Analytical Tools for Asset Management

DETAILS

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NCHRP REPORT 545

Analytical Tools for Asset Management

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SUBJECT AREAS
Planning and Administration • Pavement Design, Management, and Performance • Bridges, Other Structures, Hydraulics and Hydrology

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FOREWORD

By Christopher J. Hedges
Staff Officer
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This report presents two tools developed to support tradeoff analysis for transportation asset management. These software tools and the accompanying documentation are intended for state departments of transportation (DOTs) and other transportation agencies to help them improve their ability to identify, evaluate, and recommend investment decisions for managing the agency's infrastructure assets. A gap analysis conducted in the first phase of the study revealed that many existing asset management systems are not being used to their full potential. A need was identified for tools that could be integrated with existing systems to improve an agency's ability to analyze and predict the impacts of investments at the network and program levels on overall system performance. This report and software will be very useful tools for analysts and decision-makers in three major functional areas within state DOTs: (1) policy, planning, and program development; (2) engineering (construction, maintenance, and operations); and (3) budget and finance.

Asset management is a business process that incorporates the economic assessment of tradeoffs among alternative investment options to help make cost-effective investment decisions. Governments at the local, state, and federal levels are investing significant sums of tax revenue in transportation infrastructure, and the public has a right to expect that the investment will be well managed. Increased constraints on budget and staff resources have created an environment where the efficient management of transportation assets is even more critical. The advent of increasingly powerful computer systems has made possible the development of sophisticated asset management systems to provide the information transportation agencies need to make the best use of their investment.

Agencies wishing to improve asset management practice have been constrained by the analytic limitations of their existing management systems. Current procedures in planning, program development, and program delivery may not be geared to investigation of the full range of investment options or to the analyses needed to compare and conduct tradeoffs among alternatives. While initial steps may have already been taken to define performance measures, agencies may lack the capability to conduct tradeoff analysis for different investment levels.

Under NCHRP Project 20-57, "Analytic Tools Supporting Transportation Asset Management," a research team led by Frances Harrison of Cambridge Systematics, Inc., began with a gap analysis to determine how existing tools were being used and what kinds of new tools were needed. This analysis included a review of the capabilities and limitations of currently available asset management tools. Finally, the team developed and field tested two analytical tools: AssetManager NT and AssetManager PT. AssetManager NT is a tool to analyze the investment versus performance across infrastructure categories in the highway mode over a 10- to 20-year timeframe. Asset-

Manager PT is a tool to demonstrate the impacts of investment choices on a short-term program of projects.

A companion CD-ROM included with this report contains the software tools and User Guides. The initial release of AssetManager NT includes “robot” tools to produce required inputs from the FHWA’s Highway Economic Requirements System for State Use (HERS/ST) program and the AASHTOWare Pontis bridge management system. AssetManager PT was developed to the prototype stage as a proof-of-concept tool. The report includes recommendations for future enhancements of the AssetManager tools and for resource materials that could facilitate their implementation.

AssetManager NT and PT were designed to improve a transportation agency’s ability to identify, evaluate, and recommend investment decisions for managing the agency’s infrastructure assets. It is hoped that, over time, the tools will be adopted and used by state transportation departments and further enhanced by AASHTO with support from its member agencies.

CONTENTS

ANALYTICAL TOOLS FOR ASSET MANAGEMENT

SUMMARY

NCHRP Project 20-57 was undertaken to provide new analytical tools to support asset management. The project's research objectives emphasized the need for tools that help agencies to make difficult tradeoff decisions for resource allocation while considering asset preservation concerns and the broader set of policy objectives (e.g., mobility, safety, and economic development) that must be taken into account when making investments in transportation assets. Analytical tools already have proved to be of great value for developing asset preservation strategies, understanding life-cycle costs of different design options, and analyzing benefits and costs of alternatives at the project and program levels. However, additional tools are required that address gaps in existing capabilities and help agencies to make better decisions using the information available to them.

This project involved two phases of activity. In the initial phase, the research team analyzed gaps in analytical tools to be addressed by the project and selected two tool concepts for development. In the second phase, the two tools were designed, prototyped, tested, and refined.

The Phase I gap analysis included the following activities:

- Interviews with staff at 10 state DOTs to obtain a broad perspective on how existing tools are being used and what kinds of new tools are needed. The interview findings are summarized in Section 2 of this report; Appendix A provides more details.
- A review of existing analytical tools for asset management and documentation of their capabilities and limitations. The results of this review are presented in Section 3 of this report, and detailed tool summaries are provided in Appendix B.
- An assessment of unmet needs for analytical tools, screening of candidate tool concepts, and selection of two tools for development. The gap analysis is summarized in Section 4 of this report.

A key conclusion of the initial phase was that many existing analytical tools are not being used to their full potential to influence investment decision-making. This underutilization is related to the capabilities of the tools themselves, the credibility of input

data and models, and organizational factors. The most successful tool applications occurred when an organization had made a sustained, multiyear commitment to integrating use of the tool within its decision-making processes and supporting an internal "champion" to improve the tool over time based on feedback from end-users and decision-makers.

In determining which of the many gaps to address within the confines of this project, a major consideration was the need to produce a generic tool that would work within multiple agencies; each of which has different business processes, data structures, and legacy systems. The differences across agencies were made very apparent in the interviews: there is no standardization of asset inventory, condition, and performance data (beyond the Highway Performance Monitoring System and National Bridge Inventory formats); there are very different degrees of acceptance of economic-based evaluation methods; and agencies are using existing asset management systems in very different ways.

Given that existing tools are in place but underutilized and that there are significant variations across agencies, the research team recommended an approach that would build on the existing capabilities in an agency and encourage the agency to make better use of the tools already in place. The recommended approach was intended to provide a concrete view of what asset management tradeoff analysis looks like, given that the inputs to this tradeoff analysis and even the underlying methods can and do vary across agencies.

The two tools developed in the second phase of the project—AssetManager NT and AssetManager PT—support tradeoff analysis at the long-term network level and at the program level, respectively:

- AssetManager NT works with 10- to 20-year simulation results from existing asset management systems and allows users to explore the consequences of different levels of investment within and across asset classes. Companion "robot" tools also were developed to produce the inputs needed by AssetManager NT from FHWA's Highway Economic Requirements System for State Use tool and from the AASHTOWare Pontis bridge management system. The field testing process demonstrated the feasibility of producing the necessary inputs for AssetManager NT from commercial pavement management systems as well.
- AssetManager PT works with sets of candidate projects being considered for implementation over a 1- to 3-year period and allows users to explore the consequences of different project mixes. A fully functional prototype was developed for this second tool.

Detailed descriptions of these tools and documentation of the testing process are provided in Sections 5 and 6 of this report. A companion CD bound with this report contains the appendices to this report, the tool software, and user guides.

This report concludes with recommendations for continuing the work begun in Project 20-57. These recommendations include providing a continuing mechanism to support users of AssetManager NT and PT, converting the working prototype of AssetManager PT to a full-scale version, enhancing the functionality of both tools over time, and providing additional implementation support resources. To provide a resource for development of future research agendas, the concluding section of this report also summarizes the gaps in analytical tools that were not addressed by this project.

SECTION 1

INTRODUCTION

1.1 RESEARCH OBJECTIVES

The objective of the NCHRP Project 20-57 was "to develop a set of user-friendly analytical tools for adaptation and use by state DOTs and other transportation agencies that will improve their ability to identify, evaluate, and recommend investment decisions for managing the agency's assets. The tools should incorporate analyses of the tradeoffs associated with (1) different approaches to sustaining an asset through its service life, such as capital improvements versus preventative maintenance treatments; and (2) competing policy objectives such as preservation, mobility, access, safety, and economic development. The primary emphasis should be on the analysis of tradeoff decisions within the highway mode, but also should include limited development of tools for making multimodal investment tradeoff decisions. The tools should be compatible, to the greatest extent possible, with the existing range of legacy systems (pavement, bridge, and other asset management systems) currently used by state DOTs, and be easily used by practitioners with varying levels of technical capability."

The research objective recognizes the wide range of goals and activities necessary for successful asset management. It also recognizes the existence of numerous useful legacy systems and procedures and the need for a project such as this that can very opportunistically select and accomplish the most important and cost-effective improvements to overall asset management.

NCHRP Project 20-24(11), completed November 2002, established a comprehensive framework for transportation asset management. This framework defines asset management as a strategic approach to managing transportation infrastructure and identifies the essential elements of good asset management practice, including

- Consideration of a wide range of options for addressing transportation needs and problems;
- Analysis of investment options based on established performance objectives;
- Explicit consideration of investment tradeoffs across programs, modes, and strategies; and
- Use of economic and engineering criteria to evaluate investment options from a long-term, life-cycle perspective.

Analysis tools that help agencies to understand the implications of different investment options are a cornerstone of effective asset management practice. These tools can contribute to strengthened business processes in several areas: integration of information on transportation modes or programs; analyses of economic and other impacts of investment decisions; investigation of optimal strategies in areas such as preventive maintenance; and assessment of investment tradeoffs across programs, modes, or investment options. Most state DOTs have management systems in place that provide useful capabilities for assessing needs and recommending work for specific asset types (e.g., pavements, bridges, and public transit or aviation facilities) and specific functions (e.g., highway, airfield, or rail maintenance). In addition, specialized tools for benefit/cost analysis, life-cycle cost analysis, and investment performance analysis for selected types of strategies are in use.

As a rule however, existing tools are not well suited to helping with decisions that cross the boundaries of asset type (e.g., pavement versus bridge), mode (e.g., highway versus transit), work class (e.g., maintenance, operations, or construction), or objective (e.g., safety, preservation, or mobility). Such cross-boundary decisions include

- **Preservation versus mobility.** How to make explicit tradeoffs across programs that may have very different objectives and performance measures (i.e., the "apples versus oranges" problem).
- **Maintenance versus capital.** How to determine the best mix of routine maintenance and capital investments in infrastructure for least life-cycle costs and how to assess the cost-efficiency of different preventive versus deferred maintenance policies.
- **Cost-effective solutions.** How to determine the most cost-effective solution to a problem, without being constrained to a particular class of solutions (e.g., operational, maintenance, or capital).
- **Best combinations of projects.** How to identify packages of projects that can result in the highest long-term benefits and cost savings (e.g., by coordinated scheduling of work for a particular location) and how to identify groupings of projects of different types that have synergistic effects.

- **Impacts of project needs criteria and design standards.** How to explore how variations in design standards or project needs criteria might affect long-term costs and system performance measures.
- **Multiobjective evaluation.** How to understand the impacts of a given mix of projects, recognizing that (1) each project may have both positive and negative impacts with respect to different performance objectives and (2) cross-project elasticities may be at work (one project may have the effect of reducing or increasing the effectiveness of a second project).

Some agencies are pursuing new performance-based approaches to asset management and are seeking improved tools for addressing the cited types of questions. The capabilities of existing management systems and tools need to be strengthened, supplemented, and better integrated to address gaps in current decision-support capabilities. For example, although considerable effort is being expended to define and collect data on performance measures and although such measures are used for technical evaluations and tactical decisions, tools are lacking for more strategic applications such as tradeoff analyses.

New tools must be easy to implement and suitable for integration into transportation organizations with varying databases, systems, and decision-making processes. These tools must complement, enhance, and extend, rather than duplicate, existing tools and systems. Additionally, these tools should apply to several levels within the transportation organization. Several types of tools were therefore considered in this research effort:

- **Simulation models** that provide detailed analyses of the performance, costs, and impacts of decisions regarding transportation systems. These types of models are very useful for analyzing complex problems with many interactive elements; however, they typically require considerable input data and either a well-structured set of decision rules or repetitive runs to analyze different options.
- **Sketch-planning tools** also embody analyses of performance, costs, and impacts of transportation decisions, but at a less detailed level. They are easier and quicker to use and can be used to explore several options quickly and effectively. These tools may be built as computer applications, spreadsheet workbooks, or manuals of heuristic procedures.
- **What-if tools** can be used when very simple and easy-to-use analytic procedures are needed. Existing simulation or sketch-planning tools are applied repetitively to “solve” a particular problem; this “solution” can then be embodied in a very simple format for application by end-users. For example, the FHWA’s National Bridge Investment Analysis System (NBIAS) uses mathematical techniques to “solve” bridge investment problems as a function of key parameters. These “solutions” are then incorporated in very efficient mathematical relationships so that an end-user investigating bridge investment options in effect “sees” the implications of his or her decisions in real time. The user can fine-tune the investment parameters to achieve an optimal result quickly and effectively. With its ability to relate outputs and outcomes to decision inputs in real time, NBIAS is useful as a communications tool to policy-makers and as a decision tool to managers. Another way to apply this approach is to exercise simulation models repetitively to obtain solutions to a set of problems and then to display these several results in a convenient format (e.g., simple parametric curves, diagrams defining preferred solutions for particular combinations of inputs, or “rules of thumb” procedures).
- **Databases** can be organized to compile information on particular topics, such as highway performance standards by functional classification. Such databases can be helpful in designing and building more effective analytic components of asset management, as well as housing current information after implementation for use in cross-sectional and trend analyses.

This research has identified areas in which additional analysis support would have the most impact on asset management practice. The research has focused on building capabilities likely to be deployed in numerous agencies and unlikely to be addressed soon by other tool-development efforts.

Figure 1 illustrates a high-level vision for how new analytical tools will work with core asset information, agency business rules, and national or agency-specific parameters to provide improved decision-support capabilities.

1.2 OVERVIEW OF THE RESEARCH APPROACH

The research effort was divided into two phases. The initial phase was a 6-month process to recommend a set of tools for development, based on both an assessment of current needs and a review of existing tools. The second phase of the research consisted of a 24-month effort to design, prototype, field test, refine, and deliver the final tools.

Needs Assessment

In conducting the needs assessment, the research team analyzed key aspects of a DOT’s business processes to identify likely candidates for analytic techniques to be developed in this project. Figure 2 illustrates a generalized model for asset management decision-making that provided a framework for the needs assessment.

Key processes in this model follow:

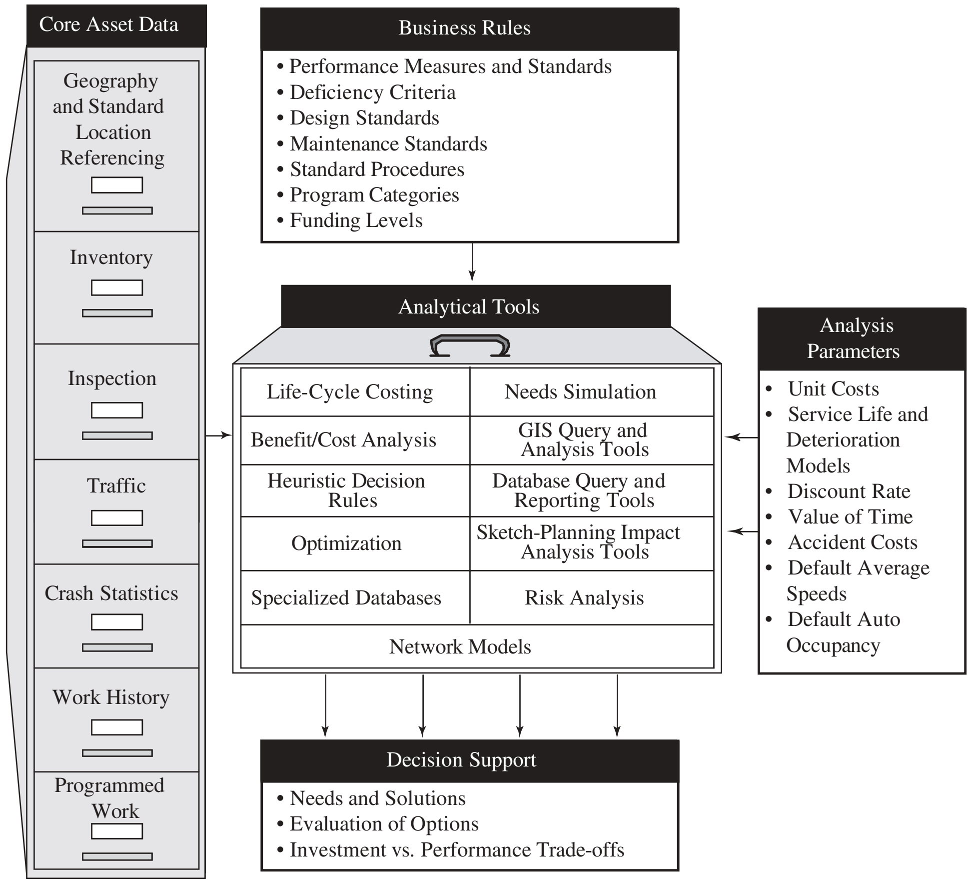

Figure 1. Context for analytical toolbox.

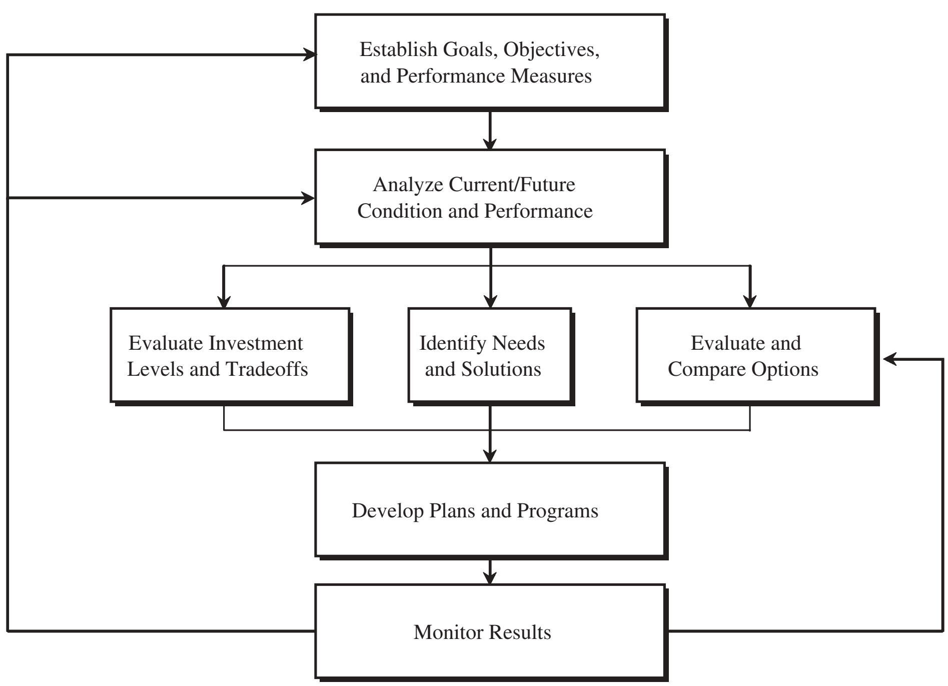

Figure 2. Generalized asset management model.

- **Establishing goals, objectives, and performance measures** to provide policy direction and an evaluation framework for asset management.
- **Analyzing current and future system condition and performance** on an aggregate level and at individual locations.
- **Evaluating investment levels and tradeoffs** to understand the relationship between funding levels for particular categories of work and likely outcomes. This analysis may be used to guide establishment of funding levels for different program categories. It also can assist in establishing performance targets (for different groups of assets) that reflect realistic budget levels.
- **Identifying needs and solutions**.
- **Evaluating and comparing options** by assessing the potential impacts of alternative solutions to identified problems. The term "solutions" here is used in a broad sense, including specific capital projects, operational strategies, preventive maintenance programs, or coordinated programs of activities (e.g., high-occupancy vehicle [HOV] lanes with park-and-ride lots).
- **Developing plans and programs** through assembly of a coordinated set of solutions constrained by a budget. This development could involve selecting projects from the pool of recommended solutions, scheduling work to achieve maximum coordination and economies of scale, and evaluating the aggregate performance impacts of different mixes of work.
- **Monitoring results** by (1) collecting information on the costs and effectiveness of projects or strategies that have been implemented, with a feedback loop into the project evaluation activities, and (2) collecting current system performance information, which is used to analyze current and future performance and to revisit and refine program objectives and priorities.

This model allows for variations in the extent and methods by which these activities are performed. For example, one agency might wish to conduct separate analyses of needs, investments levels, and solutions for pavements, bridges, and maintenance activities and then combine them at the program development stage. A second agency might collect data on conditions and deficiencies separately but conduct integrated analyses across the three areas to identify and evaluate solutions that address multiple objectives. Needs for analytical tools for these two cases could vary. In the first case, the emphasis would be on building solid investment and strategy analysis capabilities within pavement, bridge, and maintenance management systems. In the second case, tools would be needed that would (1) support geographic information system (GIS)–based integrated analysis of deficiencies and (2) provide the capability to analyze the combined effects of both capital and maintenance activities on pavements and bridges with respect to a consolidated set of performance measures.

Table 1 provides examples of different methods and associated analytical tools for the three core processes shown at the center of Figure 2: Evaluate Investment Levels and Tradeoffs, Identify Needs and Solutions, and Evaluate and Compare Options. For each of these processes, different methods and core analytical tools might be employed. Some of the analytical support functions in Table 1 are in existing systems and tools, at least for certain types of assets or classes of work. The needs assessment task identified areas where expanding or further integrating these capabilities would add value to asset management decision processes and drew conclusions about which analytical support functions are highest priority candidates for new or improved tools.

Review of Existing Relevant Research and Tools

After the needs assessment, a review of existing research and tools was conducted to ensure that this project would complement and build on the extensive base of experience and resources. The review examined work in five categories:

- Decision-making frameworks and practices for asset management and performance-based planning,
- Benefit/cost analysis or multiobjective ranking tools for individual projects or strategies,
- Life-cycle cost analysis procedures and tools,
- Investment analysis tools that can generate needs and work candidates based on engineering and economic criteria and assist with analyzing the relationships between investment levels and system performance, and
- Tools that can display and analyze integrated information across multiple management systems.

In each of these categories, the review included tools designed for network-level, program-level, and project-level analysis.

Collectively, these existing tools and research efforts provide an extremely strong base on which to build. This research endeavored to take advantage of the knowledge gained from these efforts to advance the state of the practice. Application of modern software technology provides tremendous opportunities to create a new generation of tools that are more flexible, modular, and adaptable to different needs and environments than those developed in the past.

Tool Development

The final tools were developed in the following stages:

1. Conceptual design and rough development costing analysis,
2. Selection of tools for further development,
3. Requirements specification and detailed design,

TABLE 1 Asset management methods and analytic support tools

Process	Methods	Analytical Support Tools
Evaluate Investment Levels and Tradeoffs	• Back-of-the-envelope analysis of budget level versus output	• Queries to database with average costs per unit of output (e.g., miles of resurfacing, square feet of deck area for bridge replacement)
	• Bottom-up method: identify projects within a set budget limit and estimate aggregate output and performance impacts	• Network and sketch planning tools to assess impacts of multiple projects
	• Optimization/ Simulation – project level	• Tools that select an optimal set of projects to meet a defined budget or performance target and that report both specific projects and aggregate costs and performance impacts of the selected projects
	• Optimization/ Simulation – network level	• Tools to analyze performance versus cost tradeoffs at an aggregated level (not location-specific)
Identify Needs and Solutions	• Informed engineering judgment	• Database and GIS queries of condition and performance
	• Application of standards, warrants, or rules of thumb for deficiencies and preferred solutions	• Automated identification of deficiencies and solutions based on inventory and inspection data • Database and GIS queries of deficiencies based on standards
	• Simulation/Optimization	• Automated identification of deficiencies and solutions, and recommendation of preferred solution based on economic criteria or decision rules
Evaluate and Compare Options	• Informed engineering judgment	• Queries of "knowledge base" on strategy costs and impacts • Template to display "guesstimates" of strategy costs and impacts
	• Life-cycle cost analysis	• Queries of specialized database(s) with average costs and service lives for different strategies • Simulation of alternative activity profiles over time • Automated calculation of equivalent uniform annual cost, net present value
	• Benefit/cost analysis	• Queries of specialized database(s) with average costs and impacts for different strategies • Automated calculation of strategy impacts, benefits, and costs
	• Multiobjective ranking • Multiobjective impact tableau	• Automated calculation of strategy rating/ranking given set of objectives, performance measures, weights, and impacts • Queries of specialized database(s) with average costs and impacts for different strategies • Tools to predict likely impacts of different strategies (e.g., network models, sketch-planning tools) • Template to display strategy impacts for consistent set of performance measures

4. Development of fully functional prototypes,
5. Field-testing,
6. Refinement based on test results,
7. Documentation, and
8. Product delivery.

Task Summary

The following tasks composed the work plan for this research:

1. Develop Needs Assessment Methodology,
2. Conduct Needs Assessment,
3. Review Existing Analytical Procedures and Software,
4. Recommend Tools for Development,
5. Interim Report on Tasks 1-4,
6. Preliminary Design and Test Plan,
7. Interim Report on Task 6,
8. Revised Design and Prototype Development,
9. Technical Memo on Task 8,
10. Field Test Prototypes,
11. Tool Refinement, and
12. Final Report and Tool Delivery.

1.3 CONTENTS OF REPORT

This report is the deliverable for Task 12; it documents the findings of all tasks of the research effort.

Section 2 summarizes the needs assessment methodology and its findings, including the survey of states and the literature review (Task 2).

Section 3 summarizes the findings of the review of existing analytical tools and software (Task 3).

Section 4 compares the identified needs to the existing tools to identify gaps in current capabilities and describes the process by which concept plans for new tools were recommended (Task 4).

Section 5 describes the tools that were developed (Tasks 6, 8, and 11).

Section 6 describes the testing process (Task 10).

Section 7 presents recommendations for future research on analytical tools for asset management, including work to further enhance the tools and encourage their adoption.

Appendix A presents summaries of the detailed agency survey results conducted for Task 2.

Appendix B presents summaries of the existing analytical tools reviewed for Task 3.

User guides for AssetManager NT and AssetManager PT were prepared as companion documents to this final report.

A companion CD includes the appendices to this report, the two user guides, and copies of the tools. This CD also includes a copy of draft XML schema developed as a starting point to describe data requirements for the asset management performance tradeoffs domain.

SECTION 2

NEEDS ASSESSMENT

2.1 OBJECTIVES OF THE NEEDS ASSESSMENT

The purpose of the needs assessment was to gain a better understanding of state DOT needs with respect to analytical tools for resource allocation. The needs assessment was focused on providing the research team with a clear idea of

- The types of information that agencies would like to have to improve asset investment decisions,
- The degree of the agencies' receptivity to different types of analysis methods and procedures for investment decision support as well as the likely degree of influence that analysis results would have on agency decisions,
- The typical requirements for integration with existing data and systems, and
- The desirable features of existing tools and the shortcomings that might be addressed by new or modified tools.

2.2 NEEDS ASSESSMENT METHODOLOGY

The needs assessment methodology was designed to build upon the already established experience of the research team and to provide direction for the remaining tasks in a highly efficient manner. It was not intended to produce an in-depth or comprehensive study that is fully representative of the needs and opinions of any individual state DOT and certainly not of all state DOTs. Rather, its goal was to provide insights from a variety of perspectives that could be used to guide the research team in identifying and prioritizing new types of tools for development.

The needs assessment effort consisted of the following activities:

- Literature review and summary,
- Structured interviews with target users at state DOTs, and
- Exploratory discussion with target users at conference sessions.

Each of these activities is described in the following paragraphs.

Literature Review and Summary

Recent research efforts have involved surveys of state DOT personnel on issues related to the use of decision support tools for asset management. The research team identified and summarized eight relevant studies documenting these efforts.

Structured Interviews

The primary data collection effort for the needs assessment involved interviews with target users at 10 state DOTs. Representatives from five of these DOTs were interviewed in-person; remaining interviews were by telephone.

Selection of States

Seventeen DOTs were identified as candidates for the interviews, as shown in Table 2. These DOTs represent a range of variation in size of system and transportation budget, geographic location, degree of urbanization, current use of economic analysis and analytic tools, approach to asset management, and degree of funding flexibility across modes and project types.

Based on comments from the panel, a target set of 10 DOTs was identified based on the following criteria:

- Geographic distribution,
- Variation in size of budget (with FHWA apportionment as a proxy for this),
- Inclusion of at least two DOTs that have not been adopting the asset management principles and framework as specified in NCHRP 20-24(11), and
- Variation in the extent to which resource allocation and project selection decisions are centralized versus made at the district level.

States targeted for interviews were

- Michigan,
- California,
- Massachusetts,
- Montana,

TABLE 2 Candidate states for needs assessment interviews

Size (FY 2001 FHWA Apportionment)	AASHTO Region			
	Mississippi Valley	Southeastern	Northeastern	Western
< $400 Million	Kansas	South Carolina	Vermont	Montana Colorado
$401-$900 Million	Wisconsin	Virginia	Massachusetts Maryland	Arizona Washington
>$900 Million	Michigan Ohio	Florida	New York Pennsylvania	California

- Wisconsin,
- Ohio,
- New York,
- South Carolina,
- Florida, and
- Maryland.

Users Interviewed

Interviews were conducted with potential users of new analytical tools—both the direct, hands-on users and the decision-makers who would be requesting and receiving information from the tools. These users and decision-makers include representatives of the following three major functions:

- Policy, planning, and program development;
- Engineering (construction, maintenance, operations)
  - Chief engineers or their designees
  - District engineers or their designees (in states where districts have significant resource allocation latitude); and
- Budget and finance.

While the primary emphasis of this research was on analytical tools to support decision-making within the highway mode, the target interview subjects included individuals in each state who could comment on the level of use and/or interest in tools to support multimodal investment tradeoffs.

For each state selected for inclusion in the needs assessment, the research team identified a primary contact person, with the assistance of the project panel and based on our established network of contacts. This primary contact person helped to identify two to four target users who could adequately assess their state's needs from the three previously stated perspectives. Interviews were then arranged for the target users. As noted, representatives of at least five of the selected states were interviewed in person. Because of the content of the survey, group interviews were conducted where possible to encourage discussion across different perspectives. However, individual interviews were conducted in a few cases where scheduling a group interview presented a problem.

Interview Structure and Content

Interviews consisted of four parts:

1. The first set of questions determined what types of decision support systems are in place. Tools in place were related to the level of interest in new tools; for example, if the agency already uses project-level benefit/cost analysis and indicates a low level of interest in new benefit/cost tools, the agency finds benefit/cost analysis useful, but not a capability in which it is experiencing an important gap. The systems in place also were useful for understanding integration needs for new tools.
2. The second set of questions related to the agency's current approach to asset management. These questions addressed whether the agency's current business processes would easily fit with the kinds of functions envisioned for the analytical tools to be developed in this project. For example, if an agency is not analyzing tradeoffs across categories and has no flexibility to reallocate funds across categories based on expected performance, a tool that performs such tradeoff analysis would not be expected to have a high degree of impact on resource allocation decisions.
3. The researchers presented a matrix showing different types of analyses that new analytical tools might support. Respondents were asked about their level of interest in new or enhanced tools in each category. They also were asked to suggest desired features of the tools in which they expressed a high degree of interest.
4. The final series of questions was designed to learn about the specific requirements of tools to be developed. These questions covered the shortcomings of existing tools that are to be avoided, integration issues, and the platform for the new tools. Some open-ended questions were included to elicit the respondent's viewpoint about the most desirable qualities of new tools.

The researchers used an interview guide to ensure collection of a consistent set of information that could be summarized across respondents. This guide was sent to respondents before the interviews.

Exploratory Discussions

Needs and requirements for analytical tools also were discussed with target users as part of the following forums (which included wide national representation of high-level managers involved in asset management from state DOTs):

- At the National Highway Institute (NHI) Pilot Training Course on Asset Management (Lansing, Michigan, June 2002), participants were asked to identify the top two asset management decisions that they need better analytical tools to address.
- At the joint summer meeting of the AASHTO Task Force on Asset Management and the TRB Committee on Asset Management held in conjunction with the meeting of the TRB Planning and Management Committees in Providence, Rhode Island (July 2002), informal discussions on needs for analytical tools were held with attendees. Results of these discussions are not detailed in this report but were used to supplement the state interview findings and reviews of tools in the next section.

2.3 LITERATURE REVIEW

The literature review was aimed at supplementing the survey of 10 states conducted for this research. Thus, it focused on fairly recent efforts (over the past 5 years) that have surveyed groups of states on issues related to the use of analytical tools for asset management. Eight studies were identified and are summarized below.

1999 AASHTO Survey of States on the Use of Management Systems and Decision Tools (*1*)

The survey was sent to 50 states, and 30 responses were received (thus, there may have been some self-selection bias towards states that were using decision tools). The findings of the survey were presented at the Scottsdale Peer Exchange workshop on asset management. Highlights of these survey findings follow:

- Nearly all of the respondents had a pavement and bridge management system; 70 percent had a safety management system; 70 percent had a maintenance management system; and 57 percent had a congestion management system. The number of states that reported having safety and congestion management systems was substantially lower than that found in the 1997 General Accounting Office survey (*2*) on state implementation of transportation management systems (96 percent and 90 percent, respectively).
- The majority of respondents (80 percent) said they were able to assess the impacts of investments using management systems. Of this majority, 84 percent do so for pavements and 68 percent do so for bridges.
- Eighty-two percent of respondents were using at least one decision support tool. Tools that analyze benefits/costs and life-cycle costs were the most commonly used (each was used by roughly 80 percent of all respondents). Eight of the thirty states (27 percent) used tools to analyze tradeoffs; four (13 percent) used tools to analyze quantitative investment.

Survey on the Use of Bridge Management Systems (BMSs) at State DOTs (*3*)

This paper, presented at the 8th International Bridge Management Conference in Denver, Colorado (1999), documented the use of bridge management systems in 26 states and reported that, although BMSs were in place in most agencies, the systems had not yet been used to their full potential. However, a number of the respondents indicated the interest and intention to expand the use of their BMS, and progress has been made since the time of the survey. Highlights of the survey follow:

- Fifteen of the twenty-six agencies employ a strategic planning process that includes a bridge component. Eleven of these agencies use quantitative goals in this process, typically related to sufficiency ratings, health index, or the number of deficient bridges.
- Fifteen of the respondents house their BMS in the bridge division/department; six maintain the BMS in the design department; and the remaining five operated the BMS in their maintenance or operations divisions. Primary BMS users are bridge engineers or bridge maintenance engineers. Typically, a single individual is responsible for the BMS, and this individual typically has multiple other responsibilities and limited time to devote to BMS activities.
- About one-third of the respondents use their BMS as part of their bridge management business process.
- Four of the twenty-six states use the BMS for State Transportation Improvement Program/Transportation Improvement Program (STIP/TIP) development; most of the other agencies generate bridge programs based on sufficiency ratings or state-specific prioritization formulas in conjunction with engineering judgment and inspector recommendations.
- Fifteen respondents had a maintenance management system (MMS), but only two of these indicated that the MMS information was compatible with the BMS and could be electronically linked to the BMS.

Synthesis of Asset Management Practice (*4*)

This synthesis examined current practice in asset management based on site visits to seven states and a literature review covering international experience and private sector efforts.

Findings relevant to the design of analytical tools to support asset management practice follow:

- Several states are moving from a project-centric view to a more strategic approach to asset management, including highway "tiering" systems or corridor designation systems that go beyond functional classification and provide a structure for performance monitoring, targets, and investment strategy development.
- Experience in Washington and Colorado DOTs indicates the value of establishing program categories that are consistent with high-level policy objectives. A Colorado DOT effort to establish a customer-oriented, performance-based investment category structure was noted for its support for effective tradeoff analysis and resource allocation. Investment categories were organized by policy objective as opposed to asset or project type: mobility, system quality, safety, strategic projects, and program delivery. For example, pavement, bridge, tunnel, rest area, and roadside maintenance activities are all grouped within a system quality investment category.
- States interviewed were making an effort to shift their program philosophies to put greater emphasis on preventive preservation and lowest long-term cost, as opposed to a reactive or "worst first" approach. Experience has shown that, although moving to a preventive approach is justified economically and technically, the decision to work on assets in good condition while those in poor condition are left alone is politically difficult. Analytic studies conducted by Washington and Michigan DOT staff have been helpful in building support for these new approaches.
- Almost all of the states visited had plans to upgrade their asset management systems or support tools. Use of data warehouses to consolidate asset inventory information (and in some cases project information) from different systems was a common theme, as was use of GIS platforms to provide integrated views of information from disparate systems.
- Existing asset management systems are not typically geared for use by high-level managers to support resource allocation and program tradeoff analysis. The need for this type of capability is likely to increase given new initiatives in asset management and requirements of Government Accounting Standards Board Statement 34. An example of a successful executive information system (EIS) in Washington was cited, as was a prototype EIS developed as part of a study for the Transportation Association of Canada (TAC) (*5*).
- An Organisation for Economic Co-operation and Development study (*6*) of 13 member countries noted that all respondents were using management systems for individual asset classes, but that no country had introduced an integrated system for their entire road network. The study recommended that future integrated asset management systems be developed that
  – Incorporate performance indicators and the capability to monitor performance,
  – Provide the ability to analyze maintenance options based on life-cycle costs and develop maintenance programs based on best value for the money spent, and
  – Provide the capability to value assets and depreciate this value with time or use.
- Specific asset management frameworks are described for Australia, New Zealand, Canada, and the United Kingdom—countries that have done extensive work in the asset management area.

TRB Task Force on Transportation Asset Management Report of FY 2001 Activity

This report compiled information on best practices in asset management from subcommittee members, a review of DOT web sites, and information from a Volpe National Transportation Systems Center research effort conducted in 1999 in preparation for the Asset Management Peer Exchange. The following best practices that were reported are most relevant to development and use of analytical tools:

- Use of management systems and related tools to support development of long-range strategic systems plans (Michigan, Washington) or medium-term programs (New York, Montana) based on performance or condition objectives;
- Establishment of data standards (Michigan Architecture Project);
- GIS/management system integration efforts in Arizona, Maryland, Michigan, Wyoming, and Minnesota;
- Coordinated interagency effort to establish a common GIS framework (Michigan Geographic Framework Program);
- Integrated program and project information system to handle both program development and implementation-related information (New York); and
- Meta-manager to analyze physical deterioration and safety, conduct congestion modeling, evaluate improvement alternatives, assess costs, develop priorities, and define budget needs (Wisconsin).

This report also commented on the limited progress made to date in effectively using existing management systems because of the lack of organizational alignment around an asset management approach: "Too often pavement management systems become the territory of pavement experts and bridge management systems, of bridge experts. The result is often that the systems are not used by organizations to make real investment decisions. The wealth of information that they could contribute is lost and investments are too often suboptimized."

State-of-the-Practice Review 2001 (*7*)

NCHRP 8-36 Task 7, Development of a Multimodal Tradeoffs Methodology, summarized the methods, tools, and procedures used by state DOTs to address multimodal tradeoffs, building on prior research efforts (including *NCHRP Synthesis of Highway Practice 286* [*8*]), and developed a framework for multimodal tradeoffs. Key conclusions of interest follow:

- An overall structure is needed to link asset management information systems, travel demand forecasting systems, traffic simulation models, economic analysis models, and various other related analytical tools in an integrated manner to better address decision-making needs. In many cases, these analytical capabilities exist in parallel but are not effectively integrated. If systems were better integrated and linked, tradeoff analyses would be less cumbersome, more accurate, and more likely to be pursued by DOT staff and decision-makers.
- Multimodal tradeoff analysis varies considerably from state to state: several states have made significant advances in multimodal planning and development of support tools, whereas other states have no involvement in multimodal tradeoff decisions.
- Many tools—such as management systems, travel forecasting tools, and benefit/cost techniques—can support multimodal tradeoff analysis, but these tools have not yet been integrated in a manner that would support program-level modal tradeoffs that reflect a broad range of policy objectives.
- Significant work has been accomplished in developing specific impact analysis tools and piecing together information for specific corridor studies, modal needs studies, statewide plan development efforts, and so forth; however, no state has developed a strategic, top-level, ongoing view of major tradeoffs around core agency objectives.
- State DOTs cited deficiencies in data and analytic tools as the second most serious constraint to multimodal planning.
- Development of technical tools and data to support multimodal planning should follow a dialog between customers and stakeholders (providers) of the transportation system.

Multimodal Transportation: Development of a Performance-Based Planning Process (1999) (*9*)

Phase I of NCHRP Project 8-32(2) conducted 20 case studies and 8 workshops on the topic of how performance measurement had been incorporated into planning decision-making. The following key findings are relevant to analytical tools:

- Generation and analysis of system performance data are major obstacles to implementation of outcome-based, user-oriented performance measures. The analytical methods and tools need to be refined, and these tools need to be made more readily available to a range of users.
- Replacing an inherently complex, political process with one that is overly simplified or purely quantitative is not desirable. While performance measurement can bring higher quality information to the decision process, it is most valuable as an input to the existing process and should not replace those more deliberative, qualitative processes.
- A more flexible approach to data collection, analysis, and reporting procedures in support of performance-based planning would allow public planning agencies to evolve and respond more quickly to changing needs and expectations of their customers.
- The tendency to use output and efficiency measures of the analytic system as opposed to outcome and effectiveness measures meaningful to users is in part due to limitations in data and analytical models, as well as the high initial and ongoing costs of applying and maintaining certain types of tools. The research found several cases where agencies wishing to adopt measures of accessibility and mobility were constrained not only by the lack of current data but also by the inability to estimate values for important data under hypothetical future scenarios.

NCHRP Synthesis of Highway Practice 243: Methods for Capital Programming and Project Selection (1997) (*10*)

This synthesis included a survey of 39 agencies on approaches to capital programming since the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). Key findings related to use of analytical tools for asset management follow:

- Most agencies have management systems in place and use them to track facility conditions. Pavement and bridge management systems were being used in half of the states to help set reconstruction and rehabilitation project priorities. Use of these systems to help define program-level funding was increasing in prevalence. However, use of management systems for more strategic-level decision-making such as performance measurement and investment tradeoffs across programs or modes was not well developed.
- Sufficiency rating and deficiency rating methods were widely used for setting priorities. Benefit/cost techniques were in use primarily for safety improvements. Only two surveyed states were not using any quantitative methods for setting priorities.

- Although states were improving their ability to examine a wider range of solutions and modal tradeoffs, the survey found significant barriers to multimodal programming. These barriers included institutional, organizational, and funding constraints as well as the "continued need for more effective technical tools and data to support multimodal analysis within reasonable resource constraints."
- The use of quantitative criteria for establishing goals and measuring performance was increasing but was not as comprehensive or as widespread as might be expected.

State-of-the-Practice Survey on Statewide Multimodal Planning (1999, 2000) (*11*)

This survey was conducted by the Washington State Transportation Center for the Washington State DOT as part of a research effort to develop a multimodal tradeoff decision process. A survey was mailed to all state DOTs, and 38 states responded. The survey was updated in 2000 based on follow-up calls to selected agencies (*12*). The authors summarize the results of this survey by stating, "There are more state DOTs that are uninterested in developing a multimodal program analysis tool than there are states that are interested." Specific conclusions of the survey follow:

- Many states lack interest in analyzing multimodal tradeoffs because dedicated funding is used to support specific program areas; therefore, there is no cross-modal competition to provide the motivation for tradeoff analysis.
- For some states (e.g., Minnesota, Rhode Island), multimodal planning responsibility is primarily at the metropolitan planning organization (MPO) level rather than at the state DOT level.
- Program tradeoffs, where they do occur, are made in a subjective, ad hoc environment.
- Only one state (New Jersey) reported that it currently analyzes multimodal tradeoffs. A handful of states surveyed expressed interest in developing a multimodal tradeoff methodology.

The two highest ranked impediments to implementing multimodal planning activities were (1) inadequate departmental resources and (2) lack of multimodal data and adequate tools.

2.4 STATE INTERVIEW FINDINGS

Structured interviews with representatives of 10 state DOTs were conducted in the summer and fall of 2002. These interviews yielded useful insights into the needs for new analytical tools and the factors that contribute to the success or failure of analytical tools for asset management. Detailed results of each state interview are provided in Appendix A. Tables 3 through 5 summarize the results. Key findings and their implications are discussed in the following paragraphs.

These interviews do not represent in-depth case studies and may not be fully representative of activities or needs in the subject states; the views expressed may not represent the official opinion of the agencies. In virtually all of the interviews, opinions and perspectives among the different interviewees representing an individual state varied significantly—not only regarding the perceived needs for new tools, but also regarding current asset management practice and use of existing tools. Nevertheless, the objectives of the interviews were achieved—to provide a picture of the types of information needed to improve asset management decisions, the degree of receptivity to different types of new analytical tools, and the specific types of features desired.

Current Use of Analytical Tools

Current (as of 2002) use of analytical tools is summarized in Table 3. Nearly all of the 10 states had pavement and bridge management systems, and most used these systems (in varying degrees) to support project prioritization and analyses of the relationship between investment levels and system performance. Several states had congestion, safety, and/or maintenance management systems that were used for prioritization or investment analysis. One state (Maryland) was developing a drainage management system.

Six of the ten states reported use of benefit/cost analysis tools to evaluate some types of projects or strategies. Five of the ten states have GIS-based tools for displaying and analyzing the outputs of various asset-specific management systems in order to support the program development process. Such systems are used by district staff to identify projects that reflect multiple types of needs (e.g., pavement and safety) and, in some cases, analyze the predicted impacts of a set of projects on system performance. All of the states analyzed life-cycle costs but typically only for large pavement projects, consistent with federal requirements. Two of the states were conducting or evaluating life-cycle cost analysis for bridges.

None of the states reported using analytical tools to evaluate the impacts of alternative policies or standards for project scope, timing, and design. None of the states had formal tools for analyzing budget tradeoffs across different program categories. Only two of the states had tools that supported feedback of information on actual project costs and/or effectiveness back into management systems.

Interest in New Analytical Tools

The degree of receptivity to new analytical tools and the specific types of information desired by each state are summarized in Table 4. (Additional comments on gaps in capabilities are synthesized in Section 4.1.) Respondents were

(text continues on page 20)

TABLE 3 Current (as of 2002) use of analytical tools

Type of Analysis	California	Florida	Massachusetts	Maryland	Michigan	Montana	New York	Ohio	South Carolina	Wisconsin
Investment level versus predicted performance within a program category	PMS BMS ITMS	PMS BMS MMS		PMS DMS SWS	PMS BMS Road Quality Forecasting System (RQFS)	PMS BMS SMS (manual) CMS (manual)	CMS (CNAM)	District multiyear work plan Funds mgt. spreadsheet analysis PMS (future capability)	PMS BMS MMS	PMS SMS CMS
Performance tradeoffs for different budget allocations across program categories					Spreadsheet analysis					
Predicted impacts on system condition, safety, mobility, economic growth, etc., for a set of proposed projects	ITMS	Decision Support System (DSS)				Systems performance query tool (semi manual)	Program support system/ project management information system (PSS/PMIS)			Meta-manager
Project/ strategy evaluation	California Life-Cycle/ Benefit/Cost Analysis Model (Cal-B/C) ITMS	Micro-BENCOST for construction office Present worth spreadsheet for pavement analysis		In-house tools for pavement and safety B/C analysis		SMS	In house B/C analysis tools		High-hazard safety projects B/C analysis	Highway Investment Analysis Package (HIAP) Micro-BENCOST In-house spreadsheet B/C tools

(*continued on next page*)

TABLE 3 (Continued)

Type of Analysis	California	Florida	Massachusetts	Maryland	Michigan	Montana	New York	Ohio	South Carolina	Wisconsin
Project prioritization within or across project types	PMS BMS MMS (IMMS) In-house tools for calculating Safety Index, Delay Index ITMS APMS	PMS BMS MMS CMS	PMS SMS CMS (Boston MPO)	PMS BMS SMS DMS* SWS	In-house tools based on info from transportation management system, PMS, BMS	PMS BMS SMS	CMS (CNAM) Prototype tool for cross-project prioritization based on excess user costs	District multiyear work plan	PMS BMS MMS SMS	PMS BMS CMS
Life-cycle cost (LCC)	Spreadsheet analysis for pavements	Value engineering (for projects > $20 million) Workbook describing recommended approaches	LCC for major projects	FHWA pavement LCC analysis tool	LCC for projects >$1 million	Evaluating bridge LCC, NCHRP Project 12-43	Pavement, Adaptation of FHWA Demo Project 115 system*	LCC on major pavement projects	LCC for bridges and pavements	Pavement LCC tool (in-house)
Monitoring actual project costs and effectiveness (to provide feedback into management systems)							PSS/PMIS MMS*		Financial management strategic planning system	
Other	CTIS – integrated GIS view of current and planned projects						Maintenance quality assurance program*			

*System under development.

Key: APMS – Airport Pavement Management System
BMS – Bridge Management System
CMS – Congestion Management System
DMS – Drainage Management System
ITMS – Intermodal Transportation Management System
MMS – Maintenance Management System
PMS – Pavement Management System
SMS – Safety Management System
SWS – Storm Water Management System

TABLE 4 Level of interest in new analytical tools

Type of Analysis	California	Florida	Massachusetts	Maryland	Michigan	Montana	New York	Ohio	South Carolina	Wisconsin
Investment level versus predicted performance within a program category	5: Maintenance	3	3: Maintenance	4: Congestion 3: Bridges, drainage 1/2: Others	5: Other than pavements or bridges	4: Safety 1: Bridges, pavements	1	4/5	4	1
Performance tradeoffs for different budget allocations across program categories	5	3	4	5	5	5	4/5	5	5	1
Predicted impacts on system condition, safety, mobility, economic growth, etc., for a set of proposed projects	5: Maintenance 3: Others	3	4/5	4/5	5: If includes more than roads and bridges	4	4	5	5: Bridges 1: Pavements	5
Impacts of alternative policies/standards for project scope, timing, and design	2	4	1		5	1	4	4/5	4/5: Bridges 1: Pavements	4
Project/strategy evaluation	4: Maintenance	3	4: Safety, Maintenance	5: Congestion, Drainage 3: Bridges 1: Others	5: Safety 2: Others	1	4	4/5	5	2
Project Prioritization within or across project types	5: Across asset types	1	5: For MPOs – within project types 1: Across project types	5: Congestion 4: Across asset types 3: Bridges 2: Others	1	1	5: Across asset types 1: Within asset type	4/5	4/5: Safety 1: Pavements, bridges	5

(*continued on next page*)

TABLE 4 (Continued)

Type of Analysis	California	Florida	Massachusetts	Maryland	Michigan	Montana	New York	Ohio	South Carolina	Wisconsin
Life-cycle cost	5: “Important” assets 3: Others	5	3	3/4	5	4: Bridges 1: Pavements	2	1	5: Bridges 3: Safety 1: Pavements	1
Monitoring actual project costs and effectiveness (to provide feedback into management systems)	5	4	1	5	5	5	5	5	5: Bridges, pavements 2: Safety	4/5
Other (e.g., customer feedback analysis)	5: Customer survey data	3				1	1		5	

1 = Very Low, 5 = Very High

TABLE 5 Preferences for implementation platforms

Platform	California	Florida	Massachusetts	Maryland	Michigan	Montana	New York	Ohio	South Carolina	Wisconsin
Stand-alone web-based tool	Y	Y	Y	Y	Y	N[1]	Y	Y	Y	N
Stand-alone spreadsheet-based tool	N	Y	Y	N	Y	N[1]	D[2]	N	Y	Y
Stand-alone GIS-based tool	Y	N[3]	Y[3]	Y	N[3]	N[3]	D[2]	N	Y[3]	Y
Plug-in module for integration with existing systems	Y	Y	Y	Y	Y	Y	D[2]	Y	Y	Y
Guideline/specification (as opposed to software)	Y	Y	N	N	Y	Y	N	Y	Y	D[4]
Other (specify)					Y[5]			Y[5]		

Preference Level (Y = OK or Indifferent, N = Not OK, D = Depends on Specifics)

Notes: [1] Stand-alone tools work against an integrated approach to data management and analysis.

[2] Type of tool may create data setup and interoperability issues.

[3] Tool would need to be compatible with GIS Framework.

[4] OK if accompanied by software.

[5] Client/server architectures.

asked to rate their interest in each type of analysis capability on a scale of 1 to 5 (1 indicated very low interest, and 5 indicated very high interest). Low interest indicated either a lack of perceived need for the tool or current possession of this type of analysis tool with no perceived need to improve or supplement its capabilities. Results are organized according to the key processes of the generalized asset management decision model presented in Figure 2.

Evaluate Investment Levels and Tradeoffs

Investment Level Versus Performance Within Program Categories. Six of the states indicated a high level of interest (4+) in program-level tools for analyzing the relationship between investment levels and system performance. Several of these states noted that capabilities already existed in the pavement and bridge area; a few already had these capabilities for other program categories (as noted previously). However, the need for improved capabilities to quantify the benefits of preventive maintenance and, specifically, to predict the life-extension impacts of different levels of preventive maintenance was reported by more than one respondent. Other specific gaps cited were in the congestion, safety, and maintenance program areas and for equipment, buildings, and other physical assets not covered by standard management systems. Some states said that they were not interested in pursuing predictive capabilities for safety projects because of liability implications, whereas other states did not have this concern.

Performance Tradeoffs for Different Budget Allocations Across Program Categories. Eight of the ten states indicated a high level of interest in this capability. Some were interested in tradeoffs across modes, whereas others were only interested in tradeoffs across program categories within the highway mode (e.g., preservation versus new capacity, preventive maintenance versus rehabilitation, tradeoffs across functional classes or corridors). Several respondents expressed the need for a relatively high-level analysis tool that could be used to illustrate program tradeoffs to policy-makers during the budget process. Two individuals expressed interest in a marginal analysis approach that would support decisions on where additional money would be best spent (or conversely, where needed cuts should be made) given a base program of projects.

In discussions during the TRB Providence conference, a representative from Washington State noted that methods for analyzing multimodal tradeoffs continue to be of interest to that state. WSDOT has sponsored a multimodal investment tradeoff tool (MICA) based on goal achievement analysis, which is still in the research stage. The Washington State representative felt that a tool that addresses preservation versus maintenance tradeoffs would be more methodologically tractable and (if done right) could significantly affect decisions, particularly in this era of tight budgets. Such a tool would address the impacts that cuts in the preservation budget would have on routine and responsive maintenance needs.

Predicted Impacts of a Set of Projects on System Condition/Performance. Nine of the ten states indicated a high level of interest in improved capabilities in this area. Specific gaps included (1) tools able to calculate the economic benefit for a proposed program of projects and (2) tools focused on the benefits to customers or facility users rather than benefits related to facility condition.

Identify Needs and Solutions

Impacts of alternative policies/standards for project scope, timing, and design. Six of the ten states were interested in tools in this area. Specific needs were mentioned for tools to analyze alternative work scoping/packaging and timing options—both at a project level (how do the benefits and costs change if the project is delayed by 3 years?) and at the network level (what are the impacts of a change in policy regarding what ancillary work is done with pavement projects?).

Evaluate and Compare Options

Project/Strategy evaluation. Seven of the ten states indicated a high level of interest in additional tools for project or strategy evaluation. Respondents generally acknowledged that although several existing tools addressed this need, there were some gaps to be filled, including improved capabilities to evaluate safety, congestion, and drainage projects; improved capabilities to quantify life-extension benefits of maintenance projects; improved techniques to estimate economic development benefits, and improved capabilities to represent benefits of reduced vulnerability costs (risks) associated with bridge projects.

Project prioritization. Seven of the ten states indicated a high level of interest in new tools for project prioritization. Three of these states specifically indicated an interest in new tools for prioritization *across* project types.

Life-cycle cost analysis. Six of the ten states gave life-cycle cost analysis a high rating; two of the states said that their primary interest was for bridge projects, because they already had an adequate capability in place for pavement projects. One state mentioned the need for better methods for transit vehicle life-cycle cost analysis.

Other. One state felt that an improved approach to overlay a customer perspective on the engineering-oriented decision criteria for project selection was needed.

Monitor Results

Monitoring actual project costs and effectiveness to provide feedback into management systems. All of the 10 states felt that monitoring actual project costs and effectiveness was an important capability to be improved; one state gave this a low rating because representatives felt this capability should be integral to existing management and tracking systems in a state rather than provided as part of a new tool.

Preferences for Implementation Platforms

Table 5 summarizes respondents' preferences for specific implementation platforms for new analytical tools. In general, the most negative comments were for development of a stand-alone spreadsheet or GIS-based tool. These comments reflected the desire to pursue an integrated approach to new asset management tools. A web-based tool or a plug-in module for integration with existing systems was generally considered acceptable platforms. A couple of states noted that the tool must be compatible with a client/server architecture. Four of the ten states felt that the product of this NCHRP project should be operating software (at least in prototype form) as opposed to a guideline or specification alone.

Key Factors Affecting Success

Respondents identified several barriers to and ingredients for the successful implementation of analytical tools.

Barriers to Successful Tool Implementation and Use

Agencies may lack time for staff to learn, upgrade, and maintain new tools. Additionally, staff turnover coupled with the infrequent use of many tools require new tools to be easy to use and have a self-explanatory interface.

Another barrier to successful tool implementation is the need for vertical and horizontal integration of data and tools. Developing an integrated approach to the use of data and tools across organizational units with different requirements, applied to the same domain, is challenging. Tools are typically designed and implemented with a particular user group's needs in mind. Efforts to simultaneously satisfy multiple groups and business processes within an organization require skillful direction and frequently get bogged down.

Data are not available for input into the systems. Even when sophisticated models are available, credible values for model parameters are difficult to estimate based on documented experience.

Agencies may be reluctant to trust new tools because their inner workings are overly complex and not well understood.

Finally, respondents were skeptical of the ability of analytical tools to contribute to an inherently complex, multidimensional, and highly political process.

Key Ingredients for Successful Tool Implementation and Use

For successful tool implementation and use, agencies must have a well-defined asset management business process that depends on good quality information and analysis results and tools specifically tailored to answering the right questions. Of course, using the tool is an essential part of the process.

There must be an evolutionary process to tailor modeling procedures and parameters to specific agency conditions. This process results in buy-in and ownership among agency staff.

The agency must have an organizational culture that values and encourages the use of technical analysis.

The agency must designate or hire a technical champion(s) who has a complete, in-depth understanding of the tool and how it can be applied to answer different types of questions. This champion would educate users and listen and respond to the needs of the user community through ongoing tool enhancements and/or specialized analyses.

2.5 EXPLORATORY DISCUSSIONS

Thirty-eight participants (representing the FHWA, AASHTO, NCHRP, NHI, 12 states, 1 province, and 2 universities) attended the NHI Pilot Training Course on Asset Management that was held in Lansing, Michigan, on June 25 and 26, 2002. As part of the course discussions, the participants were asked, "What are the top two asset management decisions that you need better analytic tools to address?" Some of the responses are included the following paragraphs.

A representative from the Vermont Agency of Transportation (VTrans) indicated that the agency had sufficient tools with which to manage pavements, bridges, and maintenance activities. VTrans is interested in tools that would enable staff to analyze other modes (e.g., transit, airports, pedestrian paths, rails).

A representative from the Pennsylvania DOT suggested the need for a tool that would enable agencies to evaluate the impact of a project or group of projects on system performance (e.g., if an agency spends $10 million on security projects, what will be the impact on the performance of the pavement network?).

A representative from the Montana DOT indicated that a tool that analyzes tradeoffs between reactive and capital maintenance activities would be beneficial.

A representative from the Province of Ontario identified the need for tools that (1) quantify user costs and benefits for preservation, operations, and maintenance activities and (2) analyze tradeoffs among these three types of actions.

An FHWA representative suggested that the biggest transportation issue today is costly congestion delays and that intelligent transportation systems (ITS) were the key to making progress in this area. He also added that agencies do not need another ITS tool—they need more money so that they can implement existing technologies.

A representative from the University of Wisconsin suggested that existing analytic tools are too data hungry for widespread implementation by transportation agencies. He proposed that new tools be developed to help DOTs collect/generate the data required for existing tools. He also suggested the need for more sketch-planning tools that are not data intensive.

One participant identified the need for a tool that would enable agencies to quantify the benefits of projects developed to address common priority policy areas (e.g., mobility, safety, environment). Currently, agencies develop projects (e.g., traffic calming improvements and sound walls) in response to policy priorities but have no means for analyzing the success of these efforts in meeting their objectives.

SECTION 3

REVIEW OF EXISTING TOOLS

3.1 OBJECTIVES AND SCOPE

Tools existing as of August 2002 were reviewed to ensure that:

- New tools can complement and build upon the existing base of experience and resources; and
- Tools developed as part of this effort can be designed to integrate effectively with other available tools.

The selection of tools for the review is not intended to be exhaustive; the goal was to identify the kinds of capabilities that are generally available to support asset management. Tools that have been developed by FHWA and NCHRP, which currently are available to states at low or no cost, were emphasized. However, the review also covers general classes of tools that individual agencies have developed in-house or that are available from private vendors. The choice of tools for inclusion in this review is consistent with the stated primary focus for this project on the highway mode and, secondarily, on multimodal tradeoffs.

This section presents a summary of the tool review; it is organized according to the analysis categories used in the state needs survey to facilitate a comparison of needs with available tools. Appendix B provides detailed summaries of the capabilities of and methodologies used in the PIARC HDM-4 model and the following tools developed through previous FHWA or NCHRP projects.

- NCHRP Project 12-43 Bridge Life-Cycle Cost Analysis Tool;
- EAROMAR Pavement Life-Cycle Cost Analysis Tool;
- FHWA Project 115 Pavement Life-Cycle Cost Analysis Software Tool;
- HDM-4 Roadway Investment Analysis Tool;
- Highway Economic Requirements System for State Use;
- IDAS ITS Deployment Analysis System;
- MicroBENCOST;
- National Bridge Investment Analysis System;
- Surface Transportation Efficiency Analysis Model;
- StratBENCOST; and
- TransDec.

3.2 REVIEW OF CURRENT ANALYTICAL TOOLS

Pavement, bridge, maintenance, safety, congestion, and other management systems are common in most DOTs; many of these systems have analytical capabilities spanning the full range of activities in the asset management process. The following subsection briefly describes these management systems. Subsequent subsections cover more specialized tools and are organized by the categories established in Figure 2.

Management Systems

Pavement Management Systems (PMSs)

PMSs are well established in state as well as regional and local transportation agencies. Many commercial and custom-developed PMSs are in place and provide capabilities for

- Maintaining inventory information on the road network, in some instances linked to GIS maps;
- Storing condition information (e.g., roughness, rutting, distress) and calculating summary statistics for different portions of the network;
- Projecting future changes in condition for different indicators as a function of pavement type, level of use (e.g., functional class, average daily traffic, or equivalent single-axle loads), and other characteristics;
- Applying decision rules (often implemented as condition-based triggers) for when particular treatments should be performed;
- Simulating the deterioration and application of different treatments over time (with and without budget constraints), which provides the basis for needs estimation and analysis of investment levels versus projected performance;
- Generating candidate projects and, in some cases, generating and evaluating alternatives and selecting the most cost-effective ones within the simulation framework; and
- Ranking candidate projects based on condition, benefit/cost, or other user-defined measures.

Bridge Management Systems (BMSs)

Nearly all states operate a BMS that assists with identification and evaluation of bridge preservation and improvement strategies. Several states have developed in-house systems. AASHTO licenses the Pontis® BMS to more than 45 states and other agencies. AASHTO released Pontis version 4.1 in 2002. Pontis provides the capabilities to relate performance to investment levels and to develop an optimal long-term bridge investment strategy. The system is in use in more than 30 states, although many agencies are not yet making full use of the system's modeling and optimization features. Version 4.1 of the system provides considerable new flexibility in the modeling and simulation process for users to incorporate agency-specific work packaging and selection practices.

Congestion, Safety, Public Transit, and Intermodal Management Systems

Congestion, safety, public transit, and intermodal management systems were developed by a number of states in response to the original ISTEA legislation management system requirements. These systems provide useful capabilities for identifying transportation needs, analyzing investment options, and assessing performance.

Maintenance Management Systems (MMSs)

Many states have an MMS in place primarily to plan, schedule, and track maintenance activities. Several DOTs have developed or are pursuing development of analytic capabilities within their MMSs to relate budget levels to level of service (LOS) or performance targets. California is in the process of implementing a new integrated maintenance management system (IMMS) for planning, budgeting, and scheduling of maintenance work.

Tools That Evaluate Investment Levels and Tradeoffs

Performance Tradeoffs Within Investment Categories

The FHWA sponsored the development of and continuing enhancements to the National Bridge Investment Analysis System (NBIAS), an analysis tool for predicting nationwide bridge maintenance, improvement, and rehabilitation needs and measures of effectiveness over a multiyear period for a range of budget levels. A graphically based system for conducting "what-if" analyses, NBIAS enables a user to experiment with different budget assumptions to see how the condition of the national bridge network will vary in the future based on the annual level of investment. NBIAS works with the National Bridge Inventory (NBI) data set and uses the modeling approach that is in the Pontis BMS. A series of enhancements to NBIAS is ongoing to provide improved capabilities to work with specific bridges (as opposed to aggregate populations of bridge elements simulated from NBI data). These enhancements will make feasible the use of NBIAS capabilities in conjunction with Pontis datasets from individual states.

PlanOpt, a tool with similar capabilities to NBIAS, is in use at the Swedish National Road Administration. PlanOpt was designed to work with the existing SAFEBRO bridge inventory system and uses a modeling and performance approach based on the lack of capital value (LCV) concept. LCV is a measure of overall bridge health (calculated based on the ratio of bridge restoration cost to replacement cost) and consists of bearing capacity and durability components. PlanOpt uses (1) deterioration curves to model changes in LCV over time and (2) models to estimate agency and user costs as functions of LCV.

The previously discussed management systems are most frequently used to analyze the relationship between performance and investment levels within particular program categories. However, some agencies have developed specialized tools external to their management systems. The Michigan DOT's Road Quality Forecasting System (RQFS) and components of Wisconsin's meta-manager are examples.

Performance Tradeoffs Across Investment Categories

The Highway Economic Requirements System (HERS) was originally designed in the late 1980s for use in FHWA's biennial reports on the condition and performance of the nation's transportation system. For this purpose, HERS applies a combination of economic and highway-engineering analysis to sample-section data in FHWA's Highway Performance Monitoring System (HPMS), a database that contains detailed information for a sample of approximately 100,000 sections of highways.

A version of HERS for state use (HERS/ST) has been evaluated by 17 states, and work on an enhanced version is under way. HERS/ST is a tool for analyzing the relationship between highway investment levels and performance. HERS/ST applies engineering standards and benefit/cost analysis to identify project alternatives to correct deficiencies, but also can accept overrides to its selections to reflect actual planned or programmed projects. Given either a budget constraint or a set of performance objectives, the system selects the most economically attractive project options and produces reports on the resulting network performance. HERS/ST provides users with information about individual sections of highway (which is not provided by the national HERS) and the ability to use state-specific values for the cost of highway improvements and for other parameters.

Because HERS/ST can analyze a range of investments, including system expansion and improvement as well as system preservation, it is ideally suited to analyzing tradeoffs between preservation and mobility programs for a state DOT.

The World Bank and the World Road Association (PIARC) have released an updated version of the Highway Development Model (HDM), which has been widely used throughout the world (primarily in developing countries) to analyze roadway management and investment alternatives. Prior versions of HDM emphasized project-level analysis; HDM-4 offers program and strategy analysis capabilities. HDM-4 includes a simulation capability featuring pavement deterioration models; application of user-defined standards and criteria for when different project candidates are considered; and calculation of life-cycle agency costs, road user costs, and social and environmental impacts.

Washington State DOT has sponsored the development of a prototype multimodal investment choice analysis tool (MICA) intended to assist in making budgetary tradeoffs across programs. MICA includes a set of worksheets for benefit/cost analysis for different project types. Impacts on qualitative criteria also are entered for each project. The tool selects groups of projects that fit within a specified set of budget constraints (lump sum, regional, or modal) and provide the best value according to a selected criterion or multiple criteria.

NCHRP Project 8-36(7) developed a generalized framework for multimodal tradeoff analysis, including a set of templates for

- Establishing a structure of goals, objectives, performance measures, and targets for interprogram analysis (along with identifying assessment data and procedures);
- Establishing a similar structure for intraprogram analysis;
- Identifying key programs of interest that should be analyzed in the tradeoff process;
- Applying analysis procedures to calculate performance measures for the current situation and for a set of alternative scenarios of future funding allocation; and
- Presenting tradeoff analysis information in a manner that highlights differences across alternatives.

NCHRP Project 8-36(7) provided a set of sample templates for hypothetical tradeoff analyses. See Table 6 for an example.

Predicted Performance Impacts for a Set of Projects

Some PMSs and BMSs provide network-wide performance results associated with the implementation of a set of specific projects. This capability has been built into the integrated asset management and/or work program management systems of some states (e.g., New York, Wisconsin).

Tools That Identify Needs and Solutions

Needs identification is a core function of pavement, bridge, safety, and congestion management systems, as described previously. Several states have implemented integrated approaches to needs and solution identification using the outputs of management systems together with GIS and query tools:

- Wisconsin's "meta-manager" is built around a SAS dataset that combines information on highway inventory characteristics, pavement and bridge conditions, crash data, traffic data, geometric deficiencies, and actual projects in the program. All of these data can be viewed in GIS displays.
- Montana has implemented a performance programming process that places information from the pavement, bridge, congestion, and safety management systems into an ArcView-based system performance query tool. Districts use this tool to select projects to nominate for programming that are consistent with the project mix in the funding plan.
- Michigan DOT has built an integrated transportation management system that supports integrated views of pavement, bridge, congestion, and safety information.
- Florida DOT has a GIS-based decision support system (DSS) that supports needs analysis for the intrastate highway system. DSS generates a need category or grade for segments or user-defined corridors based on five variables: pavement condition, congestion, safety, intermodal connectivity, and economic development. The system also shows projects in the current work program.
- California's new IMMS includes the core asset inventory and is intended to be used in conjunction with pavement, bridge, and highway LOS management systems to identify needs.

Impacts of Alternative Policies for Project Scope, Timing, and Design

FHWA's Strategic Work Zones Analysis Tools (SWAT) program has produced a spreadsheet analysis tool called QuickZone for analyzing the impacts of work zones and associated mitigation strategies. Additional tools providing a richer set of capabilities are under development.

QUEWZ-98 (*13*) is another tool available for analyzing traffic impacts, emissions, and road user costs associated with lane closures.

Other systems, such as EAROMAR and life-cycle cost analysis tools, also have capabilities to analyze alternative project scopes and timing.

TABLE 6 Multimodal tradeoff analysis example (assessment of inter-program effects)

		Examples				
Agencywide Goal	**Agency Performance Measures**	**Long-Term Target**	**Current Condition**	**Baseline Scenario**	**Passenger Scenario**	**Freight Scenario**
System Preservation and Maintenance	• Percentage of roadway lane-miles in good or excellent condition.	Principal arterials: >95% Other state roads: >80%	93% 81%	96% 80%	96% 80%	96% 79%
	• Percentage of bridges that are structurally sound.	Principal arterials: >98% Other state roads: >95%	98% 93%	95% 90%	94% 90%	94% 90%
	• Percentage of transit vehicles within design life-span.	>95%	>92%	>92%	>96%	>91%
	• Deferred maintenance expense (cost to "fix" everything in year 10).	N/A	N/A	$9 B	$10 B	$10 B
	• Percentage of bridges on arterials without weight restrictions.	>95%	90%	90%	89%	88%
Safety	• Crash exposure across all modes (number of persons in crashes per number of person-trips) (crashes per million person-trips).	Reduce by 10%	1.0	0.84	0.82	0.82
Support Economic Development	• Extent to which citizen's "key factors" are addressed.	N/A	Fair	Fair	Fair-poor	Fair-good
	• In-state jobs supported through transportation expenditures.	N/A	10,000	11,500	11,600	11,400
Statewide Mobility and Equity	• Sum of public sector expenditures and user costs (vehicle ownership, travel time, fees, fares, etc.).	N/A	$28 B	$36.5 B	$36 B	$34 B
	• Percentage of bridges on arterials without weight restrictions.	>95%	90%	90%	89%	88%
	• Ratio of peak to off-peak travel conditions.	<1.25	1.30	1.39	1.36	1.35

TABLE 6 (Continued)

		Examples				
Agencywide Goal	**Agency Performance Measures**	**Long-Term Target**	**Current Condition**	**Baseline Scenario**	**Passenger Scenario**	**Freight Scenario**
Statewide Mobility and Equity *(continued)*	• Percentage of trips that can be made by non-automotive modes.	Commute: >50%	40%	38%	39%	38%
		Local non-commute: >75%	65%	60%	63%	60%
	• Percentage of population with access to demand-responsive transit or paratransit.	Intercity: >50% 100%	45% 80%	40% 72%	40% 75%	40% 72%
State's General Public Policies	• Extent to which "Smart Growth" principles are supported.	N/A	Fair support	Fair support	Fair support	Fair support
	• Extent to which local planning and development decisions are supported.	N/A	Fair-good support	Fair-good support	Fair-good support	Fair support
	• Consistency with State Implementation Plan (SIP).	Meet all SIP budgets and deadlines	Met	Met	Met	Met
	• Extent to which environmental resources are protected.	N/A	Fair-Good	Fair	Fair	Fair

Source: (*9*).

Tools That Evaluate and Compare Options

Project/Strategy Evaluation

Most of the extensive array of project- and strategy-level analysis tools include benefit/cost analysis capabilities. These tools can be used to assess the merits of an individual project or strategy and can be applied sequentially to different options to compare the relative merits of different approaches for a specific facility and, in some cases, for a corridor or subarea/subnetwork. The tools vary with respect to the types of projects analyzed, the types of benefits and costs considered, and the level of detail for the analysis.

MicroBENCOST evaluates the benefits and costs of highway projects (added capacity, new location or bypass, rehabilitation, pavement improvement or overlay, bridge improvement, safety improvement, railroad crossing, high-occupancy vehicle [HOV], and combination projects). The benefits account for changes in vehicle operating costs, accident costs, travel time, fuel consumption, and vehicular emissions. This software is a DOS product, although an upgrade to Windows has been proposed.

StratBENCOST also provides benefit/cost analysis for highway improvements, but it is designed to assist in comparing large numbers of projects in the concept stage. Highway facility upgrades are defined based on the transition of a facility from 1 (of 12) facility type to another. Vehicle operating cost and emissions estimates are based on MicroBENCOST lookup tables. Accident reductions are based on the original HERS accident rates (which have been updated). One of StratBENCOST's innovations is the incorporation of risk analysis using a built-in Monte Carlo simulation to allow users to understand levels of uncertainty associated with the results.

Some states, including California and Washington, have developed their own benefit/cost analysis systems. California's system can analyze both highway and transit projects; Washington's system handles highway projects, including HOV lanes, park-and-ride lots, and safety projects.

STEAM analyzes the benefits, costs, and impacts of multimodal investments. It incorporates economic analysis to develop monetized impact estimates and provides separate estimates of energy and environmental impacts. STEAM works with input from traditional four-step transportation models. It post-processes traffic assignments to obtain more accurate highway speeds, particularly under congested conditions. STEAM incorporates risk analysis to describe the level of uncertainty in analysis results. FHWA also has developed a simpler spreadsheet model called SPASM for multimodal corridor analysis on the sketch-planning level, which can be used where travel demand model outputs are not available.

NET_BC (developed by Bernardin Lochmueller & Associates) is another example of a travel model post-processing tool that performs benefit/cost analysis. This tool was applied to analyze major corridor investment in Indiana.

IDAS is a sketch-planning tool that analyzes benefits and costs for ITS investments, such as traffic management systems, emergency management services, electronic payment systems, and incident management systems. Like STEAM, it acts as a post-processor of travel demand model data. IDAS also includes a Monte Carlo simulation capability for risk analysis.

The new 2002 AASHTO Roadside Design Guide includes an updated algorithm (and companion software, Roadway Safety Analysis Program [RSAP]) for comparing the cost-effectiveness of alternative safety improvement designs.

TransDec is a tool that provides a generic multicriteria evaluation of multimodal investment strategies. Users specify a hierarchy of goals, objectives, measures, and rating scales and provide specific performance measures for a set of alternatives. The tool calculates scores for each alternative.

Project Prioritization

Many of the previously described tools that can be used to evaluate options also can be used to rank or prioritize a set of candidate projects within a particular program category or across program categories. Projects are most commonly prioritized within pavement, bridge, and congestion and safety management systems; through previously described integrated management systems; or by simple scoring methods tailored to the needs and data available in specific agencies.

Washington State DOT has developed TOPSIS, a program that uses a benefit/cost ratio (from the in-house B/C analysis tool) together with project impacts on a set of non-quantitative evaluation criteria (e.g., community support, modal integration) to rank projects based on their distance from a theoretical ideal solution.

Life-Cycle Cost Analysis (LCCA)

Life-cycle costs are typically analyzed as part of a detailed, project-level analysis of alternative design choices for major pavement or bridge projects. However, planning-level tools are also available that calculate life-cycle costs for different maintenance strategies, both for individual facilities and networks of facilities. In addition to EAROMAR, other pavement and bridge management systems as well as HDM-4 provide capabilities for analyzing life-cycle costs of different maintenance and rehabilitation strategies.

NCHRP Project 12-43 developed a methodology and associated Visual Basic software tool (BLCCA, completed in 2002) to analyze bridge life-cycle costs.

Released in 1999 by the National Institute of Standards and Technology, Bridge LCC 1.0 is a tool that analyzes life-cycle costs to assess the cost-effectiveness of alternative bridge construction materials. This tool is intended for use at the preliminary design phase of bridge project development.

NCHRP Project 1-33 developed a methodology to improve pavement investment decisions. This life-cycle cost methodology and companion software tools incorporate user costs, based on new research on the relationship between pavement roughness and vehicle operating costs.

FHWA Demonstration Project 115 produced the comprehensive Technical Bulletin, Life-Cycle Cost Analysis in Pavement Design. This bulletin, published in September 1998, provides detailed procedures for conducting pavement LCCA. The FHWA sponsored development of a software package to automate application of these procedures.

Developed for FHWA, EAROMAR is a tool for analyzing pavement life-cycle costs on high-standard roads. This tool is older (DOS-vintage) but provides significant flexibility to analyze different types of pavement maintenance, rehabilitation, and reconstruction options and their impacts on both agency costs and user costs. It has the capability to assess capital/maintenance tradeoffs and the comparison of preventive versus deferred maintenance. Because EAROMAR employs a detailed analysis of work zones and their effects on traffic flow and congestion, it also can be used to investigate (1) the staging of projects, (2) the effects of construction or maintenance contract packaging, and (3) options to limit road occupancy to particular hours of the day or to particular months or seasons of the year.

Tools That Monitor Results

Performance and Cost Monitoring and Feedback

Construction management/estimation systems such as the BAMS/DSS and Estimator products in the AASHTO Trns•port suite have the potential to be used for cost tracking; however, careful planning is required to ensure that meaningful results can be derived from these systems, and a translation process is required to develop unit costs that are usable by most management systems.

Some PMSs and BMSs allow cost assumptions to be updated based on recorded costs of actions taken.

SECTION **4**

SELECTION OF TOOLS FOR DEVELOPMENT

4.1 GAP ANALYSIS

Table 7 presents a matrix of current tools by category along with the needs for improved analytical tools found in the interviews and supplementary literature review.

4.2 SCREENING OF CANDIDATE TOOL CONCEPTS

The analysis of needs and available tools indicates that there is an extensive and varied set of decision support needs as well as a large body of existing tools that at least partially match these decision support needs. To establish priorities for which needs should be addressed under this project, candidate tools were judged on how well they met the following five criteria:

A. **Respond to Needs.** Would the candidate tool address the needs expressed by a wide spectrum of states;
B. **Support the Core of Asset Management.** Would the candidate tool provide capabilities that address issues commonly recognized as core asset management principles and likely to advance the state-of-the-practice in asset management, consistent with the framework set forth in the Asset Management Guide developed for NCHRP Project 20-24(11);
C. **Fill a Void.** Would the candidate tool provide capabilities currently not met in existing tools and unlikely to be addressed by other research efforts over the next 3 to 5 years;
D. **Fit with a Range of Business Processes, Systems, and Data.** Would the candidate tool apply to a variety of agencies with different decision-making methods, databases, and existing systems; and
E. **Minimize Risk.** Would the candidate tool build on established techniques likely to be generally accepted by the target user group and would it be feasible to develop within the allotted budget and timeframe?

These criteria were useful for establishing a focus for development of candidate tool concepts. They provide a richer basis for screening candidate tools than the two-dimensional "value versus availability" matrix originally envisioned in the research plan for this project.

Table 8 summarizes the evaluation of candidate tools concepts against these criteria; the candidate concepts are categorized according to the major processes of the asset management decision model identified in Figure 2. Ratings were assigned on a scale of 1 to 5, where 1 is the lowest rating (e.g., relatively low need, hard to adapt to different practices, high risk) and 5 is the highest (e.g., great need, easy to adapt, low risk). The general conclusions from this screening exercise are presented in the following paragraphs.

Tools to support analysis of investment versus performance levels within individual program categories are embedded in most pavement, bridge, and other management systems. Although some agencies feel that they have pavement and bridge categories covered, others are not satisfied with the current level of decision support available in their existing tools.

A need that several agencies expressed was to have a capability to gain a better understanding of (1) the benefits of preventive maintenance (for life extension and long-term costs) and (2) how routine maintenance needs may increase as asset conditions decline. However, readily available, useful data to support this kind of tool are lacking.

Some agencies also were interested in supplementing the condition-based performance measures with measures that were more related to customer outcomes. Some agencies also had gaps in analysis capabilities in certain program categories—including safety, equipment, and buildings, but these needs are likely to be addressed in other initiatives.

Agencies expressed a reasonable degree of interest in better tools to analyze cross-program tradeoffs, which is a core principle of asset management. The challenge is to develop tools that could be used by a variety of agencies with different levels of capabilities within the existing single-category management systems. Tools that address tradeoffs within the highway mode in areas where existing management system information is available would have a lower degree of risk and a higher potential for wide use than tools addressing multimodal tradeoffs. Prior research efforts, such as NCHRP Project 20-29(2) (which produced the TransDec tool) and the NCHRP Project 8-36(7) framework, point to an "impact tableau" approach to looking at multimodal or cross-program tradeoffs. In this approach, a common set of performance measures are established across all programs, and the impacts of program investment levels are estimated through a variety of quantitative and

(*text continues on page 33*)

TABLE 7 Gaps in analysis capabilities for asset management

Type of Analysis	Current Tools*	Perceived Needs
Investment level versus predicted performance within a program category	• *HDM-4* (highway investments). • *NBIAS* (national bridge investments). • PMS (pavement). • BMS (bridge). • RQFS (MDOT – Road Quality Forecasting System). • Wisconsin DOT Meta-Manager (safety, bridge and pavement condition, congestion). • NYSDOT Congestion Needs Analysis Module (CNAM).	• Ability to analyze benefits of preventive maintenance, determine life-cycle cost and condition-related outcomes from different levels of maintenance expenditures. • Ability to show value of keeping an asset at a given condition level (for all assets). • Tools to incorporate consideration of policy initiatives such as passing lanes and upgrades to roads with seasonal weight restrictions within the condition-based needs assessment method used by management systems. • Tools for tracking ITS equipment condition, replacement needs. • Program-level safety management tool, better predictive capability (though some states are concerned about liability implications). • Network-level what-if analysis tool to understand impacts on pavement lives (and corresponding investment needs) of different truck loadings for variations in soil and snowfall conditions. • Tools for equipment management, buildings, other physical assets not covered by standard management systems.
Performance tradeoffs for different budget allocations across program categories (e.g., pavement preservation versus new capacity)	• WSDOT Multimodal Investment Choice Analysis (MICA) – prototype. • Ad hoc spreadsheet program analysis tools/manual analysis of results from individual management systems. • *HDM-4* (highway investments – segment and network level). • *HERS/ST* (highway investments).	• Cross-program and cross-modal tradeoffs (e.g., state rail/transit versus highway investments) need to find common measure(s) for comparison. • Preservation versus new capacity tradeoffs. • Tool to support analysis of current performance versus targets versus projected performance given investment levels. • What-if analysis tool to test different allocations across functional systems/classes of facilities, different corridors. • Tradeoff analysis tool that could be used with policy-makers during the budget process.
Predicted impacts on system condition, safety, mobility, economic growth, etc., for a set of proposed projects	• WisDOT Meta-Management System. • Florida Decision Support System (DSS). • MDT Systems Performance Query Tool. • NYSDOT Program Support System (PSS).	• Improved ability to calculate economic benefit for a program of projects. • Tools focused on impacts on customers/users as opposed to facility condition.

(*continued on next page*)

TABLE 7 (Continued)

Type of Analysis	Current Tools*	Perceived Needs
Impacts of alternative policies/ standards for project scope, timing and design	• QuickZone (work zone delay estimation software – project-level analysis). • Life-cycle cost analysis tools (see life-cycle cost analysis below) can analyze alternative project designs, scopes, and timing. • *HDM-4* (alternative design and maintenance standards).	• Tool to easily analyze alternative work packaging and timing options – impacts of delaying projects.
Project [or strategy] evaluation	• *MicroBENCOST* (highway projects). • *StratBENCOST* (highway improvement strategies – segment and network level). • *TransDec* (generic multicriteria evaluation of multimodal investment strategies). • *IDAS* (ITS strategies). • *STEAM* (post-processor tool to calculate costs and benefits of multimodal or demand management strategies analyzed with four-step travel demand models). • NET_BC (similar capabilities as STEAM). • RSAP – B/C analysis for roadside safety improvements; integrated with AASHTO Roadside Design Guide. • California Life-Cycle B/C Analysis Model (highway and transit projects). • WSDOT Mobility Project Benefit/Cost Software (highway projects, including HOV, park-and-ride lots, safety projects).	• Improved capabilities to quantify life-extension impacts and benefits of routine and preventive maintenance. • Representation of vulnerability costs (risks) in bridge management systems. • Tool focused on freight-related impacts and benefits of multimodal investment alternatives. • Improved estimation of economic development impacts assessment. • Improved tools for analyzing new interchanges (using results of special studies). • Need for better, more reliable input data to feed models. • Evaluation of drainage projects.
Project prioritization within a single project type (e.g., pavement preservation) *or* across different project types	*Within Project:* • PMS – pavement. • BMS – bridge. • CMS – congestion. • SMS – safety. • Benefit/Cost analysis tools above may be used for prioritization as well. • Many agencies have developed in-house methods and tools. *Across Project:* • TOPSIS (WSDOT) – used in conjunction with B/C software. • Benefit/Cost analysis tools above also may used for prioritization across project types.	• Capability to prioritize across project types. • Given a set of candidate pavement/bridge/mobility/safety projects, capability to recommend where the marginal dollar should go?

TABLE 7 (Continued)

Type of Analysis	Current Tools*	Perceived Needs
Life-Cycle Cost	• *FHWA Pavement LCCA.* • *NCHRP 12-43 Bridge LCCA.* • *EAROMAR* (High-standard roadways). • NCHRP 1-33 Pavement LCCA. • NIST Bridge LCCA.	• Need for better, more reliable input data to feed models. • Tools for transit LCCA.
Monitoring actual project costs and effectiveness (to provide feedback into management systems)	• MMS – maintenance management systems. • Construction management/estimation systems, e.g., AASHTO Trns•port BAMS/DSS and Estimator. • PMS and BMS (Some systems have modules for recording actual project costs and updating cost models).	• Improved tracking of the impacts of maintenance on facility life. • Improved ability to track outcomes and outputs. • Improved accuracy of cost estimates used in needs, project evaluation, prioritization and program tradeoffs, account for typical project amenities, add-ons (possibly using outputs from bid tabulations, maintenance management systems) – use activity-based costing, separate out different project elements (e.g., paving versus safety improvements). • Support for GASB-34 requirements by providing a tool to tie together capital and betterment investments by asset type and location. • Cradle-to-grave project tracking systems. • Query tools to provide easy access to estimated versus actual costs, past experience, lessons learned.
Other	• Several states—including CA, MT, WI, and FL—have in-house tools for consolidating results of individual management systems in a GIS framework for use in project identification/program development.	• Tool/approach to overlay customer satisfaction and priorities with engineering decisions for use in program planning and prioritization. • User-friendly statistical analysis tools, e.g., to estimate sample size requirements for condition surveys.

*Detailed summaries are provided for tools listed in *italic* in Appendix B.

qualitative methods. In the NCHRP 8-36(7) framework, these results are simply displayed in a format that highlights the tradeoff to be made. In the NCHRP 20-29(2) TransDec tool, ratings can be calculated based on user-defined weights.

New York State is developing a tradeoff tool based on the concept of excess user costs, which calculates reductions in delay costs, accident costs, and vehicle operating costs (with respect to a base acceptable level) attributable to pavement, bridge, safety, and mobility improvements. The MICA effort in Washington State, perhaps the most ambitious undertaking in cross-program analysis, uses a mix of standard benefit calculations (tailored to different project categories) and a variety of other qualitative evaluation criteria to compare alternative program scenarios. However, this project is still in the research phase.

Tools to summarize aggregate impacts of a program of projects are seen as valuable by states but would likely need to be highly tailored to each individual agency's needs.

Agencies expressed a moderate level of interest in tools to analyze project scope and timing decisions. Some of these needs could be met by existing tools for LCCA and work zone analysis. There is a gap in program-level, sketch-planning–

oriented tools, but such tools would be more of a challenge to develop generically so that they could integrate with diverse agency systems and data.

Improvements to existing tools for analyzing impacts of projects or strategies may be desirable and straightforward to implement in a manner that can be used by a number of different agencies. However, these types of improvements would not be viewed by most practitioners as addressing core asset management needs, and they may be addressed by other efforts.

A tool that would assist with project prioritization across project types would interest some agencies, but it would not have universal appeal. This need is generally best addressed via benefit/cost analysis tools that handle a diverse set of project types such as those in place in Washington and California. Agencies wishing to improve their capabilities to compare diverse projects could certainly use the tools in place in those states (and others available internationally) as a starting point.

Existing LCCA products for pavement and bridges have recently been released, and some agencies have developed their own methods. The candidate initiative in this area would be to facilitate the use of these tools (which require an extensive array of inputs) by providing some rules of thumb and sample default values that would be of assistance to users of these tools.

A nearly universal need was expressed for better tools to track actual costs and effectiveness, bringing together information on both maintenance and capital projects in a form that facilitates understanding of activity costs by asset over time and in a form that could be used to update assumptions in management systems. However, because cost-tracking methods are not standardized and the level of data varies considerably across agencies, solving this problem generically with an add-on tool would be a significant challenge.

4.3 SELECTED TOOL CONCEPTS

Based on the screening results and discussion with the research panel, two tool concepts were selected for development. These concepts were developed with an understanding of the myriad reasons why existing tools have not been used to their full potential. To avoid the same pitfalls, they were designed to be simple and flexible, to build on existing data and tools that are in use, and to provide answers to critical tradeoff questions. The need for these kinds of tools was clearly evident through the state interviews and was confirmed by the research panel, which represent a diverse set of agencies and perspectives.

The following tool concepts were recommended:

- A network tradeoff tool to analyze investment versus performance across categories for the highway mode and
- A program tradeoff tool that can be used to easily demonstrate the impacts that changes in a program of projects would have on a set of basic performance measures. (The decision was made to limit the initial development for this tool to a functional spreadsheet-based proof-of-concept system.)

Both of these tools support investment versus performance tradeoff analysis within the highway mode and are designed to make use of available management systems and project-level analysis tool results. The two tools are complementary. The first tool supports decisions about the relative mix of expenditures on different assets over the long term and works with aggregated network-level information from existing management systems. The second tool supports shorter-term program adjustment decisions that frequently must be made within a short timeframe and with limited information on how a given change would impact the program's overall outcomes.

The two tools are envisioned to be part of a family of tools or "toolbox" for analyzing transportation asset tradeoffs. To reinforce this idea, the name "AssetManager" was selected to represent the family of tools and "NT" and "PT" was selected to designate the network tradeoff and program-level tradeoff tools, respectively.

The two tools can be used in a coordinated fashion, as illustrated in Figure 3 and explained in the following paragraphs:

1. Individual management systems or simulation tools (e.g., bridge and pavement management systems, HERS/ST) are run to produce inputs for AssetManager NT. These inputs would include both outcome-oriented performance measures (e.g., pavement and bridge condition) and output-oriented measures (e.g., miles of resurfacing, number of bridges replaced).
2. AssetManager NT's what-if capabilities are used to support resource allocation decisions, providing an understanding of the performance outcomes and outputs (work done) that can be achieved with the chosen investment levels. This analysis is used to establish performance targets.
3. AssetManager PT is used to explore the performance implications of short-range (1- to 3-year) programs of projects. The output-oriented work targets from AssetManager NT are input into AssetManager PT and used as a reference point to see how close a given set of projects is tracking with targets established as part of longer-range performance versus investment analysis.

The tools that were developed are described in detail in Section 5.

TABLE 8 Screening evaluation of candidate tool concepts

Type of Analysis	Candidate Tool Concepts	Evaluation A Need	B AM	C Void	D Fit	E Risk
Investment versus performance within categories	• Preventive/Routine maintenance (all assets).	5	5	4	4	2
	• Pavement needs versus loadings.	3	5	1	3	5
	• Safety.	4	1	2	3	2
	• Equipment/Building management.	3	3	1	3	1
	• ITS.	3	3	2	3	1
Investment versus performance across categories	• Multimodal, multiobjective cross-program category tradeoffs.	3	5	4	3	2
	• Highway Mode: Impacts of marginal changes in budgets by category (based on asset type, work type, geographic area, etc.).	5	5	4	3	3
Predicted impacts for a set of proposed projects	• Tool to produce aggregate condition/ performance measures given a set of projects in the program.	4	5	3	2	3
Impacts of alternative policies/standards for project scope, timing, and design	• Tool to test alternative project scoping policies at the program level.	3	3	3	3	5
	• Tool to analyze impacts of project timing options on user costs.	3	3	3	4	5
Project [or strategy] evaluation	• Supplemental modules for existing tools to address freight-related impacts and economic development impacts.	3	1	2	5	4
	• Extension of tool capabilities to handle additional project types (e.g., drainage projects, new interchanges).	3	1	3	5	4
Project prioritization	• Cross-project prioritization tool.	2	3	4	3	2
Life-cycle cost	• Tool to support development of needed inputs to existing LCCA models – e.g., default values for different facility classes.	3	5	3	4	3
Monitoring actual project costs and effectiveness (to provide feedback into management systems)	• Model database with information on activity-based costs and effectiveness in format needed to support asset management system updating, with query tools and sample procedures for populating from maintenance and construction management systems.	5	3	5	2	1

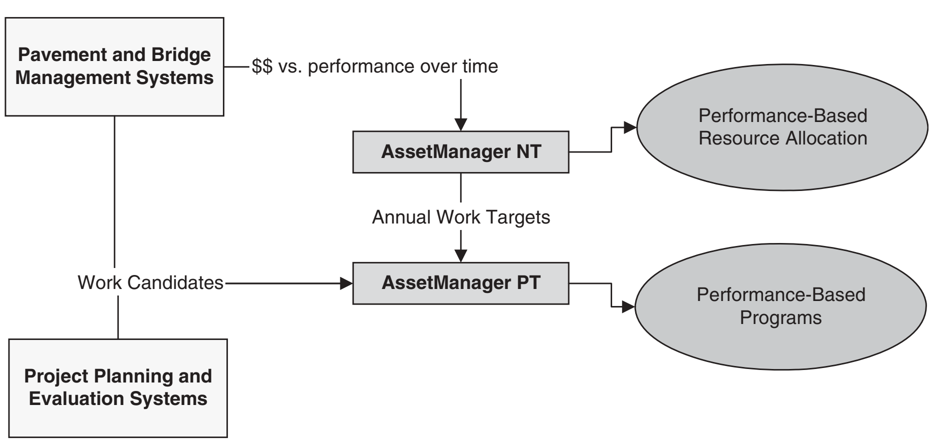

Figure 3. Coordinated use of AssetManager NT and PT.

SECTION 5

TOOL DESCRIPTIONS

5.1 OVERVIEW

This section provides a description of each tool that was developed and presents requirements that guided the development process.

User guides, provided on the bound-in CD, were developed for AssetManager NT and PT that provide step-by-step instructions on how to install and use the tools.

5.2 ASSETMANAGER NT

Tool Overview

AssetManager NT is a tool to assist transportation agency executives and program managers in understanding how different patterns of investment in transportation assets will affect the performance of the system over the long term. The tool allows a user to explore the implications of different budget levels for a set of investment categories, which can be defined based on asset types (e.g., pavement versus bridge), geographic areas (e.g., districts or regions), or system subnetworks (e.g., NHS, trunk line system, priority truck network, primary corridors). AssetManager NT brings together analysis results from the existing management systems in an agency and adds value by providing a quick-response, what-if analysis tool for testing different investment options. It does not replace existing management systems; it builds upon their capabilities and enables a more integrated (cross-stovepipe) view of asset investment tradeoffs.

Some examples of questions to be answered by the tool are:

- What happens if we make an across-the-board 30-percent decrease in both pavement and bridge investment levels?
- What happens if we increase funding for the bridge program by 20 percent and make a corresponding reduction in the pavement program?
- What happens if we spread pavement and bridge funding evenly across different districts? What would be the resulting impact on remaining life or backlog of work?
- What happens to the condition of non–National Highway System (NHS) facilities if we focus 75 percent of the resources on the NHS?

Although these types of questions can be answered using individual management systems, the process is typically time-consuming. Higher level decision-makers currently do not have a convenient way to quickly explore investment tradeoffs across different asset types in a coordinated fashion. AssetManager NT provides a motivation and a framework for running individual management systems in a consistent, coordinated way that supports tradeoff analysis. Over time, it may serve as the catalyst for enhancing management systems to produce performance measures that better allow for comparison of investments across asset types.

The overall flow of using AssetManager NT is illustrated in Figure 4.

Input Requirements

A prerequisite for this tool is one or more functioning management systems with the capability to simulate work and to store simulation results (cost and performance impacts) for different budget scenarios.

The current version of the tool is designed to operate with results for up to four asset types. However, the design allows for future expansion beyond this number. The tool requires results from a series of scenario runs at a range of budget levels from each management system. Approximately 5 to 10 runs for each investment category to be analyzed are required to provide sufficient variation in results.

Each scenario run needs to produce the following information:

- The expenditure level;
- The investment category (e.g., interstate highways in District 1); and
- Values of performance indicators associated with the simulation resulting from the scenario run (e.g., percentage of network in acceptable condition, depreciated asset value).

The tool can use any performance measure produced by a management system. The sample data sets provide both asset-specific (e.g., pavement condition index) and asset-independent (e.g., user costs, work backlog) examples of measures.

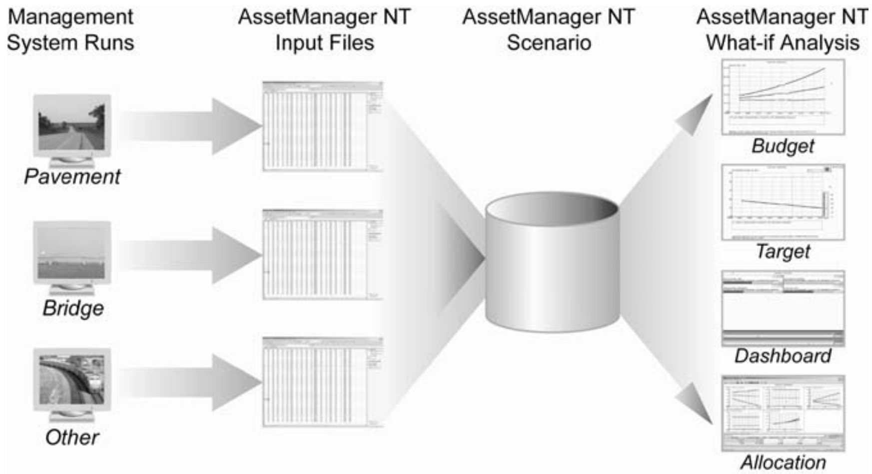

Figure 4. AssetManager NT overview.

Companion Robot Tools

Two demonstration robot tools—the pre-processor analysis routine and the what-if tool—were developed for this project to show how the process of creating inputs for AssetManager NT can be automated. These robot tools work with the AASHTO Pontis bridge management system and with FHWA's HERS/ST tool. Both robots run the management system (either Pontis or HERS/ST) multiple times and produce input files that can be read directly by AssetManager NT. These tools are described in further detail in the following subsection.

Analysis Capabilities

AssetManager NT is an interpolation engine and visualization tool that works with management system results. It does not include analytic capabilities typically found in individual asset management systems, such as deterioration modeling, simulation, strategy selection, or optimization. The software includes two components: a pre-processor of the management system run data and a what-if tool.

The pre-processor analysis routine is provided to consolidate information from the various management system runs into a format that the what-if tool can work with. This routine uses an approach similar to that of the FHWA NBIAS, currently in use to analyze national bridge needs. If the pavement and bridge management systems produce consistent performance measures (e.g., monetized user benefits or work backlog or remaining asset value), then the analysis routine can aggregate them.

The pre-processor analysis routine prepares a four-dimensional (i.e., time period, investment category, performance measures array, and budget level) matrix of results and creates a scenario file that is used by the what-if tool.

The what-if tool provides interactive on-screen views of the relationship between investment levels and performance measures by investment category. Four views are provided for what-if analysis:

- The budget view allows the user to explore the relationship between the average level of investment over time and the value of a single performance measure for a selected asset and portion of the network.
- The targeting view allows the user to determine the average annual expenditure required to reach a target performance measure value over a selected timeframe.
- The dashboard view allows the user to look at several different performance indicators at once and to explore their sensitivity to overall budget levels and the allocation of budget across assets, geographic areas, and portions of the network. For example, this view could be used to look at future pavement condition in four different regions under different geographic distribution assumptions. It also could be used to look at pavement condition, bridge condition, and total backlog of work (or asset value) for a single district under different assumptions about total budget and allocation of this budget between pavement and bridges.
- The allocation view allows the user to define different resource allocation scenarios and to see graphs that compare their performance impacts over time. Like the dashboard view, the displays are configurable to show several different performance measures or a single performance measure for different geographic areas or portions of the network.

Outputs

Reports are available for each of the four views described above. These reports show all of the graphics included in the view and are supplemented by information about the scenario definition and assumptions underlying the view.

Selection of the Application Platform

The user's primary interface is to a what-if capability from which on-screen views of the relationships between investment levels and performance measures by investment category can be explored. This interface needs to be highly interactive, to allow the user to directly manipulate various model parameters and rapidly get feedback in the form of changes to charts or graphs depicting the effects of those parameter changes. The fundamental value of this tool is linked to its ability to provide a highly interactive graphically based user interface. Therefore, interactive performance is a major requirement: the architecture selected for this tool has to ensure that the system can query the tool's data set and respond immediately to user interface events. Given the functional requirements of the tool, a roughly 40 MB source data set to support the analysis will need to be kept in memory.

Multiuser functionality is not an important requirement for the AssetManager NT tool. The tool supports tradeoff analysis, which by nature is a fairly specialized activity limited to a few key individuals in an agency and/or within each district who will be fully aware of the assumptions and limitations of the tool. The data sets for AssetManager NT are static (i.e., they will not be updated via the tool's interface once they are produced); thus, a capability for multiuser editing is not a requirement and frequent refreshes of the data sets will not be needed. The data sets will be relatively small (under 50 MB); thus, these data sets can be duplicated for use on portable computers (e.g., for presentations to decision-makers).

Given these requirements, the research team decided to implement AssetManager NT as a Windows desktop application (either on a local or a network drive) that works with a binary data set. This approach was selected to provide rapid interactivity and a rich set of user interface controls, such as sliders. Although development of a thin-client, web-based tool was seriously considered, a web application would not deliver a satisfactory level of performance (particularly with respect to rapid updates to multiple two-dimensional graphs in response to changes to model parameters). The key advantage provided by a web-based tool—access to a common data set by large numbers of distributed users, thereby eliminating the need to deploy the application to multiple computers—was not considered important, given the relative simplicity of this tool and the anticipated nature of its use. As a stand-alone desktop application, the tool will have no dependencies on browsers or versions of browsers.

Determination of Functional Requirements

To guide the tool development process, a set of functional requirements were developed. These requirements make up a checklist of capabilities that the tool should have to be useful and usable. They also define parameters needed by the system developers, such as the number of asset types to be accommodated. Definition of functional requirements was a three-step process. First, clear definitions of terminology to be used in describing the tool were established. Next, business rules were developed that describe fundamental assumptions about how the tool will be used. These rules define what is and is not allowed for the tool input data and configuration. Finally, the list of requirements was developed that cover the capabilities to be provided by the tools. These three elements—definitions, business rules, and functional requirements—are presented in the following subsections for AssetManager NT.

Definitions

Asset Type. A type of asset whose performance is modeled in an individual management system run.

Geographic Category. Categorization of the system according to a geographically based set of classes (e.g., regions, districts). Categories are assumed to be mutually exclusive and are assumed to cover the entire system.

Investment Level. The average annual expenditure within the defined scope over the scenario time horizon.

Network Category. Categorization of the system according to non-geographically based attributes (e.g., functional class, ownership, administrative or funding responsibility). Categories are assumed to be mutually exclusive and are assumed to cover the entire system.

Performance Indicator (also referred to as "Indicator"). Raw performance value associated with the given stratification cell, level of funding, and planning period.

Performance Measure. Performance value obtained as an aggregation of indicators across stratification cells or as a sum or difference of other performance measures. The following aggregation functions will be allowed: SUM, AVG (weighted average), MIN, and MAX.

Planning Period. A time period for which individual investment and performance results are reported in the scenario input file (typically 1 year).

Pre-Processor. Piece of analytical software that will process input data in a special way and generate a binary object to be manipulated by what-if analysis.

Scenario Input File. Data set (file) with information from simulation runs obtained from individual asset management systems (e.g., Pontis, HERS/ST).

Scenario Results File. Binary file generated by the pre-processor and used for what-if analysis.

Scenario Time Horizon. The number of planning periods selected for analysis in the system configuration file and therefore included in the scenario results file.

Simulation Run. An individual simulation run of an asset management system (or other simulation tool) providing input data. The tool can accept the results of up to 10 simulation runs for each asset type.

Simulation Time Horizon. The number of planning periods simulated in the simulation runs for individual asset types.

Stratification Cell. Combination of asset type, network category, and geographic category (e.g., bridges/NHS/District 1). The tool will limit the number of stratification cells to 480 (4 asset types by 10 network categories by 12 geographic categories).

System. The physical transportation system as defined by the set of all assets included in the tool.

System Metrics File. File containing essential metrics of the configuration cells (e.g., total deck area of bridges, number of bridges, length of the roads) that will be used by the system as weighting factors for calculation of the performance measure averages.

What-If Engine. Interactive user interface and built-in analysis routines to allow a user to conduct asset tradeoff analysis.

See Figure 5 for a graphical illustration of the key AssetManager NT organizing concepts and terms.

Business Rules

The following business rules are built into the AssetManager NT:

1. Results for each asset type are independent of results for other asset types. The source management systems are assumed to have already accounted for any double-counting of costs or benefits or synergistic effects that might result from combining work on different asset types.
2. A given performance indicator can apply to one or more asset types.
3. Each asset type must have one or more associated performance indicators.
4. Each performance indicator may be used for computation of one or more performance measures.
5. Each performance measure must be associated with a single metric defined in the system configuration.
6. Values for all metrics defined in the system configuration must be included in the system metrics file for all combinations of the network categories and geographic categories that have been defined in the system configuration.
7. Each simulation run for an asset type must include results for each combination of the network categories and geographic categories that has been defined in the system configuration.
8. Each simulation run for an asset type must include results for at least two planning periods.
9. Planning periods must be defined consistently across asset types; in most cases, these periods will be calendar or fiscal years. If they are defined as multiyear periods, the definitions of these periods (i.e., start and end years) must coincide across the different asset types.
10. Each simulation run must include expenditures and performance measure values for each planning period in the simulation time horizon.
11. Each simulation run for an individual asset type must have the same simulation time horizon.
12. Simulation runs for different asset types do not need to have the same simulation time horizon, but they do need to include some overlap in time.
13. The same number of planning periods must be included in the scenario time horizon for each asset type.
14. All expenditure values are to be reported by the source management systems in current dollars.
15. The what-if engine will interpolate performance measure results between simulation runs, but it will not extrapolate beyond the highest investment level included for a given scope. If a user enters a higher investment level for analysis, results from the simulation run with the highest investment level will be reported.

Functional Requirements

Requirement 1. Accept Investment and Performance Data from Asset Management Systems

1.1 The tool shall accept, in a standard, documented format, expenditure levels and associated performance indicators generated from simulation runs of asset management systems.
1.2 The tool shall allow the user to define multiple scenarios, each representing a different series of management system runs. For example, an agency might wish to analyze two scenarios that employ different assumptions about changes in future construction costs, asset deterioration rates, user cost assumptions, etc. Each scenario will have a user-defined name.
1.3 The following items shall be configurable by the user for each scenario:
   - Asset types to be included—up to four;

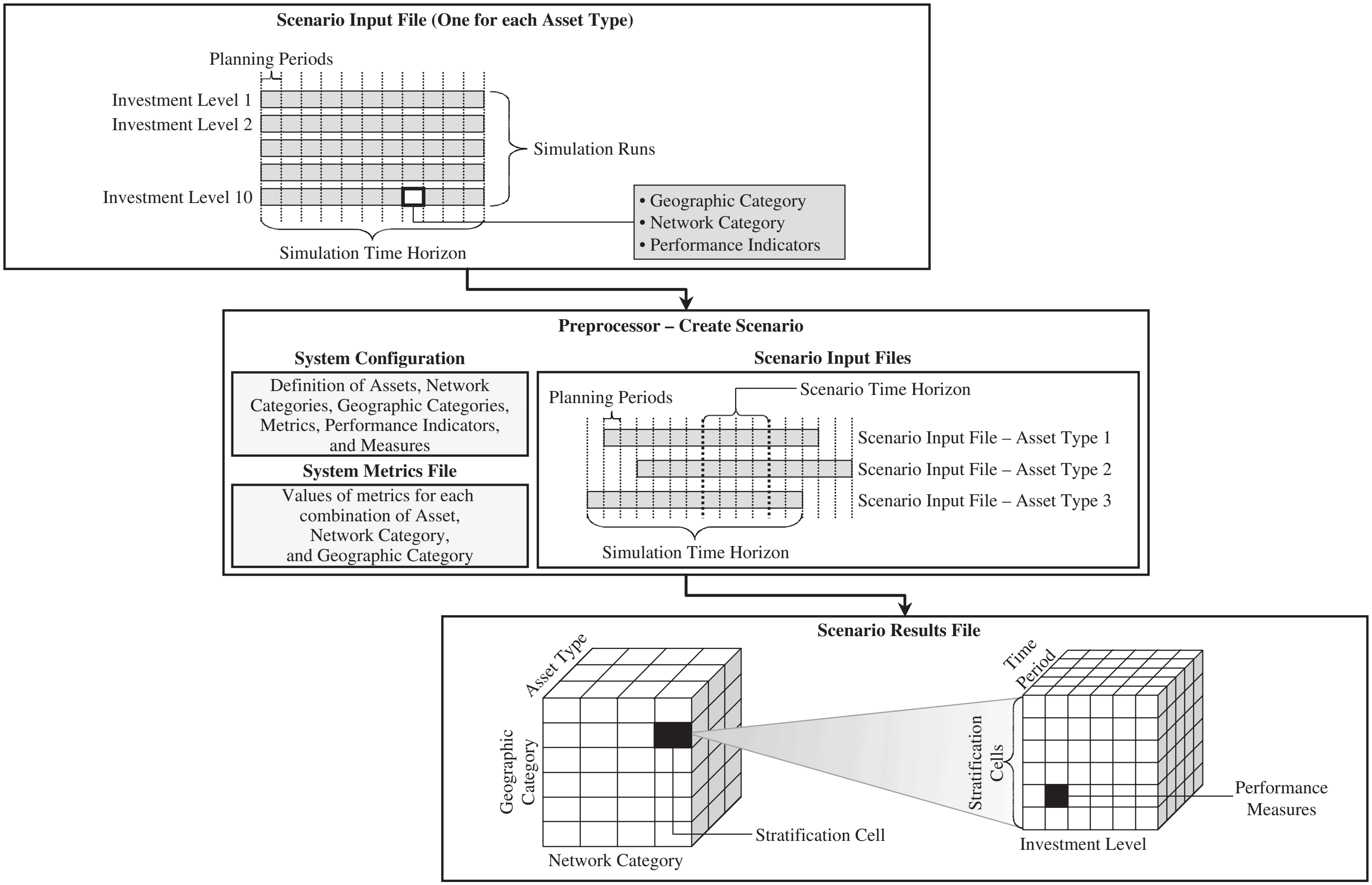

Figure 5. AssetManager NT: organizing concepts.

- Performance indicators to be included in management system results—up to 25 total for all assets;
- Performance measures (user-defined derivations of the performance indicators)—up to 40 total for all assets;
- Metrics by which weighted averages of performance measures are to be calculated;
- Network subset classes to be included—up to 10;
- Geographic categories to be included—up to 20;
- Number of planning periods (typically years) for the analysis—up to 20;
- Number of management system simulation runs—up to 10 per asset type for each scenario; and
- Scenario name.

1.4 Sample system setup input files and results input files shall be provided with the tool, allowing new users to run the tool with a demonstration data set prior to preparing data for their agencies. These sample setup files will include some standard measures that allow pavement and bridge investments to be compared.

1.5 A functional prototype robot tool to produce a results input file from the Pontis bridge management system shall be provided with the system.

1.6 A functional prototype robot tool to produce a results input file for pavement from an HPMS data set (using HERS/ST) shall be provided with the system.

1.7 The system shall allow users to provide baseline values for performance indicators as part of the scenario input files. Baseline values are defined as the actual values of performance indicators for the year prior to the initial scenario year. Baseline values shall not be required; the tool shall allow users to designate which indicators are to have baseline values.

1.8 The tool shall include the capability to generate and store multiple scenarios. Users shall be able to specify the scenario name, input file(s) for each asset type, and number of years of results to extract.

Requirement 2. Provide Capability for Interactive What-If Tradeoff Analysis

2.1 The tool shall allow a user to see how the values of performance measures for the network as a whole change as a result of changes to (1) total average annual expenditure levels, (2) the allocation of resources across asset types, and (3) the allocation of resources across geographic and network subsets.

2.2 The tool shall allow a user to see how the projected value of a selected performance measure for a selected portion of the network changes given a choice of (1) total average annual expenditure levels, (2) the allocation of resources across asset types, and (3) the allocation of resources across geographic and network subsets.

2.3 The tool shall allow users to set a target value for a performance measure for the network as a whole at the end of a selected time horizon and to see what annual expenditure level would be required to meet that performance target.

2.4 The tool shall allow users to set a target value for a performance measure for a selected portion of the network at the end of a selected time horizon and to see what annual expenditure level for that portion of the network would be required to meet that performance target.

Requirement 3. Display Results in Graphical Views

3.1 The tool shall provide a budget view that shows (on a single screen) how a selected performance measure changes over time for up to six different annual budget levels.

3.2 The tool shall provide a targeting view that allows a user to select a target value for a single performance measure and see the annual budget level that would be required to achieve that target value.

3.3 The tool shall provide a dashboard view that allows a user to see (on a single screen) how changes in an annual budget level would affect the values of several different performance measures or a single performance measure for several different portions of the system. This view shall allow the user to specify allocation of resources across assets and, optionally, across network and geographic categories.

3.4 The tool shall provide an allocation view that allows a user to see (on a single screen) how different budget allocations across assets and, optionally, network and geographic categories would affect the values over time of several different performance measures or a single performance measure for several different portions of the system.

Requirement 4. Produce Standard Reports

4.1 The tool shall produce a report that shows the graph in the currently selected view.

4.2 The tool shall produce a report that shows the current scenario settings, including the name of the scenario; a list of the performance measures, asset types, geographic categories, and network categories; and (where applicable) the current allocation of resources across asset types, network categories, and geographic categories resulting from the user’s selections.

4.3 An option shall be provided to save reports to a file format that allows graphs and tabular information to be imported into Microsoft Office software (e.g., presentations and word processing documents) and modified.

Requirement 5. Configuration Options

5.1 The tool shall include a user interface that allows entry of configuration information, including the assets to be included, geographic and network categories to be used, indicators, performance measures, and weighting metrics. This user interface eliminates the need for users to edit the configuration text file; however, this text file is still part of the system.

5.2 The tool shall allow the user to maintain an unlimited number of sets of configuration information, each of which can specify different asset classes, network and geographic subsets, weighting factors, and performance measures. Users shall be able to choose a configuration set to be used for creation of a new scenario.

5.3 ASSETMANAGER PT

Tool Overview

AssetManager PT is a program-level tool for tradeoff decisions. This tool works with a program of projects (and optionally, one or more alternatives to each project) organized into one or more program categories. The tool can work both within an agency where allocations to program categories (e.g., pavement, bridge, safety) are the focal point of the resource allocation process and within an agency where decisions about which packages of projects (including differently scoped options for given locations) should be programmed are the focal point.

The tool allows the user to adjust the program and see the impacts on a set of basic indicators of program output and network or systemwide performance. The tool allows program adjustments to be made in three ways: (1) the user can manually shift projects out of the program or replace them with alternative projects that have been defined; (2) the user can adjust the available budget level for a given program category and have the system automatically shift projects in or out of the program based on a user-specified ranking; or (3) the user can shift funds from one program category to another and have the system eliminate the lowest ranked projects from the category being cut and add the next highest-ranked projects on the list for the program category being increased. The system allows different ranking methods for each program category to be defined.

On-screen reports show the results of these project selection changes on total costs, program output indicators (e.g., miles of paving, number of bridge rehabilitations), and a set of performance measures (e.g., percentage of network in good condition, number of high-accident locations).

This tool is designed to serve related purposes:

- Provide a dynamic understanding of how modifications to the program would impact selected systemwide goals (e.g., the percentage of miles meeting a given condition target) and
- Provide a centralized organizer for information about projects in the program that emphasizes and facilitates looking at project impacts and benefits in a consistent fashion.

The tool could be used at the statewide or the district level. It can accept results from project-level analysis tools, existing program-specific priority tools, and pavement and bridge management systems that produce information on project benefits, impacts, and costs. The tool does *not* require that every project have a monetized benefit measure. This tool does *not* include any capabilities to perform benefit/cost analysis calculations, but it can store the necessary inputs to these calculations as an option.

Some examples of questions to be answered by the tool are:

- What happens to our ability to achieve stated pavement condition targets if a new major capacity project is included (or if an existing capacity project's cost escalates by 20 percent)?
- If we include minor capacity and safety improvements with our pavement rehabilitation projects on a given corridor, how many miles of resurfacing would we need to cut from the program? How would indicators of congestion, safety, and pavement condition be affected for the state as a whole?
- If a delay in a major project results in an additional $500,000 for the program period, what are the best options for spending these funds?
- What happens if we shift funds from pavement preservation into bridge rehabilitation?

The overall flow of using AssetManager PT is illustrated in Figure 6.

Input Requirements

Two types of data are required for this tool: (1) project-level information, including description/classification, performance impacts, and measures of the extent of assets affected by the projects, and (2) summaries of system-level performance information, disaggregated by district or other divisions of the network that are needed to support system-level performance impact calculations.

The tool requires the following minimum project-level information:

- Unique project identifier;
- Alternative identifier (allows multiple options for a given project to be included; the combination of project identifier and alternative identifier must be unique);

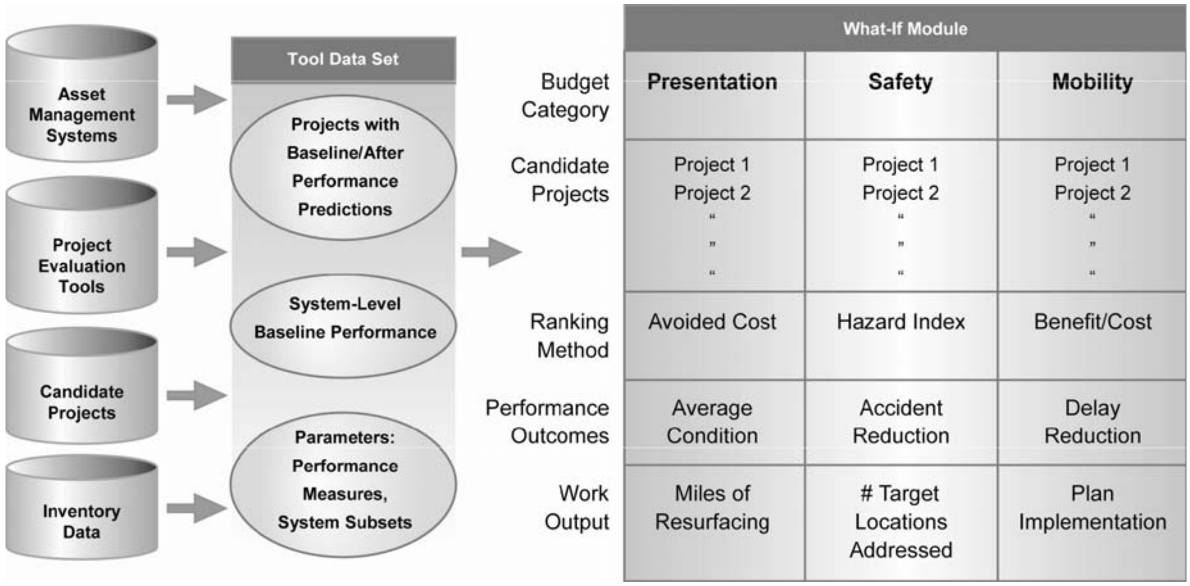

Figure 6. AssetManager PT overview.

- Project package identifier (used to maintain dependencies across individual projects in a program);
- Project name;
- Several classifications for the project: program category, asset types (e.g., road, bridge), network category (e.g., functional class, district, on/off NHS, on/off freight network), geographic category (e.g., district or region), project work type (e.g., pavement reconstruction, bridge rehabilitation, signal improvement);
- Total project cost;
- Transportation system extent or measure before and after the project (e.g., miles, number of lanes, square meters of bridge deck area); and
- Indicator(s) before and after the project, which can be a value (e.g., pavement condition index, accident rate) or classification-type indicator (e.g., poor condition pavement, posted bridge, does not meet safety standards).

In addition, suggested but optional project-level data elements include the following:

- Location referencing information (to allow for viewing of projects along a facility and linking to a GIS);
- Annual average daily traffic (AADT);
- Project year (expected completion date); and
- Project benefits and benefit/cost ratio (this information needs to be calculated in an external system).

The tool also allows users to include additional information pertaining to projects that would be helpful for sorting or ranking (e.g., project life, annualized cost, district engineer priority ratings).

The tool accommodates fixed project line items that have only an identifier, a cost, a name, and classifications, because many items in a program (e.g., inspections) are not amenable to the same type of tradeoff analysis as those projects with direct impacts on condition, mobility, safety, etc. It also allows for inclusion of scheduled projects that are not subject to removal from the program. These projects can be marked as "in the pipeline."

The tool uses the following system-level data:

- System measures (e.g., miles, number of bridges) broken down by geographic and network categories used to classify projects;
- Current values for indicators (average values or percentage distribution by categories) broken down by geographic and network categories used to classify projects;
- Target values for indicators (optional); and
- Work targets—either systemwide or broken down by geographic and/or network categories (optional).

This tool requires a combination of automated and manual data preparation steps, which will be highly dependent upon the specific project databases and management systems in place in an agency. Most agencies have some kind of candidate project listing in electronic format containing a subset of the needed items, which can serve as the starting point of the project data-loading process. Some agencies will have candidate projects in their pavement and bridge management systems with information on impacts and benefits that could be transferred into the system. For agencies that routinely use benefit/cost analysis tools for significant numbers of projects, utility programs could be developed to extract results data. (Agencies that do not have benefit/cost tools in place can refer to Appendix C of the AssetManager PT Users Guide for examples of how to calculate a benefit/cost ratio at a level of detail appropriate for prioritization.)

Some degree of manual data preparation is necessary. However, this preparation is not necessarily an overwhelming task. The tool is intended to cover a relatively short timeframe (1 to 3 years); thus, the number of distinct projects that would be subject to analysis should be less than 1,000 for most states. The number would be much less if an agency chooses to use this tool for only a particular portion of its program.

System-level information may be loaded from existing management or asset inventory systems through a one-time effort to write the necessary data extraction scripts. The scripts can be rerun periodically as the inventory is updated.

Analysis Capabilities

The tool provides the following capabilities:

- An interface for viewing projects by category and sorting/ranking projects according to a variety of user-specified criteria;
- An interface for developing program scenarios, each of which consists of a different overall budget level and/or allocation of resources across budget categories;
- Automated selection of projects for the program based on project rankings and established expenditure limits for different budget categories;
- An interface that allows users to move projects in and out of a given program scenario, select project alternatives, and easily view the impacts of these shifts on expenditures by program category and system-level performance measures; and
- Calculations of program output and performance impact indicators:
  - Amount of work by type and network category (where amount of work could be measured in miles, number of bridges, or other user-defined work units);
  - Expenditures by work type and geographic or network category; and
  - Changes in indicator values (average, sum, or distribution) by network category.

Outputs

AssetManager PT includes the following reports and graphs:

- Expenditures by budget category for a budget scenario (in tabular, bar chart, and pie chart form), which allows filtering by geographic and network category;
- Before and after performance measure values (compared to targets, if established) for a single budget scenario or comparison across budget scenarios (in tabular form);
- Expenditures by project type for a budget scenario (in tabular and bar chart form), which allows filtering by geographic and network category;
- Amount of work by type compared to established work targets for a budget scenario or comparison across budget scenarios (in tabular form); and
- List of projects selected for a given budget scenario, organized by program category (in tabular form).

Selection of Application Platform

Because of budget limitations and the desire to investigate data requirements before full-scale tool development, development of this second tool was limited to a functional proof-of-concept prototype.

The proof-of-concept tool itself was developed as a Microsoft Excel spreadsheet with supporting Visual Basic functions to perform calculations. This platform was chosen for ease of development, testing, and use.

Section 7 of this report recommends that the user interface be more developed in the production version of this tool. This new version would include a highly interactive user interface that encourages and supports the testing of alternatives. In particular, a "drag-and-drop" interface, for moving projects in and out of the program being analyzed and substituting among project alternatives, is a natural user interface choice for this tool. The tool would immediately present the impacts of these changes on system-level performance measures as graphs. A standard, off-the-shelf database (e.g., MS Access, Sybase Adaptive Server Anywhere) could be used to store project information and provide query capabilities. Alternatively, the system could be designed to work with several different common back-end databases.

Determination of Functional Requirements

Functional requirements for AssetManager PT were developed using the same three-step process described previously for AssetManager NT. The definitions, business rules, and requirements for AssetManager PT are presented in the following paragraphs.

Definitions

After. The state/value of a system measure or performance measure after completion of selected projects.

Before. The state/value of a system measure or performance measure before implementation of any projects. The term "baseline" is used as a synonym.

Budget Category. A subdivision of a program that is used to establish budget limits and track planned (and actual) expenditures.

Budget Limit. A user-specified limit on the available resources within a budget category, used to compare available versus expended funds by budget category and used by the automated project selection algorithm.

Asset Type. An optional classification for a project that describes the type of facility on which work is being performed and may be used to aggregate program expenditure information. Asset types can be used to complement the set of budget categories that have been defined. For example, if the budget categories are pavement and bridge, asset types might further subdivide these (e.g., flexible pavement, rigid pavement, culvert, concrete bridge). If the budget categories are defined based on work type (e.g., preservation, safety, capacity), then the asset-type categories could be set to broader asset classes (e.g., pavement, bridge, drainage).

Geographic Category. Categorization of the system according to a geographically based set of classes (e.g., regions, districts). Categories are assumed to be mutually exclusive and are assumed to cover the entire system. One of the geographic categories will always be the entire system ("ALL").

Measurement Unit. Metric used to measure the scale of individual projects and of different portions of the transportation system represented in the tool. For example, "lane-miles" is an example of a measurement unit.

Network Category. Categorization of the system according to non-geographically based attributes such as functional class, ownership, and administrative or funding responsibility. Categories are assumed to be mutually exclusive and are assumed to cover the entire system. One of the network categories will always be the entire network ("ALL").

Performance Measure. Indicators that describe program outcomes that result from implementation of projects. Examples are total backlog, average pavement condition, and number of restricted bridges. A performance measure is designated as one of the following types:

- A SUM-type performance measure adds a straight sum of the change in performance measure value for a project to the baseline performance measure value for the system subset to calculate the "after" value for the system subset (e.g., change in backlog).
- An AVERAGE-type performance measure uses a weighted average approach to calculate the effects of a project on the performance measure value for a system subset (e.g., average IRI), based on the reported "after" value for the project and the "before" or baseline value reported for the system subset.
- A CATEGORY-type performance measure is based on a condition being met (e.g., "bridge posted with load limit" or "pavement in poor condition"). Project impacts for category-type measures are recorded as quantities of a system measure that are in the category (e.g., number of bridges that are posted or miles in poor condition).

Program. A set of projects selected for implementation from the program worksheet.

Program Worksheet. A set of project candidates that may be funded for implementation.

Project. A proposed work activity with a cost and (optionally) a set of performance impacts.

Project Alternative. A project that is part of a set of mutually exclusive options from which decision-makers can choose. For example, several project alternatives with varying costs may exist for a corridor improvement.

Project Measure. The scale of the project expressed in one of the types of defined measurement units (e.g., lane-miles, number of bridges).

Project Package. A group of projects that must be implemented together and cannot be selected individually. For example, a roadway widening project may be dependent on the assumption that another project will widen bridges along the roadway as well.

Project Type. An optional classification for a project that describes the type of work being performed, which may be desired for aggregation of program expenditure information. Project types can be used to complement or provide further breakdowns for the set of budget categories that have been defined. Typical examples of project types might be pavement resurfacing, bridge preventive maintenance, and intersection improvements. Each project type is associated with a measurement unit that will be used for purposes of setting work targets.

Scenario. A set of defined budget levels for each program category, along with an associated set of project selections.

Selected Project. A project that has been selected for inclusion in the program, as indicated in its *program_status* flag.

System Measures. Project- and system-level quantities used for developing weighting factors in the performance measure calculation process. Examples of system measures are lane-miles of pavement, square feet of bridge deck area, number of bridges, annual vehicle miles traveled (VMT), and replacement value.

System Subset. A combination of a geographic category and a network category. Performance measures may be summarized for each system subset. One of the system subsets will always be the entire system (the combination of the "ALL" geographic category and the "ALL" network category).

Work Target. A desired level of accomplishment of a given project type to be accomplished within the program period, where work accomplishment is measured in the measurement units that are associated with that project type.

Business Rules

The following business rules are assumed within the tool:

1. A program worksheet must contain at least one project.
2. At least one budget category must be defined for a program worksheet.
3. Up to four different budget scenarios can be defined.
4. A budget category may have a budget limit associated with it for a given scenario.
5. Each project must be associated with a single budget category.
6. Expenditure levels for each budget category will be calculated as the sum of project costs within that budget category.
7. The expenditure levels for each budget category will sum to the total expenditure level for the program as a whole.
8. Each project must be associated with a single network category.
9. Each project must be associated with a single geographic category.
10. Each system subset consists of a combination of a single network category and a single geographic category. One of the system subsets will always be the entire system (the combination of the "ALL" geographic category and the "ALL" network category).
11. Each project may be associated with a single project type.
12. Each project may be associated with a single asset type.
13. Each project may be assigned a work package identifier to indicate that all projects in the work package must be treated as a unit: inclusion or exclusion of one member of the package automatically includes/excludes all of the others.
14. Each project must have an alternative identifier. If more than one project with the same project identifier is included in the program worksheet, the alternative identifiers for projects with that project identifier must be unique. Only one alternative for a project may be included in the program.
15. Each project has a *program_status* flag, which indicates whether the project has been selected for inclusion in the program. If this flag is set to IN, the project's costs and performance impacts are to be included in the program cost and impact results.
16. Each project has a *user_status* flag, which indicates whether it is a pipeline project and must be included in the program. If this status is set to IN, then the *program_status* must be set to IN and will not be modifiable either by the user or by the automated project selection process.
17. Each project has a *generated_status* flag, which indicates whether the automated project selection process has included the project in the program.
18. Each performance measure must be assigned exactly one type of measurement unit (e.g., miles, VMT, number of bridges) to be used for calculating the impacts of projects on system subsets and on the system as a whole. CATEGORY-type performance measures are always defined based on the quantity of their associated system measure meeting a specified condition.
19. Each project can be associated with zero or more performance measure impacts.
20. Each reported performance measure impact for a project must include the estimated performance measure value after completion of the project. For SUM- and CATEGORY-type performance measures, the performance measure value before implementation of the project for the defined project scope also must be reported.
21. Each project that has SUM or AVERAGE performance measures must include "before" and "after" system measure values for all types of system measures that are associated with these performance measures reported for the project. For many projects (e.g., resurfacing), the system measures will typically be the same before and after the project. However, some project types will result in a change in system measures (e.g., a lane addition would change the number of lane-miles).
22. Each measure must have a single, defined type of unit that is used consistently wherever information about that measure is used.
23. A master list of performance measures is established by the user prior to loading project data. Project impacts can only include values for performance measures that are on this master list. Similarly, system measures reported for projects must match the system measures associated with the reported performance measures for the projects.
24. "Before" or baseline system-level values for each performance measure must be provided for each system subset that has been defined.
25. Target values for each performance measure may be provided optionally for each system subset.
26. Values for each type of system measure must be provided for each system subset that has been defined.
27. "After" values of system measures for system subsets will be calculated as the sum of system subset "before"

values of system measures and the net change in system measures associated with the selected projects in those subsets.

28. Each project type may have an associated type of measurement units.
29. Work targets may be set for any combination of network category, geographic category, and project type.

Functional Requirements

Requirement 1. Allow User Definition of Performance Measures and Analysis Categories

1.1 The tool shall allow users to define system measure types and their associated units.
1.2 The tool shall allow users to specify the performance measures to be used in the analysis, along with their associated types of system measures to be used for calculating weighted averages.
1.3 The tool shall allow users to define network categories, geographic categories, and combinations of these (system subsets), which will define the portions of the system for which performance is to be summarized.
1.4 The tool shall allow users to define project types and asset types for project classification and reporting. Each project type may be assigned a type of system measure for purposes of tracking work to be accomplished in the program against established targets.
1.5 The tool shall construct pick lists from the standard performance measures, system measures, network categories, geographic categories, system subsets, project types, and asset types to ensure consistency in data entry of project and system information.

Requirement 2. Accept Project Information

2.1 The tool shall accept information about projects, including their costs, system measures, and predicted performance impacts.
2.2 The tool shall provide the flexibility to store user-defined data items pertaining to projects.
2.3 The tool shall accommodate projects that have costs but do not have impacts on performance (e.g., inspections).
2.4 The tool shall support manual entry of project information and provide pick lists for coded items established in the setup information.
2.5 (Future) The tool may support automated input of project information via a standard XML data interchange format.
2.6 (Future) The tool may allow users to click on an individual project to view detailed supporting information, including the impacts on performance measures and a user-defined set of items that are useful for understanding the project's purpose and value.

Requirement 3. Accept System-Level Information

3.1 The tool shall accept information on the quantity of each system measure for each system subset.
3.2 The tool shall allow users to define budget categories and input associated budget limits for each category for up to four scenarios.
3.3 The system shall allow the user to enter targets for the amount of work to be accomplished during the program period. These targets may be entered for any defined project type, for any combinations of geographic and network subset. The amount of work is to be expressed in terms of the system measure type that has been associated with the project type.
3.4 (Future) The system may allow users to define budget limits for individual years of the program.

Requirement 4. Calculate Impacts of a Set of Projects on System Performance and Expenditures

4.1 The tool shall calculate and aggregate the performance impacts of a user-selected set of projects on associated system subsets based on the values of user-supplied "before" and "after" performance values and system measures for each project.
4.2 The tool shall accommodate SUM-, AVERAGE-, and CATEGORY-type performance measures (see definitions section).
4.3 The tool shall calculate and aggregate the "after" system measures for system subsets based on changes in system measures associated with programmed projects.
4.4 The tool shall calculate expenditures for each budget category based on the cost of projects selected for inclusion in the program.
4.5 Program performance results shall be calculated for a single point in time, after completion of all projects in the program. The system will not account for any deterioration in condition or changes in traffic that may occur in intermediate program years, since the program time horizon is presumed to be short (1 to 3 years).

Requirement 5. Provide Interactive Interface for Adjusting Projects in the Program

5.1 If a project is one of a set of alternatives, the tool shall not allow selection of more than one of the alternatives for inclusion in the program.
5.2 If a project is designated as part of a package of projects, the tool shall ensure that if one project in the package is selected for the program, then all other members of that package are automatically selected.
5.3 The tool shall allow users to filter projects by budget categories.

5.4 The tool shall allow users to sort projects based on any individual project attribute.
5.5 The tool shall allow users to designate projects as mandatory. Mandatory projects will always be included in the program.
5.6 The tool shall allow users to assign numerical ranks to projects, either manually or based on the current sort order.
5.7 The tool shall include an automated routine that selects projects within each budget category based on their rank, until all available budgets are consumed.
5.8 The tool shall allow users the option of accepting the automatically generated list of projects, which will set the *program_status* indicator to the value of the *generated_status* indicator. This feature is needed so that users can begin with an automatically selected list of projects and make further manual adjustments as desired.
5.9 The system shall include the capability to generate and store project selections for up to four scenarios.

Requirement 6. Provide Summary Reports and Graphs of Program Performance Impacts

6.1 The tool shall produce a report showing budget limits and budget spent by budget categories.
6.2 The tool shall produce a pie chart showing the distribution of program resources by budget category and a bar chart showing the budgeted and allocated program resources by budget category.
6.3 The tool shall produce a report showing the projected versus target values of performance measures for each system subset.
6.4 The tool shall produce a report and bar chart showing resource allocation by asset type within each budget category.
6.5 The tool shall produce a report showing projects selected within each budget category.
6.6 The tool shall produce a report and bar chart showing the cost and quantity of work by project type. Quantity of work is to be shown based on the user-supplied system measure–type associated with each project type.
6.7 The tool shall produce a work targets report showing the quantity of work for each project type and the work target by system subset. Quantity of work is to be shown based on the user-supplied system measure–type associated with each project type. This report shall include only system subsets for which the user has specified work targets.
6.8 The tool shall include the capability to view results for any selected scenario. For the performance measures and work targets reports, the tool shall include the capability to view results for all four scenarios on a single display.

SECTION **6**

TESTING PROCESS

6.1 INITIAL TESTING OF PROTOTYPES

After prototype AssetManager tools were developed, the research team tested them. For AssetManager NT, a sample scenario was developed using runs from the Pontis bridge management system and the Deighton dTIMS system (provided by the Vermont Agency of Transportation). A sample common performance measure across pavements and bridges (deficiency cost) was calculated for each run and year based on the cost to replace deficient pavements and bridges using average unit costs. The input files were developed by entering management system results (as well as the derived results on deficiency costs) into two Excel worksheets and saving each to CSV format. A system metrics file was developed using data from a sample HPMS file and queries of a sample Pontis database. A scenario was run, and views were created using the what-if tool. The sample scenario dataset “Sample1” provided with AssetManager NT contains the results of this process.

AssetManager PT was initially tested using a small set of fabricated data.

The research team revised both tools as a result of this initial prototype testing period. Subsequently, a formal testing process was undertaken at two panel member states: Montana Department of Transportation (MDT) and New York State Department of Transportation (NYSDOT). The research team prepared a test plan, including a series of case-oriented test scripts covering each of the steps required to use the tools.

6.2 MDT FIELD TESTING

Montana is a rural state with a land area of 147,000 square miles (fourth largest in the nation) and a population of roughly 900,000 (seventh smallest in the nation). The Montana Department of Transportation is responsible for maintaining more than 10,800 miles of highway and about 2,100 bridges. To provide the Montana Transportation Commission with guidance on allocation of available transportation funds, the MDT established the Performance Programming Process (P^3) in 2002. This process develops a performance-based funding distribution plan for systems (e.g., Interstate, NHS, and primary), districts, and type of work (e.g., roadway reconstruction, rehabilitation, resurfacing). Investments for bridges and safety work also are linked to performance objectives. Performance measures have been established for pavement ride quality, bridge condition (e.g., the number of functionally obsolete, structurally deficient bridges), and safety (e.g., number of correctable crash sites funded for improvement).

The P^3 involves a series of tradeoff analyses using MDT’s pavement, bridge, congestion, and safety management systems. These analyses compare investment levels to performance outcomes and seek the distribution of funds that yields the best overall performance. The results of P^3 do not determine which specific projects are selected—only the distribution of funding to districts and work categories and the overall system performance expectations associated with that distribution.

The AssetManager tools were tested to explore their potential value within the P^3 as well as within related efforts to assess needs, screen project nominations, and relate candidate programs of projects to established work mix and performance objectives.

Field testing took place on February 23 through 25, 2004. During the site visit, the research team followed test scripts for both tools and recorded MDT staff comments and suggestions.

AssetManager NT

Data Preparation

MDT ran the PMS 10 times using last year’s data set. Budget levels between $50 million annually and $400 million annually in years 2008 through 2012 were run. (Budget levels in 2003 through 2007 were constant in all 10 runs, already reflecting programmed projects.) Each run took 10 to 15 minutes.

The research team developed a set of Microsoft Access tables and queries to automate the process of loading spreadsheet outputs from MDT’s PMS into AssetManager NT. These queries were used to produce the necessary input files.

The research team obtained a copy of the MDT Pontis database and added an option to the Pontis robot to allow the first 5 years of each run to be fixed based on programmed projects and variation in budget levels to start in the 6th year. The Pontis robot was then run on the MDT Pontis database to create the system metrics and bridge scenario input files. The bridge metrics information was then merged with the pavement metrics information into a single system metrics file.

The research team used MDT's standard geographic and network categories and performance measures to set up a configuration in AssetManager NT and then created an initial scenario with the pavement and bridge data. Researchers ran through the test scripts and found and corrected minor bugs in the configuration screens.

In the initial scenario, the research team observed that, when the budget is fixed for the first 5 years and the what-if analysis focuses on the last 5 years, the user still needs to input the average annual budget for the entire 10-year period. Because all users may not understand this need, a second scenario was created in which the first year of the scenario was set to 2008 (instead of 2003), and only the data for 2008 through 2012 were included. This scenario was useful for looking at annual budget levels over the 5-year period of interest; however, it did not allow the entire trend lines from the present to be seen.

On site, MDT staff conducted an additional set of PMS runs (with a different distribution of work across resurfacing, rehabilitation, and reconstruction) and created an additional NT scenario.

Testing Results

The research team demonstrated each of the NT views and walked MDT staff through using each screen. A few bugs were identified and logged.

Two possible applications of the NT tool were identified:

- To facilitate the investment versus performance analysis conducted for MDT's P^3 and
- To estimate the investment required over a 10-year period to achieve stated performance objectives for the biennial needs analyses.

Staff felt that the tool would definitely be of value for the biennial needs analysis. They felt that the tool would be of some, although limited, value for the P^3 analysis because it does not allow scenarios for different work-type mixes to be tested, which is a key requirement of P^3 analysis. However, analysis of work-type mixes is best accomplished within the pavement management system itself rather than in Asset-Manager NT.

In the end, MDT staff felt that, although AssetManager NT would not dramatically cut down the amount of effort required for P^3 (such reduction would require some enhancements to their pavement management system), it could help at the beginning of the process to estimate how much investment would be required for individual districts and network categories to meet the performance targets. Providing visualization of how sensitive different performance measures are to varying investment levels could potentially be quite helpful. They could not be sure how beneficial the tool would be until they actually used it, but they felt that it would be worth giving it a try.

Staff made the following comments:

- This tool might be useful for P^3 analysis if it could help to reduce the current number of PMS runs that must be done by providing a way to quickly see the impacts of different budget allocations on performance.
- Given that the main challenge in P^3 is to allocate a fixed budget across work types, networks, and districts in the best possible way, this tool would be more helpful if it allowed varying allocations of a given budget, rather than being focused on varying the budget level.
- This tool appears to be ideally suited for the needs analysis that is performed at MDT every 2 years, which involves estimating the amount of funds needed over a 10-year period to achieve certain performance objectives.
- In general, the process to compare two different sets of resource allocations is awkward (go to resource allocation screen, set allocations, close that screen, go to the multibudgets, look at results, close that screen, return to resource allocations, reset values, close, return to multibudgets, compare . . .). This process is not convenient to use. For this tool to really be used to compare allocations, a split screen is needed so that the user can adjust one and see the other change. The user also needs an easy way to generate a tabular report of results for different allocations. [These comments were later addressed by adding the allocation view and incorporating the resource allocation settings window within the dashboard view.]
- It is hard to draw definitive conclusions about benefits without actually using the tool as part of the P^3 or needs analysis process (i.e., putting it to the real test).

MDT staff suggested several enhancements as a result of the testing process:

- Consider modifying the system to handle the case in which the first few years of a program are fixed (with programmed projects) and variations need to be tested for the last set of years only, but the entire performance trend line still needs to be seen. This case is an extension of the "base" year concept to multiple years (however, there are expenditure levels; they just happen to be fixed).
- In the budget view, when switching selections on the first tab of the setup, enable automatic population of the budget ranges with *n*tiles (where *n* is the number of budgets selected), if any of the numbers for budgets do not fall within the ranges specified. [This comment was later addressed by adding an auto fill button on this screen.]
- Put the name of the scenario on the views.
- For the budget view, include in the report a tabular view of the data shown (i.e., budget level, PM, value, year) that is exportable to a spreadsheet. Especially with float-type indicators, it is not easy to read values given the axis scaling and labeling.

- Similarly, for the dashboard view, have a tabular report (also exportable to a spreadsheet) with PM, value, network category, geographic category, year, and annual budget.
- On the budget levels tab of the budgeting setup screen, set the tab order to navigate across budget levels directly and not to the colors/thicknesses, etc. (which are relatively rarely changed). [This comment was later addressed.]
- On the resource allocation screen, have the network categories, geographic categories, and asset types appear in the same order as they were entered in the configuration. [This comment was later addressed.]

Summary Evaluation

The MDT staff was asked to rate the tools on a scale from 1 to 10, where 10 is the most positive rating. Staff assigned the following summary ratings to AssetManager NT:

- Potential value of functionality: 7,
- Ease of data preparation: 8–9,
- User interface: 6–7 (staff commented that many "clicks" were needed to accomplish a given task), and
- Reports/Outputs: 8–9.

AssetManager PT

Data Preparation

AssetManager PT was set up with MDT's network, geographic, and project type categories as well as its performance measures.

On site, two data sets were created using a set of proposed pavement preservation projects that were being screened. Preparation of a second data set was begun and then completed after the visit. The second data set included a more complete set of capital projects from the tentative construction program.

Testing Results

The research team demonstrated each of the AssetManager PT screens and walked MDT staff through using each screen. Bugs were identified and logged.

The applications for the PT tool were initially less clear than those for the NT tool. The research team discussed how the purpose of the tool was to provide a better connection between the network-level analysis done for P^3 and the projects that are actually selected. Staff pointed out that decision-making about specific projects is highly decentralized in Montana. The PT tool, in theory, could be used by a district to help determine which projects to nominate for the program in a given year, but the staff was skeptical that districts would perceive the tool as adding value for this process. In the end, the decision was made to focus on how planning staff could use AssetManager PT to better understand the work composition and likely performance implications of the projects that were being nominated and selected. Two specific applications were suggested:

- Screening pavement preservation projects—to help planning staff recommend which pavement preservation projects should be advanced into the program (at the time of the testing process, MDT was screening pavement preservation nominations for 2006) and
- Analyzing work distribution and performance implications of nominations—to compare project mix to the P^3 recommendations and to explore the likely performance impacts of nominated projects. For this analysis, a "plug" value for the pavement preservation category would be used rather than a value for individual pavement preservation projects, because these projects are on a shorter development cycle than other projects.

Data sets were not readily available for loading into the PT tool; multiple data sources (e.g., TCP, nominations, PMS, BMS) needed to be merged. This process could be at least partially automated. In the end, staff felt that if there was a "cookbook" procedure for loading the data, the process would not be overly burdensome.

The following issues that occurred with the MDT sources are likely to occur elsewhere as well:

- Project data used for capital programming are not consistently and accurately tied to location referencing and/or cannot be conveniently linked to condition/performance data from the management systems. This lack will make deriving "before" values of performance measures for projects difficult when the major data source for projects is the capital program.
- Different types of projects are on different time cycles from a budgeting perspective. Smaller preservation projects (e.g., resurfacing projects) are often treated as "plug" line items without specific locations assigned until 1 to 2 years before implementation. Programming decisions about larger capital projects are made further in advance. Obviously, tradeoffs across project categories are not possible when the decisions for each category are made at different points in time.
- Project data used for capital programming may not be at a sufficiently disaggregated level for direct input into AssetManager PT. For example, a single project may include multiple types of work and may span multiple types of assets and geographic and/or network categories. These projects must be split into their component parts and treated as project packages for purposes of AssetManager PT.

- Construction projects are frequently implemented in phases, possibly over a longer time span than the PT tool is intended to cover. In this situation, judgment must be exercised to determine what portion of a project's impacts should be included, when only a single phase of the project is being included in the tool.

Because AssetManager PT does not predict deterioration, "before" and "after" average pavement and bridge conditions must be analyzed using the current condition as the "before" case, even though the projects being considered are to be implemented several years out. Therefore, the predicted "after" condition from AssetManager PT cannot readily be compared to a target or PMS projection for the future year when the set of projects being analyzed will actually be completed. The only solution would be to derive projected conditions from PMS simulation results. Unfortunately, obtaining this information would have required, at minimum, a new report or query capability to be added to the PMS, which was not feasible to do in an expedient fashion.

MDT staff suggested several enhancements as a result of the testing process:

- On the program analysis screen, add the capability to deal with only a subset of projects in the automated selection process.
- Add a filtering capability on reports to allow results to be viewed by geographic and network categories. [This suggestion was implemented for the final version of the tool.]
- On the performance report, add summary lines to see overall performance by network category (across geographic categories), by geographic category (across network categories), and then total across all categories.
- On the performance report, add the capability to compare different scenario results; currently comparison of two different scenarios is awkward. [This suggestion was implemented for the final version of the tool.]

Summary Evaluation

Staff assigned the following summary evaluation ratings to AssetManager PT:

- Potential value of functionality: 6–7,
- Ease of data preparation: 8–9 (if a "cookbook" were available), and
- Reports/Outputs: 5–6 (higher if reports included filtering capabilities and summaries).

6.3 NYSDOT FIELD TESTING

New York is a diverse state with a land area of 47,376 square miles and a population of roughly 19 million. The state ranks third in the nation in both total population and urban population and ranks first in the nation in the number of public transit passengers. NYSDOT is responsible for 15,000 miles of highway and roughly 7,500 bridges. Total vehicle-miles of travel in New York State approaches 135 billion, of which 45 percent is on the highway network administered by NYSDOT (*14*).

NYSDOT's asset management efforts have focused on using the capital program update process as an integrating mechanism across the various "stovepipe" programs for pavement, bridge, congestion/mobility, and safety. Management systems have been developed in-house to provide the capability to simulate needs and relate investment to performance. NYSDOT's program update process makes use of these management systems to establish performance targets for each of these program areas; the regions propose programs of projects to meet the performance targets. Programs are then centrally reviewed to ensure consistency with performance targets as well as to look horizontally across the different program areas.

New York has a program support system/project management information system (PSS/PMIS) in place that tracks candidate projects throughout their life cycles and balances alternate programs against funding sources. The capability to perform what-if analysis to determine the financial impacts of different sets of projects is handled by interfaces with a bridge needs forecasting model and a pavement needs forecasting model.

At the time the testing took place, NYSDOT had developed a prototype of an integrated asset management system that uses a common measure, "excess user costs," for comparing alternative investments and making tradeoffs across different packages of diverse project types. Excess user costs are defined as the incremental costs incurred by users as a result of a facility in less than ideal operating conditions. Three cost components are considered: delay costs (for passengers and freight), accident costs, and vehicle operating costs. This system can be used to compare candidate project proposals based on benefit/cost, where benefits are defined as the decrease in excess user costs attributable to an investment.

Field testing at NYSDOT began in late December 2003 and was concluded with a site visit by the research team on March 22, 2004.

AssetManager NT

Data Preparation

NYSDOT staff prepared two data sets for AssetManager NT using their in-house pavement and bridge analysis systems (PNAM and BNAM). The first data set included statewide results (aggregate for all regions and network categories), from five runs using different average annual budget levels over the 10-year period between 1993 and 2003. The second data set included results for four regions and two networks (on and off the NHS). Data for four budget levels were provided. Staff reported that they spent about 30 staff-hours to prepare NT data, including running the analysis systems. However, this process could be further automated to reduce data preparation time if the tool was to be used on a regular basis.

The research team created the initial configuration files for these data sets, loaded the input files, created scenarios, and sent NYSDOT the NT tool with the scenarios for testing.

The field tests used a common set of performance measures for AssetManager NT and PT, which included excess user cost, pavement condition rating, percentage of poor and fair lane-miles, bridge condition rating, and number of deficient bridges by number and percentage of deck area. In addition, several output measures were used, including the lane-miles of pavement rehabilitation and reconstruction, the lane-miles of pavement preventive maintenance, the number of bridges rehabilitated or replaced, and (for PT only) the number of bridges with maintenance work.

Testing Results

The research team demonstrated each of the AssetManager NT views. Overall, the reaction was very positive; staff felt that this tool could be very useful in exploring investment tradeoffs as part of the development process for the 5-year plan. Staff also expressed interest in exploring how the tool could be used to look at tradeoffs across corridors as well as across assets.

Currently, scenario analyses are run by request. AssetManager NT could be used to run and package multiple scenarios for executives so that they could explore variations without having to request additional runs.

NYSDOT staff made the following comments:

- The NYSDOT analysis tools predict results by multiyear funding periods, not annually (interpolation was used to produce annual results). The NT tool can also be used in this manner, which would reduce data preparation requirements. Tool documentation should be sure to say that the analysis periods need not be single years.
- NYSDOT's analysis tools also allow for different project prioritization criteria to be entered (e.g., worst-first versus minimum life-cycle cost). Different NT scenarios could be created for sets of runs using different criteria to provide a tool for visualizing the performance differences.
- A help file is needed. [A help file was developed in conjunction with the documentation.]

NYSDOT staff suggested the following enhancements:

- Add an optimization feature to find the resource allocation across a set of asset types, geographic categories, and network categories that minimizes or maximizes a single designated performance measure (in NYSDOT's case, minimizing excess user costs).
- Improve the capability to compare results across different NT scenario files.
- For the cross-criteria view, rather than having a slider for the year, have each pane show a trend graph over the scenario time horizon for the selected performance measure. [This comment was later addressed by adding the allocation view.]
- Provide an option to fix an overall budget level and then see how a performance measure changes as the allocation in resources changes across assets (and potentially geographic and network categories as well). [This comment was later addressed by adding the allocation view.]
- Add validation to the create scenario feature to check if there are different numbers of runs entered per asset/geography/network combination. If so, the process should terminate with a message to the user. Currently, the scenario is created but the results are not valid. [Validation was later added in response to this comment; errors are written to a log file.]
- Add capability to print or export tabular results as opposed to just the graphical views.

Summary Evaluation

Staff assigned the following summary assessment ratings to AssetManager NT:

- Potential value of functionality: 7 (9 if an optimization feature was provided),
- Ease of data preparation: 6 (although, producing inputs for multiyear periods would have been easier),
- User interface: 7, and
- Reports/Outputs: 8 (higher if reports included filtering capabilities and summaries).

AssetManager PT

Data Preparation

NYSDOT staff prepared two data sets for the PT tool using queried information from New York's PSS. The PSS stores approved candidate projects, and automated procedures are in place to retrieve system performance information based on candidate project location references. Both PT data sets included 473 projects scheduled for years 2009 and 2010. In the first data set, the projects were identified by region (A or B), and a single budget category was used for all projects. In the second data set, the projects were identified by region (A or B) and network (interstate, non-interstate NHS, other state system, or other touring route), and five different budget categories (maintenance, preservation, mobility, safety, and other) were used. Approximately 32 staff-hours, mostly for data cleaning, were required to produce a PT data set. Staff felt this time could be reduced to about 10 staff-hours through further automation of the process.

Testing Results

Because NYSDOT staff had logged many hours working with multiple versions of the tool before the visit, the research team did not run any tests on site. Rather, researchers reviewed each screen with the staff members and asked them for comments and suggestions.

NYSDOT staff made the following comments:

- The PT tool provides the capability to explore performance results of different project mixes, which is similar to a planned enhancement to New York's PSS.
- The PT tool also was useful for looking at the program balance, i.e., the mix of work by category (e.g., safety, mobility, pavement preservation).
- Their work with the PT tool will likely shape requirements for the PSS tool enhancements (specifically, the capability to represent changes in system measure as the result of a project).
- The ability of work targets to be set for only those types of work that are defined by a physical system measure seemed limiting at first. For example, NYSDOT specified system measures for pavement and bridge preservation projects, but not for safety and mobility projects. For these latter types of projects, NYSDOT would be more likely to specify a performance measure target (e.g., reduction in excess user costs). Performance targets may be set on the baseline performance screen.

The deterioration issue that was raised in Montana also was discussed in New York: because the PT tool's most likely use is to look at projects being considered for implementation at least 3 years into the future, projected conditions rather than current baseline conditions need to be reflected in the tool if the performance projections are to be compared to targets for a future year. This need increases the complexity of data preparation. However, even without considering deterioration, the tool is still useful for comparing different project mixes based on relative performance results.

NYSDOT staff suggested AssetManager PT could be enhanced by the addition of an option for the data entry of system measures and baseline performance indicators to have the system calculate aggregate statistics based on entries for individual geographic/network category combinations.

Summary Evaluation

Staff assigned the following summary ratings to AssetManager PT:

- Potential value of functionality: 10,
- Ease of data preparation: 10, and
- Reports/Outputs: 10.

SECTION 7

RECOMMENDED FUTURE INITIATIVES

7.1 OVERVIEW

Both of the tools that have been developed under this project can be immediately useful to transportation agencies and, in most cases, can be implemented using internal agency staff resources. However, several future initiatives are recommended to improve the tools over time and help agencies make effective use of the tools.

In addition to recommending future initiatives, this section summarizes the gaps in analytical tools for asset management that were identified as part of this project but that did not make the short list of tools to be developed. This summary is intended to be used as a resource by the asset management community as it develops future research agendas with respect to analytical tools.

The section is organized as follows:

- Improvements to AssetManager NT;
- Improvements to AssetManager PT;
- Implementation Support for the AssetManager Tools; and
- Remaining Gaps in Analytical Tools for Asset Management.

7.2 IMPROVEMENTS TO ASSETMANAGER NT

Several potential improvements to AssetManager NT are recorded here for future consideration. Some of these changes were identified during the field testing process but could not be implemented under the existing project resources; others were identified by the research team. Before these improvements are pursued, an initial shake-out period, during which user feedback is gathered, is recommended for the existing tool.

Hierarchies of Network and Geographic Categories

The current tool supports only a single set of geographic categories and a single set of network categories. This improvement would provide multiple levels of hierarchy, to allow a lower level (e.g., cities) to be rolled up into higher-level categories (e.g., counties and regions).

Option to Limit "What-If" to Program "Out" Years

This improvement creates an option for an initial fixed budget period to be followed by a period of variation in possible budget levels. This option allows the tool to handle the case in which the first few years of a program's budget are fixed (with programmed projects) and agencies want to test variations only for the last set of years but still see the entire performance trend line. The tool would show the performance results for the first set of years but exclude their budgets from the calculated average annual budget, so the user is specifying the average for the "out" years only.

Exportability of Performance Results

This improvement would allow the performance information shown in the views to be exported to a spreadsheet. The spreadsheet would contain the annual budget level, year, asset type, network category, geographic category, and performance measure and value.

Optimization

This improvement would add a feature to find the optimal allocation of resources across a set of asset types and geographic and network categories to minimize or maximize a single designated performance measure (e.g., to minimize excess user costs).

View Setting Separate from Scenario Setting

In the current tool, if a scenario is rerun, any views saved as part of that initial scenario must be recreated. This improvement would allow the data for an existing scenario to be updated while previously setup views are retained. This function would need to check that the same basic parameters are in effect in the revised scenario (e.g., asset types, geographic and network categories).

Representation of Targets on Views

This improvement allows users to specify performance targets and have these target values indicated on the graphs in the budget and allocation views.

Normalized Performance Measures

This improvement allows users the option to specify minimum acceptable and target values for each of the performance indicators, which define a new type of performance measure, called "normalized," for display in the system. This normalized performance measure transforms an indicator to a 0-1 scale, using a consistent formula based on the minimum acceptable and target values that were specified. The user can view multiple normalized measures and develop a resource allocation strategy that, first, addresses areas where the minimum acceptable performance values are not being met and, then, addresses targets.

Performance Measure Transformations

This improvement adds the capability to do simple transformations on performance indicators, e.g., dividing the indicator by 100.

Handling of "Float"-Type Indicators

Currently, graph scales are calculated automatically and the user cannot easily interpolate between the values shown on the axes. This improvement would allow users to specify standard intervals to show on graphs for float-type indicators.

Cross-Scenario Comparisons

This improvement would add the capability to compare results across different NT scenario files.

Representation of Work Type

AssetManager NT works with the total investment level for an asset; the investment level typically is composed of several types of work on an asset. For example, an investment level for pavement may consist of a mix of expenditures for resurfacing, patching, rehabilitation, and full-depth reconstruction work. AssetManager NT does not currently support decision-making about the best mix of work for a given asset type because the assumption was made in this project that such decisions are best left to individual asset management systems. Users can now include output-type performance indicators in their AssetManager NT input files to allow the amount of work by type to be viewed within the system. However, users cannot manipulate the mix of work to see how performance changes (MDT expressed interest in this capability during the field testing exercise). Such a capability is possible to implement but would require development of a variant of the current tool, with a different input data structure.

7.3 IMPROVEMENTS TO ASSETMANAGER PT

Improvements to AssetManager PT are divided into those that could be implemented within the existing tool to enhance its core functionality and those that involve porting the tool from a spreadsheet to a different software platform with an improved user interface, which can more easily be updated over time. The research team recommends that the functional enhancements be considered in conjunction with a port of the tool.

New Functionality

The following functional capabilities would be enhancements to those that were implemented in the prototype system:

- Analysis of subsets of the project list—This capability would allow the user to define a filter condition for program analysis (e.g., develop a program scenario for an individual district);
- Auto-aggregation for baseline measures and indicators—This capability would enable the system to calculate aggregate statistics based on entries for individual geographic/network category combinations;
- Accommodation of annual budget constraints—This capability would extend the tool to include budget constraints by year and to allow for project costs to be distributed across several years. The tool currently only allows for a single budget constraint for the entire program period (which may consist of several years);
- Accommodation of "plug" program items—This capability would improve the PT tool's ability to handle "plug" line items not tied to particular locations; and
- Accommodation of multiple sets of budget categories—This capability would allow any given project to be in multiple categories and what-if analysis to be performed using any set of categories.

New Platform

The decision to implement AssetManager PT initially as a spreadsheet application was a good one: the spreadsheet platform facilitated the process of testing, allowed the tool to evolve substantially throughout the course of the project as new functionalities were suggested, and provided many powerful capabilities (e.g., the ability to easily add new columns of project information).

However, the spreadsheet platform also has several disadvantages. It is far too easy for a user to inadvertently overwrite formulas or named ranges that are needed for the tool to operate properly. Data entry can be inconvenient: the user must select all of the proper codes from the pick lists and is responsible for ensuring that the one-to-many relationships between projects and measures and between projects and impacts are properly populated. Scalability also is a concern; the tool's performance is acceptable with hundreds of project candidates; but, thousands of projects would slow it down. Finally, any upgrades to a spreadsheet-based tool would put the burden on users to transfer their data from the older versions of the tool.

For all of these reasons, AssetManager PT should be ported to a more stable platform with database support and improved user interface features that facilitate use of the tool. The research team recommends a Microsoft.NET platform, with data stored in a relational database (either an inexpensive database that can be packaged with the application or an ODBC-compliant format to allow for use with commercially available databases such as Oracle and SQL Server).

A high-level list of design requirements for the ported tool includes a definitions menu option, an input data menu option, a work targets menu option, and a what-if analysis screen:

- The definitions menu option includes seven dialogues for entering/editing definitions for
  - System measures,
  - Network categories,
  - Geographic categories,
  - Project types,
  - Asset types,
  - Performance measures, and
  - Budget categories.
- The input data menu option includes submenus for project data and system baseline data:
  - The project data option allows users to enter projects, their impacts, and their changes in system measures using a master-detail approach. The capability to customize and add new project attributes (currently included in the PT tool) would be included here.
  - The system baseline data option includes screens for specification of baseline performance and baseline system measures. Each of these screens would have an import data feature (button or menu option) that allows data to be replaced or refreshed from a standard text-based format (e.g., XML or comma-delimited).
- The work targets menu option allows work targets for defined project types and geographic/network category subsets to be set.
- The what-if analysis screen implements the functionality of the current program analysis screen, which includes the following capabilities:
  - Define scenario—this tool would no longer need to be limited to a fixed number of scenarios;
  - Set a project filtering condition for a scenario;
  - Set budget levels by budget category for a scenario;
  - View, sort, and filter a list of candidate projects by any project attribute;
  - Easily access the detailed project record from the what-if screen;
  - Select and save project ranking methods for each budget category;
  - Auto-select projects given the budget constraints (using the existing algorithm);
  - Manually shift projects in and out of budget categories and instantly view the total dollars spent (via "drag-and-drop" or standard tools that allow users to move items between an "available" list and a "selected" list);
  - Generate all of the existing reports and graphs showing impacts of a given program scenario in a more interactive fashion; and
  - Export all information on project selections and program impacts to a spreadsheet (or XML format).

The research team also recommends that the design process for this full version of AssetManager PT move toward an integration of the PT and NT tools. The first logical step in this integration would be to define components that can be shared between the PT and NT tools (particularly, configuration information, baseline system measures, and performance values). These shared components can be built into the full version of AssetManager PT. Then, development of the next version of AssetManager NT can include porting it to .NET, implementing the shared components that were incorporated into PT, and updating its look-and-feel to match that of the PT tool.

7.4 IMPLEMENTATION SUPPORT FOR THE ASSETMANAGER TOOLS

The research team recommends several activities to help agencies use the AssetManager tools effectively. At least a minimum level of user support—to answer questions, troubleshoot problems, and address reported issues through workaround suggestions and/or software patches—is critical. Beyond this minimum level of support, some agencies would find external assistance useful for structuring the configuration items, identifying data sources, and writing small utility programs to translate across data formats. Additionally, the following resource materials would be valuable to support the tool implementation process and to disseminate practical results that reflect the overall findings of Project 20-57:

- A full tutorial example of how to use both AssetManager tools in combination, using work tracking as the linkage;
- A set of guidelines for project data structures that support the ability to analyze the aggregate performance of a proposed program of projects—and that, therefore, are consistent with AssetManager PT (These guidelines also should consider integration of actual cost and performance data for completed projects, thereby closing the asset management feedback loop.); and
- Sample interface tools (analogous to the NT robot tools) that take work candidates from Pontis and HERS/ST (or other systems) and populate portions of the AssetManager PT data structure.

7.5 REMAINING GAPS IN ANALYTICAL TOOLS FOR ASSET MANAGEMENT

Although this project has made significant progress in addressing gaps in decision support tools for tradeoff analysis, many needs identified in the initial interviews still remain. These needs (detailed in Section 4, Table 7, and summarized in the following subsections) are best tackled with efforts on multiple fronts: enhancements to existing tools now in use (e.g., commercial, federal, and customized); development of new special-purpose tools; and focused data gathering and additional research and development at the national level to develop and improve the data and analytical relationships that form the core of credible and useful tools.

Asset Preservation Strategies

Initial interviews identified the following needs for developing asset preservation strategies:

- Improved base of data and models based on actual experience that can be used to quantify life-extension impacts and benefits of routine and preventive maintenance;
- Improved analysis and reporting capabilities within individual asset management systems to better support the ability to
  - Analyze and present benefits of preventive maintenance,
  - Determine life-cycle cost and condition-related outcomes from different levels of maintenance expenditures, and
  - Demonstrate the value of keeping an asset at a given condition level (for all assets); and
- Network-level what-if analysis tool to understand impacts on pavement lives (and corresponding investment needs) of different truck loadings for variations in soil and snowfall conditions.

Full Benefits and Costs of Alternative Investments

Initial interviews identified the following needs for understanding the full benefits and costs of alternative investments:

- Additional research to adequately represent failure costs in bridge management systems from a risk analysis perspective;
- Analytical capabilities to assess freight-related and economic development impacts and benefits of multimodal investment alternatives;
- Improved ability to calculate economic benefit for a program of projects;
- Improved capabilities to analyze the benefits and costs of new interchanges;
- Improved capabilities to analyze the benefits and costs of drainage projects; and
- Tools that focus on impacts on customers and users rather than facility condition.

Resource Allocation Decisions

Initial interviews identified the following needs for supporting resource allocation decisions:

- Development of performance measures that facilitate comparisons across project types;
- New tools that allow agencies to incorporate consideration of policy initiatives (e.g., passing lanes and upgrades to roads with seasonal weight restrictions) within the condition-based needs assessment method used by management systems; and
- Tool or approach to overlay customer satisfaction and priorities with engineering decisions for use in program planning and prioritization.

Other Asset Management

Initial interviews identified the following needs for expanding analysis capabilities beyond pavement and bridges:

- Tools for tracking ITS equipment condition, replacement needs, and life-cycle costs;
- Tools for equipment management, buildings, and other physical assets not covered by standard management systems; and
- Tools for transit life-cycle cost analysis.

Monitoring and Feedback Support

Initial interviews identified the following needs for supporting monitoring and feedback activities:

- Improved tracking of the impacts of maintenance on facility life;
- Tools that provide improved accuracy of cost estimates used in needs, project evaluation, prioritization, and program tradeoffs and that account for typical project amenities and add-ons (possibly using outputs from bid tabulations or maintenance management systems). Such tools would use activity-based costing to separate out different project elements (e.g., paving versus safety improvements);
- Tool to tie together capital and betterment investments by asset type and location (for GASB-34 requirements);
- Cradle-to-grave project tracking systems; and
- Query tools to provide easy access to estimated versus actual costs, experience, and lessons learned.

SECTION **8**

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APPENDICES

The following appendices are published on the accompanying CD (CRP-CD-57):

- Appendix A: State Interview Summaries and
- Appendix B: Review of Existing Tools.

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation