolated group (Ohio)

Leadership support, integration, and building upon existing capabilities are attributes of best practices used by nearly all TAM systems considered in this review. These are the same qualities of a TAM system that will be described in greater detail in the next chapter for five states: Maryland, New York, North Carolina, Oregon, and Vermont. Each state agency is unique, and no two TAM systems are the same. However, where the policies, procedures and methods employed in support of TAM are developed to support an overarching, coherent vision or mission of the TAM program, then it is likely that a coherent effective management system will have the best opportunity to emerge.

V. DETAILED CASE STUDIES

This portion of the report examines, in greater detail, TAM programs of five states in an effort to highlight additional, more subtle aspects of TAM systems relevant to Connecticut.

STATE SELECTION

Nearly every state that has implemented some form of TAM has relevant lessons for Connecticut. However, the selected states—Maryland, New York, North Carolina, Oregon, and Vermont—excelled in certain criteria with relevance to Connecticut. These criteria are summarized in Table 2.

Geography

States that are close to Connecticut geographically were favored, as similar geographic locations may have somewhat similar climates, demographics, and terrain. Geographically similar states to Connecticut include Vermont and New York.

Size

Larger states must often contend with multiple climates, many regional authorities, and substantial cultural differences within the state that offer challenges that are different than those experienced by smaller states. Since Connecticut is a small state, its TAM system will have different potential and face different challenges than those of larger, more diverse states. Vermont and Maryland are smaller states that may offer insight for Connecticut.

Criteria	Maryland	New York	North Carolina	Oregon	Vermont
Similar Geography		X			X
Similar Maturity	X			X	
Mature Example		X	X		
Similar Size	X				X
Familiarity		X	X		X

TABLE 2: DETAILED CASE STUDY SELECTION CRITERIA

Maturity of TAM System

Because Connecticut is in a relative early stage of TAM implementation, some representation of states with newer TAM systems was determined to be valuable. Challenges faced in these early stages of implementation are much different than those found in mature systems, and examples of these challenges, and methods to overcome them, are important. Oregon and Maryland are good examples of states with early stage TAM systems.

Conversely, mature systems present a worthy goal for a Connecticut system. North Carolina and New York are mature systems with significant experience, while Oregon and Maryland are somewhat newer systems that may serve as helpful examples for states looking to implement a new TAM system.

ConnDOT Familiarity

It was also desirable to include states where ConnDOT currently maintains a relationship or from which TAM information is readily available. North Carolina, New York and Vermont all have existing relationships with ConnDOT that will be useful in developing its TAM system.

MARYLAND (MARYLAND DOT)

Introduction

Maryland covers 12,407 square miles of total area (9,774 square miles of land area) and has a population of 5,615,727. The state has a mix of rural and urban areas: 23 urban areas contain 86% of the population with the remaining 14% located in rural areas. A variety of landscape features affect the state's transportation system. The Maryland DOT has divided the state's transportation system into modal administrations: the Maryland Transportation Authority (MdTA), State Highway Administration (SHA), Motor Vehicle Administration (MVA), Maryland Transit Authority (MTA), Maryland Aviation Administration (MAA), and Maryland Port Administration (MPA). The Maryland DOT manages and maintains 30,494 miles of public roads of which 481 miles are interstate highway, 4,963 road bridges, 835 miles railroad tracks, 35 airports, and 532 miles of inland waterways. In 2006 there were approximately 56,319 million vehicle miles traveled (VMT) on all highways (BTS2006). Maryland DOT is funded by the Transportation Trust Fund that receives its revenue from taxes, bond sales and the revenue generated by the modes.

The secretary of transportation, appointed by the governor, leads the Maryland DOT with executive staff, and boards and commissions supporting the department's mission. Operating staff and the modal administrations provide further support through the office of the deputy secretary. The secretary's office provides overall policy direction and management for Maryland DOT. The secretary's office also funds a grant program to various entities for transportation-related purposes (Pagano et al. 2004, 2005). The department employs 1,600 employees in the various modal administrations that are responsible for maintaining, developing, and operating the transportation system. Maryland DOT utilizes a centralized, top-down management approach for its planning process.

Strategic Planning and Decision Making

The Maryland Transportation Plan (MTP) is the state's strategic plan that is developed by a series of internal and external goal-development processes (Maryland DOT 2004). Smart growth, smart transportation, system preservation, transportation facility and system performance, safety and security are five of the 10 policy goals that are outlined in the MTP. The Office of Planning and Capital Programming is responsible for developing the MTP, with each mode providing representatives who assist in the development of the plan. During the policy goal development process, others also provide input including an advisory committee, the governor's office, business groups, transportation civic groups, elected officials, other state government agencies, and the public, through a 1,000-person telephone survey of randomly selected residents from around the state.

SHA has a comprehensive and formal program that includes elements of TAM. Condition assessment, network-level planning, project selection, project advertisement and construction

are the steps taken by the SHA as part of its strategic planning. The main objective of SHA is system preservation and all decisions are made consistent with this objective. As part of system preservation, funds are also utilized to reduce accidents, relieve congestion, enhance urban roadways, as well as to improve access for pedestrians and bicyclists.

Asset Management

The SHA is the only modal administration that has developed a comprehensive and formal asset management program. This program is currently in place only within the Pavement Division of SHA (Pagano et al. 2004, 2005). Maryland DOT assesses the condition of its highways as very good, good, fair, mediocre, or poor depending upon ride quality. A linear programming (LP) model is used to determine the optimal number of lane miles to be treated, as well as the type of treatment to be applied to a road. The objective of this LP model is to improve pavement condition. A software tool, Project Selection Tool (PST), developed by SHA is then used to demonstrate candidate projects to district officials and the Office of the Chief Engineer. The tool displays the lane miles to be treated in each district and the benefits of the selected treatment. Districts then select projects that are reviewed by the Office of the Chief Engineer to determine which will receive funding. Projects are then advertised and constructed.

The Bridge Division of SHA uses a systematic process to identify and repair or replace bridges, but unlike the Pavement Division, it does not have a focus on overall system health (Pagano et al. 2004, 2005). Several other offices in Maryland DOT are beginning to adopt TAM concepts.

Systems and Methodology

SHA uses a variety of tools to manage each of its system preservation programs. Operational plans are established by the program managers to achieve the program objectives. Trade-offs between each program are debated at an annual meeting of program managers with the SHA administrator. Currently, SHA does not have the capability of objectively evaluating the benefits and consequences of trade-offs other than the use of good engineering judgment and past performance, although some of the programs include tools to predict the consequences of funding allocation scenarios (Hendren 2005).

Each program within SHA establishes operational plans in a unique manner. However, a design team was formed by SHA to integrate statewide planning, design and maintenance activities through common systems. Several tools were developed by SHA for its TAM. Most of the system data are stored in a GIS database. A variety of other internal tools have been developed that allow for access to construction history data, pavement and bridge condition information, bridge inventory information, and traffic and accident data (Hendren 2005). PONTIS is used to rate the condition of bridges and large structures, whereas a scoring system based on various factors (primarily community requests) is used to identify and prioritize urban revitalization projects. A project- and life-cycle-based system driven by needs and age prioritization is used for drainage projects, yet only a project-based system driven by needs identification is used by the Congestion Relief and Safety programs.

Performance Measures

Performance measures play a vital role in resource allocation, as they demonstrate how well an objective is achieved through asset management processes. Maryland's small size gives it the

advantage of being able to use a single inspection team for gathering statewide performance data, promoting greater consistency compared to using multiple teams. Maryland recognizes targets in short (2 years), medium (6 years), and long (20 years) range contexts (NCHRP 2006). Maryland DOT's performance is summarized and documented in Maryland's Annual Attainment Report (Cambridge Systematics 2007) based on the policy goals of efficiency, mobility, safety and security, and productivity and quality required by legislation passed in 2000 (Volpe 2003).

EFFICIENCY

Extending the service life of the existing facilities and equipment and maximizing the operational performance and capacity of existing systems are the two objectives of this goal. Utilization of a pavement management program to maximize roadway performance through optimized use of available funding and stricter implementation of ride quality standards for newly constructed pavements improved the performance of pavements in 2006. The various performance measures used to evaluate the achievement of this goal are

- percentage of SHA roadway mileage with acceptable ride quality;

- percentage of bridges along Maryland SHA and MdTA portions of the National Highway System (NHS) that will allow for the safe passage of all legally loaded vehicles;

- percentage of MTA service provided on time; and

- total reduction in incident congestion delay.

MOBILITY

Relieving congestion by adding key system links and supporting different modal needs with cost-effective options are the two policy objectives of this goal. The completion of several major capacity expansion projects and optimizing traffic signal timing on approximately 550 signals has resulted in improved performance in 2006. The performance measures used are

- percentage of lane miles with average annual volumes below congested levels;

- peak-period congestion of freeways in Baltimore/Washington regions;

- percentage of electronic toll transactions;

- annual vehicle revenue miles of MTA service provided; and

- number of non-stop airline markets served.

SAFETY AND SECURITY

Reducing injuries, fatalities, and risks and ensuring security of the public are the objectives of this goal. The performance measures used are

- annual number and rate of traffic fatalities on all roads in Maryland and MdTA facilities;

- annual number and rate of personal injuries on all roads in Maryland and MdTA facilities;

- customer perceptions of safety on the MTA system;

- bus incidents per million vehicle revenue miles;

- airport compliance with annual FAA Part 139 safety certification (Pass/Fail); and

- Maryland's Port of Baltimore compliance with the Maritime Transportation Security Act of 2002.

PRODUCTIVITY AND QUALITY

Reducing project implementation time through process improvements, incorporating environmental stewardship into all projects and activities, containing costs, and leveraging resources with business-like organization and innovative approaches to funding and service delivery are objectives of this goal. Performance measures used by SHA and MTA are

- transportation-related emissions by region;

- percentage of overall Maryland driver satisfaction rating "A" or "B";

- customer service rating with MTA;

- maintenance expenditures per lane mile;

- MTA operating cost per passenger; and

- MTA operating cost per passenger mile.

Performance measures used by Maryland DOT help track the impacts of various investment decisions, and raise its public and political accountability and credibility.

Summary

Maryland is relatively small state with a mixture of large cities and rural areas, making it similar to Connecticut.

The key advantages of Maryland DOT's TAM implementation include well-defined goals, objectives and performance measures for each goal, and an annual review of these measures. The systematic selection of projects helps achieve the goals of system preservation and customer satisfaction. SHA is the only Maryland DOT administration entity that has implemented asset management and is doing it efficiently. Maryland DOT is now trying to implement asset management programs in other administrations as well. This type of phasing provides Maryland DOT an opportunity to better understand the implementation process in a single administration and then deploy it to other administrations much more efficiently and effectively. Further, phasing helps initially concentrate efforts entirely on a single administration when the expertise is low and helps in learning and improving the process before expanding it in other areas.

Maryland DOT's phased approach for TAM implementation provides the department with the advantage of learning from its own experience; but it also has the impact of extending the time required for implementation.

A few important steps that were taken and are being taken by the Maryland DOT to make the implementation of TAM a success are as follows:

- Maryland developed a strategic plan, the Maryland Transportation Plan (MTP), that outlines ten policy goals. Each modal agency develops its own strategic plan. The plan then provides a foundation for the development of well-defined objectives and performance measures for each goal. This is an important step, since a strong strategic plan that is well developed will guide the state's TAM implementation process.

- Maryland DOT first implemented TAM only in SHA. This provided the department the benefit of understanding the process clearly by applying it in a single asset class and improving upon it. The expertise obtained by implementing TAM in SHA is subsequently being used to apply TAM in other administrations.

NEW YORK (NYSDOT)

Introduction

New York covers 54,465 square miles of total area (47,214 square miles of land area) and is the third most populated state in the country with a population of about 19.3 million. Of the population, 92% lives in urban areas, though much of the state is rural in character. More than 40% of the state's population lives in New York City, which makes it the largest city in the United States. New York State has the most extensive and the oldest transportation infrastructure in the country; it has a total of 112,783 miles of public roads, 1,675 miles of interstate and 17,387 road bridges. New York's transportation system includes 2,258 miles of Class I railroad trackage (including an extensive commuter rail system that serves the greater New York City region), 394 miles of inland waterways and 25 airports (BTS 2006).

New York was among the first states in the country to automate its highway information systems and to apply economic analysis in considering highway investments. NYSDOT began using some asset management principles and tools in the early 1960s, using super computers available at that time to process pavement, bridge, and safety data to help with resource allocation decisions.

Decision Making

NYSDOT reviewed its decision-making procedures in the 1980s due to deteriorating highways, bridges and other transportation assets. The department divided the responsibilities among its regional offices for infrastructure project selection and delivery (FHWA 2003). Program offices located at NYSDOT headquarters were given the responsibilities of policy and quality assurance. Formal goals and performance measures for pavements, bridges, safety and mobility were developed during the implementation of the Program Upgrade Process. These goals have continued to shape the department's program development process (FHWA 2003).

In 1990, NYSDOT began to develop a Project and Program Management Information System (P/PMIS) to improve its decision-making process. This database was designed to integrate department information on programs and projects obtained from various systems, including its general management system, financial information system, and other department databases.

Currently, P/PMIS is the single financial management tool for both the Program Update Process and daily management of NYSDOT's capital programs. The P/PMIS contains planning, finance, and project information and tracks each project from its initial development stage to construction completion and final payment. NYSDOT started developing a feedback tool in 2001 to analyze options at the program level utilizing inputs from the already existing pavements, bridges, safety, and mobility management systems (FHWA 2003).

Asset Management Systems

NYSDOT has developed a unique integrated management system for each of its transportation components. The current version applies to the following areas (FHWA 2003):

- Pavement Management: pavement inventory, inspection, and forecasting of condition needs are performed by NYSDOT's automated systems, which have been refined every decade since 1981.

- Bridge Management: A bridge management database and a network-level forecasting of resources needed to maintain condition targets are used by the NYSDOT to manage and maintain its bridges. Formal least-cost analysis procedures such as rehabilitation versus replacement are utilized for assessing its bridge treatment alternatives

- Safety Management: Crash data is used to identify high accident rate locations for the Highway Safety Improvement Program. These high accident rate locations are investigated and alternative counter measures are analyzed, so that the alternative with the highest benefit cost ratio is selected.

- Mobility: NYSDOT forecasts times, locations, and magnitudes of vehicular congestion on the state highway system. Excess user costs incurred due to the delay for automobiles and freight carriers are then calculated. Strategies such as travel demand management actions and transportation system management are evaluated at a project level using the benefit cost analysis.

Performance Measures

The performance measures used by NYSDOT are specific to its objectives of safety, preservation and serviceability. Maintaining an acceptable level of bridge and pavement infrastructure condition are the primary objectives. The following are a selection of performance measures that NYSDOT established for each transportation asset component (NYSDOT 2008):

BRIDGES
- Percentage of deficient bridges
- Customer travel (vehicle-miles traveled) on deficient bridges
- Percentage of bridges with seriously deteriorated critical elements
- Number of bridges with load or clearance postings on NHS and other specifically identified routes

PAVEMENTS

- Percentage of lane miles with surface conditions rated "fair" or "poor"

- Percentage of lane miles with rough ride quality (International Roughness Index [IRI] greater than 170)

- Customer travel (vehicle-miles traveled) on rough roads (IRI greater than 170)

MOBILITY

- Person-hours of delay (PHD) on state highway network

- PHD by major trade corridor

- PHD due to incidents on state highway network

- PHD due to incidents by major trade corridor

SAFETY

- Transportation fatalities

- Transportation injuries

Summary

NYSDOT has built a strong foundation for the implementation of Asset Management processes. The department

- established clear lines of management responsibility;

- implemented goal-oriented programming;

- improved its management systems;

- integrated the department's information systems.

The department's trade-off analysis model was developed to make the decision-making process easier. It takes inputs from each asset class management system and assesses investment decisions by ranking projects both within a program and among the program areas. New York implemented TAM at the department level, which is expected to accelerate full implementation of TAM processes.

NORTH CAROLINA (NCDOT)

Introduction

North Carolina covers a total area of 53,814 square miles of total area (48,711 square miles of land area). The state is ranked 28th with respect to its area and 10th with respect to its population of 8,856,505 in the United States. North Carolina has three metropolitan areas (The Metrolina [Charlotte-Gastonia-Salisbury], The Triangle [Raleigh-Durham-Cary] and The Piedmont Triad

[Greensboro--Winston-Salem--High Point]) each with a population over 1 million. The state has a total of 99,813 miles of public roads of which 1,024 miles are interstates, and NCDOT maintains and operates 75% of the state's roadways.   There are a total of 16,822 road bridges, 2,588 miles of Class I railroad trackage, 1,152 miles of inland waterways, and 17 airports in the state (BTS 2006).

NCDOT's organizational structure includes the following divisions that operate and maintain the corresponding transportation infrastructure: Aviation, Bicycle & Pedestrian, Motor Vehicles, Ferry, Highways, Public Transportation, and Rail.

Decision Making

NCDOT's Transportation Planning Branch is responsible for developing a statewide long-range strategic plan as well as for technical support for Metropolitan Planning Organizations (MPOs), in the programming of capacity-related projects (FHWA 2005). The Program Development Branch holds public meetings across the state to solicit input from citizens, local governments, Regional Planning Organizations and MPOs in the development of the State Transportation Improvement Program (STIP). In MPO areas, MPOs identify projects for capacity expansion. These projects are then submitted to the NCDOT Board of Transportation for consideration for inclusion in the STIP. The planning staff of NCDOT provides technical assistance and coordinates the process as projects move from the identification to the programming stage.

The Long Range Statewide Transportation plan (covered in more detail below) guides NCDOT's decision-making process. It was initiated by the department's leadership and is supported by its upper management. The various divisions of NCDOT defined the goals and objectives, identified the investment needs, and suggested the initiatives for meeting the needs of the system in the long-range plan. Though the long-range plan suggests a system preservation strategy, growing population and legislative requirements have forced the state to devote substantial funds for system expansion. The decision-making processes that allocate resources for capacity expansion is balanced by maintenance, operations, and preservation needs through the department's Asset Management division (FHWA 2005).

The prioritization of capacity expansion and preservation projects is done at a decentralized level and includes input that the department receives from MPOs and regional planning agencies (RPAs). Funding for capacity improvement projects is bound by state law that identifies the amount of regional funding and requires that selection of projects must be balanced by the availability of eligible funds by region.

The allocation of funds to the STIP is subject to legal requirements. While the state law requires certain funds to be dedicated for the STIP, management, maintenance and preservation needs are addressed through annual legislative appropriations based on historical trends and the needs identified by NCDOT staff (FHWA 2005).

Asset Management

North Carolina began its asset management efforts in 1998 by developing a maintenance quality assurance program to report its maintenance needs to the North Carolina General Assembly. In 2001, the state started a pavement preservation initiative to develop system preservation strategies based on maintenance condition reports.

In 2000, NCDOT established a 13-member multimodal steering committee to develop a Long Range Statewide Transportation plan that was adopted by NCDOT in 2004. It was decided that the NCDOT planners would review the state's infrastructure and develop two methodologies to categorize infrastructure concerns:

- The first method classifies transportation facilities and service needs into one of several scope groups: statewide, regional or sub-regional.

- The second method categorizes needs by improvement categories: maintenance, system preservation, modernization and expansion. Examination of the future needs using this categorization procedure has helped enhance public dialogue regarding NCDOT's management of its resources. This method also provides a basis for comparison of past expenditures and investment patterns (FHWA 2007b).

NCDOT's Operations group oversees TAM and manages and supports the following central units of the department (NCDOT 2008):

- **Bridge Management Unit:** inspection, analysis, inventory, and administration of maintenance policies and procedures of the bridges.

- **Pavement Management Unit:** pavement assets are analyzed, rated and prioritized based on the information collected through a pavement condition survey. A recommended treatment is suggested for the deficient sections and this recommendation is next used as a guideline for developing the actual treatment. This unit is also responsible for developing and implementing a Pavement Management System (PMS).

- **Intelligent Transportation Systems (ITS) Unit:** this unit manages and maintains the states Travel Information System that provides incident management services.

- **Equipment and Inventory Control Unit:** this unit supports the DOT's equipment and material needs for the operation of the state's transportation system.

- **Secondary Roads Unit:** this unit maintains the inventory of all the secondary, paved and unpaved roads under the NCDOT system.

- **State Road Maintenance Unit:** this unit implements and manages programs for maintaining roads on the NCDOT system.

Summary

North Carolina's success in implementing TAM can be attributed to its high-level support, understanding of asset management objectives, and development of its long-range plan. NCDOT has found a good balance between the system preservation program and capacity expansion programs as a result of comprehensive data-driven analysis and strong cooperation among staff in asset management, planning, and other functional areas (FHWA 2007b).

The support provided by the upper management and the continuous efforts of NCDOT have made the TAM program in North Carolina a success. NCDOT is putting significant effort into moving from a capacity expansion to a system preservation strategy even with pressure from a growing population and the state's legislature to consider capacity expansion projects.

OREGON (ODOT)

Introduction

Oregon covers 98,380 square miles of total area (95,997 square miles of land area) and has a population of 3,700,758. There are total of 66,902 miles of public roads including 727 miles of interstates, 7,257 road bridges, 1,427 miles of Class 1 railroad trackage, 12 airports and 681 miles of inland waterways in the state. ODOT manages the transportation system in the state and consists of the following divisions: Highway, Public Transit, Motor Carrier Transportation, Rail, Transportation Development, and Transportation Safety.

Strategic Planning and Decision Making

ODOT is guided by the Oregon Transportation Commission (OTC) in its decision- making and project prioritizing process and views TAM as a fully integrated part of its management structure, as depicted in Figure 1. OTC uses a policy document, the Oregon Transportation Plan (OTP), established in 2006 that contains goals and strategies that guide the state in its project selection decision-making process.
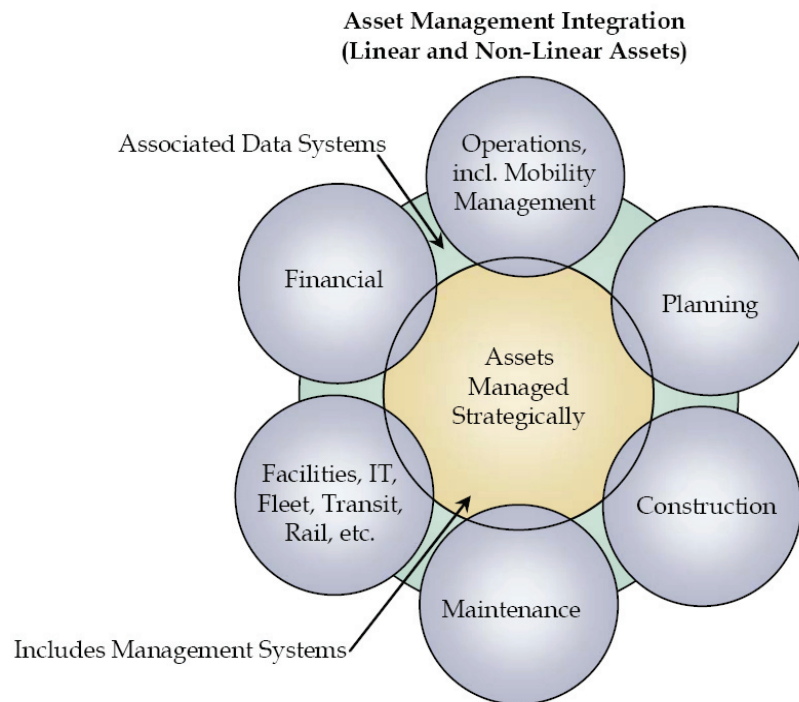

(Source: NCHRP 2007)

**FIGURE 1: OREGON DOT'S VISION OF A
FULLY INTEGRATED ASSET MANAGEMENT SYSTEM**

(NOTE: LINEAR ASSETS ARE THOSE ASSETS ASSOCIATED WITH ROADS AND THE ROADSIDE SUCH AS PAVEMENTS, BRIDGES, AND SIGNS; NON-LINEAR ASSETS INCLUDE ASSETS SUCH AS FACILITIES, EQUIPMENT, AND SOFTWARE.)

The key strategies in the plan include

- managing the existing system;

- improving system efficiency and operational capacity; and

- adding new facilities to the existing system.

The OTP does not identify projects to be developed, but it provides a framework for prioritizing the projects that is followed by the individual modal plans. When the overall policies are identified, funding is established for the next six years based on budget plans (NCHRP 2007).

In recent years, legislation was enacted that implemented the Oregon Transportation Investment Act (OTIA). It requires the Oregon Transportation Commission to use bond proceeds to finance increased lane capacity and interchange enhancements, bridge repair and construction, and road preservation (ODOT 2007a). It also directed the OTC to select projects based on the following criteria (ODOT 2007a):

- Highways that need increased lane capacity, chosen from a financially constrained list

- Highways and bridges with weight limitations

- State and local bridges based on a bridge rating system

- Interchanges on multi-lane highways where safety would be enhanced by constructing a grade-separated interchange to replace an at-grade crossing

- District highways in cities and counties that need preservation and that can be easily transferred from state to local government

- Projects that are equitably distributed throughout the state, using the same criteria as the Statewide Transportation Improvement Program

According to the legislation, OTC has to consult with local governments, metropolitan planning organizations, and regional advisory groups when making project selection decisions. In January 2002, OTC approved a final list of projects after a seven-month process that included extensive participation from citizens, elected officials, advisory committees, and Area Commissions on Transportation (ACT). House Bill 2041 signed in 2003 directs $2.46 billion to replace and repair state and local bridges, **for county and city maintenance and preservation, and for statewide modernization projects.**

## *Asset Management Systems and Methodology*

Oregon Transportation Management System (OTMS) is a program developed to manage highway pavement, bridges, highway safety, traffic congestion, public transportation facilities and equipment, intermodal transportation facilities and systems, and traffic monitoring for highways. This management tool helps the decision makers in selecting cost-effective programs and projects.

The function of OTMS is to
- inventory roadway and other transportation assets;

- collect, analyze, and summarize data;

- identify and track performance measures;

- identify needs and help determine strategies and actions to address those needs; and

- monitor and evaluate the effectiveness of strategies and actions that are implemented (ODOT 2007b).

There are nine managing systems included in the OTMS, as shown in Figure 2: Future Assets, Bridges, Pavements, Freight & Intermodal, Congestion, Environmental, Safety, Maintenance, and Traffic. This system enables each asset class and operational data source individuality and the freedom to choose its asset-specific tools, while remaining part of the overall performance-based TAM system.
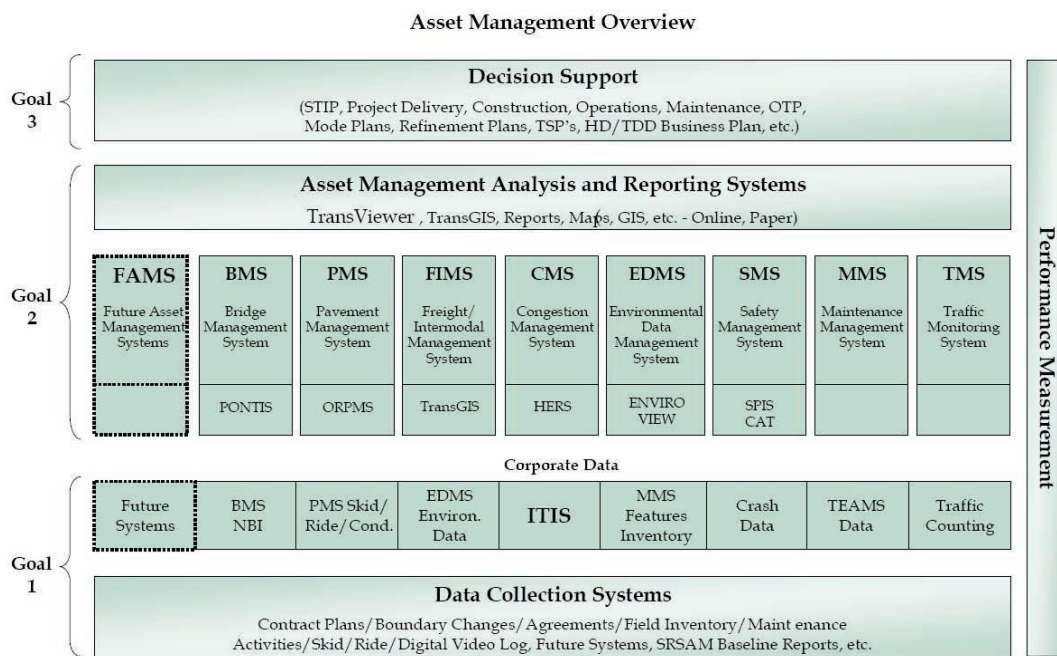
(Source: NCHRP 2007)

FIGURE 2: ODOT'S VISION FOR ASSET MANAGEMENT REPORTING SYSTEMS

Asset Management

Asset management in Oregon is not mandated by legislation. However, ODOT has requested that the legislature provide additional resources to support the key program functions identified in ODOT's "Linear Asset Management Strategic Plan" and "Linear Asset Management Implementation Plan." Further, the goals, policies and strategies in the OTP clearly show ODOT's emphasis on transportation asset management. To promote its use of TAM, the ODOT developed a specific asset management communication plan that is focused on increasing awareness of the need for asset management among ODOT employees and general public.

The executive owner of the asset management initiative is the Transportation Development Division (TDD) Administrator. Several asset management teams have been created, covering

numerous organizational hierarchies and technical disciplines, including (NCHRP 2007) the following:

- Asset Management Executive Steering Committee

- Asset Management Steering Committee

- Asset Management Tactical Committee

- Asset Management Region 2 Pilot Team

- ODOT GIS Steering Committee

Performance Measures

ODOT uses the percent of pavement lane-miles rated fair or better compared to total lane-miles on the state highway system to evaluate pavement performance in their entire system. This measure shows how well the network is being maintained and helps ODOT find the most deficient locations. Each ODOT region has a specific mileage target for improving "poor" condition roads. The condition of bike and pedestrian lanes is also measured in a similar way, which yields performance data that complement the pavement measures.

ODOT rates bridges that are not structurally deficient or functionally obsolete utilizing a performance measurement process that considers certain criteria including economic and quality-of-life costs. This type of analysis allowed ODOT to make progress in shifting from a worst-first, to a more strategic, corridor-by-corridor approach to addressing the state's bridge repair and replacement needs.

For fleet vehicles, ODOT calculates the percentage of vehicles that are in fair or good condition. This information provides ODOT with guidance that enables the department to keep its vehicle fleet in a safe and operational condition. Currently 77% of the fleet meets the minimum requirement.

Summary

Though ODOT just recently formalized the use of TAM in its 2006 Transportation Master Plan, it has already taken important initial steps critical to attain future success in using asset management to support investment decisions. ODOT's implementation plan emphasized securing a sustainable political commitment and leadership from its executive staff. It allowed existing data collection processes and information systems to serve new applications and built a system-wide TAM foundation.

In November 2005, ODOT signed an agreement to develop a multi-phased asset management study to answer questions such as:

- "What are the best asset features to document for a first level effort; where are the gaps in data availability?"

- "What level of effort is necessary to integrate existing data?"

ODOT developed an asset management communication plan to help its staff and the general public to better understand the asset management process. This helped ODOT win the confidence and support of stakeholders that are critical for successful implementation of TAM.

VERMONT (VTrans)

Introduction

Vermont covers 9,616 square miles of total area (9,250 square miles of land area) and has a population of 623,908, making it the second least populated state in the United States. VTrans is the state transportation department that manages the state's infrastructure, which consists of 2,708 miles of paved state and interstate highways, 2,675 bridges that are longer than 20 feet, 305 miles of rail line with 265 bridges, 411 buildings, and various other assets. The total transportation capital and operating budget of VTrans for the 2009 fiscal year is $431.7 million, $207.4 million of which is federal funds.

The VTrans organizational structure consists of the office of the secretary of VTrans and five divisions, each headed by a director: Program Development, Operations, Policy and Planning, Finance and Administration, and Motor Vehicles. VTrans employs 1,300 people throughout the state. VTrans is highly centralized, with senior management, project managers, information technology, engineering, finance, contracting, and legal staff located in one headquarters building in Montpelier. The department's small size and central location means that staff at all levels are accessible, thereby, fostering better communications and coordination. The state is divided into nine districts to manage the normal highway operational activities. In terms of planning, VTrans is supported by 11 Regional Planning Commissions (RPC) and one MPO (VTrans 2007a). These supporting organizations perform a very important role in the decision-making and project prioritization process in Vermont.

Decision Making

The decision-making process in VTrans involves prioritizing projects and selecting the project with the top priority. Before the concept of a project moves forward for the legislature's approval, it has to fulfill one of the current needs statements. Once a project is approved, it is then typically evaluated by engineers, planners and citizens for feasibility and scope (Selle 2008).

Like other states, VTrans prioritizes projects to preserve and improve the state's transportation assets within its budget constraints. Selle (2008) provides a detailed outline of the project prioritization process in Vermont. Project prioritization is mandated by legislation enacted in 2005 and 2006. As per statute, VTrans rates its projects depending upon several factors such as safety, traffic volume, priorities assigned by the RPCs and the MPO. The legislature also requires VTrans to consider how the project will help improve the local economy and environment.

Priorities of the RPCs and the MPO are considered first, then matched with the VTrans priorities. VTrans uses a different formula for each asset type to prioritize a project in a particular class. The program managers present the proposed budget to the VTrans Budget Committee, which consists of the deputy secretary, five deputy directors, the VTrans federal

funds administrator, and two other members from its Policy & Planning Division. The committee and the program managers discuss preliminary budget figures, asset performance measures, and prioritization results. The project scores/ratings drive the proposed program. At times a low priority project may be selected due to permitting issues, rights-of-way, federal funding availability, or congressional earmarks. The budget is available for public scrutiny after the governor presents it to the legislature.

VTrans has a very long project backlog and thus does not accept any new projects from the RPCs and the MPO unless they are of a critical nature, or when a new project replaces a different project in the same region of the state. The RPCs and MPO must submit any project changes/additions to VTrans early in the year. After the transportation program is developed, VTrans is prepared to explain project priorities and choices to any interested party, including legislators and town managers.

Asset Management

Asset Management in Vermont supports the key goals of safety, preservation, excellence, and planning, following a vision articulated in 2002 (Cambridge Systematics, 2002). VTrans uses asset management in making transportation investments in an effective way to maximize the value of existing transportation infrastructure, including the ability to predict asset conditions under different funding levels.

Vermont is one of the few states that has asset management and performance measures mandated by state statute. VTrans was involved on a cooperative basis with the General Assembly, the Joint Fiscal Office, and the Legislative Council in developing the legislation that requires VTrans to (VTrans 2007a)

- develop an asset management plan that is a systematic goal and performance-oriented management and decision-making process of operating, maintaining, and upgrading transportation assets cost-effectively;

- include deterioration rates for infrastructure assets; and

- determine, long-term, the annual funds necessary to fund infrastructure maintenance at the recommended performance level.

As part of its AM program, VTrans has taken important initial steps to define goals, objectives and performance measures. VTrans recognizes the importance of preventive maintenance and has implemented the Road to Affordability program that emphasizes fixing existing infrastructure. VTrans has been continuously refining its long-range plans and its life-cycle cost strategies to eliminate worst-first project selection. VTrans conducted various customer surveys to develop a customer-oriented approach to transportation asset management, and is considering public perception of asset conditions to update its policy objectives. The Long Range Transportation Business Plan sets a policy direction and provides guidance for transportation planning, project development, operations and maintenance. It is updated every five years to reflect any changes in VTrans' areas of emphasis and the role of transportation in the state.

Systems and Methodology

Vermont uses TAM systems that can analyze investments within an asset class. VTrans uses the following:

1. Deighton's dTIMS pavement management software to develop its paving program.

2. AASHTO's PONTIS bridge management software, and is working to make more use of the PONTIS deterioration models and a bridge health index to plan effective preventive maintenance.

3. MATS (Maintenance Activity Tracking System) as part of the department's maintenance management activities to record its highway maintenance work. It is being expanded to track inventory and condition of ancillary assets.

4. AIMS (Airport Information Management System) to identify, prioritize and track progress on airport related projects.

Performance Measures

VTrans has been developing performance measures since 2001 and they are an integral part of its asset management system. The performance measures are developed and organized according to type of transportation asset. Target performance measures are identified for each performance measure. VTrans is continuing to develop threshold values based on collected historical data (VTrans 2007b) for those performance measures where targets have not yet been established. VTrans typically uses a descriptive rating system, from "Excellent" to "Very Poor" and explains the meaning of each condition in clear terms.

PAVEMENTS

Data on roughness, rutting, and cracking of state highways are collected by utilizing a specially equipped van. This data is fed into a PMS that calculates the pavement condition index that is used by decision makers to manage the highway system. Roads that have higher vehicle miles traveled are given higher priority in making investment decisions, while pavements with lower vehicle miles traveled are maintained at a minimum level to ensure mobility and safety.

BRIDGES:

The bridges that VTrans is responsible for are inspected at least every other year and are reported to the FHWA for the National Bridge Inventory. Many of Vermont's bridges that were rebuilt after a 1927 flood and during the interstate era are now in need of major repairs or replacement. Deferred maintenance of bridges has resulted in repair needs that exceed annual available funding levels.

Summary

Vermont was chosen as a case study for this project because it is similar to Connecticut in terms of its location and size.

Vermont's Asset Management Program is legislatively mandated. This has greatly helped and guided VTrans' TAM development process. Moreover, VTrans is constantly trying to improve its TAM system by reviewing and establishing new target performance levels for each asset class. Also, the VTrans Information Technology division is investigating an integrated database that will help link assets by location, condition, value, and usage. Performance levels are investigated to bring them to the sufficient operational level. Also, VTrans has developed asset management policy plans for rail, aviation and public transit, and has made excellent progress in improving its TAM system over the past several years.

The success of TAM in Vermont can be attributed to the state statute that requires VTrans to develop an asset management plan that provides a systematic goal and performance-driven management and decision-making process.

This legislation also requires VTrans to consider a project's impact on the local economy and environment.

VTrans has taken important initial steps to clearly define its goals, objectives and performance measures, and is in the process of reviewing and refining its performance measures. VTrans' actions are examples of their recognition of the importance of a performance-driven, outcome-based approach to planning and resource allocation.

VI. LIFE-CYCLE COST ANALYSIS (LCCA)

Successful TAM systems seek to align system performance and resources. This realignment includes a shift towards evaluating maintenance activities, rehabilitation activities and new construction in a life-cycle context that incorporating construction, operating and user costs. Life-cycle cost analysis (LCCA) is a tool that implicitly transitions from worst-first decision-making to taking a holistic, long-term, systemic view of allocating resources. The mechanics of LCCA are well established and documented. The primary mechanism utilized is the discounting of costs and benefits to a particular year (usually the current year), which depends on having relevant and accurate cost and benefit data for those costs and benefits that need to be included in the analysis.

FHWA recommends LCCA as an economic tool for transportation agencies to use in simulating cost distributions for different management alternatives for a given project (AASHTO 2001). LCCA can be used for new projects as well as for existing transportation assets. The analysis considers not only initial investments but also all agency maintenance and operational expenditures together with road user costs. According to FHWA (FHWA 2001), LCCA addresses the following:

1. Which alternative gives the lowest total cost to the agency over the entire life of the project?

2. What level of detail was considered for the project alternatives?

3. Are user costs considered and what are their impacts on different alternative strategies?

A typical LCCA procedure consists of the following steps (FHWA 2001):

1. Establish several alternative strategies for a given project, including all maintenance and rehabilitation activities.

2. Estimate optimal timing for all activities in the alternative strategies.

3. Estimate agency costs and road user costs.

4. Determine life-cycle cost and net present value (NPV) for different strategies.

First, several design alternatives must be considered to perform the most effective LCCA. For each design alternative, initial construction activities as well as expected future maintenance and rehabilitation activities, together with their optimal timing, should be determined. A typical lifespan of one alternative strategy with two rehabilitation activities is presented in Figure 3.
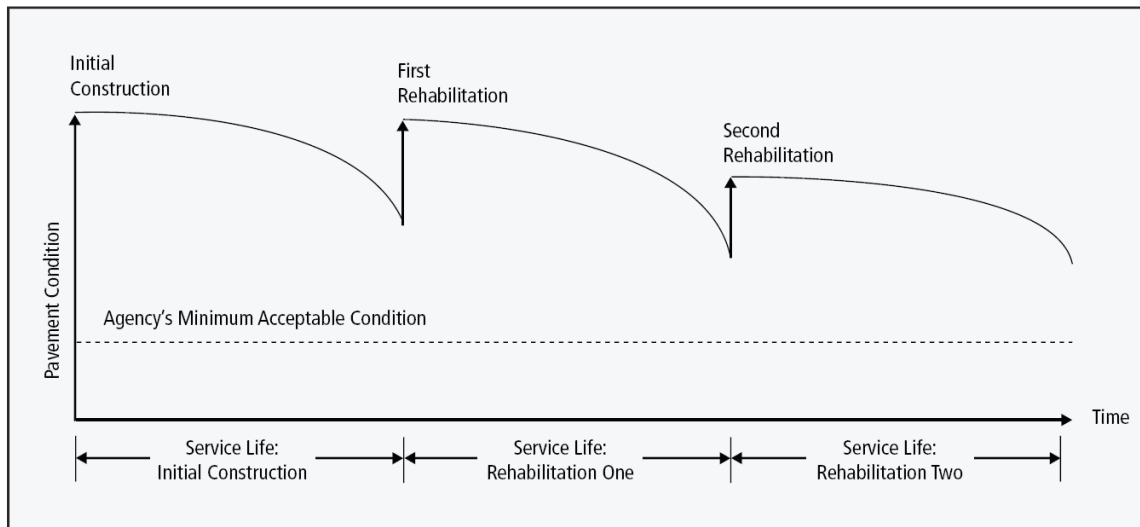
FIGURE 3: DETERIORATION CURVE OF AN ALTERNATIVE MANAGEMENT STRATEGY
(AFTER FHWA 2002)

Preventive maintenance activities performed at the right time represent the most cost-effective approach to pavement preservation (Peshkin et al. 2003). Preventive maintenance is intended to preserve the pavement system, postpone deterioration, and maintain or improve the functional condition of the pavement without increasing structural capacity. Because preventive maintenance activities of flexible pavements are usually applied to the pavement surface, they are also called "surface treatments" or "surface rehabilitation techniques." The most popular surface treatment activities reported in the literature for flexible pavements in the United States include: crack seals, fog seals, rejuvenators, slurry seals, seal coats, microsurfacings, and thin hot mix overlays.

Second, costs for initial construction and all planned activities should be determined. For the most comprehensive and thorough comparison of the strategies, road user cost should be also considered. User costs usually consider vehicle-operating costs, and costs of accidents, discomfort, and user delay. In some cases, user delay costs are considered to be non-agency costs, but AASHTO (NCHRP 20-7/24) states that delay costs may be significant contributor to the entire alternative cost and should be included in the LCCA.

Several factors govern the magnitude of delay costs such as traffic handling, hourly traffic volumes, work period, length of work zone, road geometrics, and availability of alternative routes. The FHWA reports (Focus 2007) that 14 states currently consider user costs in the LCCA, and several of these states use FHWA's RealCost LCCA software for performing analyses. RealCost has the capability of identifying cost differences between design alternatives, accounting for both initial and future agency and user costs (MAPA 2007).

Finally, once the timing and costs of all activities for all alternative strategies are established, the LCCA is performed over the entire analysis period, typically 35-40 years for flexible pavements. To provide a fair comparison, a net present value (NPV) is calculated to discount anticipated future cost to present values. In this way, the entire lifespan cost of different alternatives can

be directly compared in a present value. Based on this comparison, the most cost-effective alternative can be identified and considered for implementation.

One of the major advantages of LCCA methodology is the potential for performing an impact analysis. Alternative strategies with various activities and different timing options can be compared and evaluated in terms of their present and future costs as well as their likely impact on considered performance measures. Such impact analysis can then be utilized to support the selected alternative for project funding (FHWA 2004b).

Two examples of states that have actively used LCCA to determine the most cost-effective projects are Georgia and Pennsylvania (FHWA 2008a, 2008b). Both states have successfully performed LCCA on larger projects since early 1990s, and both consider road user costs associated with work zones. GDOT incorporates calculated user costs as a factor in a weighted decision matrix after performing LCCA on direct agency costs, without user costs. PennDOT inputs user costs directly into the LCCA.

Both states plan on improving and refining their procedures, especially towards incorporating uncertainty and risk in their analysis procedures.

VI. SUMMARY OF FINDINGS AND CONCLUDING REMARKS

SUMMARY OF FINDINGS

The findings of this study indicate that ConnDOT should consider utilizing five concepts — identified as the 5Cs—as a strategy for TAM implementation. The 5Cs organize and provide a structure for five concepts that were consistently identified as critical for achieving success in TAM. The 5Cs embody the principles of TAM that were highlighted in many previous studies and reports and within the focus group discussions conducted as part of this project. The 5Cs of Asset Management provide a focus for ConnDOT's development of a sustainable TAM program to guide the state's investment in the acquisition, repair, preservation, and construction of the state's transportation assets. These concepts are described as follows:

Clarity

A clearly stated vision and a process for implementation are necessary for successful implementation of any TAM system.

- ConnDOT needs to clearly define its goals, objectives and performance measures to assure that a strong foundation and framework is created for its TAM program. It is suggested that the TAM system should provide flexibility to accommodate and adapt to the changing needs and goals of the state's transportation system. This clarity includes well-defined roles for OPM and the General Assembly.

- One potential implementation strategy for Connecticut would be to adopt legislation that would mandate the use of TAM in determining the state's investment in its transportation assets. Legislation that recognizes TAM as the state's principal system for transportation asset investment decision making provides a means for clarifying goals and formalizing constructive collaboration between ConnDOT management and decision makers in the executive and legislative branches of state government. If not mandating the entire TAM process, Connecticut could enact legislation that would mandate parts of the TAM process. This was done in Vermont through statute § 10g(l), (m) of Title 19 (Highways) that mandates the rating of the transportation projects depending upon factors such as safety, traffic volume, priorities assigned by the RPCs and the MPO.

Communication

Communication is a common theme in TAM literature. TAM tools are novel and useful in that they support managing transportation assets from a systems and life-cycle perspective, as opposed to utilizing class-specific, worst-first asset management. Communication throughout the organization, both vertically and horizontally and with other agencies and branches of state government, is critical for creating a successful TAM system.

- A clear communication channel between ConnDOT's senior management, the executive branch, and legislators would improve coordination, management and unbiased performance reporting.

- Inter-bureau communication is needed to effectively disseminate the message from the leadership, maintain the consistency of the message and policies, and help reduce redundancy in efforts. Both the support of management and communication will be essential to fulfill the need to move towards a life-cycle cost perspective in selecting projects. Success will, in part, depend upon the level of resources that will be available, along with the application of life-cycle costing. Since it is expected that this transition will take place in an environment of finite resources, this difficult transition could be somewhat mitigated by using the experience of other bureaus and combining efforts on mutually beneficial projects.

- The pavement management group has conducted "What if?" analyses that have sought to quantify the performance-related results of various funding scenarios. ConnDOT leadership may find significant utility in such reports from all bureaus involved in TAM if the reports are standardized and part of a consistent overarching TAM philosophy.

Champion

Visible and active ConnDOT champion(s) are needed to guide and support successful TAM implementation and sustainability.

- Strong and consistent support at the leadership level is necessary to implement an effective and comprehensive TAM system. An initial step in this process would be to engage in outreach activities with executive branch and legislative leaders to get their input and ideas and to make them aware of TAM implementation and functioning issues.

- ConnDOT senior management and staff need to be committed to the asset management program and understand the value and benefits of implementing TAM.

- For broader support, ConnDOT should seek to develop public awareness of its TAM initiative.

Consistency

Consistency on several levels is important: consistency in the message from the state leadership to those in the field; consistency in the priorities across various administrations; and consistency within the data collection and sharing practices among ConnDOT bureaus. The following steps are suggested:

- A TAM steering committee should be established that includes key senior ConnDOT management staff with representation from all bureaus. The Bureau of Policy and Planning's Transportation Infrastructure Performance Management group would provide the administrative support for the committee. The committee would include subgroups that report to the steering committee, consisting of central and field personnel, and would be assigned specific responsibilities, such as developing performance measures, policy statements, or data integration. A goal of this process is

to engage and involve ConnDOT staff in the process, to get buy-in, and benefit from the expertise that already exists in the department. This process is a driving force behind the TAM implementation initiative effort and is crucial in securing support throughout the department to assure the integration of TAM principles and philosophy into the day-to-day activities of the department's workforce. Depending upon the selected TAM implementation strategy employed by the department, a smaller, less comprehensively structured steering committee might be created if the initial effort is only focused on a single bureau.

- A coordinated system of inter-bureau information sharing regarding TAM topics should be developed. For example, the CORE and GIS systems are valuable existing data management systems that could be incorporated into data exchange procedures.

Comprehensive

It is necessary to recognize that each asset class of transportation infrastructure is part of an overall transportation system, and that the goal of managing this system is not to "get by" year to year, but to best manage resources and investments over the long term—that is over the life cycle of the assets

- Worst-first management ignores life-cycle costs, as does a philosophy of always selecting the least expensive short-term alternative. In moving away from a worst-first and lowest cost practice, ConnDOT should consider pursuing a life-cycle cost-effectiveness strategy.

    - It is important to note that moving away from worst-first investment strategy does not imply that pressing safety needs are ignored or allowed to progress unabated. Safety remains a top priority in any TAM system and must be addressed. A high-quality, well-performing TAM system is intended to address important safety issues in a proactive, strategic manner, as compared to addressing them in an isolated or reactionary manner.

- These needs highlight the principles of TAM that have been identified in the general literature review and the individual case studies. For any overarching philosophical change, such as moving from incremental to performance-based budgeting, support from the state's leadership – that is, from ConnDOT, the executive branch, including the Office of Policy and Management, the governor, the General Assembly and other agencies impacted or with interests and responsibilities related to transportation issues – is crucial. Without the support and resources from ConnDOT's leadership, TAM will remain isolated in pockets throughout the organization.

- Critical features of TAM include asset preservation, congestion management and safety management. Decisions are based upon an LCCA strategy that incorporates not only deterioration costs, but also additional user costs and system costs.

- Connecticut should consider joining LCCA user groups and drawing upon the support of other states that are currently using LCCA in their asset management decision-making processes.

- A pilot study in Connecticut will help in understanding how best to develop a fully integrated asset management system.

IMPLEMENTATION STRATEGY

It is suggested that ConnDOT consider adopting an implementation strategy to progress from its current practices to an integrated, intermodal TAM system. To accomplish this change, bottom-up and top-down strategies should be considered. Consideration should be given to

- building an understanding of the benefits and value of TAM and support within the department using existing TAM expertise and practices as a foundation;

- developing an implementation plan timeline that begins with internal development activities and leads to external efforts to secure support and agreement for TAM implementation;

- developing and securing adoption of TAM-enabling legislation to support its implementation as the mandated strategy for transportation investment decision making;

- aligning TAM system with federal requirements as may be appropriate; and

- identifying correlations between TAM principles and Results Based Accountability that is currently used by the General Assembly for its evaluation of some programs.

A shift to a TAM system is a major change in the way the department and the state approach investment in the state's transportation assets, a change that demands a clear vision, excellent communication, champion(s), and a comprehensive perspective to assure success. Around the country, states are finding this shift worthwhile, as they are steadily seeing the condition of their assets improve and their resource allocation decisions galvanize around an increasingly coherent vision for their transportation infrastructure.

APPENDIX A

ConnDOT Focus Group Administration Guide

Introduction: A very brief (< 5 minute) introduction of the moderator, assistant moderator, and the general topic. Questions will not be fielded at this point and a discussion of the details of the study will not be presented. This time will be primarily used to get the group focused on the task at hand, make them comfortable and introduce the moderators.

TOPIC 1: Definition of Transportation Asset Management (TAM)
1) What is your experience with Transportation Asset Management?
   [Contrast Probe: Pavements, bridges, signs? LCCA?]
2) How is it currently deployed within your bureau or division?
   [Structural Probe: Coordination with Infrastructure Performance Management? Technical or methodological implementations?]

TOPIC 2: Implementation of TAM
3) In your experience, how are resources tied to performance at ConnDOT?
   [Structural Probe: Specific infrastructure performance measures?]
   [Contrast Probe: What is your experience with Incremental budgeting vs. performance-based budgeting]
   [Structural Probe: Experiences regarding performance measure target affordability and balance across asset classes?]
4) How do you communicate with policy components of ConnDOT and decision-makers?
   [Structural Probe: Mechanisms for requesting resources, sharing information and resources?]

TOPIC 3: Improvements necessary to better manage transportation assets
5) What/who are good models of TAM?
   [Category Probe: With respect to: performance measures, statewide policy, local buy-in?]
6) What needs to change to better manage CT transportation assets?
   [Category Probe: Communication, current methods, resources, policy, organization?]

APPENDIX B

Leadership Focus Group Administration Guide

Introduction

A brief (5 minute) introduction of the moderator, assistant moderator, and the general topic was provided. This introduction will define TAM broadly and try to get the participants in the proper mindset. Emphasis will be placed on the fact that we are discussing "systematic resource allocation", something that is no doubt currently undertaken to a degree in Connecticut, but could stand for some improvement. Questions will not be fielded at this point and a discussion of the details of the study will not be presented. This time will be primarily used to get the group focused on the task at hand, make them comfortable and introduce the moderators.

TOPIC 1: Definition of Transportation Asset Management (TAM) – Transportation Resource Allocation in Connecticut
1) How are resources currently allocated to transportation projects in CT?
   [Structural Probe: Performance of system? Incremental budgeting?]
2) Is the current method systematic and systemic?
   [Contrast Probe: What does CT currently do well? Not do well?]

TOPIC 2: TAM mechanisms – Communication
3) In your experience, how are transportation resources tied to system performance in CT?
   [Structural Probe: Specific infrastructure performance measures?]
4) What are the communication mechanisms between the leadership and those deploying and evaluating the currently strategy?
   [Structural Probe: Mechanisms for requesting resources, sharing information and resources?]

TOPIC 3: Model systems and ways to improve
5) What/who are good models of investing in transportation systems?
   [Category Probe: With respect to: performance measures, statewide policy, local buy-in?]
6) What needs to change to better manage CT transportation assets?
   [Category Probe: Communication, current methods, resources, policy, organization?]

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