Phase I Report

Task 1 of 3: Synthesis of Asset Management Practice

Prepared for:

National Cooperative Highway Research Program
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Foreword

State transportation officials at all levels face the task of managing a wide range of assets to meet public, agency, and legislative expectations. These assets include the physical transportation infrastructure (e.g., guideways, structures, and associated features and appurtenances) as well as other types of assets: e.g., an agency's human resources, financial capacity, equipment and vehicle fleets, materials stocks, real estate, and corporate data and information.

Recognizing its growing importance to transportation agencies worldwide, the American Association of State Highway and Transportation Officials (AASHTO) in 1998 adopted transportation asset management as a priority initiative. At that time a Task Force was formed to develop and implement a ***Strategic Plan for the Task Force on Transportation Asset Management 2000-2010***. To respond to several tasks in this ***Strategic Plan***, the National Cooperative Highway Research Program (NCHRP) awarded Project 20-24(11) to a study team headed by Cambridge Systematics, Inc. The goal of this NCHRP project is to develop information on transportation asset management and to apply these findings in producing a ***Transportation Asset Management Guide*** for use by AASHTO members and other transportation agencies. The ***Guide*** will help agencies to develop and apply the principles, techniques, and tools that can advance the management of their transportation assets.

The overall management framework that has been developed in this study is flexible enough to be adapted and refined for use with, respectively, each type of transportation agency asset listed above. To develop the depth as well as breadth of material needed to build a meaningful first-edition ***Transportation Asset Management Guide***, however, the scope of this study has focused on the particular set of assets that constitutes an agency's **physical transportation infrastructure**. This concentration enables asset management principles, methods, examples, and research recommendations to be developed in a concrete, practical, and understandable way. It facilitates comparisons with corresponding work by transportation agencies overseas and by the private sector, which have for the most part adopted a similar scope in their studies. It provides a specific frame of reference within which differences among state departments of transportation (DOTs) can be addressed by particular business management models, approaches, and procedures.

This study therefore interprets transportation asset management as a **strategic approach to managing physical transportation infrastructure**. Transportation asset management in this context promotes more effective resource allocation and utilization based upon quality information. This concept covers a broad array of DOT functions, activities, and decisions: e.g., transportation investment policies; institutional relationships between DOTs and other public and private groups; multimodal transportation planning; program development for capital projects and for maintenance and operations; delivery of agency programs and services; and real-time and periodic system monitoring. All of these management processes have important implications for an agency's attainment of its goals in public policy, financial resource availability, engineering standards and criteria, maintenance and operations levels of service, and overall system performance.

A number of support activities are involved as well. Information technology can inform many of these management processes, and agencies have already expended considerable sums to develop asset management systems, databases, and other analytic tools. These systems must, however, complement the decision-making processes and organizational structures of individual agencies if they are to operate effectively and support good asset management at all organizational levels. Effective communication of information on asset management between an agency and its governing bodies, stakeholders, and customers is likewise critical to success.

The objectives of this study are to gather information on asset management practices in the U.S. and overseas, develop a framework for transportation asset management, and apply this framework to produce the ***Transportation Asset Management Guide.*** The study is organized in two phases:

- Phase I encompasses information gathering, framework development, and recommendation of a research program; and

- Phase II deals with production of the ***Guide***.

Work to date has completed Phase I. The products of Phase I have been issued in three separate volumes:

- Task 1: A synthesis of current information and practices in asset management;

- Task 2: A comprehensive framework for transportation asset management to provide the framework for development of the ***Guide***; and

- Task 3: A prioritized program of research in asset management.

This report constitutes the first volume above, providing a synthesis of current practice. Agencies worldwide have studied asset management concepts and techniques for several years to see how they apply to transportation and other civil infrastructure. Several transportation and public works agencies overseas have already developed handbooks and references describing asset management and its applications. The Organization for Economic Cooperation and Development (OECD), representing countries with advanced economies in North America, Europe, Australia, and Asia, has recently conducted a study of its member nations to document current asset management practices. Within the U.S., AASHTO and the Federal Highway Administration (FHWA) have co-sponsored a series of national workshops. These workshops have explored "what is asset management?" and identified how practices and techniques applied in public- and private-sector organizations can apply to transportation specifically. AASHTO's ***Strategic Plan for the Task Force on Transportation Asset Management*** outlines several goals, strategies, and tasks to nurture and promote transportation asset management among member agencies over a 10-year period. The FHWA has organized an Office of Transportation Asset Management and produced a **Primer** that describes relevant concepts, practices, and tools.

State departments of transportation (DOTs) have also begun to consider how asset management can apply to their management and decision processes. Some agencies have undertaken formal studies of where asset management can improve their practices and

information, and have developed asset management plans to coordinate actions long-term. Other DOTs may not have produced a formal plan; they have, however, identified goals, business and decision processes, management systems, and organizational responsibilities that can improve their "way of doing business" and thereby advance their transportation asset management approaches.

This report summarizes this state of practice in asset management and its application to transportation infrastructure. It reviews work by national, state, and provincial transportation agencies and professional associations in the U.S. and overseas, and related studies by international organizations. It also describes private-sector asset management approaches that are used in selected industries, to identify principles and practices that may have value in public-sector applications. This information will provide background to development of the ***Transportation Asset Management Guide*** in Phase II of this study. An important finding of this synthesis is that while good asset management is guided by a set of basic principles of good practice, state DOTs differ significantly in the types of asset management challenges that they face. Their asset management focus and the specific techniques that may be of most value must be tailored to their institutional, organizational, financial, technological, and managerial settings.

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Summary

S.1 Introduction

This report presents a synthesis of current practice in asset management. It reviews current approaches by transportation agencies and other organizations in the U.S. and overseas, and examples from selected private industries for comparison.

Several trends have driven a growing interest in transportation asset management in the U.S. These include a transition from a period of major construction to one focusing more on operations and maintenance, increasing demands on transportation systems, continuing constraints on resources, and financial reporting standards for infrastructure assets. The need to assess tradeoffs in resource allocation and utilization decisions is becoming more evident in several areas: e.g., among competing modes, between system preservation and improvement or expansion, across transportation program categories, and between preventive and corrective work.

Several organizations in the U.S. and overseas have conducted asset management studies in transportation and other public works. While a number of definitions of asset management have been proposed, they have certain themes in common:

- Asset management adopts a comprehensive view of physical assets, embodying all classes of infrastructure that are addressed in an agency's programs.
- Asset management considers the entire life-cycle of an asset from initial acquisition through maintenance, operations, and renewal, and to abandonment if needed.
- Asset management entails a systematic analysis of asset needs and recommended allocations of resources to address these needs.
- While it depends upon information technology, asset management represents more than simply an integration of existing management systems.
- Asset management combines engineering principles with economic methods and sound business and decision processes. It seeks economic efficiency and cost-effectiveness in its outcomes.
- Asset management seeks to make the best use of existing processes and tools, and to build upon them rather than duplicate them.

Many agencies today already routinely engage in a number of practices that potentially can contribute to good asset management. This report acknowledges the potentially widespread understanding, if not application, of these activities: e.g., the definition of performance measures, use of management systems and information, and adoption of

performance-based planning and programming procedures. However, rather than documenting each instance of these types of approaches, the focus is on how they can be combined or enhanced to improve asset management practice more strategically: e.g., the capability to merge data and systems to obtain a more holistic view of asset condition and performance, and the embodiment of planning and programming procedures within a policy-driven, customer-oriented framework.

S.2 Transportation Asset Management in the U.S.

National Organizations

The American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) have played leadership roles in building an awareness of transportation asset management throughout the U.S. transportation community. These organizations co-sponsored a series of executive workshops or seminars on the subject to help formulate and crystallize key ideas and action steps needed to begin developing an approach to transportation asset management in the U.S. National workshops were held in Washington, D.C., in 1996; at Rensselaer Polytechnic University in 1997; and in Scottsdale, Arizona, in 1999.

Recognizing the growing importance of asset management to transportation agencies worldwide, AASHTO in 1998 formed a Task Force on Transportation Asset Management. This Task Force developed a 10-year Strategic Plan outlining goals, strategies, and tasks needed to implement transportation asset management within the U.S. This NCHRP study responds to a number of the tasks in this Strategic Plan.

The Federal Highway Administration (FHWA) has created an Office of Asset Management to provide leadership in, and serve as an advocate for, more systematic management of highway infrastructure as a public investment. This office plays a strong role in promoting system preservation, management tools such as pavement management, bridge management, and applications for economic analysis of system investments, new technology, and outreach and partnering activities. It works with the public and private sector and academia to conduct nationwide programs in asset management.

In 1999, the FHWA Office of Asset Management developed an Asset Management Primer to build a foundation for discussion throughout the FHWA and among other interested parties regarding asset management. This document was an early and effective mechanism to structure and communicate ideas regarding transportation asset management as it applied to U.S. transportation organizations.

Other national organizations such as the American Public Works Association (APWA), the Civil Engineering Research Foundation (CERF), the National Science and Technology Council (NSTC), and the Transportation Research Board (TRB) have formed task forces and/or sponsored research and workshops on asset management. Several universities have established programs to provide educational and academic research services in support of asset management.

State Transportation Agencies

Site visits were made to departments of transportation (DOTs) in Arizona, California, Colorado, Michigan, New York, Pennsylvania, and Washington State. The purpose of these visits was to obtain examples of current asset management practice and to discuss with key managers the objectives, approaches, and priorities with which they anticipated pursuing asset management in the future. Some of these DOTs have begun to develop their own asset management plans; others have undertaken management innovations that, while not necessarily part of a formally adopted asset management approach, are nonetheless interesting examples of ways in which asset management practice can be improved.

It is clear from the DOT interviews that there is no single, "correct" approach to asset management. Rather, the practice must be evaluated in the context of several factors affecting the agency's infrastructure and its management principles and culture. The types of advances that practices in these agencies illustrate include the following:

- Improved planning, programming, and monitoring:
  - Strategic view of transportation systems;
  - Performance-based planning and prioritization;
  - Executive-level program review;
  - Performance measures; and
  - Proactive Risk Reduction.
- Better information and analytic capabilities (i.e., management and data systems);
- Transportation operations strategies;
- Organizational practices;
- Institutionalizing asset management statewide; and
- GASB 34 reporting compliance.

S.3 International Experience

Asset management has been studied by transportation and public works organizations overseas for several years. Detailed methodological handbooks and reports have been produced, for example, by different levels of government and industry groups in Australia, and by New Zealand and Canada. Other countries, states, provinces, or cities have taken steps to improve individual aspects of asset management, even if these are not yet part of a comprehensive plan. This report reviews asset management documents from the following international sources, summarizing the definitions, concepts, procedures, and techniques as they are presented in each source.

- **Organization for Economic Cooperation and Development (OECD).** The OECD is an organization of industrialized nations of North America, Europe, Asia, and Australia. It provides a forum for its members to share, discuss, and develop economic policies. The OECD established an expert group of engineers, economists, and road administrators from 15 member countries to compile information on asset management practices in member countries.

- **Australia and New Zealand.** Australia and New Zealand have each been active in asset management for several years. Both countries have national legislation requiring government agencies to utilize asset management systems. Much of their early activities in asset management were focused on satisfying this legislative requirement. While that statutory aspect still exists, emphasis has shifted more recently to maximizing the benefits to be realized from asset management. Several manuals and reports on asset management have been developed by agencies and professional organizations individually and jointly in these two countries.

- **Transportation Association of Canada (TAC).** Much of the investigation into asset management principles in Canada has been conducted under the auspices of the TAC. The report summarizes two TAC publications: a primer on asset management, and a subsequent study report that addresses asset valuation, performance measures and executive information systems.

- **United Kingdom: English Highway Agency (HA).** The HA is mandated by legislation emanating from the UK to adopt an asset management-oriented approach to infrastructure development and maintenance. HA is just now embarking upon a 12-month effort to develop a geographically referenced database to support an online pavement management system. This system is envisioned as the first building block of a comprehensive asset management approach, to which other functions will be added in the future. This process is expected to require several years.

- **Government of Victoria Asset Management Series.** The Asset Management Series was developed by the Government of Victoria in Australia in 1995 as part of an initiative to improve management of the state's assets. The objective of the series is to make asset managers and financial managers throughout Victoria aware of their management responsibilities and of the information networks available to them.

- **Asset Management in a Competitive Environment.** Asset Management in a Competitive Environment was funded by a National Foundation for Local Government Engineering Fellowship Award in 1998. The objective of the paper is to identify best practices in asset management by municipalities in the United States and the United Kingdom that outsource engineering or infrastructure operations and maintenance to the private sector through long-term contracts.

- **Auckland.** Auckland utilizes a strategic approach to asset management that includes a vision statement, a Long-Term Financial Strategy, and a series of specific asset management plans.

S.4 Private Sector Experience

Asset management has been practiced in the private sector for some time, as recognized in the first FHWA-AASHTO Asset Management Workshop in 1996. To identify and compare practices between the public and private sectors, this report reviews the asset management practices of companies in four private-sector industries: automotive manufacturing, banking, railway, and ocean shipping.

While private-sector entities operate in a different organization and institutional environment than that familiar to the public sector, there are nevertheless lessons from the private sector that can suggest improvements in asset management approaches by state DOTs. Among these are the following:

- High value of time associated with asset availability;
- Strong alignment between corporate goals and methods, practices, and actions;
- Employee incentives that are strongly aligned with corporate goals;
- Program, budget, and procurement flexibility;
- Management strategies that vary by asset criticality;
- Importance of preventive maintenance;
- Advantages of outsourcing;
- Extensive tradeoff analyses;
- Electronic data collection;
- Accountability through clear asset "ownership"; and
- Risk management strategies.

S.5 Concluding Observations

While asset management is still an evolving field, considerable work has already been accomplished. Reports and detailed procedural manuals have already been prepared by several transportation and public works organizations overseas. State DOTs in the U.S. continue to develop and implement innovative management approaches for their transportation systems, and some agencies have begun to develop transportation asset management plans to guide long-term advances. On-site discussions with managers in several DOTs indicate the strong relationship between the specific priorities, procedures, and tools that they would associate with good asset management, and the particular characteristics of their agency in several key areas: e.g., policy and institutional framework, asset inventory and condition, technological capability, organizational roles and responsibilities, and management philosophy.

Transportation asset management can provide several benefits in terms of more cost-effective solutions, better service to customers, and increased management accountability. Nevertheless, DOTs will face several challenges in its implementation, both institutionally and technically:

- **Institutional Challenges**
  - To integrate decision-making and allocation of resources across asset classes.
  - To combine the financial, management, engineering, and operational perspectives of a department within this decision process.
  - To define system performance measures that reflect customer perspective and user costs effectively.
  - To secure senior management support and leadership throughout the period of asset management implementation, which may extend over several years.
  - To develop new public and private sector roles that enable an agency to fulfill its mission in the face of change, and to implement these roles effectively.
- **Technical Challenges**
  - To integrate legacy systems and stand-alone databases established for individual asset classes or functions.
  - To develop comprehensive, GIS-compatible, enterprise-wide databases that better serve asset management.
  - To create next-generation management systems or specialized analytic tools that support a wide range of "what-if" analyses reflecting different budget and performance assumptions (e.g., for tradeoff analyses).
  - To improve life-cycle analysis methods and incorporate them fully within planning and program development.
  - To strengthen transportation system monitoring capabilities and use of this information for program evaluation and policy formulation.

1.0 Introduction

1.1 Purpose

This report reviews the current state-of-practice in transportation asset management in the U.S. and overseas. The importance of asset management is growing as agencies recognize the implications of a number of trends:

- A transportation system that is emerging from a period of major construction and that now presents investment decisions that must account for competing needs among new construction, reconstruction, rehabilitation, maintenance, operations, and if necessary, abandonment;
- Increasing demands on the existing system in terms of traffic volumes and vehicle loads;
- Continuing constraints on resources: financial, human, and in some cases, equipment;
- Heightened expectations on the part of the traveling public regarding desired system performance and levels of service;
- A trend in the public sector toward increasing accountability and efficiency in the planning and delivery of services; and
- New financial reporting standards that call for the inclusion of transportation infrastructure and disclosure of target and actual condition levels and expenditures for maintenance and preservation.

This report summarizes current practice in asset management, with emphasis on transportation, but providing examples from other industries where helpful. It considers both U.S. and overseas transportation organizations in the public sector. It also includes examples from selected private industries for comparison.

Many DOTs today routinely engage in a number of practices that potentially may contribute to good asset management. Examples of just a few of these practices would include the use of asset management systems, the definition and use of performance measures, the identification of alternatives in addressing a problem or need in the transportation system, and the adoption of performance-based planning and programming techniques. This report has not attempted to document each instance of these types of approaches. Rather, the focus is on the more strategic aspects of asset management: e.g., the capability to merge data and systems to obtain a more holistic view of asset condition and performance, the embodiment of planning and programming procedures within a policy-driven, customer-oriented framework, and the monitoring of program delivery to ensure that the

projects and services that were originally committed to in programs and budgets were in fact delivered as intended.

1.2 Definitions

An agency's definition of transportation asset management shapes its vision of an improved way of doing business. The studies of transportation asset management conducted in the U.S. and internationally in the past several years have produced several definitions of the concept; a selection from the literature is presented in Table 1.1. While the definitions vary in their detail and speak to different objectives or groups of physical assets, they converge on the following themes:

- Asset management adopts a broad and comprehensive view of physical assets, which can encompass all classes of infrastructure that are addressed in an agency's programs.
- Asset management considers the entire life-cycle of an asset from initial acquisition through maintenance, operations, and renewal, and to abandonment if needed.
- Asset management entails a systematic analysis of asset needs and recommended allocations of resources to address these needs.
- While it depends upon information technology, asset management represents more than simply an integration of existing management systems and data.
- Asset management combines engineering principles with economic methods and sound business and decision processes. It seeks economic efficiency and cost-effectiveness in its outcomes.
- Asset management seeks to make the best use of existing processes and tools, and to build upon them rather than duplicate them.

Understanding how others have defined asset management is instructive in two ways. First, the common themes above help establish a connection between this work and the body of knowledge and practice that has preceded it, and lay the groundwork for international exchange of ideas and experience in the future. Second, to the extent that the definitions in Table 1.1 reflect differences in scope, approach, and emphasis, they illustrate a flexibility that will be necessary in applying asset management in the U.S. across a spectrum of transportation agency characteristics.

Table 1.1 Definitions of Transportation Asset Management

Source	Definition
U.S. Federal Highway Administration (FHWA) Asset Management Primer *(1), p. 7*	Asset management is a systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making. Thus, asset management provides a framework for handling both short- and long-range planning.
American Public Works Association Asset Management Task Force *(2), pp. 2, 4*	Assets management is a methodology to efficiently and equitably allocate resources amongst valid and competing goals and objectives. Assets management, as we have defined it, seeks to enhance the usefulness of individual management systems and use their output to provide sound investment data that has been subjected to rigorous analysis. It does not replace existing systems or methodology but becomes an amplifier and rectifier for their outputs.
Organization for Economic Cooperation and Development (OECD) *(3), p. 2*	A systematic process of maintaining, upgrading and operating assets, combining engineering principles with sound business practice and economic rationale, and providing tools to facilitate a more organized and flexible approach to making the decisions necessary to achieve the public's expectations.
Austroads *(4), p. 4*	Asset management may be defined as a comprehensive and structured approach to the long-term management of assets as tools for the efficient and effective delivery of community benefits.
New Zealand National Asset Management Steering (NZ NAMS) Group and Institute of Public Works Engineering of Australia (IPWEA) *(5), p. 1.3*	The goal of infrastructure asset management is to meet a required level of service in the most cost-effective way through the creation, acquisition, maintenance, operation, rehabilitation, and disposal of assets to provide for present and future customers. The key elements of infrastructure asset management are: taking a lifecycle approach; developing cost-effective management strategies for the long term; providing a defined level of service and monitoring performance; managing risks associated with asset failures; sustainable use of physical resources; continuous improvement in asset management practices.

Table 1.1 Definitions of Transportation Asset Management (continued)

Source	Definition
Transportation Association of Canada (TAC) *(6), p.* 2	Managing highway assets is not a new concept; highway agencies have been using pavement, bridge and maintenance management systems for decades. What sets asset management systems apart today is the move to merge these single-asset management systems into an integrated whole. Asset management is a comprehensive process that allocates funds effectively and efficiently among competing pavement, structure, and other infrastructure needs.
CERF/Partnership for Advancement of Infrastructure and its Renewal (PAIR) *(7), p. 5*	Asset management is a process for extending infrastructure life at the lowest possible costs. An asset is anything with monetary value. In the context of infrastructure, schools, streets, highways, bridges, rights-of-way, airports, and utilities are all assets. Even though asset management employs information management and computer technology, it is not a computer program. Rather, it is a decision-making process for identifying optimal (cost-effective) methods for the design, construction, maintenance, rehabilitation, retrofit, replacement, or even abandonment of an asset.
Government of Victoria Asset Management Series *(8)*	Asset management is the process of guiding the acquisition, use and disposal of assets to make the most of their service delivery potential and manage the related risks and costs over their entire life.

Subsequent sections will provide additional information on the asset management practices by the organizations cited in Table 1.1.

1.3 Outline of Report

The remainder of this report is organized as follows:

- Section 2.0 outlines national efforts in transportation asset management in the U.S., particularly the activities of the American Association of State Highway and Transportation Officials (AASHTO) and of the Federal Highway Administration (FHWA).
- Section 3.0 discusses current practices in transportation asset management as reviewed in selected state DOTs.
- Section 4.0 reviews international practice in asset management as documented in a number of studies, papers, and reports.
- Section 5.0 discusses asset management as practiced in a number of private sector industries.
- Section 6.0 concludes the report.

2.0 National Experience

2.1 Asset Management Executive Workshops

U.S. transportation officials at all levels are faced with the task of managing a wide range of transportation assets that must continually respond to public expectations. Recognizing the growing importance of asset management to transportation agencies worldwide, the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) began in 1996 to co-sponsor a series of executive-level national workshops in transportation asset management. These workshops raised the awareness of asset management within the U.S. transportation industry, identified practices in other sectors that could advance asset management applications in transportation, and helped to shape an understanding of what needed to be done to move ahead in this field.

The September 1996 workshop in Washington, D.C., helped crystallize asset management as a concept in the U.S.*(9)* It defined asset management as "a systematic process of maintaining, upgrading, and operating physical assets cost-effectively." It recognized that principles, practices, and tools of good asset management practice cut across distinctions between public and private organizations. It synthesized this information to look to the future and to identify future trends and areas where transportation asset management can be improved. Attendees included representatives from the leadership of AASHTO, the FHWA, state DOTs, private industry, utility companies, quasi-government agencies, and research and supplier communities.

A second workshop held in October 1997 at the Center for Infrastructure and Transportation Studies at Rensselaer Polytechnic Institute.*(10)* This session built upon the findings of the earlier seminar to explore in greater depth the practices, processes, and tools of asset management as they apply to state DOTs. Presentations were given in several relevant areas to describe current practice and identify areas of potential improvement: e.g., the need for higher-level systems and integration of single-focus systems, for stronger forecasting and analytic tools to evaluate scenarios and tradeoffs, for new metrics to support strategic, performance-based decision-making, and for more effective application of technology and information systems. Certain practices and principles of private-sector asset management were considered transferable to the DOT environment, such as a strong value-of-time concept, innovative procurement methods, cost-effectiveness in proj??ect and service delivery, and a balance of value of service or product against cost. Organizational requirements to implement asset management were also identified: e.g., strong executive leadership, a clear approach to development and implementation of improvements, and training. These discussions took place among high-level officials of AASHTO, the FHWA, and state DOTs; directors of interested national organizations and professional associations; and representatives of the private sector, and academia.

This workshop identified a number of specific steps that would be needed to advance asset management at the national level. These steps included the following:

- Establish an AASHTO task force to assist with innovative approaches and development of processes and tools for asset management;
- Create a strategic plan to focus vision, mission, goals, and actions and to provide an effective, positive mechanism at the national level for introducing the change that will be brought about by asset management;
- Develop an AASHTO Guide on asset management to provide a source document on the subject;
- Continue the series of executive workshops on asset management to foster a dialog on the subject and to exchange ideas and approaches;
- Prepare an inventory of the tools now available to support asset management, and case studies as a way of sharing information;
- Define and coordinate the interactions among asset management, strategic planning, and quality improvement, and establish a comprehensive framework for evaluating tradeoffs in investment, new materials and technology, and evaluation of quality efforts;
- Develop a "lead state" model for documentation and sharing of case studies by lead states to accelerate the deployment of asset management techniques; and
- Consider an AASHTO resolution urging member agencies to work toward asset management implementation and to cooperate in developing needed tools and processes.

The results of this second executive workshop influenced further organizational initiatives by AASHTO and the FHWA that are described in the next section.

A third executive workshop was held in Scottsdale, AZ, in December 1999 in the context of a peer exchange among representatives of state DOTs.*(11)* Its focus was to share ideas and experiences among DOT managers in their current activities in asset management, and to increase the understanding of tools and processes that can improve their asset management practice. In contrast with previous executive seminars, invited attendees to the Scottsdale workshop constituted a much higher proportion of state DOT officials. Other participants included representatives of the FHWA and other federal agencies involved in asset management, representatives of the Governmental Accounting Standards Board (GASB) to speak about the standards relating to financial reporting of transportation infrastructure in GASB Statement 34*(12)*, and consulting firms and academic institutions that work with state DOTs.

The workshop was organized around five thematic sessions in which participants listened to prepared presentations and held detailed discussions:

- Moving from a Concept to an Action Plan;
- Integrated Maintenance Management;
- Integrated Management Systems;
- Preservation and Improvement Tradeoffs; and
- Data Integration Issues.

There were also plenary session presentations on national efforts by the FHWA and AASHTO. These initiatives are covered in the next section. Many of these advances were based upon recommendations developed in the second workshop, as described above.

The presentations at the Scottsdale workshop explicitly recognized that asset management will not occur as the result of mandates or regulatory requirements. Rather, asset management must be seen as motivated by the needs and desires of transportation customers, and driven by the efforts of state DOTs to improve performance, cost-effectiveness, and accountability. While specific asset management approaches must be tailored to the needs of each agency, there are common themes that are important to the success of asset management:

- Gain upper-level management support;
- Dedicate resources for system development;
- Integrate new and emerging technologies into asset management;
- Use existing systems and data to initiate the process;
- Institute better management, where appropriate, that is modeled after successful initiatives in the private sector; and
- Involve MPOs and other organizations in the process.

2.2 Organizational Initiatives

In November 1997 the AASHTO Board of Directors created the Task Force on Transportation Asset Management, and in 1998 adopted several action items that had been recommended in the second asset management workshop. These action items have been embodied in a 10-year *Strategic Plan for Transportation Asset Management* developed by the Task Force.*(13)* The *Strategic Plan* will ultimately meet five goals:

1. To establish partnerships with other agencies and stakeholders in pursuing asset management;

2. To promote a better understanding of asset management and how it can be used by member states;

3. To foster the development of better asset management techniques, tools, and associated research;

4. To communicate with and inform the leadership of member states on how they can use asset management; and

5. To assist member states as they evaluate and use asset management.

The FHWA has created an Office of Asset Management to provide leadership and advocacy for more systematic management of highway infrastructure as a public investment. It plays a strong role in promoting system preservation, management tools such as pavement management, bridge management, and applications for economic analysis of system investments, new technology, and outreach and partnering activities. It works with the public and private sector and academia to conduct nationwide programs in asset management.

Both AASHTO and the FHWA have thus played leadership roles in building an awareness of transportation asset management throughout the U.S. transportation community. AASHTO and the FHWA have jointly funded this National Cooperative Highway Research Program study through NCHRP Project 20-24(11). This study is to develop a framework of asset management and document it in a ***Transportation Asset Management Guide*** for U.S. transportation agencies. In addition to AASHTO and the FHWA, the Federal Transit Administration (FTA) participates in the Panel review of this NCHRP project.

AASHTO and the FHWA also support research in transportation asset management. This research will assist in the future to implement the objectives of the AASHTO Task Force ***Strategic Plan*** and to further the FHWA's goals in promoting asset management systems and techniques among U.S. transportation departments.

Other national organizations such as the American Public Works Association (APWA)*(2)*, the Civil Engineering Research Foundation (CERF), the National Science and Technology Council (NSTC), and the Transportation Research Board (TRB) have formed task forces and/or sponsored research and workshops on asset management. CERF and NTSC collaborate through a Partnership for the Advancement of Infrastructure and its Renewal (PAIR) to investigate partnerships among public and private groups that would reduce the lead time to deploy advanced construction technologies more broadly.*(7)* Several universities have established programs to provide educational and academic research services in support of asset management.

2.3 FHWA Asset Management Primer

The FHWA Office of Asset Management developed an ***Asset Management Primer*** in 1999 to build a foundation for discussion throughout the FHWA and among other interested parties regarding asset management.*(1)* This document was an early and effective mechanism to structure and communicate ideas regarding transportation asset management as it applied to U.S. transportation organizations.

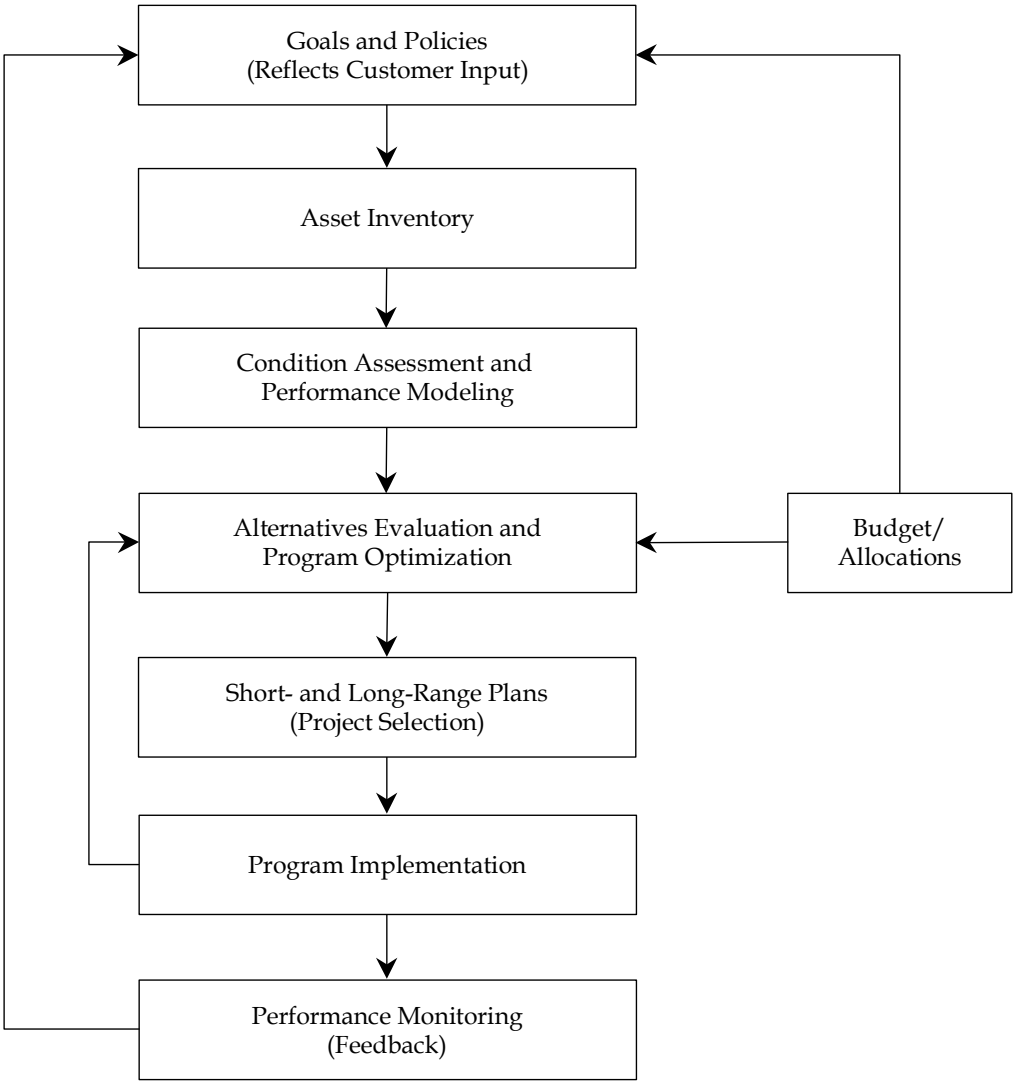
While asset management is an emerging concept in the highway industry, the ***Primer*** identifies several guiding principles that have been developed. These principles reflect a process that is focused on the customer, mission-driven, system-oriented, long-term in outlook, accessible and user-friendly, and flexible.

According to the ***Primer***, asset management provides a systematic, fact-based, and reproducible decision-making approach to analyzing the tradeoffs between investments and improvement decisions at the system and project levels. The ***Primer's*** definition of assets includes physical infrastructure, operational hardware, equipment, vehicles, real-estate, materials, human resources, and data.

The FHWA has found that although state DOT's vary widely in their approach to infrastructure management, three similarities exist: a long-term strategic plan, a short-term program, and technical tools, such as pavement or bridge management systems. In addition, there is a general trend towards supplementing subjective decision-making processes with objective ones. However, this change has both technical and practical challenges, such as maintaining a trained work force, replacing short-term political decisions with long-term solutions, and shifting from an agency responsible for construction to one responsible for preservation.

The ***Primer*** describes the asset management system illustrated in Figure 2.1. The system is supported with goals and policies, horizontal and vertical organizational integration, and technical information and tools.

Figure 2.1 FHWA's Generalized Asset Management System Components



Source: Ref. (1), p. 19.

3.0 State DOT Practice

3.1 Overview

Several state DOTs were visited to obtain comparative information on how these agencies are dealing with asset management. Visits entailed interviews with managers in several key areas, including planning and programming, financial management, information technology, and facilities management and maintenance. Supporting documents were also obtained for background and reference, typically including descriptions of asset management systems, long-range plans and capital programs, information on maintenance management levels of service, and descriptions of proposed work in asset management or to meet the financial reporting requirements of GASB Statement 34.*(12)*

While transportation asset management is still a nascent discipline, some of these agencies may be regarded as "leaders" in that they have taken a proactive stance in asset management as an overall departmental initiative. Other states visited have not yet engaged asset management as a strategic perspective, but they have made a significant advance in some aspect of infrastructure management that strongly reinforces the objectives of good asset management practice and contributes to this review. The states visited are Arizona, California, Colorado, Michigan, New York, Pennsylvania, and Washington State.

- New York State DOT (NYSDOT) has had an active asset management program in place for several years.*(14)* Michigan DOT (MDOT) has been pursuing several business process and information technology advances since the mid-1990s, which have now been folded into a departmental asset management initiative.

- Arizona DOT, Colorado DOT, and PennDOT are just beginning their development of an asset management plan and strategy, although they have already undertaken advances in practice during the past several years that conform readily to good asset management practice.

- Washington State DOT (WSDOT) and California DOT (Caltrans) do not have formal asset management plans yet. However, each manages highway systems with significant structures, traversing a wide range of climate and terrain. WSDOT over the past decade has implemented both a renewed programming process for its highway capital programs*(15)* and a level-of-service-based performance budgeting process for its maintenance program.*(16)* Caltrans is now implementing a comprehensive level-of-service approach to its maintenance program.*(17)*

The consulting team has supplemented these findings with background information from previous engagements with these and other transportation agencies in studies of capital programming, maintenance management, performance-based planning, and management system design and application.

As a general comment, it is clear from the interviews that there is no one, single, "correct" approach to asset management. Rather, the practice must be evaluated in the context of several factors affecting the agency's infrastructure and its management principles and culture, including:

- Maturity of the transportation system and factors affecting system demand;
- State and departmental policy goals, objectives, and issues;
- Funding levels and mechanisms, including legislatively mandated projects and resource caps;
- Degree of agency centralization, and evolution of organizational roles and responsibilities; and
- Institutional and inter-jurisdictional relationships.

These factors influence both the condition and performance of an agency's infrastructure, and how the agency approaches managing, investing in, and operating that infrastructure. For example, institutional and funding considerations delimit the agency's latitude in defining alternatives and making decisions. Policy goals and objectives influence the priorities of actions and choices. An agency facing significant population and economic growth pressures, such as Arizona DOT, defines and approaches asset management differently from an agency where deteriorating infrastructure and constraints on additional system expansion tend to focus choices on preservation – a situation faced by New York State DOT, for example.

Nonetheless, there are several useful examples of practices among the states interviewed that illustrate techniques that can improve asset management. These are presented in several sections below. A concluding discussion will identify potential challenges to asset management implementation that have been inferred from these interviews.

3.2 Improved Planning, Programming, and Monitoring

Strategic View of Transportation System

Asset management has focused increasing attention on the inventory of assets for which a DOT is responsible, and – for those agencies wishing to take the organization of inventory one step further – the classification of assets within "tiers." A tiered structure serves several purposes with respect to asset management:

- It helps identify the transportation roles served by infrastructure assets in ways that other methods of classification (e.g., functional classification) do not, particularly at a regional or local level;

- It provides a basis for assigning levels of service or performance measure targets to sections of highway that reflect their importance to transportation; and

- It provides a context in which to interpret system performance more effectively.

Colorado DOT is now investigating a tiered structure for its highway assets as part of its asset management plan development. While the specifics of this structure are still under development, the current proposal is to organize the tiered structure as a function of the following state highway attributes:

- The location designation (urban or rural) and functional class (Interstate, Other National Highway System (NHS), and Other Classes);

- A new designation for each major segment of highway, denoting its primary transportation service: Interregional, Intraregional, or Both;

- Intervals of annual average daily traffic (AADT);

- Designations as to whether the segment is a major conveyor of transit and of freight; and

- Other designations that may be needed for specialized analyses (e.g., pavement type, as for highway preservation strategies).

While other DOTs interviewed do not have an asset tier structure in a formal, comprehensive, hierarchical sense, they do employ route designations to identify segments or corridors of unique significance. For example, Caltrans employs several individual classification schemes for particular programs. Its highway maintenance classification, comprising three classes of roads denoting relative priority, is based upon highway functional classification and is a simple example of tiering. Other examples in Caltrans, such as its High Emphasis Interregional Routes and a subset, High Emphasis Focus Routes, denote relative priority for investment in future statewide programs to bring these routes to a uniform defined standard. These classifications are based, however, more on programmatic designations rather than upon specific, objective highway characteristics and usage, as anticipated in CDOT's tiering process. These Caltrans route designations also correlate in some degree with designations based upon statewide policy goals: e.g., Intermodal Corridors of Economic Significance, and Transportation Gateways of Statewide Significance.

Several states are moving from a view of projects as individual elements of a program to a more strategic approach that groups projects for consideration by corridor or another logical set: e.g., joined sections of two or more routes or corridors. This approach helps maintain network connectivity and preserve the consistency of route characteristics in a corridor, and may reduce the number of road occupancy periods for construction.

Performance-Based Planning and Programming

WSDOT Capital Programming and Prioritization

While many state DOTs are implementing performance measures within planning and programming, Washington State has recently done so within the context of a completely renewed and integrated long-range planning and capital programming process. Key elements of this process include the following:

- Vertical integration and consistency throughout the process, from policy guidance through definition of planning service objectives, formulation of prioritization formulas, and definition of system performance measures.

- Prioritization formulas and project selection criteria that are based on a benefit-cost criterion where possible, supplemented by additional considerations as appropriate: e.g., environmental impacts, intermodal connections, network connectivity, and contribution to economic opportunity. These formulas and criteria help to rationalize the allocation of funds for statewide projects. However, the implications of these allocations are modified by "hold harmless" or other guaranteed distributions of a portion of program funds to DOT regions, apart from the statewide competition.

- Performance-based planning employing specific service objectives in each program area. While its long-range plan might now be considered a policy plan, WSDOT is considering moving toward a project-oriented plan. WSDOT is now working with the University of Washington to investigate methods for multimodal tradeoffs in its planning process.

CDOT's Customer-Oriented, Performance-Based Investment Category Structure

Colorado DOT (CDOT) has embarked on a major effort to relate decisions on highway investments to their effects on system performance, and to include customer perceptions in program performance measures. To do this more effectively, CDOT has defined *Investment Categories* to organize its programs.*(18)* Five Investment Categories are defined: Mobility, System Quality, Safety, Strategic Projects, and Program Delivery. While other DOTs in the U.S. have likewise created policy-responsive and performance-based approaches to planning and programming, the CDOT approach is unique in that individual Investment Categories may encompass all types of statewide transportation programs – maintenance and operating as well as capital.

Individual program identities (such as for pavement preservation, bridge projects, safety, maintenance, and so forth) are still maintained to correlate with funding sources and for operational management. However, for purposes of strategic management, components of these programs are reflected in their respective Investment Categories, depending upon the basic policy objective that they serve. As an example, components of the maintenance program appear in several Investment Categories. Pavement, bridge, tunnel, rest area, and roadside maintenance activities are related to System Quality; snow and ice maintenance and courtesy patrols are reflected in Mobility; sign maintenance and pavement

markings are included in Safety; and maintenance of yards and equipment and maintenance planning, engineering, and training are considered in Program Delivery.

Investment Categories enable CDOT and the Colorado Transportation Commission to relate statewide programs to explicit policy goals and objectives, monitor progress and provide accountability through defined performance measures and targets, and structure high-level tradeoffs among programs to evaluate investment choices and their impacts on system performance and customer satisfaction. The definition of performance measures and analytic tools for the Investment Categories is still evolving. Nonetheless, preliminary measures and models have been defined, and the Investment Categories have already provided a useful framework for planning, programming, and resource allocation decisions by the Colorado Transportation Commission and CDOT. The Investment Category structure will provide the foundation for CDOT's future approach to asset management, and is a key part of its asset management plan.

Executive-Level Program Review

Reviews of program recommendations are normally the final step before submittal to executive or legislative bodies for adoption and approval. New York State DOT has formalized this part of the process in a way that explicitly considers trends in program performance. It has instituted an executive-level body to review its transportation program submittals just prior to final recommendation. This Capital Program Management Team comprises the First Deputy Commissioner, the chief of staff, chief engineer, and managers from planning, communications, budget and finance, and the chief counsel (for contracting and procurement). The purpose of its review is to perform a high-level, performance-based, non-technical assessment of forecast program accomplishment and compare with past trends, to judge whether established program targets are or are not being met statewide, and to determine the causes of identified problems. The review integrates pavement and bridge program recommendations (embodying NYSDOT's focus on preservation), and is accomplished in conjunction with executive-level performance standards and integrated management system support, as discussed separately in sections below.

Performance Measures

State DOTs generally are focused on developing performance standards to assist long-range planning and program development. While the technical definitions of these measures differ among states to reflect particular standards, measures of deterioration, management philosophies, customer perceptions, or data collection methods, overall they are similar in nature to one another. Where state practices diverge more fundamentally, however, is in the ability to relate performance measures to broader policy goals and objectives that govern respective programs. WSDOT's experience, for example, indicates that consistency between overall policy and more detailed program elements (planning service objectives and prioritization formulas as well as performance measures) must be a conscious objective in the structuring of program categories and procedures. A program structure such as CDOT's Investment Categories (described above) provides a device that helps ensure this consistency.

New York State DOT has, in its asset management approach, supplemented technical performance measures with executive-level measures that identify quickly the status of current and forecast program accomplishment by program and geographic region (e.g., counties). For example, the following measures can be easily color-coded and displayed on a map for NYSDOT's pavement and bridge programs:

- Last program OK, this program OK;
- Last program not OK, this program OK;
- Last program not OK, this program improving;
- Last program not OK, this program worse; and
- Last program OK, this program not OK.

Note that these measures capture simultaneously the satisfaction of a target and the direction of a trend. Targets are established by NYSDOT for pavements and for bridges based upon defined condition standards, analogous to those used by CDOT in its pavement and bridge programs. Decisions on which pavements and bridge projects should be recommended in a given program, and coordination among these projects where appropriate, are resolved by technical managers prior to submitting the program to the Capital Program Management Team for review (refer to prior section). The Team considers the recommended program accomplishments overall in light of the five measures above, displayed on a statewide map by county or other geographic division. Where the result is deemed unacceptable or questionable, the program is returned to technical and regional managers for review and modification as needed.

Proactive Risk Reduction

A theme emerging from practices of the states interviewed concerns an effort to move their program philosophies from a reactive or "worst first" approach to a more proactive, "optimizing" approach. This shift in philosophy takes the following forms:

- **Greater emphasis on preventive preservation and lowest long-term cost**. This approach results directly from the "least life-cycle cost" concept that is the basis of technical and economic analyses of performance, particularly as applied to pavements and bridges, but also with growing applications to other highway features such as pavement markings. While pavement and bridge management systems have long been based on assumptions of least life-cycle cost or long-term cost-effectiveness, DOTs may have had to incur backlogs in needed work because of resource constraints or other limits on optimal preservation strategies. Moving to a preventive approach is justified economically and technically. However, it is a politically difficult decision because it entails a short-term increase in cost to reduce the backlog to manageable proportions, and it implies preventive work on road features that are still in good condition while damaged features (former candidates for "worst first" funding) may receive reduced or no investment short-term. WSDOT and Michigan DOT have addressed this issue through analytic studies communicated to their governing bodies in support of the change in philosophy to the least life-cycle-cost approach.

- **More effective accident risk reduction**. Safety projects have traditionally been based upon projected accident reduction in demonstrably hazardous locations or corridors, and in blanket risk reduction efforts – the latter prompted, for example, by federally mandated safety improvements associated with highway rehabilitation projects (e.g., need for clear zones adjacent to shoulders). WSDOT has worked with its FHWA division office to promote a more focused approach to accident risk reduction, based on analyses of the likelihood of future accidents at particular locations or under particular conditions. WSDOT and the FHWA have negotiated, as part of their stewardship agreement, provisions to fund pre-emptive safety projects at these locations where their impact holds greatest likelihood of preventing future accidents. This is in contrast to a broader application of safety funds along an entire route length, where impact on ultimate performance may vary.

- **Earlier environmental reviews**. In areas of environmental sensitivity, reviews of proj??ects and challenges to their environmental acceptability can consume significant time and delay a project schedule by months or years. A unique construction project undertaken by WSDOT entailing a public-private partnership experimented with, among other facets of project delivery, an earlier environmental review. The start of this review coincided with initiation of preliminary project design, rather than waiting for completion of some percentage of design as might occur in conventional projects. The case study indicated that potential issues were identified earlier, and that project design could accommodate environmental mitigation more economically and effectively.

3.3 Better Information and Analytic Capabilities

Surveys of State Practice

Information on current DOT use of management systems is contained in two surveys of state DOT practices in asset management that were conducted in 1999. An Asset Management Survey was conducted by AASHTO prior to the Scottsdale Peer Exchange Workshop.[1] Survey results based upon 33 responses were summarized and reported at the Peer Exchange. The second effort was based on an Asset Management Peer Exchange Questionnaire, which was completed by Peer Exchange attendees and submitted at the Workshop. Twenty-four responses were obtained by this mechanism. The results reported below are drawn from both of these surveys. (The AASHTO survey will be designated below as Survey 1; the Peer Exchange Questionnaire, as Survey 2.)

Table 3.1 includes a list of steps in the progression of a comprehensive asset management system, particularly as they relate to current and planned use of existing management systems, the subject of several questions in each survey. It identifies the percentage of states that have reached each step, according to the results of the two asset management surveys.

[1] A summary of survey responses is included in Appendix A of Ref. (11). A detailed tabulation of these results is provided in Ref. (19).

Table 3.1 Results of Asset Management Surveys

No.	Item	Survey 1 or 2	Response
1	Database with inventory information	1	100%
2	Database with condition information	1	100%
3	A management system in place	1	100%
4	Performance measures in a system	1	97%
5	Use of a system in decision process	2	62%
6	Multiple management systems in place	1	100%
7	Performance measures in multiple systems	1	94%
8	Use of multiple systems in decision process	2	48%
9	Plan to integrate systems across modes	2	54%
10	Integration of systems across all modes	2	0%

The survey results indicate that all states responding have multiple management systems in place, and at least one of these systems has inventory and condition information on transportation assets. Comments on the survey responses indicate that the systems in greatest use include pavement management (97 percent of responses), bridge management (97 percent), safety management (70 percent), and maintenance management (70 percent). These systems are also the most likely tools to apply performance measures. Inventory data are most likely to be collected for bridges (98 percent), roads and highways (93 percent), pavement (93 percent), and traffic signals (80 percent). Condition information is most prevalent for these asset classes as well.

The survey comments also note that those states that have a single point of contact for asset management, rather than having responsibility dispersed among several managers (e.g., by asset class or district), are five times as likely (66 percent of responses versus 13 percent) to be taking steps toward system integration. These states are also twice as likely (28 percent versus 13 percent) to use economic tools such as life-cycle cost analysis, tradeoff analysis, cost-benefit analysis, or quantitative investment analysis.

The survey results in Table 3.1 echo results reported in earlier surveys regarding the use of management systems within DOTs.*(20, 21)* These earlier surveys have found that management systems tend to be used primarily to process technical information: e.g., to record and monitor the inventory and condition of transportation infrastructure. When asked how management system information is used in broader policy and management situations such as developing goals, establishing program funding levels, and identifying

and prioritizing projects, the percentage of responding DOTs with systems used in these roles typically falls to 20 percent or less. The decision-support capabilities of existing asset management systems are underutilized, particularly at a program level, even before integration is considered.

Next-Generation Management and Data Systems

DOTs are dealing with how to update legacy systems that would play a strong role in asset management. The strategies available to accomplish this may range from a comprehensive renewal or updating of asset management systems and databases, to more selective and limited system updates, small-scale system and database integration, and development of new, specialized tools and procedures. Several of the DOTs interviewed, including Caltrans, CDOT, WSDOT, ADOT, Michigan DOT, and PennDOT have upgraded or are about to upgrade asset management systems in order to place them on a more modern platform or to incorporate new capabilities: e.g., new decision support techniques, performance measures, or levels of service. Notwithstanding the different approaches to updating systems and data capabilities for more effective asset management, the following themes emerge:

- **GIS platform for integration**. New York State DOT now integrates its pavement management and bridge management information on a GIS platform as part of its asset management development. A typical display shows a map with the highway system, on which are superimposed color-coded symbols indicating pavement or bridge proj??ects, respectively. Double-clicking on a project symbol opens a window displaying detailed information on the project. An analogous approach is now under development in Michigan DOT and Arizona DOT, and is proposed in CDOT. MDOT has compiled a unified data repository, ADOT is designing and developing a data warehouse, and an extension of CDOT's data warehouse to asset management is now proposed. These data warehouses will consolidate asset inventory information and potential proj??ect information from asset management systems, communicate with a GIS to display asset information spatially, and generate management reports efficiently, including reports designed and formatted for higher-level management.

- **Executive-level information**. Most states employ asset management systems: particularly for pavements and bridges, but also for safety, public transit, intermodal facilities, other system features and appurtenances, construction projects, maintenance, and traffic operations. Surveys conducted by NCHRP*(20)* and the FHWA*(21)* indicate that these systems are widely used for technical and research purposes, including detailed program development. However, their use by higher-level or executive management for decisions such as resource allocation and program tradeoffs is much less frequent. Initiatives in asset management and compliance with GASB Statement 34 (see below) will likely change this outlook. WSDOT has for several years successfully employed an executive information system that provides high-level programmatic and financial information to WSDOT managers, legislators, commission members, and staff. WSDOT's maintenance levels of service are likewise implemented in this executive-level system, complete with color photographs illustrating each level of service within a maintenance program area. Users can apply the system to explore budget implications of changes in level of service within each program area. Michigan DOT

has been contemplating to build such a system upon its existing asset management applications. NYSDOT's maps of its high-level program performance measures (discussed above) are also an effective illustration of information tailored to executives.

Other New System Developments

In addition to information and management system developments by state DOTs, the FHWA's Office of Asset Management is also undertaking two major system initiatives that will contribute to asset management.

- **HERS/ST**. FHWA's Highway Economic Requirements System (HERS) is being promoted for state DOT use, a program referred to as HERS/ST. The HERS application is based on the Highway Performance Monitoring System (HPMS) database, and is intended to replace HPMS as the source of biennial federal needs studies submitted to Congress. The HERS algorithms address both highway capacity and pavement preservation needs. Thus, HERS/ST is uniquely suited to asset management studies that are more comprehensive than those addressed by individual management systems (e.g., pavement management and congestion management). For example, HERS/ST could be applied to explore tradeoffs between system preservation and improvement/ expansion.

- **Tunnel Management**. The FHWA, in cooperation with the Federal Transit Administration (FTA), has recently awarded a project to design a Tunnel Management system. The project entails a number of components:

  – A compilation of data on U.S. highway and transit tunnels, and recommendation of a tunnel database structure;

  – Manuals presenting guidelines for tunnel management; and

  – Preliminary design of a Tunnel Management system, building on the database above, and describing key system components and reports.

3.4 Transportation Operations Strategies

Transportation system operations are a component of asset management that is likely to receive increased attention in congested areas and in growth areas. Operations centers have been established in metropolitan areas in several states to provide real-time monitoring of system performance. With the implementation of intelligent transportation systems (ITS), operations managers can issue and coordinate traffic advisories, variable message signs, ramp metering, and other measures of traffic control and guidance. Caltrans has developed formal, comprehensive Traffic Operations Strategies (TOPS) that seek to reduce congestion through improved system management. Elements of TOPS include the following:

1. Completing the "intelligence" component of existing infrastructure;

2. Correcting infrastructure "bottlenecks" at the corridor and system levels through physical improvements;

3. Filling gaps in the high-occupancy-vehicle (HOV) network to eliminate traffic disruptions at merge points with general purpose lanes; and

4. Modifying selected freeway-to-freeway interchanges to minimize traffic disruptions.

These objectives are organized within three investment levels, with initial funding focused on the first level:

- Level 1 focuses on choke points that can be corrected through minor operational improvements: e.g., auxiliary lanes, intersection modifications, and the addition and coordination of intelligent system devices. Level 1 encompasses the first two components listed above.

- Level 2 adds HOV capacity and operational improvements, addressing the third component above.

- Level 3 includes major operational improvements addressing component number 4 above.

3.5 Organizational Practices

Asset management has potentially significant implications for organizational roles and responsibilities and both internal and external communications by an agency. The institution of new business processes, such as the Capital Program Management Team by NYSDOT described earlier, is one example of business process change as a direct result of asset management implementation. More generally, improved asset management techniques have evolved from new business models adopted by agencies that are customer-oriented and performance-based: e.g., the use of input from customer surveys for program and performance evaluation, definition of customer-oriented performance measures for transportation programs, and application of performance budgeting and level-of-service concepts to highway maintenance. Some approaches that have been used by state DOTs include the following:

- **Internal vision workshops**. As part of its development of an asset management strategic plan, PennDOT has held a departmental vision workshop to review the proposed framework, tasks, and intended benefits associated with specific asset management steps. This workshop provided the benefit of both knowledge-building as well as team-building. While it succeeded in communicating what is asset management and its importance to the department, it also fostered the improved communication across departmental units that is needed for successful asset management implementation.

- **Asset management communication package**. Michigan DOT has developed a "marketing" package advertising its activities and objectives in asset management. This color presentation comprises a number of "fact sheets" summarizing key topics and activities. Individual sheets present a primer on asset management, descriptions of key management systems, an overview of the process, introduction to asset management as a way of doing business, historical perspective, and descriptions of specific activities.

- **Report cards**. The PennDOT Secretary of Transportation issues a monthly report card to its customers on measures of agency programs and performance. These cover a variety of topics, including roadway smoothness, pothole maintenance, safety of rail crossings, winter services, safe driving statistics, and customer services, among others.

- **Inter-jurisdictional cooperation**. PennDOT engages in the Agility Program, which establishes cooperative relationships with other jurisdictions to offer seamless transportation services. For example, PennDOT may paint markings on a township's roads while the township mows grass on a state highway within its jurisdiction.

3.6 Institutionalizing Asset Management Statewide

In some states there has been an attempt to "institutionalize" the practice of asset management for transportation resource allocation decisions statewide, by enacting a statute mandating the use of asset management principles and processes. Michigan is one such state. While the legislation in this case did not pass, the exercise is nevertheless instructive for the scope of this activity and the considerations that go into such efforts.

Michigan's proposed legislation emanated from the recommendation of a Study Committee established to "review transportation funding options, transportation investment priorities, and potential strategies for maximizing returns on transportation investments." The Study Committee recommended that "a long-term, planned asset management process be extended to statewide use for transportation facilities."*(22)* The implications of this and related recommendations were broad, since a statewide asset management approach could be seen to affect resource allocation among different classes of assets (such as pavements and bridges), different jurisdictions involved in transportation (e.g., state trunkline highways and local systems), and between modes (e.g., highways and transit). The Study Committee also recommended the following, as excerpted from Ref. (22):

- **Technical Advisory Panel (TAP) –** The Study Committee recommended the creation of a technical advisory panel (TAP) to be "responsible for oversight of the components of the asset management process." The report indicated that the TAP could be composed of representatives of Metropolitan Planning Organizations, the County Road Association of Michigan, the Michigan Association of Counties, the Michigan Department of Transportation, the Michigan Municipal League, the Michigan Public Transit Association, and the Michigan Township Association.

- **Statewide GIS –** The Study Committee recommended that road and bridge data for all jurisdictions be collected and maintained on a statewide Geographic Information System (GIS). The system would be under the direction of the TAP. This statewide GIS would represent the asset inventory component of a statewide asset management system.

- **Performance Measures –** The Study Committee recommended that "system performance measures, along with associated standards and criteria, be selected by the Technical Advisory Panel for all elements of the roadway infrastructure." The recommendation further notes that performance measures should be of system performance and not just condition.

- **Life-Cycle Cost Analysis –** The Study Committee recommended that "roadway assets be managed so as to maximize performance at the lowest life-cycle cost, including agency first cost, lifetime maintenance cost, and user cost." Life-cycle cost analysis is a tool for evaluating the cost of various capital and maintenance alternatives. Michigan state statute (Act 51 Section 1h) currently requires that MDOT develop and implement life-cycle cost analysis for each project for which pavement costs exceed $1 million. The House Fiscal Agency memorandum notes that "there are technical concerns related to the accuracy of life-cycle cost analysis."

- **Base Funding for Maintenance –** This recommendation indicates that "any asset management-based formula take into account the need for a base level of funding for the routine maintenance of all roads." This recommendation recognizes equity issues in the distribution of public road funds which would not normally be considered in private company asset management systems.

- **Retain Current Formulas –** The Study Committee recommended that the current statutory formulas for distribution of state and federal transportation funds not be changed "until implementation of an asset management process, which may result in future distribution changes." The recommendation continues: "while not proposing a specific formula revision at this time, we recognize that a proposed asset management-based formula could result in a funding distribution which focuses on the function or use of a road, while taking into account the base level of funding needed for routine maintenance."

3.7 GASB 34 Reporting Compliance

As of the dates of the respective interviews, several of the states visited had decided to conform to GASB 34 standards using the modified method. Caltrans, ADOT, CDOT, and MDOT are working through the details of identifying the sources of the specific information and the nature of the calculations and adjustments needed to produce the requisite reports and supplementary information. Those states that are actively developing asset management plans and approaches (among those listed above: ADOT, CDOT, and MDOT) tend to see GASB financial reporting and asset management information needs as complementary.

The relationship between GASB reporting standards and asset management processes and information is not a determinate one, however, and State DOTs evaluate this interaction on a case-by-case basis. The modified approach in particular places certain requirements on a DOT's management system capabilities, and those DOTs that either cannot now meet these standards, or that for any reason wish to defer adopting the modified approach, may select the depreciation method, at least in the short-term. PennDOT, for example, will use the depreciation approach until management systems are in place that enable it to switch to the modified approach.

4.0 International Experience

4.1 Overview

Asset management has been studied by transportation and public works organizations overseas for several years. Detailed methodological handbooks and reports have been produced, for example, by different levels of government and industry groups in Australia, and by New Zealand, and Canada. Other countries, states, provinces, or cities have taken steps to improve individual aspects of asset management, even if these are not yet part of a comprehensive plan. This section reviews several sources in the international literature addressing transportation asset management, summarizing the definitions, concepts, procedures, and techniques as they are presented in each source.

4.2 Organization for Economic Cooperation and Development

Overview

The Organization for Economic Cooperation and Development (OECD) is an organization of industrialized nations of North America, Europe, Asia, and Australia. It provides a forum for its members to share, discuss, and develop economic policies. Recently OECD established an Expert Group of engineers, economists, and road administrators from 15 member countries to prepare a publication describing current practice in highway asset management. The objectives of this study are to document the implementation of asset management practices throughout the participating countries, identify the benefits of asset management systems, review system requirements, and examine the challenges inherent in system implementation. The study has focused mainly on systems and data, but it does not address the effective use of this information for decision-making at different levels of an organization. Examples of questions that have been directed to member countries are as follows:

- Their experience with asset management systems in facilitating road investment decision-making, including the degree of application of such systems;
- The key components of asset management systems, including the relationship between investment in roads vis-à-vis other transport modes;
- Their expectations of outputs from the OECD study to improve decision-making in their countries;

- How best to market and disseminate the results of the study; and
- Related research in progress in member countries or other international organizations to avoid duplication of effort.

Definitions and Concepts

The result of this OECD study is presented in a report, which documents individual asset management efforts by 13 member countries[2].*(3)* The OECD defines asset management as "a systematic process of maintaining, upgrading and operating assets, combining engineering principles with sound business practice and economic rationale, and providing tools to facilitate a more organized and flexible approach to making the decisions necessary to achieve the public's expectations." The OECD's definition of assets encompasses physical infrastructure, human resources, equipment, material, right-of-way, data, hardware, software, methods, and partners.

In this context, asset management systems consist of all processes, data, tools, and policies needed to effectively manage an agency's assets. These systems have the following general attributes: customer focus, mission-driven, long-term outlook, easy accessibility and user-friendliness, and flexibility. The development of an asset management system is an evolutionary process from the management of individual programs and projects to a broader perspective. The report proposes that although many agencies have solid asset management foundations, opportunities for improvement exist throughout the system process highlighted in Figure 4.1. This process is supported by several procedures: e.g., data collection, storage, management, and analysis; asset valuation and depreciation methods; and use of performance indicators.

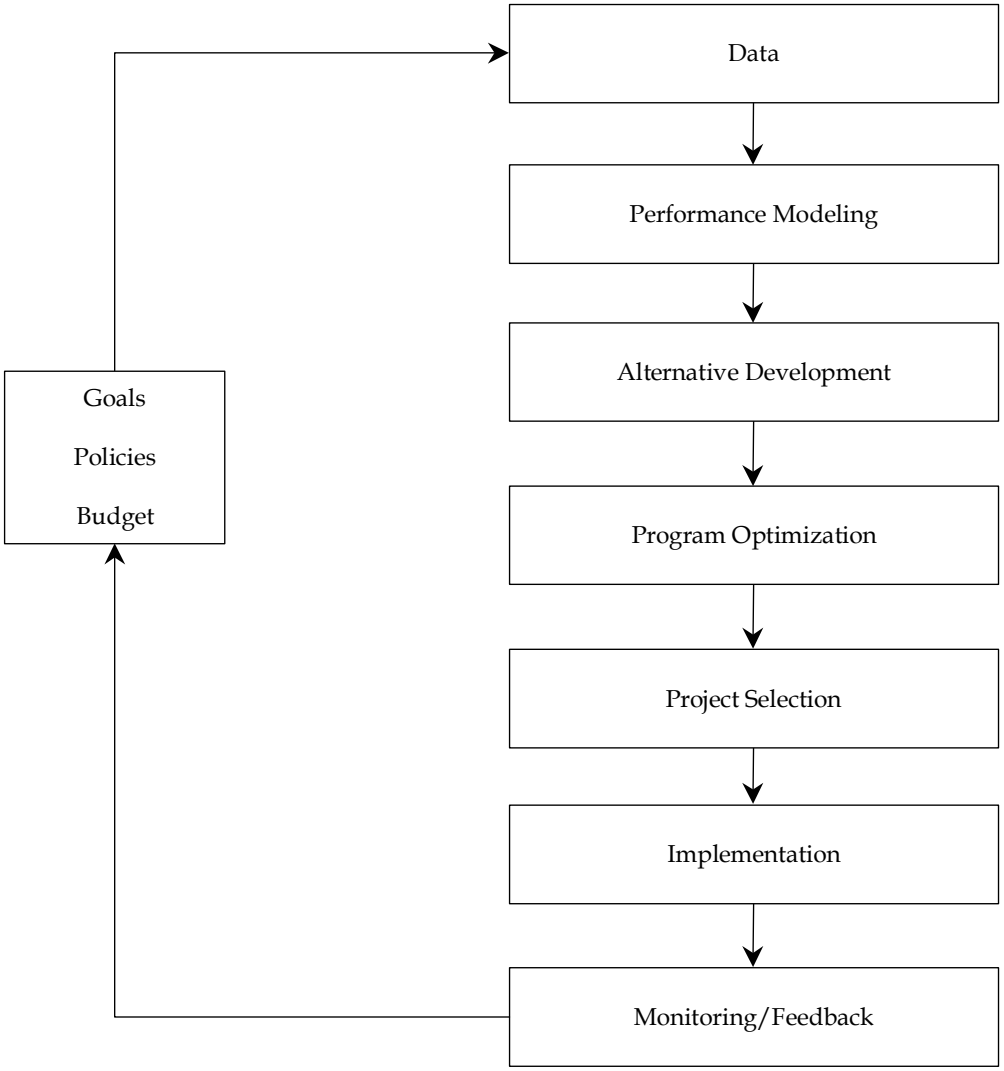
The benefits of implementing an asset management system are categorized in the report within six areas: internal and external communication, condition and level of service of asset inventory, road network performance, asset management tools, budget process, and staff development.

Implementation of Asset Management

All 13 of the member countries surveyed as part of this study apply management systems to individual asset classes, such as pavements or bridges. However, no country has yet introduced an integrated system for their entire national road network. The major benefit of such systems reported by participating countries is the proper budget allocation for road and bridge maintenance and repair.

[2] Australia, Belgium, Canada, Finland, France, Hungary, Japan, Italy, Mexico, Netherlands, Poland, United Kingdom, and the United States participated in the development of the OECD asset management report.

Figure 4.1 OECD's Asset Management System Process



Source: Ref. (3), p. 2.

The OECD report identifies 15 road-related performance indicators (10 quantitative and five qualitative) used by member countries. The use of performance measures varies greatly by country and sometimes by jurisdictions within a country. The most common indicators are related to physical characteristics of roads. Fewer counties use indicators related to public satisfaction or the environment.

The report also finds that several member countries are moving towards standard infrastructure accounting and capitalization methods. However, the majority of these countries are still in the implementation phase of this transition.

Given the benefits of integrated asset management systems, the OECD believes that it is inevitable that countries will implement such systems. The OECD recommends that the following items be considered during implementation:

- Integration of individual management systems early in the process;
- Inclusion of key information within the asset management system: the location and condition of assets, performance data for each part of an asset, and a method to develop maintenance programs based on best value for the money spent;
- Ability to analyze maintenance options based on life-cycle costs;
- Capability to value assets and depreciate this value with time or use; and
- Use of indicators to monitor performance.

Asset Management Development Model

One example of practice that can be used to help an agency get started in asset management is given in the form of a Development Model.[3] Key elements of the model are two matrices, each of which defines a range of potential actions or information for a particular aspect of asset management. The matrices have been designed to 1) identify current practice within an agency, 2) define targets for improvement, and 3) chart progress toward targets. The intention is to provide direction rather than detail.

The first matrix assesses an organization's asset management practice with respect to function or process. The horizontal axis of the first lists four functions in asset management: planning, implementing, reviewing, and improving. Implementing is subdivided into five subareas that describe the asset management cycle: acquisition; operation; maintenance; rejuvenate (i.e., rehabilitation and minor improvements or augmentation); and rationalize (i.e., reduce or dispose). The vertical axis is a numeric rating system ranging from zero to 10, denoting the following stages of development: excelling (9 and 10), achieving (7 and 8), practicing (5 and 6), formalizing (3 and 4), informing (1 and 2), and ignoring (0). The body of the matrix consists of a brief description for each area at each numeric value. For example, the following description for level 10 maintenance is provided: "Highly responsive to market and community forces – monitored, assessed and used to advantage."[4]

The status of an agency can be identified by locating the numerical level to which it practices each function or process. For example, it may rate planning as 4, the several

[3] The Asset Management Development Model is described in Appendix 7 of Ref. (3). It is based on work by the following authors: Shelley Pike, Executive Manager Strategic Services, Shire of Swan, and Neville Binning, Former Consultant and now of Main Roads Western Australia. Its description was an entry in *Asset Management Quarterly*'s Australia and New Zealand Asset Management Competition, 1996.

[4] Ref. (3), page 65.

implementing actions between 5 and 7, reviewing as 3, and so forth. The agency may then establish targets for improvement: e.g., to improve planning from 4 to 6, and so on. The matrix may be revisited periodically to gauge progress, or to reassess targets.

The second matrix focuses on asset management information. It is similar in structure to the first, but the horizontal axis identifies the following five information-related areas: decisions types, analysis methods, information types, data collection methods, and storage/retrieval systems. Information types are broken into the following four subareas: financial/economic, technical, social, and environmental.

4.3 Australia and New Zealand

Australia and New Zealand have long been active in asset management. Both countries have national legislation requiring government agencies to utilize asset management systems. Much of their early activity in asset management was focused on satisfying this legislative requirement. While that aspect is still present, the emphasis has shifted more recently to maximizing the benefits to be realized from asset management. Following are several examples of advances made by these two nations individually and jointly in the past several years.

Austroads

Austroads is the cooperative association of Australian and New Zealand road transport and traffic authorities. Its mission is to promote the effective management and safe use of roads, and to provide professional advice and support to ministerial councils and national bodies. Its essential purpose is to promote national uniformity and harmony, to avoid unnecessary duplication, and to support the identification and application of world-best-practice in the management of Australia's roads. Within this context, Austroads provides strategic direction for the integrated development, management, and operation of Australia's and New Zealand's highways.

Austroads has published two documents on asset management, which support a broad, comprehensive, and strategic approach to infrastructure management, an idea captured within the term "total asset management."*(4, 23)* Austroads' definition of road assets encompass pavements, bridges, tunnels, roadsides, footpaths and bicycle paths, drainage facilities, street lighting, signs and line marking, traffic control signals, and the land beneath the pavements. These assets can be managed individually (e.g., replacing a damaged sign), collectively (e.g., by type, such as a lamp replacement strategy), or collectively by road segment, corridor, regional network, or road system. Strategic asset management decisions are generally made at the collective level for local, regional, state, or national road systems. These strategies identify a programmed set of management actions that direct physical treatments to the asset, or controls on the use of the asset, so as to affect its physical or operational performance, consequent level of service provided to users, and other benefits to the community.

Community benefits include accessibility, economic development, social justice (in terms of an equitable level of accessibility for all members of the community), security (effective movement of both emergency and defense vehicles), and environmental benefits. Actions to gauge levels of service in these areas include community surveys and market research, economic analyses, reviews of applicable government policies that define priorities for economic and social objectives, and road network strategies and industry studies that identify the context and function of the road network and its significance to specific industries.

Ref. (4) identifies four priority areas for cooperation among Austroads member road agencies:

1. Communications among road agencies and key stakeholders;
2. Consistency of parameters used for asset inventory, condition, and use;
3. Road system performance; and
4. Tools to support asset management, particularly in life-cycle analyses.

Ref. (4) also lists specific strategies, actions (with timetable and responsible organization), and associated outputs and benefits in each of these areas. These actions are supported by technical information in Ref. (23).

Transit New Zealand

Transit New Zealand (or TNZ, the national highway agency) is responsible for the maintenance and improvement of New Zealand's highway system. It is a long-time practitioner of asset management principles, and is a member of Austroads, whose work in asset management is described above. TNZ has published its ***Perspective****(24)* on asset management, and a newly updated ***State Highway Asset Management Manual****.(25)*

Perspective on Asset Management

Ref. (24) relates TNZ's view of asset management systems. This ***Perspective*** defines asset management as a component of the agency's overall business system process, which also includes performance management, funding management, financial management, and project management. The elements of asset management include:

- An inventory of assets and their condition;
- Treatment intelligence, which includes probabilistic and deterministic modeling of condition;
- Condition monitoring;
- Trend analysis;
- Maintenance program;
- Annual financial plan for the program;

- Maintenance intervention strategy; and
- Project management system.

Elements of the business process not encompassed by asset management include:

- Contract monitoring;
- Fund allocation model; and
- Project ranking and justification.

Management Context

A period of intensive infrastructure development in New Zealand came to a close in the 1960s. Since then, the priority has shifted increasingly to preservation to the point where annual road infrastructure expenditures are evenly divided between maintenance and improvements. The ***Perspective*** posits that road management systems are based on a balance of two governing principles: 1) the retention of service levels, and 2) cost-effective life-cycle maintenance.

Service level is measured by the following concepts:

- **Availability –** focused on capacity, delay, and clearing of blockages;
- **Safety –** many standards addressing design criteria and maintenance performance are applied; and
- **Standard of Travel –** quality of ride, as measured by pavement roughness indices.

Cost-effective life-cycle maintenance attempts to minimize ownership costs through the entire life of the asset. Thus, it entails selecting appropriate maintenance treatments and applying them at the optimum times.

These two principles are recognized as being in tension with each other, and road management is viewed as attempting to strike the right balance between the two. Cost-effective life-cycle principles tend to control the level of investment while service-level criteria often influence the timing of intervention.

Investment analyses are conducted at both the network level and project level. Network analysis assesses maintenance strategies in terms of overall network condition, while proj??ect analysis identifies the most appropriate treatment and timing for a particular section of the network.

In TNZ's operation of the State Highway network, management systems operate at the strategic, tactical, and operational levels.

- The strategic level includes a corporate plan that outlines a vision, mission and goals and a statement of intent that builds on this plan to describe, at a high level, how the mission will be accomplished.

- At the tactical level, the key documents include the following:
  - **National State Highway Strategy –** describes the classification of roads and established service levels and provides specific operational objectives in the areas of efficiency and safety improvements, traffic and road management, access and highway protection, road user services, community services, and environmental protection.
  - **Asset Management Plan –** documents business practices and systems; described as "an asset management tool in which a combination of management, financial, economic, engineering and other practices are applied to physical assets in pursuit of economic life-cycle costs."[5] This plan includes level of service, demand analysis, life-cycle management plans, new assets and divestments, financial summary, and improvement plan.
  - **Operational Practices and Pro Forma Documents –** describe best practices in specifications, instructions, and manuals.
- The operational level consists of regional strategies to provide a site-specific identification of issues, a forward works program detailing interventions in a 10-year planning period, and a maintenance intervention strategy.

The ***Perspective*** describes asset management plans in this context as tools at the tactical level "in which a combination of management, financial, economic, engineering and other practices are applied to physical assets in pursuit of economic life-cycle costs."[6] These plans document "all of the business practices and systems that will be used to manage the asset to achieve the priorities and objectives outlined in the National State Highway Strategy."[7]

Asset Management Manual

The ***Manual*** (25) describes an asset management process that includes breaking the highway system into segments, developing an assessment of needs for each segment into a program, communicating the program to those responsible for implementation, continually assessing treatments and strategies, and monitoring the effectiveness of the program and the programming process.

The major part of the ***Manual*** focuses on project-level methodologies for pavement maintenance management and safety management. In this context, project-level methodologies are targeted to specific highway segments. For example, the pavement maintenance management section discusses maintenance strategies, deterioration modeling, project selection, performance monitoring, and pavement life-cycle costs in great detail.

[5] Ref. (24), page 11.

[6] *Ibid*.

[7] Ref. (24), page 10.

Local Level

At the local government level, asset management in New Zealand is guided by the Local Government Amendment Act (No. 3), 1996. This legislation requires that local authorities prepare and adopt a long-term (10 or more years) financial strategy every three years, taking account of asset creation and realization as well as loss of asset service potential, and having regard for the benefits and costs of different options. Loss of service potential (i.e., depreciation) is to be funded, or otherwise provided for, effective July 1999.

International Infrastructure Management Manual

A leading proponent of asset management in Australia is the Institute for Public Works Engineering Australia (IPWEA). For several years, IPWEA has distributed a how-to guide on asset management. In 2000, IPWEA joined forces with New Zealand's National Asset Management Steering Group (NAMS) to produce the ***International Infrastructure Management Manual.****(5)* This new manual places greater emphasis on the strategic aspects of asset management, encompassing transportation networks, energy supply systems, parks and recreational facilities, water and wastewater utilities, flood protection and land drainage systems, educational and health facilities, and telecommunications networks.

The objective of the ***Manual*** is to outline a formal and systematic process for the management of a wide variety of assets throughout the public and private sectors. The document describes asset management concepts in general terms. These broad discussions are often followed by examples to highlight specific implementation options.

The ***Manual*** defines infrastructure assets as "stationary systems (or networks) that serve defined communities where the system as a whole is intended to be maintained indefinitely to a specified level of service by the continuing replacement and refurbishment of its components." The goal of asset management is "to meet a required level of service in the most cost-effective way through the creation, acquisition, maintenance, operation, rehabilitation and disposal of assets to provide for present and future customers."[8] Asset management, as defined in the ***Manual***, includes the following elements:

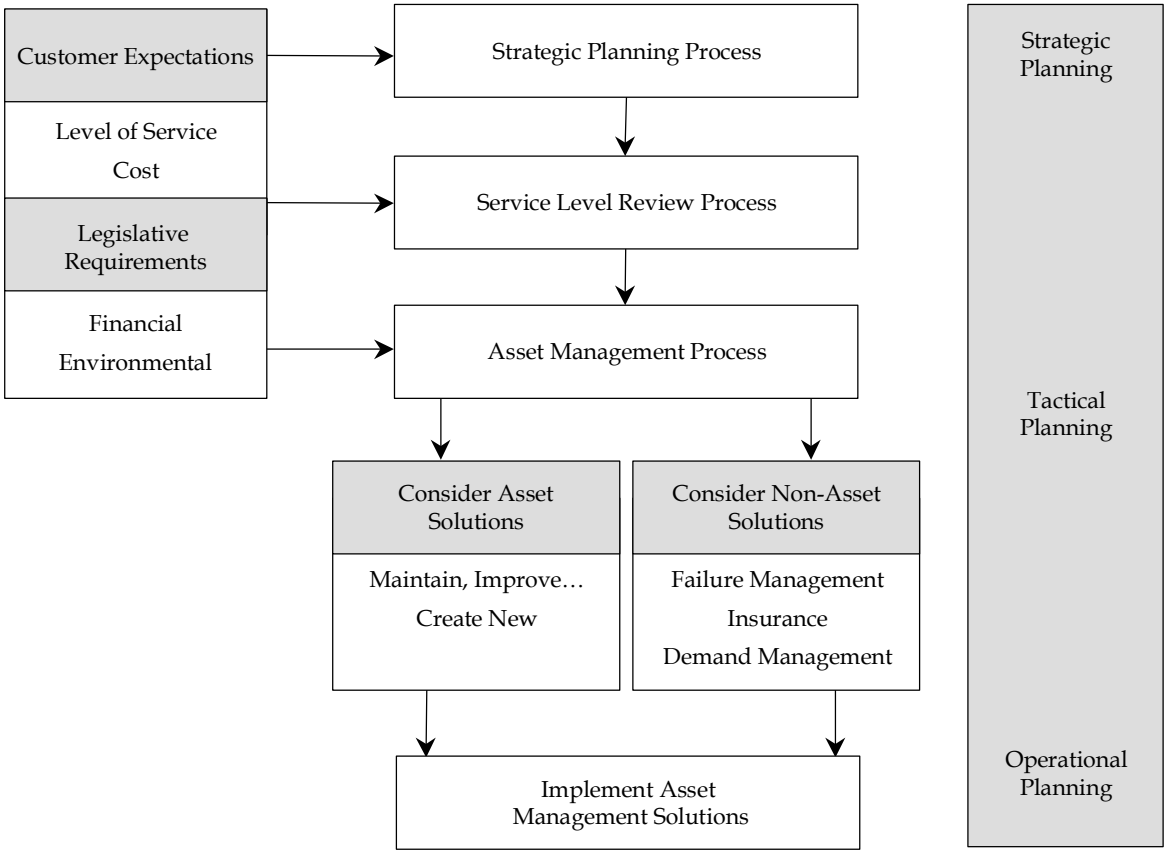
- A life-cycle approach to infrastructure management;
- Cost-effective management strategies for the long-term;
- Providing a defined level of service and monitoring performance;
- Managing risks associated with asset failures;
- Sustainable use of physical resources; and
- Continuous improvement in asset management practices.

[8] Ref. (5), page 1.3.

The key benefits of asset management are seen in terms of improvements in stewardship and accountability, communications and relationships with service users, risk management, and financial efficiency.

Figure 4.2 depicts the total asset management process described in the ***Manual***, encompassing strategic, tactical, and operational elements. Within this broad framework, there is a tactical asset management process that translates an organization's strategic objectives into a cost-effective tactical plan. The major part of the ***Manual*** pertains to the development and implementation of this tactical process, which involves the consideration of all options and strategies throughout the life-cycle of an asset, from planning to disposal.

Figure 4.2 Infrastructure Manual's Total Asset Management Process



Source: Ref. (27), p. 1.6.

Asset Management Implementation

The ***Manual*** identifies the following key steps toward implementing asset management within an agency:

- Define agency-wide asset management direction – obtaining organizational commitment and establishing asset management goals and objectives.

- Appoint a corporate asset management team, an asset management sponsor, and a asset management team to coordinate implementation efforts throughout an agency.

- Plan for asset management improvement – assessing current practices, performing a gap analysis, and drafting improvement programs. The ***Manual*** recommends two levels of asset management implementation. The first step is to identify opportunities to minimize life-cycle costs by improving practices and technologies. This phase should also bring an agency into compliance with all existing accounting and legislative requirements. An advanced phase is designed to optimize asset management throughout an agency through predictive modeling, optimized decision-making, and risk management.

- Prepare an asset management plan based on the planning effort. The document proposes the following sections for the plan: levels of service, future demand, life-cycle management, financial strategy, asset management practices, and plan improvement and monitoring.

- Implement the plan.

- Audit the implementation effort to track progress. For auditing purposes, the ***Manual*** provides several examples of matrices and ranking systems for evaluating an agency's asset management practices.

Asset Management Techniques

Section 3 of the ***Manual*** details asset management techniques that can be applied to an individual asset or a network. This is the heart of the ***Manual*** – a wide variety of techniques are identified and described to varying levels of specificity. The techniques are grouped into the following categories:

- Levels of service and performance measures – emphasis is upon measuring levels of service and comparing these levels with customer expectations and customers willingness to pay.

- Demand forecasting – uncertainty of demand forecasts (especially long-term) is emphasized; safety factors to provide a buffer are recommended.

- Condition assessment and performance monitoring – knowledge of assets and asset condition is highlighted as the most important aspect of asset management.

- Failure mode analysis – understanding the critical failure mode, monitoring performance, developing failure predictive models and identifying corrective treatment strategies.

- Risk assessment and management – principal steps are setting the framework, identifying, evaluating and treating risks, and monitoring/review.

- Optimized decision-making – defined as an optimization process for considering and prioritizing all options to rectify existing or potential performance failure of assets.

- Maintenance analysis and management – maintenance is divided into planned and unplanned categories with a plan and procedures for each. The objective is to manage the rate of consumption of the asset.

- Demand management – the goal is to modify (i.e., reduce) customer demands in order to defer the need for additional assets while still meeting the organization's strategic objectives (e.g., water conservation as a means of curtailing the need for new dam facilities).

- Valuation and Financial Issues – this section is limited to an overview of valuation and financial issues, recognizing the high degree of variability of standards and legislation among countries and sectors. Alternative methods of calculating depreciation and life-cycle costing procedures are described.

Asset Management Information Systems

The ***Manual*** also reviews asset management information systems and data management. The former is defined as "a combination of processes, data and software applied to provide the essential outputs for effective asset management such as reduced risk and optimum infrastructure investment."[9] Electronic form is not a requirement, but is recommended. A computerized asset management system is characterized as having five components – hardware, software, data, procedures and standards, and people – and each of these is to be balanced in developing or upgrading a system. In addition, a method of evaluating asset management software and alternative methods of asset hierarchy and asset identification are presented. In both cases, the key issues are to appropriately scale the magnitude and complexity of the approach to fit the assets being managed.

The ***Manual*** defines a wide range of key system elements and establishes a framework by which to evaluate management systems. According to the document, such an evaluation should consider system functionality, the tradeoffs between generic applications and asset-specific applications, resources available to operate the system effectively, the level of sophistication required to support agency procedures, integration with other applications, and enabling web applications.

[9] Ref. (5), page 4.2.

With respect to data management, the emphasis is on the data collection phase. The key steps are defining the objectives and issues, identifying user data needs and existing data resources and opportunities, analyzing available methods, testing the identified approach with a pilot program, and implementing the full collection program. As the database is established and then maintained, data currency becomes a critical issue.

4.4 Transportation Association of Canada

Much of the investigation into asset management principles in Canada has been conducted under the auspices of the Transportation Association of Canada (TAC). Two publications of the TAC will be discussed here: a ***Primer*** on asset management, and a subsequent study report.

Primer

In 1999 TAC published a ***Primer*** on highway asset management systems.*(6)* The ***Primer*** characterizes asset management as "a comprehensive process that employs people, information and technology to allocate funds effectively and efficiently among competing asset needs."[10]

The ***Primer*** views the principal benefit of asset management as relating to the evaluation of alternative improvement scenarios and the provision of systems data to support management decisions. These evaluations can take the form of alternative funding levels, prioritizing work requirements, optimizing expenditures, and improving management reports. Secondary benefits also are identified in the ***Primer***, but these are mostly variations of the principal benefit. The ***Primer*** emphasizes that benefits will be realized only if the agency fully utilizes the asset management system and subjects it to continuous improvement.

The ***Primer*** describes the principal components of an asset management system as the following:

- Asset inventory – usually, but not always, a computer database that establishes type and location for each asset using GIS or another geographic referencing system. Asset attributes include condition, use and value.

- Performance prediction models – predicted rates of deterioration, calibrated by actual performance.

[10] Ref. (6), page 2.

- Project-specific analytical tools – used to identify and prioritize maintenance treatments and schedules (for example, benefit-cost analysis tools).

- Decision-aid tools – tradeoff procedures used to prioritize competing programs.

Critical success factors include a clear, shared vision of the need for an asset management system, an integrated development approach, a determination that business needs drive the information technology (rather than the reverse), involvement of agency staff on a continuing and fully-informed basis, and a commitment to continuous improvement.

The ***Primer*** identifies seven key steps to implement an asset management system:

- Identify objectives – key factor is involvement of all stakeholders through consultation and communication.

- Review current process and analyze gaps – the agency's business practices are evaluated in order to identify weaknesses, which may be a lack of suitable technical tools, gaps in the database, or lack adequate controls in critical processes.

- Identify scope of framework – important factors include which processes will be used, assessment of costs and benefits in relation to objectives, and approach to asset valuation.

- Benefit-cost analysis – an analysis of benefits and costs for the identified framework scope is conducted in order to assure that the investment in the system is warranted. Budgetary limitations may mandate limitations.

- Assess internal expertise – specialized skill sets are required for asset management that may be outside what is currently available to the organization. An assessment may identify the need for external assistance and/or a need for staff training programs.

- Change management – asset management often implies a fundamental change to an agency's operations. Thus, buy-in by affected staff and external stakeholders, facilitated by complete communications, is a key to successful transition.

- Performance measures – the ability to quantitatively assess performance, in terms of both functional performance and investment strategies, is a central element of asset management.

The TAC ***Primer*** notes that the implementation of asset management lends itself to partnering, either between provinces or a single province teaming with major local governments. Partnering can reduce the costs and staff workload required for an individual jurisdiction. Further, the involvement of multiple jurisdictions promotes benchmarking, a principal tool for measuring cost-effectiveness and determining best practice. In order for partnering to be feasible, the participating jurisdictions must share a common vision on elements such as system type, development process and timetable.

Study Report

Following up on this ***Primer***, TAC engaged a consultant to produce a more detailed study on asset value, condition, and performance.*(26)* The principal objectives of this effort were to develop recommendations for the calculation of highway asset value, the use of performance indicators to measure condition and performance, and the effective communication of performance measures to external audiences.

The TAC offers two asset management frameworks. The first framework, representing overall asset management, is illustrated in Figure 4.3. The second represents individual asset management systems. It is very similar to the overall framework except that the decision component is broken into three elements: alternative delivery programs, expected program outcomes, and selection of optimal program. According to the report, "one of the major challenges of asset management is to develop a means for effective integration of the individual systems within an overall corporate strategy for asset management."[11]

With respect to asset valuation, the TAC study emphasizes two principal methodologies: financial accounting, based upon historical cost that is depreciated, and management accounting, characterized as written down replacement cost (WDRC) based upon condition. This mirrors the GASB alternatives in the U.S. for the reporting on infrastructure assets: the depreciation approach and the modified approach. The study identifies a framework for asset valuation that applies to any methodology. For each asset class, the key steps are inventory, condition or status, and valuation method. This information populates a database that generates reports for an executive information system.

Regarding performance indicators, the study identifies five key considerations:

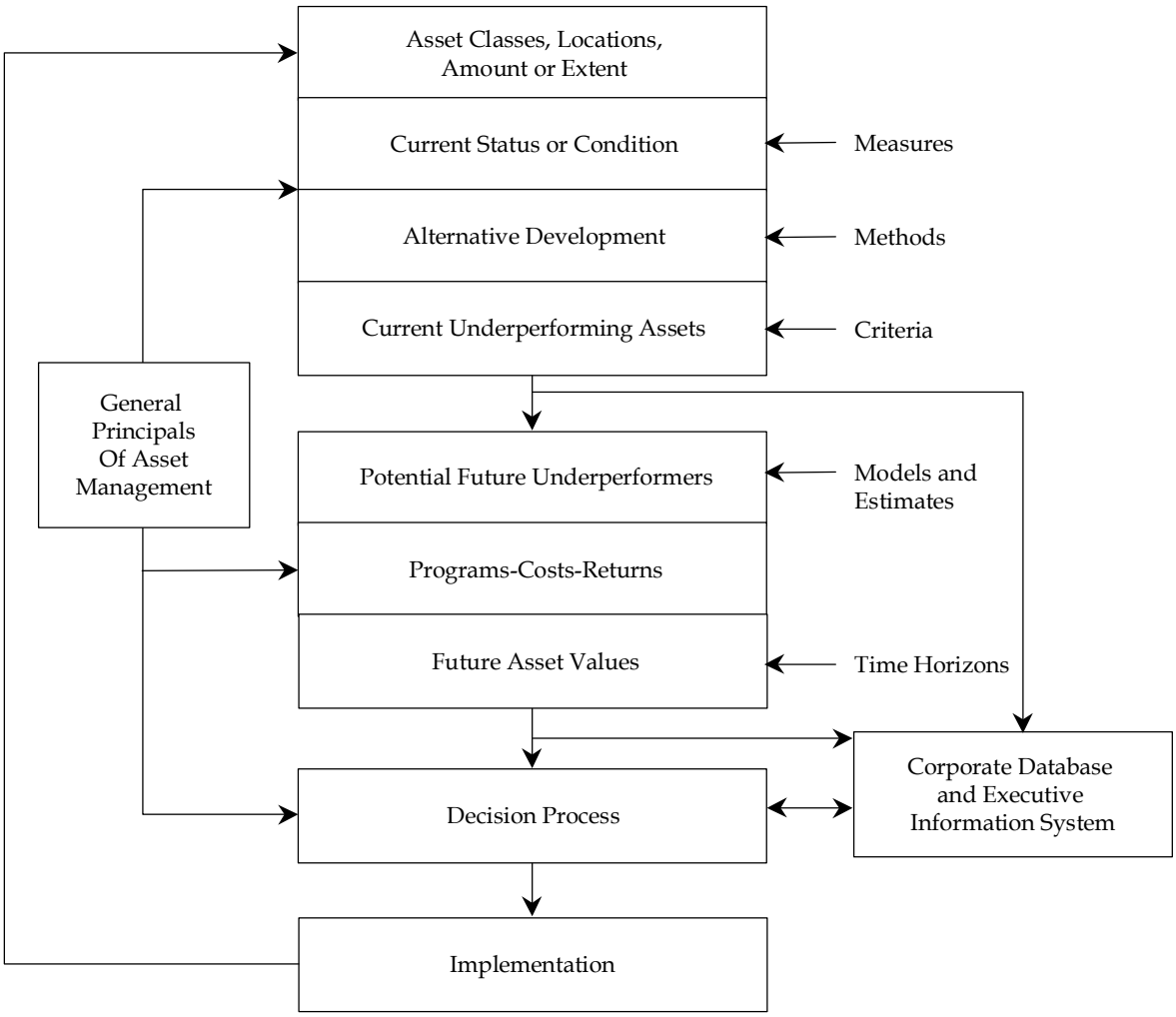
- **Stakeholder involvement –** a wide range of stakeholders with disparate backgrounds and knowledge are involved in the measurement of performance; the measures must achieve a common, objective basis satisfactory to all groups.

- **Balanced view –** the performance measures employed should be balanced in detail and emphasis so as to address stakeholder concerns in an even-handed manner. This is challenging because some areas of concern lend themselves more to quantitative measurement than others. However, undue emphasis upon such areas will distort the message that the agency is attempting to convey.

- **Efficiency and effectiveness –** effectiveness measures address the achievement of maximum performance levels at a specified funding level, while efficiency measures address the unit cost of achieving a particular objective. Either type of analysis may be appropriate depending upon the question at hand.

[11] Ref. (26), page 2.10.

Figure 4.3 TAC Asset Management Framework



Source: Ref. (26), p. 2.11.

- **Transportation values –** a useful starting point is to identify what aspects of the transportation system are valued by various stakeholders, i.e., what do they expect of the system. The performance measures should directly connect to these values/ expectations.

- **Objectivity –** performance measures should be objectively quantifiable through proven processes or surveys. Also, since comparison among agencies in different circumstances is often problematic, the most meaningful measurements are often time series data that track an agency's improvement in performance or lack thereof.

Guided by these considerations, the TAC study develops an application framework with both first-level performance indicators (macro-level view) and second-level indicators for

specific components (e.g., ride quality as measured by IRI as an indicator of comfort/ convenience.

The third major element of the TAC study is effective communications, also termed Executive Information Systems (EIS). The EIS audience extends beyond the agency's executives to include elected officials and the general public. In this era of greater accountability and demand for value for money, public agencies are confronted with increasing scrutiny of their mission and method of doing business. An effective EIS can form the basis for responding to this scrutiny. The study identifies four categories of EIS users: public users, elected officials, executive users and technical users. Moving down that hierarchy, the information becomes less aggregated and the accountability for accuracy increases.

The study describes two EIS models: 1) embedded within an integrated management system in which the individual applications have their own reporting mechanisms and the EIS is used for summary information only, and 2) an umbrella model in which the EIS handles reporting for the entire suite. The study concludes with a series of screen mock-ups to illustrate typical formats for graphical reports.

4.5 United Kingdom: English Highways Agency

The English Highways Agency (HA) is mandated by legislation emanating from the UK to adopt an asset management-oriented approach to infrastructure development and maintenance. The vision of this agency's leadership is one of a seamless, comprehensive asset management process in which there is a direct linkage between the collection of technical data and the business process for resource allocation. However, they acknowledge that the agency is years away from accomplishing this goal.

Their current system is essentially a series of silos with little linkage between sectors (e.g., pavements and structures), or between the field and the policy level. The vertical linkages within a sector (e.g., from engineering to finance within, say, pavements) tends to be stronger than the horizontal linkages among sectors.

HA is just now embarking upon a 12-month effort to develop a geographically referenced database to support an online pavement management system. This system is envisioned as the first building block of a comprehensive asset management approach, to which other functions will be added in the future. This process is expected to require several years. A resource accounting requirement of the national legislation, akin to the GASB Statement 34 requirement in the U.S., will likely also play a role in driving this effort.

4.6 Government of Victoria Asset Management Series

The Asset Management Series was developed by the Victorian Government in Australia in 1995 as part of an initiative to improve management of the State's assets.*(8)* The objective of the series is to make asset managers and financial managers throughout Victoria aware of their management responsibilities and of the information networks available to them.

Definition

The Victorian Government defines asset management as "the process of guiding the acquisition, use and disposal of assets to make the most of their service delivery potential and manage the related risks and costs over their entire life." The series addresses physical assets, such as buildings, infrastructure, equipment, cultural collections, and natural resources. It does not apply to human, financial, or information assets.

Asset Management Framework

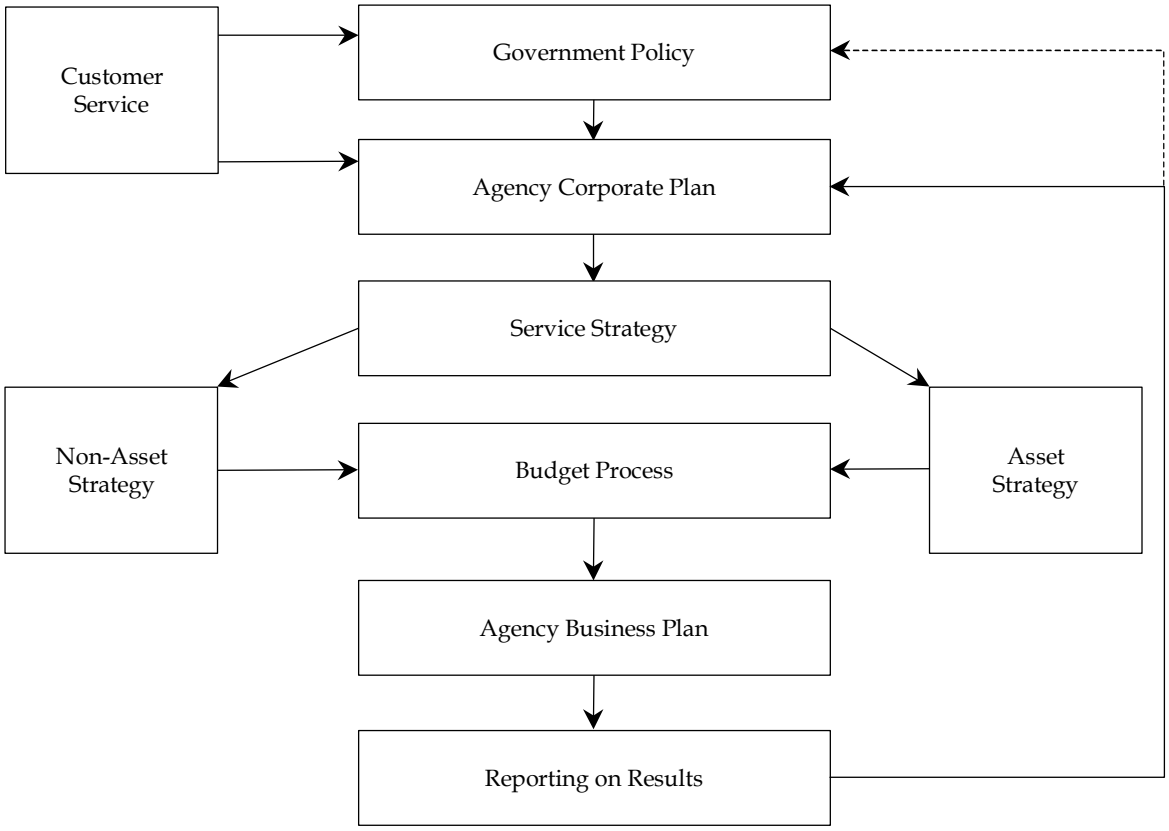
Part I of the series defines the principles of asset management and describes the approach to asset management represented in Figure 4.4. This approach is backed by the following asset management principles:

- Focus on service delivery;
- Informed decision-making;
- Accountability and responsibility established and communicated;
- Actions are within an asset management policy framework; and
- Asset-level planning and management are integrated with broader business planning and management.

Asset Management Guidance

Part II of the series provides explanations and high-level guidelines for the application of asset management principles throughout the asset life-cycle: planning and budgeting, acquisition, operation and maintenance, and removal. For example, the operations and maintenance section requires asset performance to be reported, and then defines and lists the benefits of four categories of performance measures: physical condition, utilization, functionality, and financial performance. However, because the document is designed to be applicable to several departments and types of assets, no specific measures are provided. In addition, this section establishes requirements for asset valuation and reporting, mainly by referencing guidelines from the Department of Treasury and Finance.

Figure 4.4 Victoria's Integrated Approach to Asset Management



Source: Ref. (8)

Asset Management Catalogue

Part III of the series is a compilation of legislation, policies, standards, and guidelines from both the public and private sector related to asset management in Victoria. Each entry includes the name of the item, the date established, a brief description, the source of the item, contact information, and a list of asset categories to which it is applicable.

4.7 Asset Management in a Competitive Environment

Asset Management in a Competitive Environment is a paper, preparation of which was funded by a National Foundation for Local Government Engineering Fellowship Award in 1998.*(27)* The objective of the paper is to identify best practices in asset management by

municipalities in the United States and the United Kingdom that outsource engineering or infrastructure operations and maintenance to the private sector through long-term contracts.[12]

Examples of best practices identified in the report include:

- Dorset County in the UK minimized the life-cycle cost of a secondary school with a build, own, operate, transfer (BOOT) contract with a 30-year term.
- In the UK, municipalities are required to use a "Best Value" Performance Management Framework to justify services to the paying public. The framework includes establishing objectives and targets, tracking and reporting performance, and addressing shortcomings.
- Scottsdale, AZ has developed a Project Peer Review process aimed at improving the overall quality and safety of projects and services and lowering life-cycle costs. The process includes hiring an independent firm for cost management, value engineering, and constructability reviews.
- Indianapolis, IN uses an extensive project scoping reporting system to improve project definition and justification. A typical report includes project needs, alternatives, estimates, benefit/cost analyses, schedule, measures of success and failure, and a variety of other project information.

4.8 Auckland

Auckland, the largest city in New Zealand, employs an asset management process that follows the model established by NAMS. Auckland utilizes a strategic approach that begins with a vision statement:

> *Auckland will be the Outstanding City of the South Pacific offering a superb environment merging sea and land and fostering diverse lifestyles and cultures in a community which respects commercial and social values in the interests of all its residents and visitors.*

[12] The research included visits to: Costa Mesa, CA; Scottsdale, AZ; Indianapolis, IN; Charlotte, NC; Dorset County, Dorchester, England; Hampshire County, Winchester, England; Perth and Kinross, Perth, Scotland; Bedfordshire County, Bedford, England; Hertfordshire County, Herford, England; and the London Borough of Hillingdon, Uxbridge, England.

The strategic plan proceeds to establish five dimensions deemed essential to an "Outstanding City":

1. A City that is Alive and Exciting;
2. An environment that is ***Clean and Green;***
3. A Good place for Work and Business;
4. Great Communities to belong to; and
5. A place where it is ***Easy to get Around.***

The City has developed a "Dimension Plan" in order to realize each of these objectives. To complement these, the City has prepared a Long-Term Financial Strategy aimed at funding the activities required to accomplish the strategic plan. Asset Management plans are a critical component of this process, serving as the bridge between the strategic plan and the implementing activities.

The development and adoption of asset management plans is guided by an Asset Management Steering Team. Individual plans are prepared by designated groups including operational managers and, if necessary, consulting firms. Plans prepared to date address a somewhat eclectic group of topics: the Art Gallery, Closed Landfills, Community Facilities, Libraries, Parks and Open Spaces, Leisure Facilities, Pensioner Housing, Property, Roads and Transportation, Stormwater, Street Environments, the Edge (the civic center), and the Zoo.

The initial draft Asset Management Plans were adopted in 1999. However, they were not fully integrated with the Strategic Plan and instead focused on identifying levels of service and works of improvement. A second generation is now in process and is focused upon a more rigorous financial analysis.

5.0 Private Sector Experience

5.1 Nature of Review

Asset management has been practiced in the private sector for some time, as recognized in the first AASHTO Asset Management Workshop in 1996. This section synthesizes examples of good asset management practice by private sector organizations that may serve as potential lessons to State DOTs.

The material presented in this section draws upon the experience of members of the study team who have worked on asset management for a variety of clients in the private sector. This experience has been augmented with interviews of representatives from automotive manufacturing, banking, railway, and ocean shipping businesses.

5.2 Summary of Findings

The study team has identified several lessons from the public sector that are applicable to improved asset management by state DOTs. The following items are discussed in detail in later sections.

- High value of time associated with assets;
- Strong alignment between actions and goals;
- Employee incentives;
- Program, budget, and procurement flexibility;
- Management strategies vary by asset criticality;
- Importance of preventive maintenance;
- Advantages of outsourcing;
- Extensive tradeoff analyses;
- Electronic data collection;
- Accountability through clear asset "ownership"; and
- Risk management strategies.

5.3 General Public versus Private Comparisons

Public sector agencies operate in a different organizational and institutional environment from that familiar to the private sector. Thus, in this analysis, the study team considered differences between public sector and private sector perspectives in several areas, including the following:

- **Legal, regulatory, and institutional environment in which the organization operates.** A major difference between public and private sector organizations is their legal framework or charter. Public agencies are typically created by legislative acts to perform specific functions and with specific funding arrangements, especially within the transportation sector (e.g., highway trust funds, toll authorities). In many cases, the enabling legislation dictates certain methods of operation (e.g., submittal of long-range plans to the legislature of funding approval) or earmarking funds for narrowly restricted used (e.g., school bus railroad crossings).

  By contrast, with few exceptions, the private sector has no comparable legal constraints. Private companies are free to establish and configure themselves as they see fit and are able to respond to changes in the marketplace to ensure that products and services remain competitive. In addition, rewards and consequences of business decisions are usually realized in the short term, if not immediately. Stockholders may exercise a degree of control over business decisions, but again, the rewards and consequences are readily apparent.

- **Organizational goals.** Public sector goals encompass a wide range of economic and social priorities. Common state DOT goals include public safety, mobility, accessibility, environmental protection, and efficient resource usage. While private organizations may reflect certain social objectives within their strategy and operations, priorities and performance are ultimately financially driven. Measurement of effective asset management in the private sector is well established in terms of return on investment, return on assets, and overall profitability.

- **Planning horizon.** Public sector planning horizons are typically much longer than those in the private sector for several reasons. First of all, given the size and deteriorating condition of public infrastructure networks relative to the amount of available funds, there is typically a large backlog of needs. Therefore, a long-term plan is needed to address the entire network. Secondly, due to procurement laws and environmental regulations, capital improvements in the public sector require long lead times. In contrast, private sector planning horizons are tied to market fluctuations, which are difficult to project for long time periods. Therefore, private sector planning horizons are typically much shorter.

- **Budgeting.** Public sector budgets are based on legislative mandates and bonding efforts. These funds are much more stable than funds available to the private sector, which are tied to demand and revenue projections. Exceptions include funds generated through stock issues and bank loans.

- **Resource management practices.** In the public sector, resource levels are not always tied to the business and financial plans of the organization. In the private sector, staffing levels, fleet sizes, and facilities are directly tied to the short-term business and financial plans of the organizations. Therefore, resource management activities commonly practiced in the private sector (e.g., fleet sizing, replacement strategies, preventive maintenance programs, and utilization and availability monitoring) are vital to survival.

5.4 Industry and Company Backgrounds

This section provides background on the organizations and industries from which examples of good asset management have been drawn.

Automotive Industry

The automotive industry, which is composed of the producers and marketers of autos and trucks and their related parts, comprises primarily three first tier companies – General Motors, Ford and DaimlerChrysler – and several second tier companies such as Toyota, Honda, Nissan and Fiat. One of the second tier companies has been examined in this study.

The company manufactures automobiles in the United States and in foreign locations. Its infrastructure assets include a number of facilities:

- Manufacturing facilities;
- Parts distribution centers;
- Headquarters campus;
- Dealership facilities;
- Port receiving facilities; and
- Several kinds of specialty facilities such as air flight and corporate housing

These facilities can be classified as either industrial-type assets, where the facilities are typically warehouses, dock facilities, or vehicle and parts storage facilities with modern and highly sophisticated building systems; or, they can be classified as prestigious campuses with an emphasis on aesthetics and extremely high standards of appearance and condition. Infrastructure asset management falls within the responsibilities of the financial and administrative division of the company.

Banking Industry

Background

The banking industry continues to undergo rapid and profound changes. Heavy consolidation has occurred, resulting in several nationwide banks with thousands of facilities spread across the United States; approximately 50 large regional or super-regional banks, with hundreds of facilities; and more than a thousand small niche banks serving local communities through limited numbers of facilities. This consolidation will continue resulting in a bimodal distribution of banking between very large and very small banks. The consolidation determines in large part the marketing philosophy and consequently the real estate philosophy of banks.

Internally, banks are generally organized into lines of business that produce revenue: e.g., retail banking, private banking, lock box, and trust and loan businesses. There are also support groups such as information technology, human resources, legal, administrative services, security, and real estate.

Assets

Bank non-financial assets fall generally into two categories. The first, physical facilities, includes elements such as banking centers, remote ATM's, data or operations centers, corporate offices, furniture and fittings. The second, communication and data processing systems, includes mainframe computing systems, data storage, transaction processing, teller systems, account management systems, customer service center systems, ATM networks and telecom networks.

Historically, banks have owned a high percentage of real estate occupied by their facilities. This has been particularly true for corporate office facilities, where a bank owned space far exceeding its needs, leasing the excess space to other firms and becoming a landlord. As banks merged, many of the corporate offices became redundant or surplus, yet banks continued to own large amounts of office space that was not required by the bank to conduct business. In an effort to increase return on assets, banks have radically reduced the number of owned larger facilities. This most often occurs through a sale/lease back where the bank sells the facility and becomes a tenant in its own space – thereby freeing capital tied up in the ownership of the facility. Banks generally retain ownership in critical data centers to maintain maximum control and flexibility.

In addition to this change, large banks have focused more on the delivery of service through electronic sources such as remote ATM's, web-based banking and telephone banking, decreasing their reliance on full service banking facilities.

Ocean Shipping Industry

Background

The shipping company researched for this study is a provider of rail, barge, and container shipping and other logistical services. The company owns or operates a fleet of container ships, shipping containers, chassis and dozens of port terminals and container yards around the world. Their container ships call at over 100 ports in over 70 countries. The company handles over 1.5 million container loads annually, generating billions of dollars in revenue.

As a publicly traded company, the organization has an obligation to its shareholders to produce a profit and to generate a superior return on its asset base. The company works to squeeze every last ounce of life out of its assets and is constantly seeking ways to extend asset life and defer capital investment. As interest rates fluctuate and commodity prices change, decisions to lease or purchase assets are made to minimize asset-carrying costs. These goals are offset by commercial considerations, such as operating newer, faster vessels, or utilizing larger, lighter containers. Thus, tension exists between the company's Operations Department and its Commercial Department, creating a healthy balance of interests within the organization.

Assets

The principal assets of the shipper include:

- Vessels;
- Containers;
- Chassis;
- Yard handling equipment such as gantry cranes and straddle carriers; and
- Port terminals and container yard facilities.

Additionally, the company leases a significant number of containers, and charters approximately 40 percent of its total operating vessel fleet. Depending upon the type and duration of the leasing or chartering arrangement, the company may have responsibility for maintenance associated with the leased or chartered assets in addition to that of their owned assets.

To take one example from the list of assets discussed above, let us consider terminal facilities in more detail. It is the company's operating philosophy to control its terminal facilities to the greatest degree possible, enabling them to provide a higher level of service to their customers. By operating and maintaining their own exclusive use terminals, the shipper can offer greater flexibility in terms of hours of operation and services provided, for which they can demand a premium from the market.

In certain locations, the volume of business does not generate the economies necessary to justify an exclusive-use terminal facility. Likewise, port development in certain countries

or the physical limitations of the port itself allow only a common-use facility. However, where it makes business sense, the company has made every effort to obtain a portion of the overall port infrastructure for exclusive operation.

Terminal facilities typically include a paved container yard, a cargo storage warehouse, a container/chassis repair shop, a small office building and a receiving/discharge gate, which resembles a highway toll plaza. If the terminal has gantry cranes, sufficient space is required at the quay for the tracks upon which the cranes are mounted. The entire facility is normally lighted (for nighttime operations) and enclosed by a security fence.

The cost of terminal facilities varies widely depending upon location, size and construction materials used. The facilities are depreciated over a 25-year life, but will last far beyond the accounting life with proper maintenance and timely rehabilitation.

Railroad Industry

The study team contacted a major western railroad to obtain details on their asset management practices. The primary source of income for the railroad is the transportation of industrial and consumer goods throughout the United States. In addition, they run several multimodal distribution facilities.

The company's assets include:

- Over 30,000 miles of track (rail, ties, ballast);
- Signals;
- Nearly 60,000 structures;
- Machinery;
- Vehicles (thousands of locomotives and tens of thousands of freight cars);
- Stations;
- Computer hardware and software;
- Distribution centers;
- Telecomm system; and
- Equipment (e.g., cranes, high rail vehicles).

The railroad spends approximately 15 percent of its total budget, which is between $5 and $10 billion, for maintenance, three percent for expansion, and 82 percent for operations.

5.5 Practices Applicable to Asset Management

Despite the organizational and institutional differences between the private and public sectors described above, there are several private industry practices that can contribute to improved asset management by state DOTs. Examples are presented in this section.

High Value of Time

In asset-intensive industries, the functionality of assets is critical to the success of an organization. In these industries, down time associated with major repairs or renovations significantly impacts the financial performance of an organization. Therefore, there is often a high value of time associated with assets in the private sector. For example, in the banking industry, the availability of systems is critical since customers depend upon access to funds and services 24 hours per day. A bank's data center may allow one planned maintenance shutdown per year from 2:00 a.m. to 4:00 a.m. on a Sunday morning.

In the shipping industry, ships, gantry cranes, containers, chassis, and yard handling equipment all need to be in good working order to ensure timely, reliable transportation of cargo. A terminal facility that is not well maintained can increase chassis and container repairs significantly, and can become a safety/security problem for employees. As each asset is interrelated to the other, a breakdown or outage in one area can have a detrimental effect on the entire supply chain.

The high value of time associated with assets significantly influences asset management in the private sector. The importance of preventive maintenance strategies, and the application of heightened asset management programs to assets identified as most critical to a company's operations are examples. These topics are discussed in more detail later in this section.

In the public sector, a high value of time relates to user benefits. These benefits reflect the impact of investment strategies and specific projects on the traveling public (e.g., the economic impacts of travel delays due to congestion and extra costs associated with detours caused by construction or structure deficiencies). The value of time associated with a state DOT's infrastructure network will be dependent on the relative importance of mobility compared to the agency's other goals.

Alignment between Actions and Goals

Private sector firms that practice asset management exhibit a high degree of alignment in their policies and practices: i.e., the importance of asset management to a company's operations and profitability is clear throughout the organization, and both corporate and individual incentives are aligned to promote highly effective management practices. For example, the railroad contact interviewed for this study prefaced all of his comments with this point. He stressed that a critical factor in enabling improvements in asset

management at the railroad is the fact that the company is extremely well focused on achieving a well-defined set of financial goals.

In the automotive industry, the scope and magnitude of the recapitalization program is generally determined by the changing needs of the product lines and by the year-to-year profitability trends. Annually corporate staff, in consultation with the operational and plant managers, determines the need and general scope for asset renewal.

In the banking industry, real estate support groups are measured in terms of their ability to support the direct service producing lines of business (e.g., retail banking, private banking, etc.). Historically these support groups often operated in a vacuum with their own set of goals and objectives that often did not support or upon occasion directly conflicted with the goals of the lines of business. For example, a Corporate Real Estate Department might replace a roof on a existing banking center or extend a lease option an additional five years to retain a low lease payment, despite the fact that the banking center was performing poorly because of poor location as the market shifted geographically. The retail bank might have preferred to renovate the facility to a new purpose or move to another location. Over the past several years, banks have focused considerable efforts on melding the goals of support groups to the goals of the lines of business. In the case of real estate, the purpose of the Corporate Real Estate Group is to manage the physical facilities of the bank to maximize the efforts of the lines of business as they seek to increase market share and generate profit for the bank.

Corporate Real Estate therefore sees the bank's lines of business as its customer. The focus is clearly on supporting and responding to organization-wide goals instead of operating facilities in a vacuum.

Generally, in the banking industry, infrastructure budgets are established on an annual basis. While banks perform surveys to determine infrastructure project needs, the reality is that infrastructure funding approval is generally set by the profitability standards of the bank for the projected year and only minimally by the actual maintenance requirements of its facilities. Discretionary projects are treated similarly, but often receive substantially higher funding approval by dollar volume since these projects are perceived to be in direct support of the principal goals of the bank's line of businesses. In summary, capital project funding is principally based upon the needs of the lines of business to capture market share, operate reliably and efficiently, and generate profit.

Alignment between actions and goals is also apparent in the shipping industry. Shipping lines are in business for just one reason – to generate a profit and provide a superior return to their shareholders. Everything they do is directed toward the achievement of this goal. As an asset-intensive business, maximizing asset life, acquiring the assets under favorable terms and minimizing the assets required to handle the anticipated volumes keeps their cost base at the lowest level possible. For example, the goal of every terminal manager is to load and unload a vessel at the lowest expense possible. Only by properly maintaining the assets at the terminal is the manager is able to minimize delays to the operation. Due to the highly competitive and variable nature of the containerized shipping industry, proper asset management can make the difference between profit and loss for a shipping line.

Employee Incentives

A powerful vehicle to align actions and goals in the private sector is employee incentives. For example, the compensation of management within the shipping company includes a base salary and various types of incentive compensation. For junior managers, this is normally a bonus based upon the achievement of individual, divisional and company-wide objectives. For senior managers, this also includes stock and stock options awards, again based upon the successful achievement of clearly defined objectives. The incentive compensation of some managers exceeds their base salary, driving them to meet and exceed their objectives on a continual basis.

Program, Budget, and Procurement Flexibility

Private-sector organizations typically maintain a high level of flexibility throughout their asset management efforts. This ability is largely the result of the alignment between actions and goals described above. The private sector will amend programs, budgets, and procurement strategies as needed to address fluctuating market conditions and corporate strategies.

Programming

In the auto company, the annual maintenance work program for all facilities is dependent on the overall profitability of the organization, and will increase or decrease accordingly. The impacts of budget changes are translated into work program changes through service-level reviews. The overall results of the asset management efforts are monitored and reviewed periodically. Adjustments to subsequent year work programs are made as a result of these reviews, ensuring that the work planning process is a dynamic one, continually adjusting to meet the changing needs as determined by firm's business goal of manufacturing and marketing automobiles.

Budgeting

The railroad company offers an excellent example of maintaining a flexible budget. Once the railroad has established an annual budget, it is reviewed on a monthly basis at budgeting meetings. At these meetings, budget reallocations are made. Once made, these decisions are quickly implemented. The monthly review of asset allocations is a key feature of the railroad's approach to asset management.

Procurement

Banking centers are often relocated on short notice, increasing the difficulty of long-term planning for capital repair and renovation. Since business cycles and planning have shortened considerably, corporate real estate divisions must respond much faster than historically accepted norms for the conception, design, and construction of capital proj??ects. Completion of renovations is often expected in months as opposed to a year or

more, and in is no longer unusual to expect the delivery of a $100,000 project from concept through construction in a matter of weeks.

Management Strategy Tied to Asset Criticality

In the private sector, the main function of assets is to support an organization's core business. Depending on the industry, certain types of assets are more critical for optimal operations then others. It is common for private entities to identify these critical assets and adjust asset management strategies accordingly – the most critical assets receive the most attention. The most detailed example of this practice identified as part of this project is in the ocean shipping industry. As described below, the asset management strategies for each asset vary widely depending on their perceived importance.

Vessels – There are two categories of maintenance on shipping vessels – maintenance during dry-dock and routine maintenance. The vessel manager and vessel's chief engineer keep detailed logs of a ship's performance. These logs also track the regularly scheduled maintenance (filters, oil changes, etc.) and the work to be scheduled during the ensuing dry-dock. Most routine engine maintenance is performed while the vessel is at port, and is based upon the number of hours the vessel has been operated. Non-engine-related routine maintenance is performed at the discretion of the chief engineer or captain, and is not managed as closely as the engine-related work.

Containers – Until containers reach the end of their useful life, normally estimated to be 15 years, they are eligible for repair. Typical repairs include patching roof or sidewall holes, straightening or replacing corner posts, replacing or patching floors and painting, either a the company logo or the entire container. Approximately 15 to 20 percent of the container inventory will require some form of repair in a given year.

A container is inspected each time it is released to a customer's trucker. If it is inspected and deemed unsuitable for customer use, it is put into a repair status in the equipment tracking system. When it is considered uneconomic to repair or has reached the end of its useful life, it goes into "Permanently Out of Service" status. There is no planned or programmed maintenance for containers. The discovery of damage triggers all repair work.

Chassis – The rules for chassis repair closely resemble those of container repair, with two exceptions. Chassis must have roadworthy tires, and chassis must have functional turn signals. Each time a chassis leaves the port terminal, it is to be inspected to ensure that these items are safe and operational. As with containers, there is no planned or programmed maintenance for chassis.

Gantry cranes – A port terminal's gantry cranes are critical to its operation. Each crane undergoes strict preventive and routine maintenance on a regular schedule to assure maximum uptime and productivity. Each crane has an estimated service speed and capability, to which the maintenance is programmed to consistently achieve. All electrical, mechanical and cabling systems are checked thoroughly and a logbook is kept for each unit. Spare parts are kept in inventory at each port, and if a part is unavailable, it is normally shipped from the manufacturer directly to the port at very high cost. Gantry cranes

are rarely taken out of service for more than 24 hours, as they are the lifeblood of a terminal operation.

Other handling equipment – The other terminal handling equipment is not maintained as stringently as are the gantry cranes. Routine and preventive maintenance is performed, but does not carry the same level of scrutiny as with the cranes. It should be noted that while detailed programs exist and are followed for gantry cranes, the quality of maintenance for the other terminal handling equipment varies widely by port.

Facilities – As with other terminal handling equipment, the quality of maintenance for facility assets varies widely by location. Some port terminals are managed closely, and the maintenance of the structures and the facility itself is planned and controlled well. In other locations, terminal facilities are repaired only when broken, and receive little if any preventive or routine maintenance.

Equivalent practices in the public sector include Caltrans route designations, which denote relative priority for investment in future statewide programs and correlate with statewide policy goals, and CDOT's tiering process, which provides a basis for identifying different levels of functional importance, and allocating resources according to these tiers. However, these priorities imply relative resource levels, not differences in asset management strategy.

Asset Valuation

Assets in the private sector are generally viewed as tangible entities on financial balance sheets that can be valued by sale at public auction. Current efforts in the public sector, notably the asset valuation requirements of GASB Statement 34, will attempt to develop an analogous view of public infrastructure assets to meet a financial objective of clearer, more complete financial reporting by state and local agencies. Certain state DOTs in the U.S. may also take the opportunity to investigate asset valuation specifically as an asset management tool, above and beyond the necessary matter of financial reporting. Asset valuation thus may provide an example of a private-sector concept that could be usefully employed in a public sector context for asset management.

Importance of Preventive Maintenance

Another common theme among the industries studied is that preventive maintenance is widely recognized for its value in prolonging asset life and delaying recapitalization requirements. For example, a key component of the automotive company's asset management strategy is a preventive maintenance program that covers all elements of its facility assets. The scope of the program includes the following:

- Electrical systems, including predictive component replacement for interior and exterior lighting;
- Value and seat replacement programs for plumbing fixtures to prevent leaks and control water usage;
- Annual and predictive roof inspections with a planned replacement program;
- Periodic testing and operation of fire protection systems, pneumatic transfer systems, towlines and other handling systems; and
- Quarterly preventive maintenance on all HVAC systems.

In the annual asset management planning process, these work activities and preventive maintenance budget are not sacrificed in budget-cutting exercises. As such, this portion of the program and budget is consistent from one year to the next.

In both the shipping and banking industries, preventive maintenance is the basis of the management strategies for assets identified as most critical to company operations and financial performance.

Outsourcing

The advantages of outsourcing include cost reductions, access to capabilities not found within the firm, and freeing of resources to concentrate on the core business of an enterprise. The banking and automotive industries rely heavily on this practice for their asset management activities. In contrast, the shipping company believes that by keeping functions in-house, a stronger degree of control is possible. Therefore, the company has chosen to perform its maintenance with in-house forces.

Most major banks have outsourced some of the key elements of their real estate function, including maintenance, project management, and real estate acquisition and disposition. There is no consistent standard to the outsourced services except that there is a distinct trend to out-source the direct maintenance technicians performing routine, corrective and preventive maintenance to firms that specialize in providing maintenance staffing and services. The management of this staff may or may not be outsourced. Outsourcing maintenance services may also include maintenance materials incorporated into a "Total Maintenance Package" for routine and preventive maintenance services, thereby providing an incentive to the out-source vendor to focus on long-term preventive maintenance approaches, instead of simply billing the bank on a time and material basis.

The automotive company interviewed for this study serves as an example of a successful wide-scale outsourcing asset management policy. The operation and management of the company's assets were performed primarily with in-house managers, engineers, technicians, and laborers until 1984. Then, because the firm had been unable to systemically plan and perform preventive maintenance with it's in-house forces, it looked to the private sector for potential improvements. As success was achieved, these initial outsourcing efforts were gradually increased in scope over the next several years to include some of

the routine maintenance items along with minor project management efforts associated with interior improvements. These initial outsourced efforts were also confined to one geographical area and one type of facility – the parts distribution centers.

The prioritized goals of these efforts as mutually defined by the company and the vendor were to:

- Provide quick response to emergency call-out services;
- Work as a team with the vendor being an extension of company staff;
- Provide written standards to perform quality maintenance services;
- Maintain facilities within budget constraints; and
- Provide feedback for continual improvements.

Success in meeting these goals led to the expansion of the outsourced services to include all nationwide regions and all facilities except the manufacturing plants. Some 15 years after initiation of the outsourcing efforts, all the asset management efforts on more than 100 facilities at over 60 sites are performed by a preferred vendor.

The asset management responsibilities performed by the vendor include all efforts associated with the operation and maintenance of the company's assets and are grouped under three categories:

- Preventive and routine maintenance work;
- Rehabilitation and renewal of assets; and
- Collateral efforts to support the operation or utilization of the facilities.

Outsourcing is a key component of the program delivery evaluation matrix. Current public sector practices in this area include inter-governmental agreements, partnering, outsourcing, and managed competition. Success stories in the private sector provide motivation for state DOTs to continue to refine these practices and implement them fully when appropriate.

Tradeoff Analyses

The railroad and shipping companies interviewed for this project rely heavily on tradeoff analyses to support their investment decisions. For example, the railroad company is very aggressive about evaluating tradeoffs between different asset classes. These tradeoffs are considered on a monthly basis at budgeting meetings. Tradeoffs between expansion and capital maintenance are evaluated annually through the programming process. Routine maintenance, such as spot replacement of ties, is handled through a separate process.

In addition to program-related tradeoffs, the shipping and railroad companies both consider tradeoffs between different ownership and delivery options. For example, in maintaining or purchasing equipment, the railroad carefully evaluates the costs and benefits of leasing versus owning equipment.

Electronic Data Collection

The study team identified an example of a successful electronic data collection imitative in the private sector. The railroad company designed and launched a Structure Inspection Reporting System in 1999. The system enables over 125 field and design personnel to automatically record and communicate bridge and culvert inspection results. Before the product was released, inspectors used a combination of pencil, paper, and telephones to record their findings. The new system automatically updates the corporate asset database, which contains inventory and condition information for all of the company's structures, with inspection results.

Clear Asset "Ownership"

A common practice among private sector industries is to improve operations by creating clear accountability among key employees. One method to establish accountability in asset management is to define clear asset "ownership." For example, in the shipping company, the Vessel Operations department is responsible for the continuing operation of all vessels, whether owned or leased. The department must comply with U.S. Coast Guard regulations at a minimum for all U.S. flag vessels, while ensuring maximum ship performance for all vessels. Normally, a Vessel Manager is assigned responsibility for up to five vessels, which includes all operational, financial and regulatory issues. It is this employee's job to keep the vessels operational for the greatest percentage of time possible at the most economical cost.

Additional examples of asset "ownership" include:

- Terminal managers within the shipping company are responsible for maximizing efficiency of loading and unloading vessels at "their" port.
- Local area technicians within the automotive company are responsible for ensuring that all emergencies at "their" facility receive immediate attention by the maintenance contractor.

Risk Management

Risk management strategies in the private sector vary widely by organization. For example, the shipping company does not have a quality assurance program that could be considered failsafe. In reaching this decision, the firm likely considered the cost of implementing such a system against the potential cost of a major failure and the financial incentives already in place that motivate management to perform as flawlessly as possible on a daily basis.

In contrast, the banking industry takes a much more proactive risk management approach. Risk Management for the banking industry focuses in two major areas. The first area is composed of failure scenarios that may prevent the bank from delivering services to its customers. The second area consists of liabilities that exist in the operation of physical facilities that could harm customers or employees.

In the first case, banks generally take an aggressive posture to risk management as it concerns the bank's ability to deliver service. For example, data centers are generally well protected from power loss by the use Uninterruptible Power Systems, supplemental power generation equipment, redundant electrical panels and redundant HVAC systems. Banks maintain Disaster Teams with representatives from each major banking area trained in disaster recovery procedures. These may include planned procedures for hurricanes, tornadoes, earthquakes, sabotage, building fires, explosions or other disasters. This emphasis on planning and practice was evident during the year 2000 computer date procedures. Banks began modifications to their systems years in advance and conducted drills during the final months of the year to deal with remaining problems.

The second area of risk involves dealing with the potential liability associated with operating large numbers of facilities with high volumes of customers and employees entering the facility on a daily basis. These may include the potential for slip and fall, accidents related to ongoing construction work in an occupied building, fire and life safety, and other general liability issues. Risk also includes liability associated with statutory and environmental hazards, such as asbestos abatement, requirements of the Americans with Disabilities Act, and security lighting. Banks take different approaches to this second category of risks, including insurance and requirements for subcontractors to maintain high levels of insurance and to provide evidence of such insurance as a condition for performing work. In statutory liability, banks generally follow industry norm or existing regulation.

6.0 Conclusion

6.1 State of Asset Management Practice

While asset management is still an evolving field, considerable work has already been accomplished by transportation and public works agencies worldwide. Reports and detailed procedural manuals have already been prepared by several agencies and associations overseas. Reviews of these documents have been summarized in this report. Work by AASHTO and the FHWA have initiated a focus on transportation asset management in the U.S. Early efforts included a series of executive workshops or seminars, which led to the formation of an AASHTO Task Force for Transportation Asset Management and development of a ***Strategic Plan***. As part of an agency-wide reorganization, the FHWA formed the Office of Asset Management, which published a ***Primer*** on Transportation Asset Management.

State DOTs in the U.S. continue to develop and implement innovative management approaches for their transportation systems, and some agencies have begun to develop transportation asset management plans to guide long-term advances. On-site discussions with managers in several DOTs indicate the strong relationship between the specific priorities, procedures, and tools that they would associate with good asset management, and the particular characteristics of their agency in several key areas: e.g., policy and institutional framework, asset inventory and condition, technological capability, organizational roles and responsibilities, and management philosophy.

These discussions also suggest that agencies in general do not necessarily adopt asset management advances uniformly and simultaneously across all aspects of their standard business practice. For example, an agency may introduce improved business processes (e.g., in capital programming, maintenance management, or outsourcing for program delivery), but information technology support for these procedures may need to be strengthened. As another example, an agency may excel in its collection of data on technical measures of transportation system performance, but its management systems may be ill suited to produce the strategic information needed by executives. In a third example, an agency may possess state-of-the art management systems that produce excellent information at all organizational levels, but this information may need to be better integrated to see the "big picture."

The implications of this situation are as follows:

- It may be simplistic to characterize agencies in terms of overall asset management practice. Rather, it may be more useful to consider specific aspects or areas of asset management. It is likely that an individual DOT may exhibit certain characteristics that typify good practice, and other characteristics that suggest current or future need for improvement.

- As a corollary to the preceding point, even those agencies that have relatively good asset management procedures in place across-the-board can likely still find specific areas for improvement. Conversely, those agencies that may feel considerable need for improvement in asset management can likely find specific functions and procedures that work well and provide a point of departure for addressing problem areas.

- Given the breadth of asset management, agencies will likely stage their planned improvements to focus on priority areas first. It is for this reason that several DOTs have undertaken asset management planning as a first step. Moreover, the concept of staged improvement suggests that an agency can begin to address asset management immediately, with their current staff, information technology, and other resources. They should not wait until "everything is in place," since such an ideal state is unlikely ever to be reached, and the principles of asset management can be applied even in the presence of technical, organizational, or institutional constraints.

Transportation asset management can provide several benefits in terms of more cost-effective solutions, better service to customers, and increased management accountability. A number of the studies reviewed in this report cite potential benefits in these categories, although the practice of asset management appears yet to be too young to provide substantial quantitative indications of these benefits. Benefits may also be qualitative: e.g., in terms a wider set of alternatives considered.

6.2 Challenges to Asset Management Implementation

Private sector firms that practice asset management exhibit a high degree of alignment in their policies and practices: i.e., the importance of asset management to a company's operations and profitability is clear throughout the organization, and both corporate and individual incentives are aligned to promote highly effective management practices. A key challenge in implementing asset management principles in the public sector is that the nature of a transportation agency's organizational, institutional and financial environment, coupled with constraints imposed by other bodies, may impede a similarly strong alignment, or make it more difficult to identify where the alignment exists. Characteristics of this environment that may complicate asset management implementation include the following:

- Responsibility for different modes or for different segments of the transportation system is fragmented across several agencies.

- Funding is often constrained by mode and function, limiting the latitude by which a DOT could otherwise assign funds to where they are most needed.

- Within a highway transportation organization, the pavement, bridge, maintenance, and other organizational units involved in asset management are not integrated. While channels of vertical communication may be adequate within these areas of core expertise, horizontal communication may be not be sufficient for good asset management, or may not occur at the appropriate management levels.

- Management systems and databases are often stand-alone and of different vintages, complicating issues of system integration and data integrity, accuracy, completeness, and currency.

- Senior management does not have access to sufficient quality information to analyze tradeoffs and make resource allocation decisions effectively, as noted earlier. There are likely a number of historical reasons for this.

- The increased scope and complexity of departmental responsibilities must be balanced against resource limits and imposed constraints. Change management is therefore very much an issue faced by DOTs, but agencies across the Nation have dealt with the problem differently.

As a result of these characteristics, asset management implementation within a DOT will face a number of challenges. For simplicity, these have been organized below into two groups: institutional, and technical. It is the sense among those DOT managers who were interviewed that the institutional challenges are more significant and potentially difficult to deal with.

Institutional Challenges

- To integrate decision-making and allocation of resources across asset classes.

- To combine the financial, management, engineering, and operational perspectives of a department within this decision process.

- To define system performance measures that reflect customer perspective and user costs effectively.

- To secure senior management support and leadership throughout the period of asset management implementation, which may extend over several years.

- To develop new public and private sector roles that enable an agency to fulfill its mission in the face of change, and to implement these roles effectively.

Technical Challenges

- To integrate "stovepipe" or "silo-based" legacy systems and stand-alone databases established for different asset classes or functions.

- To develop comprehensive, GIS-compatible, enterprise-wide databases that better serve asset management.

- To create next generation management systems or specialized analytic tools that support a wide range of "what-if" analyses reflecting different budget and performance assumptions (e.g., for tradeoff analyses).

- To improve life-cycle analysis methods and incorporate them fully within planning and program development.

- To strengthen transportation system monitoring capabilities and use of this information for program evaluation and policy formulation.

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