222

National Cooperative Highway Research Program

NCHRP Synthesis 222

Pavement Management Methodologies to Select Projects and Recommend Preservation Treatments

A Synthesis of Highway Practice

Transportation Research Board
National Research Council

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Pavement Management Methodologies to Select Projects and Recommend Preservation Treatments

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff Transportation Research Board

This synthesis will be of interest to highway administrators; pavement management systems (PMS), maintenance, and computer engineers; and technologists involved with data collection and computer programming for the purposes of a PMS. This synthesis describes the state of the practice with respect to pavement management methodologies to select projects and recommend preservation treatments.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

This report of the Transportation Research Board describes the predominant pavement management methodologies being used by U.S. state and Canadian provincial highway agencies; provides a general description of each methodology; and summarizes the requirements, benefits, hindrances, and constraints associated with each. It includes a review of domestic literature and a survey of current practices in North America. In addition, case studies are included to illustrate the use of these methodologies within highway agencies. Operational and soon-to-be implemented technologies are also discussed, and an extensive bibliography is provided for further reference.

This synthesis discusses the pavement management methodologies to select projects and recommend preservation treatments that are in use; however, it does not compare the results of the decisions made "with" and "without" the methodologies nor does it include a "look-back" analysis to see how many projects were actually completed in comparison to those identified for any one methodology. The comparisons of "with" and "without" a specific methodology actually take place via simulations on a computer of one management philosophy versus another. Based on the results of these simulations, decisions are made. In order to "look back" and analyze the effectiveness of the decisions, strong feedback processes between the PMS and the design have to be established. This helps to evaluate the effectiveness of performance criteria, deterioration models, life-cycle costing, and other models used in the PMS. To date, the PMS and design functions have been separate and no follow-up has been done to verify assumptions made by either group. This will be an area to focus on in the next few years.

During the development of this synthesis, work on the National Highway System (NHS) designation legislation was in progress between House and Senate transportation leaders. An agreement between the House and the Senate was reached and sent to the President for signature in November 1995. The NHS legislation contained a provision for making compliance with the management systems called for in the Intermodal Surface Transportation Efficiency Act (ISTEA) Interim Final Rule optional. The President signed the NHS legislation on November 28, 1995. The influence of the previous ISTEA management system requirements on agency PMS practices was reflected in the responses to the survey for this study. Therefore, within this synthesis, the numerous references to the ISTEA management system requirements, including PMS, have been revised to indicate that these interim requirements are now optional.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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Scott A. Sabol, Senior Program Officer, National Cooperative Highway Research Program, assisted the NCHRP 20-5 staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

PAVEMENT MANAGEMENT METHODOLOGIES TO SELECT PROJECTS AND RECOMMEND PRESERVATION TREATMENTS

SUMMARY

Highway agencies use a number of different pavement management methodologies to select projects and recommend preservation treatments for their highway networks. In some cases, agencies have highly sophisticated, computerized processes in place. In other cases, agencies make decisions based on more traditional approaches to managing the network, including visual ratings and panel decisions regarding preservation actions. In light of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, which mandated the use of management systems (to include pavement management systems) for the selection of cost-effective strategies to improve the performance of transportation systems, many highway agencies evaluated their methodologies to determine whether they had the tools necessary to provide this type of information. However, it should be noted that the passage of the National Highway System (NHS) legislation in 1995 made the use of management systems optional rather than mandatory.

This synthesis includes a review of the predominant pavement management methodologies being used by U.S. state and Canadian provincial highway agencies; a general description of each methodology; and a summary of the requirements, benefits, hindrances, and constraints associated with each. Case studies are also included to illustrate the use of these methodologies within highway agencies.

Three predominant methodologies are discussed in this synthesis: pavement condition analysis, priority assessment models, and network optimization models. Based on data collected from a survey of agencies, pavement condition analysis was the most common methodology, with almost one-half of the agencies indicating use of this approach to some extent. The remaining agencies were equally divided among the use of network optimization models, priority assessment models, or some other approach to pavement management. With primarily three predominant methodologies being used, there are many similarities among agencies in the basic pavement management components of data collection and analysis. Even so, similar objectives for these components resulted in dramatically different data requirements and analytical techniques among agencies.

Although pavement management has been practiced since the late 1970s, many of the agencies are still using manual and subjective approaches. Several highway agencies indicated that their pavement management systems (PMS) are fully automated; however, the majority of agencies indicated that only a portion of their system is automated. Of those agencies, many reported that they would probably never fully automate their systems.

ISTEA has greatly influenced the pavement management practices of a number of agencies. Agencies with previously certified PMS were required to be recertified by the Federal Highway Administration (FHWA), a process that required agencies to upgrade their existing capabilities. Issues that agencies were required to address in this regard

include adding multiyear analysis, developing and using prediction models, providing PMS coverage for non-National Highway System (NHS) federal-aid highways (including city and county streets), incorporating life-cycle costs, and considering alternate project or network strategies.

Pavement management methodologies provide information to agencies to assist them in selecting projects and identifying treatments. By using a systematic, objective approach, pavement management methodologies have been shown to provide substantial benefits to agencies, including longer service life, better functional satisfaction, and a greater number of users served by the highway network. The use of these objective, analytical procedures can easily be shown to be a cost-effective use of taxpayers' dollars.

As highway agency personnel become more familiar with the concepts of pavement management and the differences between the methodologies used (through training and other technology transfer efforts), additional benefits are expected to be realized. Computer technology remains an underutilized resource that has the potential to dramatically impact the analytical capabilities of most highway agencies. Other advancements in the areas of prioritization, optimization, and life-cycle costing will also enhance the benefits that pavement management can provide.

Ultimately, each agency will have to determine the methodology that is most appropriate to meet its unique organizational structure, reporting needs, and resource availability. This synthesis provides information for an agency to better determine which approach best fits its pavement management goals and objectives.

During the development of this synthesis, work on the NHS designation legislation was in progress between House and Senate transportation leaders. An agreement between the House and the Senate was reached and sent to the President for signature in November 1995. The NHS legislation agreement contained a provision for making compliance with the management systems called for in the ISTEA Interim Final Rule optional. The President signed the NHS legislation on November 28, 1995.

The influence of the previous ISTEA management system requirements on agency PMS practices was reflected in the responses to the survey for this study. Therefore, within the synthesis, the numerous references to the ISTEA management system requirements, including PMS, have been revised to indicate that these interim requirements are now optional.

CHAPTER ONE

INTRODUCTION

PURPOSE AND SCOPE OF SYNTHESIS

Methodologies to select projects and their associated treatments for pavement preservation vary in level of sophistication and automation. Some highway agencies have highly sophisticated, automatic processes with minimal subjective bias and with full explicit justification for project selection and preservation treatment recommendations. Other highway agencies use more heuristic approaches, basing decisions on engineering judgment, historical methods of dealing with pavement data, consensus management, or other factors.

This synthesis presents the results of a survey conducted in U.S. state and Canadian provincial highway agencies to determine current methodologies used to select projects and their associated treatments for pavement preservation. Additionally, a review and brief discussion of literature in the subject area is included. This synthesis addresses the requirements for each methodology, as well as the highway agency pavement preservation goals that determine the selection of each methodology. Operational and soon-to-be-implemented methodologies are also discussed. Specific items addressed for each methodology include the following:

- General basis and description of the methodology,
- Demonstrated and potential benefits,
- Hindrances to implementation of the various steps or stages comprising the methodology,
- Applicability to various types of highway networks,
- Practical and theoretical constraints and requirements (e.g., data, resources) of the methodology, and
- Factors influencing the selection of projects and treatments.

INTRODUCTION TO PAVEMENT MANAGEMENT METHODOLOGIES

Background

Pavement management provides agencies with the tools necessary to forecast future pavement performance so that agencies can identify the optimal timing for pavement preservation in conjunction with identifying strategies that address the goals of the organization and deficiencies in the highway network. In the December 1, 1993 *Federal Register*, the Federal Highway Administration (FHWA) outlined a "systematic process, designed to assist decision makers in selecting cost-effective strategies/actions to improve the efficiency and safety of, and protect the investment in, the nation's transportation infrastructure" through the use of integrated management systems, as shown in Figure 1 (*1*). According to this same source, a management system consists of tools or methods to

- Identify performance measures,
- Collect and analyze data,
- Determine needs,
- Evaluate and select appropriate strategies/actions to address the needs, and
- Evaluate the effectiveness of the implemented strategies/actions.

For today's transportation agencies to be successful, they will need to better integrate the operation and preservation of the existing transportation system with their long-range transportation development and performance planning objectives. This includes the ability to develop interrelationships between the information provided by each of the management systems with the long-range planning process at the network level. The successful integration of technical strategies with the long-range planning process is the key to implementing procedures that result in an overall improvement in network performance.

In 1991, the federal government passed the Intermodal Surface Transportation Efficiency Act (ISTEA) mandating the use of management systems. This landmark legislation was followed by regulations published in the *Federal Register* for states to develop, establish, and implement systems for managing federal-aid highways and other transportation facilities. The Interim Final Rule states that the overall objective of ISTEA is the "improved performance of statewide and metropolitan transportation systems through preservation, operational, and capacity enhancements" (*1*). ISTEA also requires that the six management systems identified in Figure 1 be used in developing metropolitan and statewide transportation plans and in making project selection decisions. Therefore, all of the management systems are expected to provide outputs that are integrated into the decision process and directed at enhancing the performance of current and future transportation systems. At a minimum, a pavement management methodology should be able to provide information to answer these basic questions (*2*):

- Is the network in acceptable condition according to the agency's policy?
- Is the trend in condition staying the same, improving, or declining?
- Is there a backlog, and if so, how large is it?

PMS have been used successfully since the late 1970s to help agencies improve the effectiveness of long-range planning and project and program development processes, and to provide feedback concerning the relationship between estimates used for the decision-making process and actual outcomes. PMS have been used to improve the objectiveness of the decisions made, and to help ensure the consistency of decisions throughout the various levels within an organization (*3*).

The process of systematically and objectively ranking pavement rehabilitation projects has proven to be extremely beneficial to agencies where no planning is being performed.

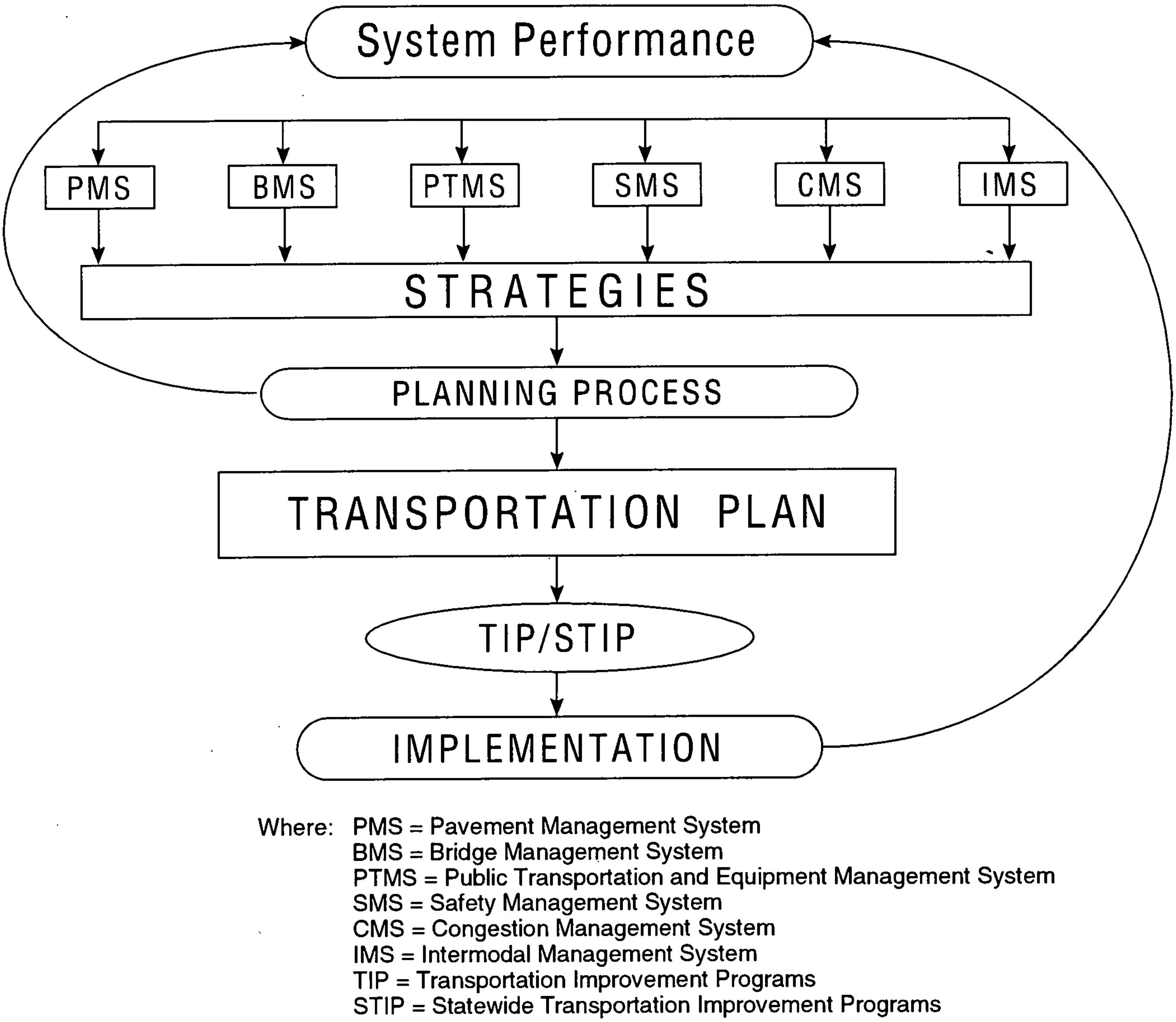


FIGURE 1 Management system overview *(1)*.

Lytton has found that simple ranking procedures can provide an agency with 20 to 40 percent more benefit than the old, subjective project selection techniques. Another 10 to 20 percent benefit can be achieved by adopting optimization methodologies over ranking procedures. Lytton defines the benefits to the agency in terms of longer service life, better satisfaction of its intended function, and a greater number of users served (Lytton, R.L., "Optimization Techniques," unpublished, May 1994, and (*4*)).

During the development of this synthesis, work on the National Highway System (NHS) designation legislation was in progress between House and Senate transportation leaders. An agreement between the House and the Senate was reached, and was sent to the President for signature in November 1995. The NHS legislation agreement contained a provision for making compliance with the management systems called for in the ISTEA Interim Final Rule optional. The President signed the NHS legislation on November 28, 1995. The influence of the previous ISTEA management system requirements on agency PMS practices was reflected in the responses to the survey for this study.

Methodologies

The approaches agencies use, or are developing, to address the overall objectives of ISTEA, in addition to preserving individual agency goals, vary in level of sophistication and automation. The preservation of highways consists of both objective and subjective issues. The design service life of a project treatment is an example of an objective issue. Deciding whether to improve the agency's pavement ride quality or remove safety deficiencies is an example of a subjective issue agencies must deal with. Pavement management methodologies can help to make subjective decisions more objective by providing decision makers with objective information, such as the outcome of alternative actions. Some agencies have developed automated processes that are highly structured with the purpose to minimize bias on objective issues. Other agencies use, or are developing, approaches that are based purely on the subjective input of several individuals. However, the majority of agencies appear to use processes that range in sophistication between these two extremes.

The American Heritage Dictionary defines a methodology as "the system of principles, practices, and procedures applied to any specific branch of knowledge" (*5*). Within the area of pavement management, three predominant methodologies are used to select projects and recommend preservation treatments: pavement condition analysis, priority assessment models, and network optimization models.

These methodologies were introduced in the 1990 *AASHTO Guidelines for Pavement Management Systems* (*6*). In a general sense, each of the three approaches is listed in increasing order of sophistication. The selection of the appropriate methodology within an agency must be evaluated carefully; the decision should be based on the needs of the agency and the resources available. In many instances, the ideal approach may be a combination of characteristics from two or more strategies.

A brief discussion of each of these methodologies follows. Chapter 2 provides a more detailed discussion of the methodologies.

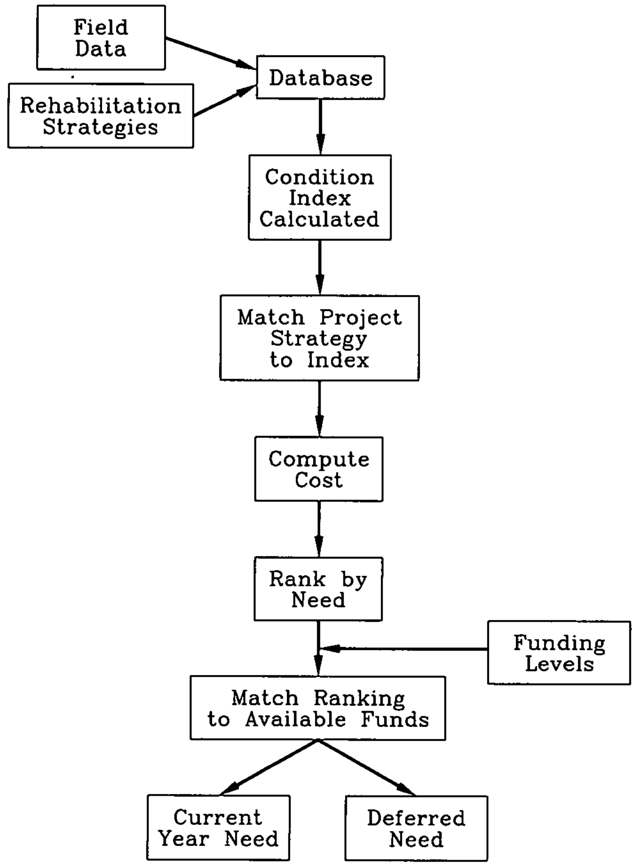


FIGURE 2 Pavement condition analysis.

Pavement Condition Analysis

The basic pavement condition analysis approach is perhaps the simplest of the three most common methodologies used in pavement management. As shown in Figure 2, this methodology uses pavement condition information obtained in the field to determine a pavement condition index of some type. Based on the calculated condition index and a preselected determination of maintenance and rehabilitation strategies to match various condition indices, a ranked strategy can be identified for a given budget level. Rankings are typically based on the current condition level. The pavement condition analysis is typically based only on an assessment of current pavement conditions, so multiyear analysis cannot normally be performed and the previous ISTEA requirements for the NHS could not be met. If multiyear programs are developed, they are usually made up of lower priority projects for which needed funds were not available. This approach could be made more sophisticated by developing pavement performance prediction models or remaining service life estimates, both of which forecast the network's rate of deterioration over time. The use of these methods allows agencies to forecast future conditions, which in turn permits agencies to develop multiyear plans based on the effect of alternative strategies on long-term network condition rather than on prior survey results that may be outdated.

Priority Assessment Models

A more sophisticated methodology, the priority assessment model, is illustrated in Figure 3. This approach uses prediction models to forecast pavement conditions and prioritization as tools to identify the most cost-effective strategies for various funding levels. A number of different approaches can be used to prioritize various pavement rehabilitation needs so that the strategy with the highest priority over the analysis period is selected. The most common approaches for prioritizing needs include benefit/cost ratios or life-cycle cost analysis. Benefits can be defined as road user benefits, agency benefits, or a combination of the two.

An advantage of this approach is that a number of alternative treatment strategies can be evaluated for each candidate project. Another advantage is that life-cycle costing is normally used instead of focusing only on initial costs, providing the agency with a better understanding of the total cost of a decision to the agency.

The sophistication of this methodology can vary depending on how needs are prioritized. A benefit/cost approach may be as simple as calculating the area under a pavement condition versus time curve for each alternative treatment. Using benefits, such as road user costs and cost per year of acceptable service, increases the system's level of sophistication and requires more data to support the system.

Network Optimization Models

Optimization methodologies have been used successfully in the area of pavement management since the early 1980s. An

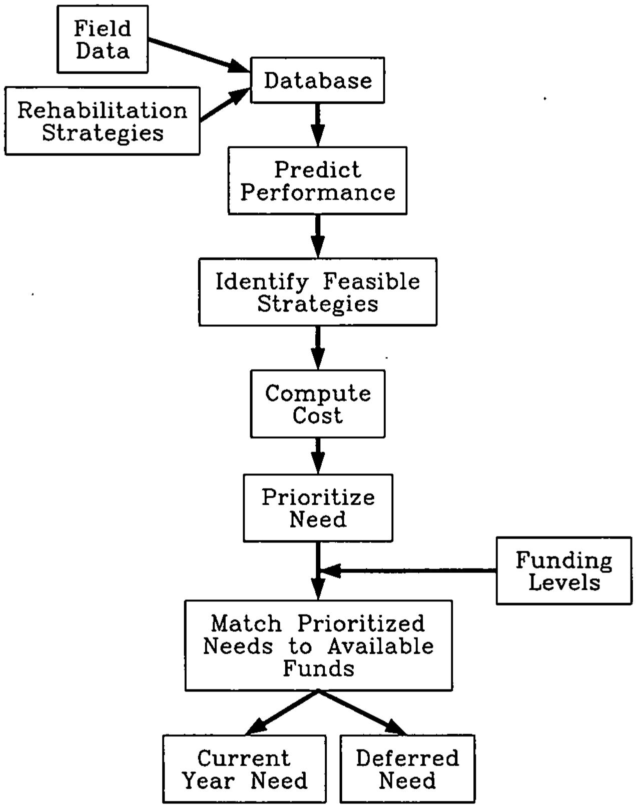


FIGURE 3 Priority assessment model.

approach based on optimization (see Figure 4) allows a simultaneous evaluation of an entire pavement network, where optimal network strategies are identified first and specific rehabilitation projects and treatments are selected afterwards. Although the outputs of a system based on optimization may be similar to the outputs from an approach that uses priority assessment, the analysis methods are actually quite different. This is largely due to the "top down" approach that is characteristic of optimization techniques.

An agency that bases its pavement management approach on optimization views the concurrent optimization of various management strategies and tradeoffs for the network as a whole as the first level of analysis. The second level of analysis is the selection of projects and the recommendation of treatments, both of which are typically performed concurrently. For example, an agency may use optimization to determine whether smaller, more expensive projects should be selected for a given budget rather than larger, less expensive projects. Only after this decision is made can an agency move to the second step, identifying candidate projects with specific treatments.

Other Methodologies

Not all agencies rely on project and treatment selection methodologies that follow the decision process of the three predominant strategies discussed previously. Some agencies, such as the Michigan Department of Transportation, rely on methodologies that involve applying techniques commonly used in other fields. The techniques are typically tailored by in-house staff to meet any specific requirements necessary to make project and treatment decisions.

Michigan's PMS analysis methodology, described as a generative method, is based on management principles that require a shift from linear approaches for complex systems towards systemic thinking. This shift in thinking is believed to simplify the management of pavement networks because the new approach studies the patterns of behavior and the interrelationships among projects, treatments, and programs. The interrelationships are further evaluated in terms of events (reactive), patterns of behavior (responsive), and systemic structure or root causes (generative) (*7*). Event explanations, such as pavement condition, are the most common; however, they often trigger reactive measures. Pattern of behavior explanations, such as transverse crack spacing, focus on seeing longer-term trends and assessing their implications. The third level of explanation is the least common and most powerful. It focuses on the underlying or root causes of patterns of behavior.

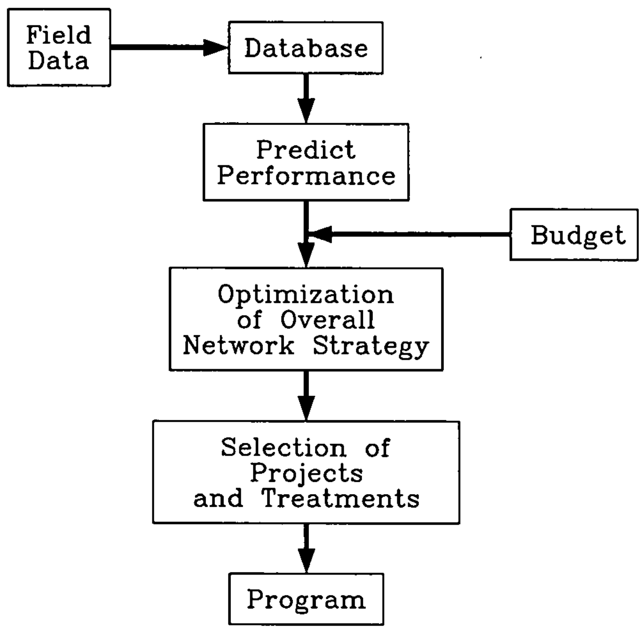


FIGURE 4 Network optimization model.

The developers of the Michigan system felt that all three levels of analysis were necessary for a truly comprehensive analysis of an increasingly complex management issue. They did not find conventional PMS methodologies adequate to provide this type of analysis because linear thinking does not address problems with the following types of complexities: subtle cause and effect relationships, and duplicate actions that can have different effects in the short and long runs. This methodology is described in more detail in the Michigan case study in Chapter 4. This approach is further defined in the literature (*7–10*). A project level approach that uses a systemic structure is also discussed in the literature (*3*).

ORGANIZATION OF SYNTHESIS

Each of the predominant project and treatment selection methodologies introduced in this chapter will be discussed in more detail in Chapter 2. A summary of practice, which presents the requirements, benefits, hindrances, and constraints associated with each methodology, is provided in Chapter 3. Chapter 4 presents case studies that illustrate how four highway agencies use these methodologies, followed by conclusions presented in Chapter 5. A bibliography of PMS materials, organized by topic, follows the references. The survey and summary of responses to the survey can be found in Appendices A and B, respectively.

CHAPTER TWO

PAVEMENT MANAGEMENT METHODOLOGIES

OVERVIEW

As discussed in Chapter 1, there are a variety of methodologies that can be used to select projects for pavement preservation. The methodologies vary in the types of information necessary to generate the analysis, the time frame over which an analysis is run, and the process that is being used to optimize or prioritize maintenance and rehabilitation needs. No one approach is appropriate in all situations. Having a better understanding of the basic principles of each approach will permit an agency to better identify the solution that is most appropriate for its particular network.

This chapter discusses in more detail each of the three predominant methodologies that were introduced in Chapter 1. Examples of agencies using each of these methodologies can be found in Chapter 4.

PAVEMENT CONDITION ANALYSIS

A methodology based only on current condition is the most basic of the methodologies being used today for pavement management purposes. The fundamental premise of the approach is that, through an assessment of the current condition of the entire network and the funding levels available for the network's preservation, pavement rehabilitation and maintenance needs can be identified and prioritized. In agencies where funding levels are not adequate to meet the preservation needs of the roadway network, projects must be ranked to determine which needs can be postponed until a later year (*11*).

A variety of criteria are used to rank the preservation projects within highway agencies. Some of the most common criteria include the following:

- Rank by condition
- Rank by initial cost
- Rank by cost and timing
- Rank by life-cycle cost
- Rank by benefit/cost ratio.

The majority of agencies responding to the survey reported that ranking by current condition is by far the most common criterion for programming purposes.

In most cases, these agencies also use the current condition to identify necessary levels of repair. Based on the condition level of the pavement, or the types of distresses that are present, appropriate maintenance and rehabilitation (M&R) strategies are identified to address the existing deficiencies. In most of the agencies using the current condition, only one or two treatment strategies are considered for each pavement section requiring repair. The process for developing M&R strategies simply requires ranking the needs of each pavement section based on condition levels and matching the M&R strategies to the levels of deterioration present. Once the treatment strategies have been identified, costs can be determined and programs can be developed to match the funding levels available.

In some cases, agencies that use a pavement condition analysis make basic assumptions regarding the deterioration patterns of their pavement sections. These assumptions allow agencies to consider future conditions for the development of longer-range programs. Less than one-half of the agencies using pavement condition analysis consider more than one year in their analyses. The single year analysis did not meet the minimum requirements outlined in the *Federal Register* (*1*) or Executive Order 12893, "Principles for Federal Infrastructure Investments" (*12*), at the time.

Because agencies consider only a few treatments when using this approach, treatment selection typically takes place as part of the project selection process, which is initiated by reaching a trigger value that indicates a rehabilitation need. In most cases, when there are choices to be made among treatment types, the primary basis for treatment selection is to see that the treatment addresses the needs determined through the condition survey. In some instances, decision trees or matrices that permit the agency to more narrowly focus treatment selection to the deficiencies identified may be used. However, the use of these tools is much more common with some of the other analysis methods.

An agency can more easily implement a pavement management system (PMS) using pavement condition analysis instead of the other methodologies because of its simplicity. Pavement network and condition information is required on a cyclical basis, and automated or manual approaches may be used to obtain this information. Historical condition data is only required if the agency chooses to define deterioration patterns for its road network. This information is supplemented with a list of treatment strategies considered for each section in the network needing repair. Although pavement condition analysis may be done manually, it can be done much more expediently when it is computerized.

One of the greatest benefits associated with this approach is its simplicity. Responding agencies reported making better, more informed decisions because of the condition data being evaluated, and noted that preservation choices better match the needs observed in the pavement. Agencies also reported that by using a systematic approach to prioritizing projects, immediate rehabilitation needs are regularly addressed, often resulting in an improved overall network condition.

Most of the factors that have hindered agencies seeking to apply a pavement condition analysis methodology are not unique to that methodology. In fact, the predominant factors keeping a PMS from being implemented are lack of sufficient personnel to support the system, lack of computer skills, and lack of funding to support the pavement management effort. Together, these factors have contributed to the fact that most agencies using this approach are only partially automated with no more than the database computerized.

The simplicity of this approach contributes greatly to the constraints associated with it. Several agencies reported that their condition ratings and prioritization approaches are subjective, leading to decisions based on opinion. Others reported that there is resistance to any type of change within their organizations, so the approaches that have been used for years continue to be used.

One disadvantage to this approach, and a primary deficiency with respect to previous ISTEA requirements, is that basing decisions solely on prioritization of current condition levels does not ensure that the best long-term decisions are being made. Another disadvantage is that in most instances, little historical information is available for a life-cycle cost analysis, and rehabilitation decisions are based primarily on initial project construction costs, rather than on the total project and maintenance costs over time. Without computerized systems, most agencies consider only one treatment for each situation, potentially overlooking more cost-effective treatments.

PRIORITY ASSESSMENT MODELS

Priority assessment models take the pavement condition models a few steps further. Models of this type allow an agency to perform multiyear programming to determine what its needs will be in later years and what level of rehabilitation will be necessary at that time. To perform this level of analysis, the development of performance prediction models, or remaining service life estimates, must be incorporated into the PMS. This makes it possible for an agency to identify which pavement sections are ready for rehabilitation in the first year, and to predict when each section of the network will reach its trigger point for signaling rehabilitation needs in later years. In some agencies, this approach is referred to as multiyear prioritization.

The process for identifying preservation needs and selecting feasible rehabilitation treatments is very similar to pavement condition analysis. One major difference, however, is that instead of simply identifying current needs, an agency can develop specific programs for future years through the use of pavement deterioration models and remaining service life estimates. Candidate projects are still ranked within each year of the analysis, but the ranking procedure becomes more sophisticated. The majority of agencies that reported use of this methodology have computerized their processes, thus making a sophisticated analysis easy to accomplish.

The priority assessment methodology is sometimes referred to as being a "bottom up" approach because feasible maintenance and rehabilitation treatments are usually identified first in the analysis and then prioritized based on agency selected criteria. The most common procedure is for several feasible alternatives to be identified for each project requiring rehabilitation. The benefit of each alternative can be represented in a number of ways, including determining benefits to the road users, benefits to the agency, or a combination of benefits to both. The definitions of road user benefits and agency benefits are addressed in two AASHTO publications: *AASHTO Guidelines for Pavement Management Systems* (*10*) and *A Manual on User Benefit Analysis of Highway and Bus Transit Improvements* (*13*).

The cost effectiveness of each alternative treatment is a commonly used benefit; it is estimated as the ratio of the area under the performance versus time curve to the treatment life-cycle cost. The area (illustrated in Figure 5) is said to represent the additional life obtained by the particular treatment. In addition to determining the benefit, the life-cycle costs of the treatments are determined and divided into the calculated benefit. The recommended treatment is then identified by choosing the treatment that generates the highest benefit/cost ratio.

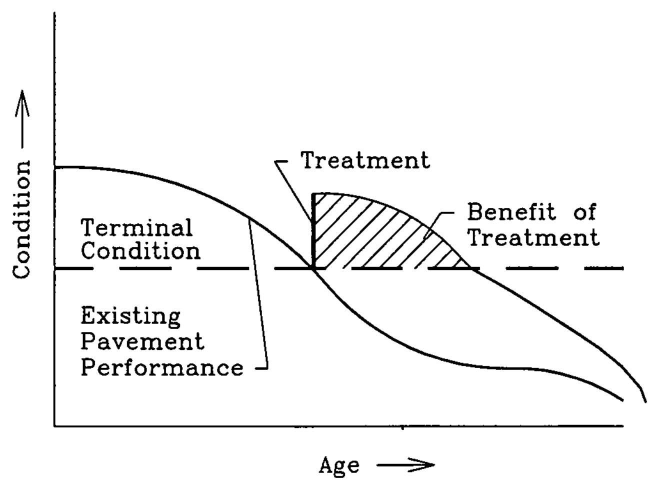


FIGURE 5 Illustration of treatment benefit.

Once the recommended treatment has been selected for each project, the projects are prioritized and multiyear programs are developed. In some instances, due to the limitation of funding levels available, certain projects must be deferred until later years. In most cases, the projects that provide the greatest benefit to the agency or its users will be ranked higher in the program priority. In some systems, prioritization models are built into the PMS to assist with the programming of projects in each year of the analysis.

The sophistication of this type of analysis lends itself best to computerized systems. Developing performance curves, predicting future condition, determining benefit for various treatments, and prioritizing various treatments over a number of years would be extremely labor intensive if performed manually. Some of the features of this approach (specifically, considering various rehabilitation treatments and calculating benefits for each) would be practically impossible to do manually. Most of the responding agencies using this approach have computerized the analysis portion of their PMS.

The sophistication of the analysis also tends to increase the level of resource requirements needed by the agency to support it. In most cases, agencies that use this methodology must have a computerized system to support the analysis. In addition, condition data must be available and updated on a regular basis. The fundamental aspect of the analysis lies in the predicted condition, so deterioration models become extremely important components of the system and must be reviewed and updated regularly. The estimated cost of each of the treatments considered in the analysis must also be reviewed regularly to ensure the treatments are based on current pricing.

There are a number of benefits associated with this type of analysis, one of the most important of which is that agencies are able to understand the type of analysis performed and can manually reconstruct the decision process used in program development. The methodology considers several years in the analysis period, thereby increasing the long-term effectiveness of the decisions being made. Life-cycle costs, or uniform annual equivalent costs, are considered in the prioritization models, again improving the basis for long-term decisions. Agencies reported that, because of performance models, they are able to improve the timing of their rehabilitation decisions by identifying preventive or minor rehabilitative treatments prior to the time at which only very expensive alternatives can be considered. This capability has improved overall average network condition, remaining service life, and objectivity of decision-making processes. Agencies reported that selecting cost-effective project strategies and treatments assists in making the best use of the limited dollars available for pavement preservation.

Agencies using this approach identified several hindrances, the most specific of which was a lack of personnel capable of generating this type of analysis or supporting the data requirements of the system. Some agencies stated that they did not have the computer skills in-house to develop the software systems or maintain them after they were implemented by a consultant. Other agencies listed apprehension of change and complexity as hindrances.

A few practical and theoretical constraints of this methodology were identified. The most significant constraint listed was that the methodology did not account for subjective and political issues, which frequently influenced the overall funding and selection of projects. Other agencies using this methodology stated that their ability to use this type of system to its greatest benefit was constrained by the amount of funding available to implement the recommendations. This comment was not limited to this particular methodology.

NETWORK OPTIMIZATION MODELS

The ranking and prioritization approaches discussed previously perform the programming and financial planning functions of the network PMS process in a sequential fashion. Within these approaches, the network decisions are essentially sums of decisions for pavement sections within the network. Network optimization models provide an agency with the ability to perform a simultaneous evaluation of an entire pavement network while considering multiple tradeoffs between various factors such as maximizing benefit (e.g., ride quality, network condition, reduced rates of deterioration, lower number of safety deficiencies) or minimizing cost (e.g., lowest life-cycle cost). Network optimization is considered a top down approach because overall network goals are established first so that projects and treatments can be selected to achieve the desired goal. Most network optimization models optimize the relationship between a measure of network condition and the program's budget level.

Prior to beginning an optimization analysis, an agency must define the goal of the optimization procedure, known as an objective function. The general form of the objective function is to achieve the desired agency goal (e.g., maximize the total benefit to the network or minimize cost) subject to resource constraints, serviceability targets, and other constraints identified by the agency. Due to the potentially large number of constraints and variables that can be considered in this type of analysis, the analysis is often simplified by breaking pavements into various classes (e.g., condition level, pavement class). The identity of each section in the network is removed, and the model analyzes the total volume of pavements in each of the classes. The goal of the objective function is to determine the funding levels required to maintain the network condition above a predetermined level, or to maintain the service life of pavements in each class at a predetermined level. In simplistic terms, this can be stated as establishing the long-term relationship between any given funding level and the resulting network performance.

Because the planning of network preservation is not a static process, pavement management applications of optimization have focused on probability as a tool to determine the future condition of a pavement section. Markov transition matrices (*11,14*) and semi-Markov transition time distributions are the most common tools used in optimization methodologies. In the Markov approach, the condition of a pavement at any given time is thought of as occupying one of a finite number of "states." Over a pavement's life, it moves from one state to another according to some probability distribution that is time independent. This concept is illustrated in Figure 6. In this example, the agency determined that for a pavement in state 1, there is a 20 percent chance that the pavement condition state next year will be the same as the condition state this year. There is a 40 percent chance that the condition state will change to state 2, a 30 percent chance that it will drop to state 3, and so on. These probabilities are referred to as "transition probabilities," and are considered independent of the path the pavement may have followed prior to arriving at the given state.

PRESENT STATE NO.	FUTURE STATE NO. 1	2	3	4
1	0.2	0.4	0.3	0.1
2	–	0.2	0.6	0.2
3	–	0.1	0.3	0.6
4	–	–	0.1	0.9

FIGURE 6 Sample Markov transition matrix *(4)*.

A number of mathematical programming methods are capable of determining optimal solutions in accordance with the objective function selected by an agency. These methods include techniques that are capable of achieving "true" optimization, and several heuristic methods, which are aimed at approximating the true solution. In effect, the heuristic methods give near optimal solutions that are often simpler and more computationally efficient than the mathematical programming methods. A heuristic approach, however, should periodically be compared to the mathematical programming methods to ensure that it is consistently representing optimal or near optimal solutions.

There are four predominant mathematical programming methods used in pavement management: linear, non-linear, integer, and dynamic programming. Linear and non-linear programming are similar in that they seek to find the best solution from an infinite number of solutions using continuous variables. The primary difference in the two is that in linear programming, both the objective function and the constraints are represented by linear functions that are time independent; in non-linear programming, the objective function and some of the constraints may be curvilinear or time dependent. Both methods are based on the premise of moving the objective function to the point at which it first intersects the feasible solution set, subject to the given constraints. These concepts are illustrated in Figure 7.

Integer programming simplifies the analysis by considering only two variables: a decision not to do something (0) or a decision to do something (1). This mathematical method results in a decision matrix that clearly presents the decisions made.

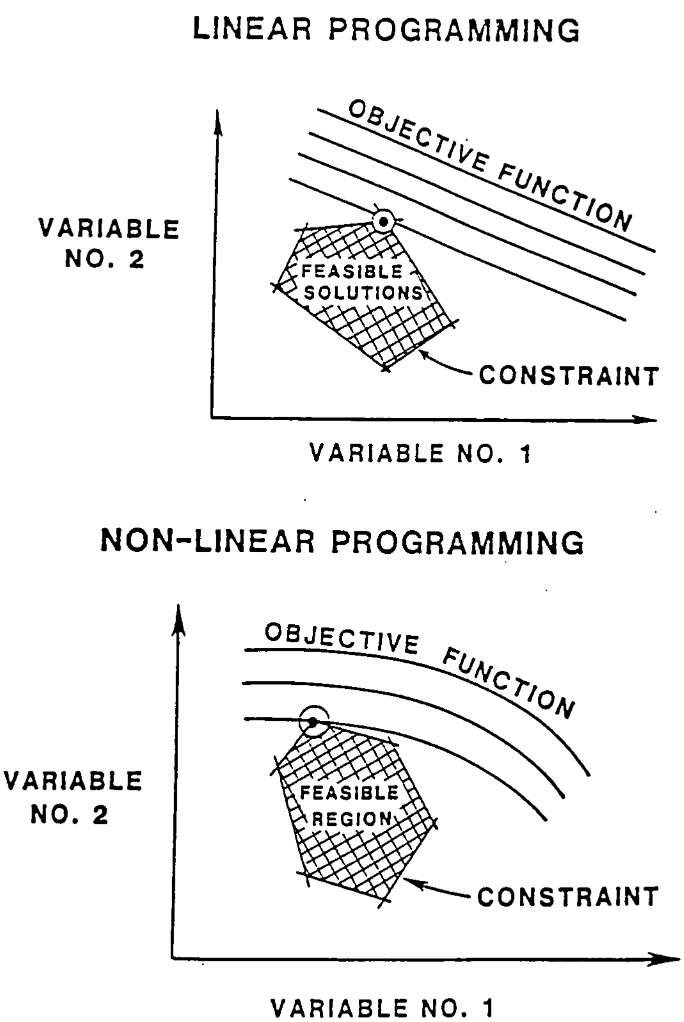


FIGURE 7 Illustration of linear and non-linear programming *(4)*.

Dynamic programming can be used in a situation that requires a number of sequential decisions that impact each other. Dynamic programming uses a procedure that starts at the final solution desired and works backwards to find the optimal solution for the designated objective function associated with each decision. In very simple terms, dynamic programming takes a large, complex problem and breaks it down into a series of smaller and simpler sub-problems.

Several heuristic methods are also used in conjunction with network optimization models in pavement management. By trial and error, heuristic methods have been found to give answers that are close approximations to those answers derived from mathematically optimal solutions. To be confident in the decisions made with a heuristic model, it is imperative that sample solutions be generated with one of the mathematical programming methods and compared to the heuristic approach. The use of incremental benefit/cost analysis is one example of a heuristic approach that provides solutions similar to a dynamic programming model, because the incremental benefit/cost algorithm and dynamic programming go through a similar sequence of decisions to determine the set of alternatives and projects that provide the greatest benefit for the total amount of money spent (Lytton, R.L., "Optimization Techniques," unpublished, May 1994).

Due to the complexity of this type of analysis, additional resources are required. An optimization analysis must be computerized, and it requires advanced, top of the line computer equipment. Personnel familiar with the use of the computerized system are required, as are individuals who understand the transition probability distributions associated with each pavement type. Several agencies stated that these programs are not user friendly, so very sophisticated skills are required to maintain and run them.

Agencies that have used this methodology noted demonstrated benefits through support from executive management and state legislatures. These agencies expressed confidence in that they are truly optimizing the allocation of their resources for preservation projects and realistically estimating future funding needs. Other agencies that are moving toward using the optimization methodology reported that the methodology will improve the objectivity of their prioritization approaches and help them better understand the long-range consequences of reduced budgets and other imposed constraints.

The sophistication of this approach has contributed significantly to the hindrances encountered by agencies implementing these systems. The lack of necessary funding, sufficient specialized personnel, and computer equipment were often listed as problems with implementing this methodology. The complexity of this approach was also listed as a hindrance and often contributed to the apprehension that technical aspects of the program would not be understood. Through extensive use of technical committees, a number of agencies have successfully addressed this apprehension.

Responding agencies reported several constraints associated with the use of this methodology. Several agencies stated that this approach was much too complicated for small road systems, and thus would not translate well to municipal agencies. In addition, agencies stated that it is sometimes difficult to translate network results into specific project results. This is a complicated procedure because network recommendations are often based on the optimization of short kilometer or mile segments, and project limits must then be developed by aggregating several segments over a number of years.

This particular methodology is the most dependent on a feedback process to provide reasonable recommendations each year. The probability matrix must be updated regularly through an ongoing process that provides the necessary adjustments. Without the development and use of the feedback process, the system recommendations will be quickly outdated.

CHAPTER THREE

SUMMARY OF PRACTICE

INTRODUCTION

Highway agencies use several basic methodologies for selecting or prioritizing projects with their corresponding treatment selection. The most common methodologies have been discussed in the previous chapter. This chapter discusses in more detail results of the survey that was sent to individuals involved in the pavement management activities of highway agencies in the United States, Washington D.C., Puerto Rico, and the twelve Canadian provinces. Of the 52 surveys sent to the United States and its territories, 46 responses were received (88 percent). Ten of the twelve Canadian provinces responded to the survey (83 percent). A copy of the questionnaire and a summary of the responses obtained are presented in Appendices A and B, respectively.

It should be noted that there were several issues with regard to interpreting the survey responses. For instance, some respondents appear to have been confused with the terms that were used in the questionnaire. Although the *AASHTO Guidelines for Pavement Management Systems* was referred to for definitions, there were some responses that indicated that the definitions were not clearly understood.

Another issue was the variation in responses that were provided. In some cases, agencies provided more than one response to a given question, resulting in more total responses for that question than total respondents. In most cases, these responses occurred where several responses were chosen from a list or where planned improvements were different from existing practices and both systems were described. Clarification was sought from respondents in a number of instances. It is believed, however, that the overall trends depicted by the survey results are not misrepresented.

PAVEMENT MANAGEMENT METHODOLOGIES FOR PROJECT AND TREATMENT SELECTION

Agencies were asked to indicate the type of methodology that best described their approach to selecting projects and treatments. By far, the most common methodology was pavement condition analysis, with 29 of 62 responses (47 percent). Twelve of the responding agencies (19 percent) use network optimization models, and 10 agencies (16 percent) use priority assessment models. Thirteen agencies (21 percent) reported that they use either a systematic methodology, some other approach, or that they had no formalized methodology. Some agencies responded in more than one category, indicating that their pavement management system (PMS) uses several approaches or that their current PMS uses one approach while their anticipated revisions would use a different approach.

Agencies were also asked whether the methodology they described is fully implemented within their agency. Of the 53 agencies responding to that question, 36 indicated that the methodology was fully implemented, and 16 indicated that it was not. One indicated that the current methodology was implemented but the planned improvements had not been implemented. Nine of the original respondents did not answer this question or many of the following questions.

Priority Assessment Models

Agencies that reported using priority assessment models were asked to identify the methods that they use to prioritize project and treatment selection. The following responses were provided:

Method	Number of Responses
Condition ranking	29
Benefit-cost (or incremental benefit/cost)	12
Life-cycle costing	6
Cost and timing	4
Other	4
Initial cost	1

Other factors listed by agencies as important items to consider in their priority assessment included traffic volume and travel speed, cost per vehicle mile traveled per year, cost per lane mile per year, district priority, maintenance savings, user savings, maintenance levels, user needs, and local considerations.

Network Optimization Models

Agencies that reported using network optimization models to select projects and treatments were asked specific questions concerning processes, such as to identify methods that were used to optimize project and treatment selection. Linear programming models were most often used by these agencies, but heuristic models were also common. No agencies indicated that they were using integer programming. Agencies that indicated in an earlier survey question that they are not using optimization models were not considered in the responses received in this section. Figure 8 represents the breakdown of responses by type of optimization model used.

Agencies using optimization models typically use one or more constraints in the selection process. These constraints establish the boundaries within which the project and treatment selection must be optimized. The two most common constraints reported by agencies include limits on the budget levels and limits on the overall network condition. In some cases, rehabilitation budgets are set to provide a specified

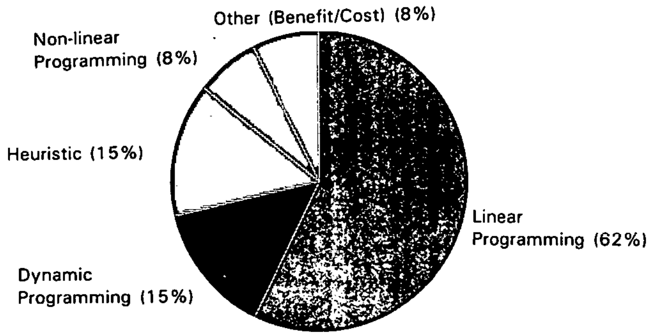


FIGURE 8 Type of optimization model used.

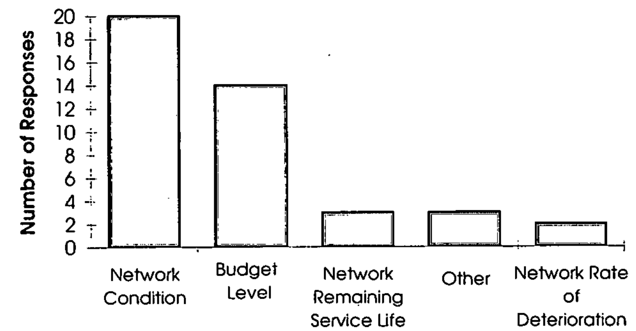


FIGURE 10 Constraints used in optimization at the network level.

average condition level at the lowest possible cost. Other constraints used in the models include the overall rate of deterioration of the network, the remaining service life of the network, or some representation of benefit. Agencies using benefits listed overall serviceability of the system as a function of the budget or the maximization of improvement effectiveness as the predominant characteristics. Figure 9 shows the breakdown of constraints reported by responding agencies.

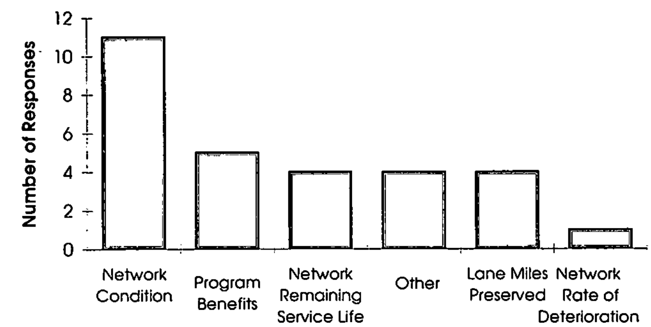


FIGURE 11 Constraints used in optimization at the program development level.

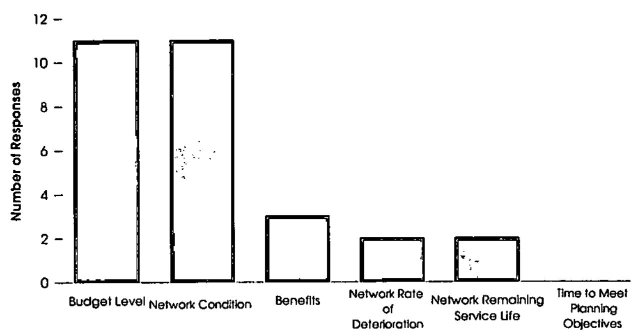


FIGURE 9 Constraints used in optimization.

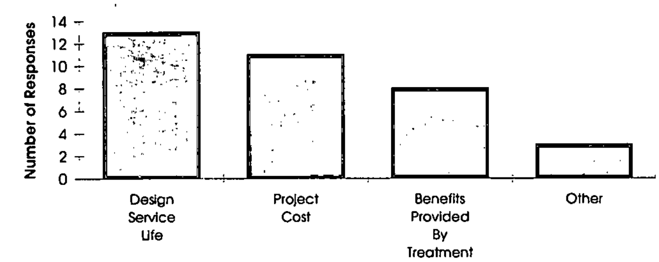


FIGURE 12 Constraints used in optimization at the project development level.

Agencies were also asked to identify the different constraints that they optimized at different levels of analysis. This was based on the assumption that different factors would be optimized at the network level, the program development level, and the project development level. It was further assumed that at the network level, policy decisions were optimized. At the next level, programs were developed to achieve the network level objectives. Finally, projects were developed so the program could be implemented. Although this question was geared towards agencies using optimization models, a number of agencies using the other methodologies responded to this question, indicating that even within other methodologies, different factors are considered when analyzing programs and project selection. Figures 10–12 present the frequency of responses at each level of analysis.

ESTABLISHING VALUE OF CANDIDATE PROJECTS

Agencies were asked to identify the variables that help them to establish the worth of candidate preservation projects in either a planned system or the current operational system. Almost all of the agencies responding to this question indicated that distress condition and roughness are used to establish the value of a preservation project. Other variables that are commonly used (or that agencies are planning to use) include rut depth, project cost, and project design service life. More than one-half of the agencies identified surface friction as another variable used. This is interesting to note in light of the findings of *NCHRP Synthesis 203: Current Practices in Determining Pavement Condition*, which indicated that although some agencies incorporate friction data into the calculation of their pavement condition ratings, most agencies used the data independent of their PMS or as part of a safety program activity (*15*). This same finding was verified in two later questions in the survey for this synthesis that asked respondents to indicate the variables used to report network and project conditions. The responses received are reflected in Figure 13.

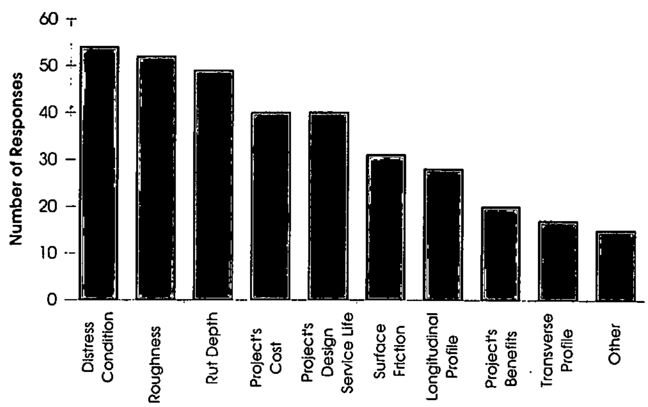


FIGURE 13 Variables used to establish the worth of projects.

Agencies that listed project benefits as a variable measured the benefits in terms of future condition, savings in agency cost, user costs, serviceability, reduced maintenance costs, safety improvements, effectiveness, benefit/cost ratios, and overall quality. Variables identified in the "other" classification included functional class, structural adequacy, traffic, appearance, public complaints, excessive maintenance costs, accidents, and shoulder upgrading.

It is interesting to note that rate of pavement deterioration was not identified as one of the factors considered in determining the worth of a project. The rate of deterioration has a tremendous impact on the appropriate timing for pavement preservation and the cost effectiveness of a given treatment.

PROJECT/TREATMENT SELECTION PROCESS

Agencies were asked in the survey to indicate when the identification and selection of projects within the program development process took place. Of the 53 agencies responding to this question, 30 indicated that project selection takes place after the budget-setting process. Fifteen agencies noted that project selection takes place before the budget is set, and is used as a tool in identifying the optimal spending levels needed, while 15 other agencies reported that project selection takes place as part of the budget-setting process.

Three of the seven agencies that identified using two of the above processes indicated that one process was currently being used and another would be used by an updated PMS. All three of these agencies indicated that their improved systems would move project selection closer to the budget-setting process. Michigan indicated that project selection by the districts takes place before the budget-setting process, while a committee finalizes project selection after the budget has been finalized. Utah and Alberta indicated that project selection takes place both as part of budget setting and after budget setting is finalized. It is assumed that this means the project selection is finalized once the final budget is set.

In the majority of agencies responding to the question on when treatment selection takes place, 30 out of 54 indicated that it most commonly occurs as part of the project selection process. It appears to be almost as common, however, for treatment selection to take place after project selection is completed (22 out of 54 responses). Five agencies indicated that treatments are selected prior to the project selection process. In most cases, agencies that had more than one response indicated that there would be differences in planned procedures from those that were in current use.

The most important basis for treatment selection was finding the treatment that best meets the project needs in terms of addressing the observed deficiencies and preventing their reoccurrence. In approximately 40 percent of the agencies responding to this question, benefits provided by the various treatments were used to select treatments. Other, less common bases for treatment selection included the life-cycle cost of the treatment, decision trees and decision matrices, meeting overall network needs, and heuristic approaches. Markov Chain linear programming was identified by one agency as the basis for treatment selection, although this more likely describes the method used rather than the basis for the decision. Michigan uses department and AASHTO guidelines for treatment selection. The number of agencies considering life-cycle cost factors in treatment selection is expected to increase due to requirements at the time stated in the *Federal Register*. The breakdown of responses is shown in Figure 14.

In agencies where more than one treatment is considered for a project, a number of different factors are used to evaluate the various options. The most common factors used in selecting one treatment over another include the total cost of the treatment, the design service life of one treatment over another, the current condition of the pavement, the functional classification of the pavement, and the surface type of the pavement being restored. Although the cause of the pavement deterioration was not explicitly listed as one of the factors used to evaluate different treatment options, it was assumed to be implied in the current pavement condition response. The breakdown of responses from 54 agencies is shown in Figure 15.

The majority of agencies responding to the survey indicated that they consider multiple treatments in their PMS. When asked to identify the number of candidate treatments considered for each project, more than one-half of the respondents (28 agencies) indicated that they consider three to four treatments. Fifteen respondents reported that they only consider one to two treatments for each project. Several states indicated that their current systems only consider one to two treatments for a project, but their enhancements will expand that to three or four treatments for each project.

A number of different treatments were listed for potential consideration in a PMS. The most common treatments considered for pavement preservation projects included the following:

Asphalt	Concrete
Routine maintenance	Slab grinding
Surface seal coats	Full- and partial-depth repairs
Milling and inlays	Crack and seat
Thin overlay	Thin-bonded overlay
Thick overlay	Unbonded overlay
Mill and overlay	Micro-surface overlay
Reconstruction	Slab replacement
	Reconstruction

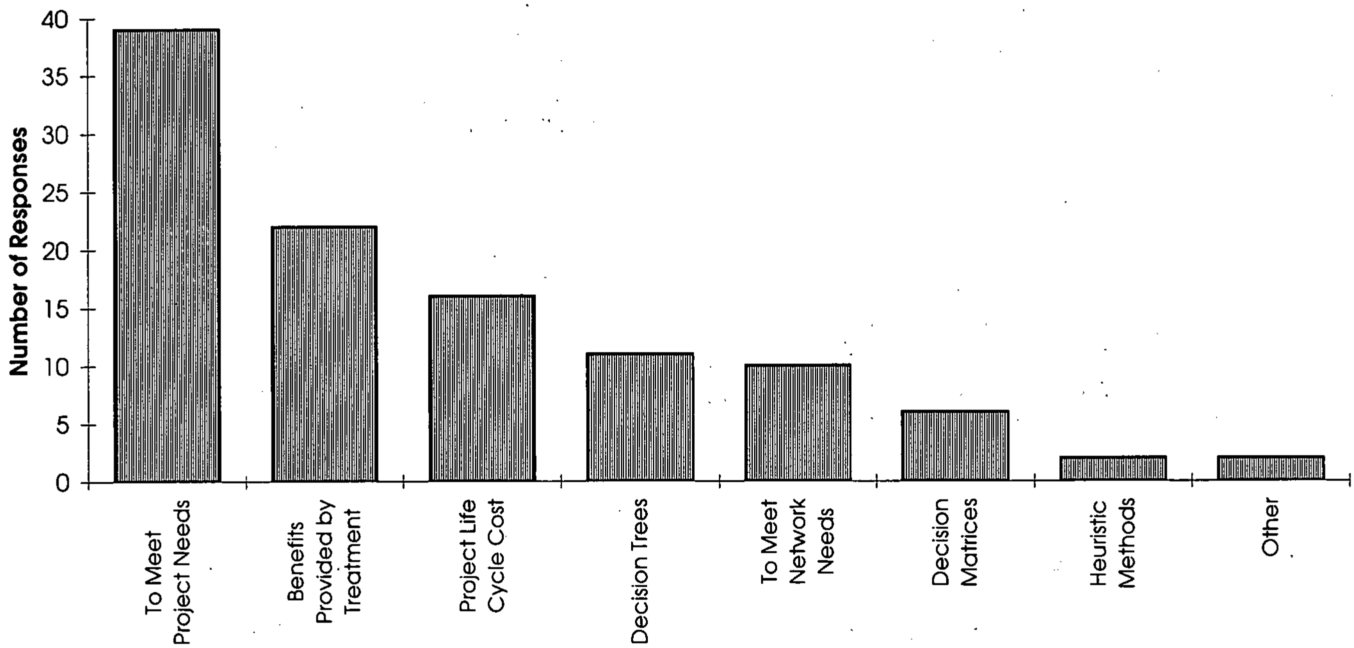


FIGURE 14 Basis for treatment selection.

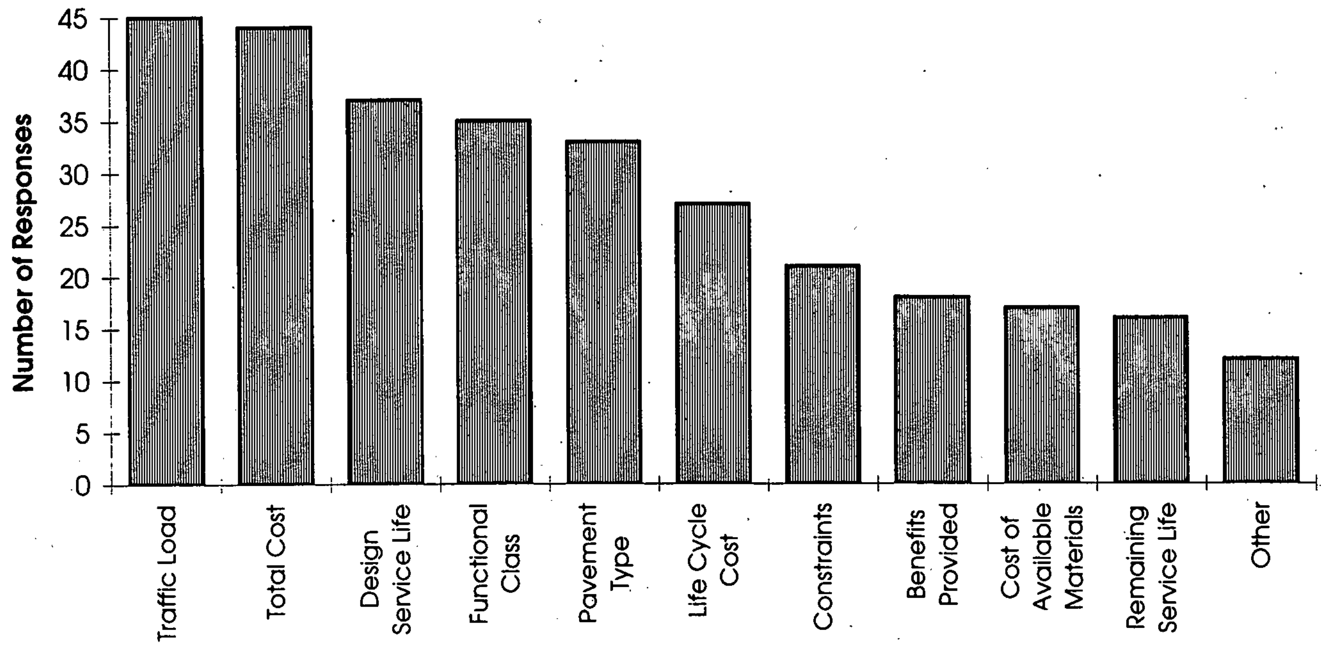


FIGURE 15 Factors used to evaluate treatments.

Most of the agencies responding to the survey also indicated that their pavement management methodologies consider multiple years in their analyses. Fourteen agencies reported an analysis period of 3 to 5 years, twelve agencies reported a period of 6 to 10 years, and 8 agencies reported a period of 11 or more. Only seven of the respondents indicated that they look at less than 2 years in their analyses. It is interesting to note that 22 agencies did not respond to this question, perhaps indicating that they did not know the number of years in their analyses, they did not want to report the answer, or they did not feel that their methodology controls future network condition or budget levels.

Out of 38 responses to the question on whether the project and treatment selection methodology in use was helpful in controlling either long-term network condition or long-term budget needs, 22 agencies indicated that their methodology assisted in long-term network condition. Sixteen agencies reported that their methodology helped control long-term budget levels, and 14 of these indicated that their methodology also helps them control long-term network condition. Only New

York and Vermont indicated that they could use their methodology to control long-term budget levels but not long-term network condition.

Agencies listed the variables they used to report the condition of their networks and their projects. The predominant variables reported were broken down into the following four categories: distress/condition rating; ride quality or roughness; structural analysis or service life; and other (including friction, pavement type, age, cost, depreciated value, geometrics, drainage condition, maintenance effort required, and capacity). The distress/condition rating was the most common variable for reporting condition of both networks and projects. The other variables followed similar trends in each case, with ride or roughness being the next most common, followed by structural analysis or service life.

These findings directly correlate to *NCHRP Synthesis 203: Current Practices in Determining Pavement Condition*, which reported that nearly all agencies performed some type of ride or roughness testing and that those practices were the most standardized of all condition data being collected (*15*). Structural capacity was evaluated by many of the agencies, but there were a variety of methods used in programming, conducting, and reporting procedures. Structural capacity was found to be used more at the project level than the network level. Friction data appeared to be used independently of pavement management, often as part of a safety program activity.

Even though distress data are the most commonly collected condition data, the study for *NCHRP Synthesis 203* found the greatest variation to be in this type of condition data. Because of this, it was found that there was little opportunity for the exchange of distress data among highway agencies.

BENEFITS DERIVED FROM EACH METHODOLOGY

Responding agencies indicated that there were both demonstrated and potential benefits realized through the implementation of a pavement management methodology; 47 responses were received from agencies addressing this question. To classify the benefits under the methodologies discussed in this synthesis, responses were classed in accordance with the methodology being used by each agency. In some cases, respondents indicated that several methodologies reflected the procedures used to select projects and treatments. In those cases, the benefits are reported in each of the corresponding classifications.

Pavement Condition Analysis

The benefits shown in Table 1 were identified by agencies in which a methodology based primarily on an analysis of pavement condition was used.

TABLE 1
BENEFITS OF PAVEMENT CONDITION ANALYSIS

Benefit Described	Number of Responses
Selection of best treatment by consistent and systematic process	11
Improvement of overall network condition at less cost	7
Consistent measurement of distress and overall condition	4
Reduced miles of "rough" pavement or pavement in poor condition	2
Integration of minor and major maintenance	2
Ability to track conditions with time	2
Reduction of lane miles with immediate rehabilitation needs	1
Equalization of pavement conditions statewide	1
Support provided for treatment selection	1
Priorities can be developed based on any variable	1
Development of an effective program within budget constraints	1
Have measures with which to establish goals	1
Ability to extend useful life of the infrastructure	1
Ability to target "low life-cycle cost" time to perform rehabilitation	1
Total Responses	36

Priority Assessment Models

Table 2 lists the benefits that were identified by agencies in which priority assessment models were the predominant feature of their methodologies for project and treatment selection.

Network Optimization Models

Of the 12 agencies that indicated project and treatment selection was based on network optimization models, 10 provided input regarding the benefits they had observed. These benefits are listed in Table 3.

BARRIERS TO IMPLEMENTATION OF THE METHODOLOGIES

The implementation of any process within an organization often meets with some resistance. Within the pavement management

TABLE 2
BENEFITS OF PRIORITY ASSESSMENT MODELS

Benefit Described	Number of Responses
Selection of best treatment by consistent and systematic process	3
Have demonstrated the benefit of treatments applied at a particular time in the pavement's life	1
Selection of the most cost-effective strategies	1
Improvement of average condition and remaining service life	1
Improvement of overall network condition at less cost	1
Integration of minor and major maintenance	1
Politics are removed from the process	1
Programs are developed from statewide needs, not regional needs	1
Ability to track conditions with time	1
Base decisions on actual, rather than perceived, condition	1
Methodology is easily understood and accepted by districts	1
Total Responses	13

field, these types of issues, commonly referred to as institutional issues, have been receiving a great deal of attention since the Second North American Conference on Managing Pavements in 1987 (*16*). The topic of institutional issues was featured in the FHWA's *Advanced Course on Pavement Management* (*4*), as well as in the *Third International Conference on Managing Pavements* (*17,18*), and has been the focus of many presentations at technical conferences.

One of the closing presentations at the Third International Conference on Managing Pavements emphasized that institutional issues are often more difficult to resolve than technical ones (*19*). This presentation quoted Kinslinger:

> There is ample evidence to show that, given sufficient funding, we have the knowledge and skills to solve the technical problems . . . The more difficult and vexing challenges have always been the institutional ones of achieving effective decision making among different advocacy groups, and power sharing among federal, state, and local elected officials, and bringing together and synthesizing vastly different sets of values and priorities (*20*).

Another speaker summarized this point by saying that in the end, " . . . it comes down to people: high level management with long-term vision, mid level management with the talent and dedication to direct system development and operation, and the users who must apply the technology to real problems" (*21*).

One of the main reasons for the attention to these issues is the effect that institutional issues can have on the successful implementation of a PMS. If proper attention is not paid to these issues, a technically sound system can sit unused within an agency, providing no benefit to anyone.

As part of the survey for this synthesis, agencies were asked to discuss factors that hindered either the development or application of their methodology. A summary of responses is presented in Figure 16. The main hindrance to agencies trying to develop and apply methodologies is lack of personnel to operate and maintain the PMS. In many cases, lack of computer skills within the organization was listed in conjunction with lack of personnel, perhaps indicating that the people with the necessary skills were not available within the organization.

A large number of the responses indicated that there was a general lack of sufficient levels of support for the pavement management methodologies. Lack of funds, personnel, support, or computer resources all indicate that organizations are either not able, or not willing, to fully support the pavement management efforts. The three other types of hindrances—fear

TABLE 3
BENEFITS OF NETWORK OPTIMIZATION MODELS

Benefit Described	Number of Responses
Optimal resource allocation for preservation projects	4
Optimum pavement design, project priorities, budget requirements, treatment selection	2
Executive management decision support	1
Legislative support of recommendations demonstrated through budget allocations	1
Reduced pavement design life-cycle costs	1
Realistic estimates of budget needs	1
Monitoring of overall network quality	1
Advance notification of needs for budget adjustment	1
Ability to time the implementation of preservation strategies	1
Reduction in the rate of network deterioration	1
Total Responses	14

of diminished input, complexity of methodology, and general negative attitude toward PMS—deal with the general anxieties people express regarding change.

Another frequent comment by responding agencies regarded the reluctance within the organization to accept the concepts of pavement management and the changes that would occur as a result of implementing new strategies. Some agencies appeared resistant to the lesser involvement of humans in the decision process and perceived that their input would be replaced. In some cases, complicated programs have kept systems from being accepted, or conflicts have risen over where control (i.e., in what division) of the system would be based. Almost all of the agencies that listed a lack of support for their efforts indicated that there was a lack of support from policy and decision makers.

It is interesting to note that most of these hindrances were discussed at the Second North American Conference on Managing Pavements and still exist today. In his opening presentation at the Third International Conference on Managing Pavements, Finn discussed what he called ". . . a built-in resistance or inability to change the traditional ways of doing business, and to a certain amount of *black box* phobia or fear and mistrust of PMS by management" (*22*). Of the 44 agencies that identified one or more hindrances to methodology development or system implementation, only 15 of these had systems that were not fully implemented. Twenty-eight of the 44 respondents indicated that their systems are fully implemented, implying that these hindrances have been successfully overcome or have not been able to completely stop the implementation. Only one state, Alaska, reported that it had addressed all fears and negativity through an extensive use of committees.

Training and increased communication within each organization are the most effective tools for addressing these issues.

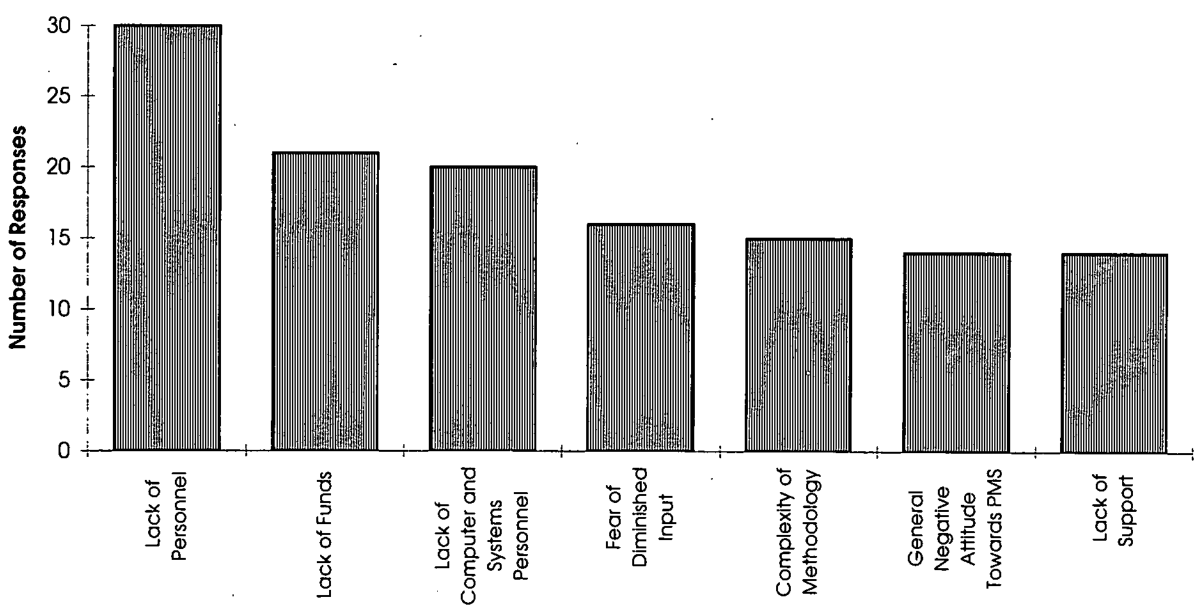


FIGURE 16 Hindrances to the development of application of a methodology.

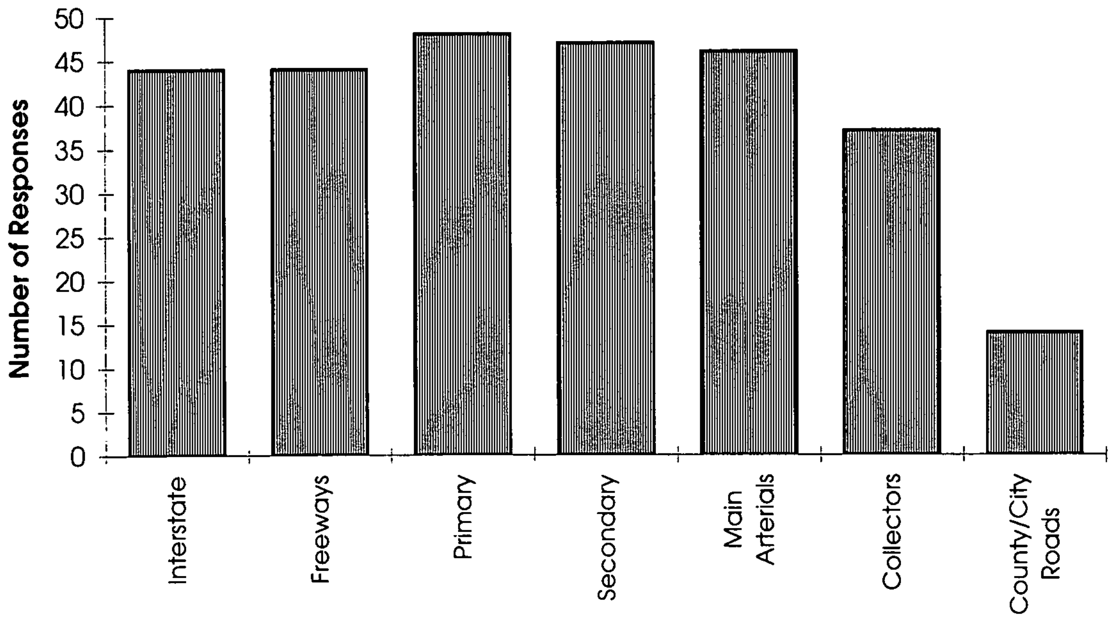


FIGURE 17 Network applications of a methodology.

Techniques that have been used by other agencies can be found in the course notebook for the FHWA's *Advanced Course in Pavement Management* (*4*) and the *Proceedings of the Third International Conference for Managing Pavements* (*17,18*). Technology transfer efforts to demonstrate the benefits realized by highway agencies successfully using PMS technology are also needed.

APPLICABILITY OF METHODOLOGIES TO VARIOUS HIGHWAY NETWORKS

With one exception, there seems to be no distinction between the types of highway networks to which the various methodologies apply. In most instances, agencies that reported use of network optimization models tended to consider fewer highway classifications in their analyses. This tendency is probably due to the level of analysis performed by the optimization programs. To speed up the analysis, fewer highway classifications would be included in the analysis set. The only exceptions to this generalization appear to be Alaska, Arkansas, and Louisiana.

As shown in Figure 17, 14 of the 54 respondents indicated that their methodology was applicable to city roads and streets. Under the proposed rules defined in the December 1, 1993 *Federal Register* (*1*), federal compliance would eventually require the use of PMS on the National Highway System (NHS) and on non-NHS federal-aid highways. This rule would dramatically impact the needs at the city level and the extension of methodologies used at the state level to local agencies. With the passing of the NHS legislation in November 1995, the use of a PMS is now optional. Several agencies made comments regarding the efforts of local agencies to adopt pavement management methodologies for their pavement networks.

REQUIREMENTS OF EACH METHODOLOGY

Each of the methodologies discussed in this synthesis has resource requirements associated with it. Agencies were asked to describe the requirements associated with their methodology in terms of the following: data, computer hardware and software, personnel, and equipment. As one would expect, the more sophisticated the methodology, the more sophisticated the requirements.

General Data Requirements

Several requirements were common to all of the pavement management methodologies used by responding agencies. Each of the methodologies requires data from which the current condition can be assessed; responding agencies listed equipment and personnel that were needed to perform these surveys. There were differences, however, in the extent to which each of these resources is required. Agencies that had automated their procedures required computers capable of storing the inventory data and running the analytical programs.

The following types of data were common requirements for many of the agencies responding to the survey: profile (longitudinal and transverse); condition (distress, structural, roughness, and friction); historical (construction and maintenance); cost; and location.

Special Data Requirements

No unusual data requirements were highlighted in the survey. Maryland specifically listed life-cycle cost data as a requirement to support life-cycle cost analysis. Several agencies also listed that interaction between divisions is critical to successfully obtaining some of the data required by the pavement management methodology. North Carolina reported using a relational database that could handle the different referencing systems typical of the varied data collection activities within an agency.

Special Computer Hardware and Software Requirements

Several agencies identified the need for mainframe or minicomputers in addition to the personal computers required to perform an analysis. The mainframes and minis were identified primarily as the location of large data files maintained by the agencies over the years. Most agencies with automated systems mentioned that they had several personal computers dedicated to their pavement management needs. Agencies in which optimization models are used listed high requirements for their computers. One agency also specified the need for a plotter to support its system.

In some cases, software requirements were also listed. The most commonly identified requirements included a database, some type of analytical program, and graphics packages. Other application programs were required in some cases, as were proprietary programs that supported systems developed by consultants.

Personnel Requirements

Responding agencies listed several types of personnel as being necessary to support their pavement management methodologies. Engineers and technicians were required to support the data collection activities. Engineers and programmers were also identified to perform the analysis and computer operations to support the pavement management programs. Agencies specified that these people needed to be highly trained in computer technology, mathematics, or pavement engineering to be most effective. This was especially true in agencies using optimization approaches for program development. Individuals who had design, maintenance, and planning experience were very valuable to support the pavement management needs.

Another problem facing highway agencies is the turnover within the pavement management area. Due to the limited amount of formal training in pavement management, there is a significant shortage of people who understand the pavement management concepts. In many agencies, once individuals receive training or gain experience, they are promoted or transferred to other jobs. Recent studies indicate that the annual turnover rate for state PMS engineers has been approximately 25 percent over the past 5 years (2). This has a tremendous negative impact on the ability of a highway agency to operate and rely on their PMS recommendations.

Several agencies also indicated that the individuals running the pavement management programs need to be dedicated to the pavement management unit. Many agencies stated that they needed at least five individuals within their pavement management sections; however, many operate with only one person overseeing the management and daily operation of the PMS program.

Special Equipment Requirements

The majority of responding agencies reported having access to equipment that was needed for data collection activities. Several agencies indicated that they had moved toward automated distress data collection, which required the purchase of new equipment, or the contracting of outside firms to collect the data. The South Dakota profiler, ridemeter, skid trailer, and nondestructive testing equipment were frequently mentioned in the survey. The specific types of equipment being used by highway agencies to collect condition data were summarized in *NCHRP Synthesis 203* (*15*). Electrical and mechanical shops were listed as being necessary to support all of the data collection equipment.

Other Requirements

Although not specifically listed in the survey, several agencies mentioned that they need the support and commitment of their regional and headquarters' staff for their pavement management methodologies to be effective. Continued funding to support their missions was also listed.

PRACTICAL AND THEORETICAL CONSTRAINTS

Each of the methodologies is somewhat restricted by both practical and theoretical constraints. Some of the practical constraints are caused by the size and variability of the highway network itself and the subjectivity of the data collected by human beings. Most agencies do not have the resources to sample 100 percent of their networks for data collection, so the accuracy of their methodologies is limited by the representation of the samples selected. This accuracy is further limited by the ability of the raters to identify and interpret distress when sitting inside a vehicle or the accuracy of computer algorithms designed to identify distress automatically. In most cases, these data were not available for county and city streets.

Project selection is constrained by the accuracy of data collection efforts and the criteria used to select projects. Projects clearly within the treatment ranges often used with rehabilitation decision trees are easily identified in a pavement condition analysis or priority assessment analysis. For example, if preventive maintenance activities are recommended for pavements in excellent or very good condition (i.e., condition rating above 80 on a 100-point scale), it is relatively easy to identify projects in this category. It becomes harder when the condition of pavement sections falls on the borders of various categories. These cases must be considered on a case-by-case basis. In some cases, by the time a treatment is identified, the condition has often deteriorated to a far worse condition. Available budget levels were also identified as a key constraint in project and treatment selection.

Several agencies listed theoretical constraints of the pavement condition analysis. These agencies reported that the lack of performance models and multiyear analysis limited the value of recommendations made by the system. Agencies noted that they were required to select projects based on a "worst first" approach that did not ensure the selection of the most cost-effective, long-term plan. Without a more sophisticated system, the agencies stated that they could not develop long-term network-level strategies. Even those agencies using priority assessment models mentioned that they were not confident that their methodology optimized to produce the highest condition levels over time for the entire network.

Agencies that adopted optimization to perform their pavement management functions reported that their systems are too complicated to be used by smaller agencies, such as local highway agencies. These agencies also stated that it is sometimes difficult to translate network goals into project-specific objectives.

Organizational issues were frequently listed as constraints to the success of pavement management objectives. Internal resistance to change was identified by several agencies as a constraint that appears to be decreasing with time and training. The reliance on teamwork and cooperation between districts and the central office was also listed. Agencies that identified these as constraints indicated that they did not feel the communication between individuals was used to the fullest extent. Other internal factors that contributed to constraints affecting the system were the influence of political factors on project selection, the acceptance of recommendations within the agency, and the lack of adequate personnel to operate the system.

Most agencies seemed to agree that their pavement management objectives were more constrained by the practical factors than by the theoretical constraints, once again supporting the statement that institutional issues are more difficult to resolve than technical ones.

FACTORS THAT INFLUENCE PROJECT AND TREATMENT SELECTION

Responding agencies listed several factors that influence the selection of projects and treatments and are common to all of the methodologies for pavement management. In most cases, the factors listed were not likely to change or disappear. For this reason, it is important for the selected methodology to accommodate these factors through a manual adjustment or through automated means. The following factors were the most commonly identified influences on project and treatment selection:

- Geographical boundaries and the balance of work between districts,
- Political influences or citizen requests,
- Combination with other types of projects for program development,
- Influence or bias of individuals developing the program,
- Geometric constraints,
- In-house design capabilities,
- Traffic operations and safety upgrading,
- Locally available resources, and
- Policies and mandates.

AUTOMATION OF PROCESSES FOR PAVEMENT MANAGEMENT METHODOLOGIES

Although pavement management has been practiced since the late 1970s, the majority of agencies have practiced it through manual, rather than automated, means. Twenty years later, the majority of agencies still have not converted all analytical functions to computers.

When asked to describe the state of automation within each agency, only Virginia and Nova Scotia responded that none of their processes are automated. Only 11 agencies stated that their entire PMS is fully automated, and 41 responded that some portion of their system is automated. The majority of agencies with systems that are only partially automated indicated that they consider their methodology to be a manual process that is assisted through the use of computers; these agencies' systems will most likely never become fully automated, probably due to the fact that pavement management consists of both objective and subjective issues. Objective issues, such as treatment selection, can be computerized or automated. Subjective issues, such as the decision to eliminate safety deficiencies over improved frictional resistance, are harder to automate but require high-quality data so that the impacts on overall network performance can be evaluated.

Eleven agencies stated that only their data collection efforts are automated at this time. Other respondents varied in the level of automation used, but it appeared that, in many cases, computers were not used to their fullest extent. All of the agencies using optimization approaches appeared to have fairly sophisticated levels of automation. The majority of agencies that only had their data collection efforts automated appeared to be using a pavement condition analysis. The majority of agencies using priority assessment models used some level of automation to perform their analysis.

INFLUENCE OF ISTEA ON PAVEMENT MANAGEMENT METHODOLOGIES

In several cases, pavement management methodologies had been adopted by agencies prior to the (now optional) 1991 ISTEA legislation, which mandated the use of management systems (to include PMS). The influence of ISTEA had the potential to greatly affect agencies where pavement management was already established, especially with regard to data collection and analysis requirements.

The survey participants for this synthesis were asked to indicate whether ISTEA would influence their current approach for project and treatment selection. No Canadian provinces responded to this question because they are not subject to the ISTEA rules. A total of 44 U.S. agencies did respond, with 26 indicating that ISTEA would influence their approach, and 18 responding that it would not impact them in any way. Comments by agencies that indicated they would be affected by the ISTEA rules include the following:

- Multiyear analysis will need to be added,
- Optimization needs will be implemented to justify expenditures,
- County and city streets will be considered in project selection,
- Life-cycle costs will be incorporated,
- More miles will be covered by the system,
- Ground tire (crumb) rubber must be considered,
- Additional data must be collected,
- Alternate strategies will be considered, and
- Project selection will be more objective.

Even so, most agencies did not appear to be greatly concerned about the influence of ISTEA on their pavement management approach. Only 5 of the 44 agencies—Montana, Nevada, Tennessee, Utah, and Vermont—indicated that their PMS had not been approved by FHWA. Most stated that they were in the process of upgrading to meet FHWA standards. Training classes on the concepts used in a multiyear analysis would be beneficial to agencies upgrading from a pavement condition analysis.

OTHER INFORMATION OBTAINED THROUGH THE SURVEY

Two other questions were asked of the survey respondents concerning their pavement management methodologies. The first question concerned the location of pavement management responsibilities in their agencies, and the second focused on the use of the methodology by central and district offices.

With regard to the first question, a large number of agencies indicated that pavement management functions were predominantly located in the planning or engineering divisions. Maintenance, research, operations, and construction divisions were also listed by some agencies as the locations for pavement management functions.

Concerning the second question, the majority of responding agencies reported that pavement management functions were used in headquarters to make decisions for the entire network. Almost as many agencies indicated that the system was used by the headquarters as well as the districts or regions within the state or province. Only three agencies—Maryland, New York, and British Columbia—indicated that the system was just used by the districts or regions. There did not appear to be a difference based on the methodology used. Any differences are probably based on organizational variations, such as centralized and de-centralized structures. Centralized organizations would tend to perform more functions at headquarters, and de-centralized organizations would tend to have decisions made by both districts (regions) and headquarters.

SUMMARY

Highway agencies are using three predominant pavement management methodologies to identify candidate projects (and their treatments) in an objective and consistent manner: pavement condition analysis, priority assessment models, and network optimization models. The majority of state and provincial highway agencies are using a pavement condition analysis for pavement preservation project and treatment decisions, a methodology that does not meet the minimum requirements (at the time) outlined in the *Federal Register*. Project selection is often based on an evaluation of distress, roughness, design life, and cost of rehabilitation. Several candidate treatments are considered for each project, but the selected treatment most often is selected to address the current pavement condition and traffic loads. Multiyear analysis cannot be performed adequately due to the lack of performance prediction models for forecasting future condition levels. As a result, respondents reported that they were not necessarily selecting the most cost-effective, long-term projects. Agencies using this methodology are hesitant to adopt more complex approaches due to a lack of understanding of the higher level systems, a lack of available staff and computers to perform the analysis, and the resistance of agency personnel to change.

Approximately one-third of the survey respondents indicated that they were using priority assessment or network optimization models for project and treatment selection. The use of these more advanced methodologies often requires more sophisticated hardware and software to perform the multiyear analysis previously required by ISTEA. They also require the development of pavement deterioration models to forecast future pavement conditions. Technology transfer efforts to demonstrate the use of these methodologies in highway agencies and introduce the analysis techniques will help agencies using a pavement condition analysis to upgrade their capabilities.

In most instances, the selection of a treatment for a particular project is most often done in conjunction with the project selection process. If not, it is conducted after completion of the project selection process. Selecting a treatment to address project needs was most often cited as the basis for treatment selection. It was interesting to note that life-cycle costs were not frequently considered in the treatment selection process. This finding is expected to change as agencies adjust to meet the requirements of ISTEA (prior to the passage of the NHS legislation, which made the management systems optional).

The evaluation of network condition is most often reported by an assessment of distress, roughness, and structural condition. Distress/condition data collection was most prevalent in highway agencies, but was also the most variable procedure. Roughness was the next most common condition assessment procedure, and it was one of the most standardized procedures being used.

Even though the concepts of pavement management have been practiced for almost 25 years, there are still a number of institutional issues that have hindered the complete implementation of these methodologies. The majority of hindrances that were identified dealt with a lack of support by policy/decision makers as evidenced by a lack of necessary funds, personnel, support, or computer resources.

Only 20 percent of the responding agencies indicated that their PMS were fully automated. The majority of the remaining agencies indicated that some portions of their systems were automated. Unless priority assessment or network optimization models were being used, the agencies with partially automated systems had primarily automated their data collection and database functions.

At the time of the survey for this synthesis, ISTEA had an effect on the way highway agencies in the United States were selecting projects and treatments. The impacts will be felt in the number of miles that will be managed using one of the pavement management methodologies, the integration of life-cycle costs into the decision process, and the use of deterioration models so that a multiyear analysis can be performed. Several agencies reported that they intend to extend their pavement management methodologies to roadways under city or county jurisdiction.

At the time of the survey, many agencies were in the process of enhancing their methodologies to meet the requirements outlined in the *Federal Register* (*1*). The perceived changes in the way their decisions will be made once the enhancements are implemented were often reflected in the answers provided in the questionnaire.

CHAPTER FOUR

CASE STUDIES

This chapter briefly describes the application of several analytical techniques in four states—California, North Dakota, Kansas, and Michigan.

CASE STUDY 1: CALIFORNIA'S PAVEMENT CONDITION ANALYSIS

The State of California has been using a pavement condition analysis for its pavement management system (PMS) based primarily on distress for managing 15,000 centerline (47,000 lane) miles of highways since the late 1970s. The methodology is well documented in the literature and provides the California Department of Transportation (Caltrans) with a strategy to perform the following functions:

- Inventory pavement condition,
- Analyze condition extent and severity,
- Identify appropriate repair strategies,
- Identify cost-effective strategies and reasonable alternatives,
- Organize candidate projects by appropriate groupings, and
- Report repair strategies.

Caltrans believes that the structured approach its methodology provides allows the agency to quantify and justify program levels and rehabilitation trends within the agency, to the public, and to elected officials.

System Overview

Caltrans collects pavement condition information for its entire highway network on a 2-year cycle. The rating system identifies the severity and extent for each of six pavement problems on flexible pavements and eight problems on rigid pavements. In addition, the agency collects ride information. Reports published in 1978 indicate that surface friction information was also collected; but Caltrans noted in its survey response that it does not report frictional resistance as a variable that currently influences the selection of preservation projects.

Caltrans has developed a series of decision trees for each of the distresses that is evaluated in the condition survey. The decision trees (see Figure 18) present rehabilitation strategies based on the severity and extent of the distress. Each of the distresses found in the section is assigned a rehabilitation strategy from these decision trees. The strategies for a pavement section are then evaluated, and a dominant strategy for the section is identified and recommended as the candidate treatment.

Caltrans' central office issues a list of problem pavement locations, indicated dominant repair strategies, anticipated strategy service life, and estimated project costs to each of the districts. The districts review the list provided by the central office and select a final prioritized program based on field review, funding constraints, or level of service. Districts are also responsible for adjusting the project cost estimates, if necessary.

System Components

The PMS consists of the condition rating and pavement condition evaluation systems.

Condition Rating System

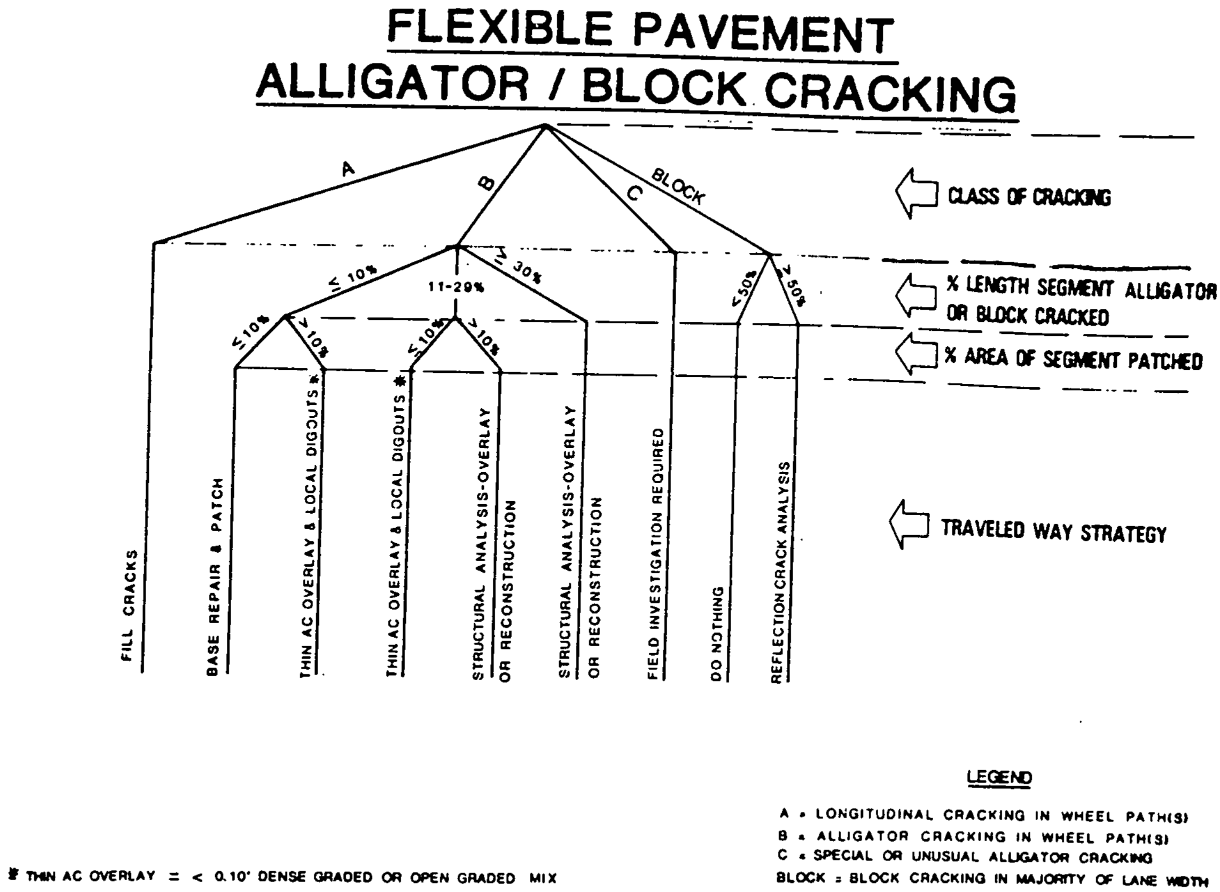
The present condition rating system, developed by an in-house committee, is based on the results of extensive research into the developments of other agencies. As discussed previously, the rating system evaluates the severity and extent of six distresses on flexible pavements and eight distresses on rigid pavements. The following types of distresses are evaluated in the biannual surveys:

Flexible Pavements	Rigid Pavements
Alligator/block cracking	Slab breakup
Transverse cracking	Patching
Longitudinal cracking	Faulting
Ravel	Lane/shoulder joint separation
Rutting	Lane/shoulder displacement
Patching	Right should condition
	Bridge approach ride comfort
	Bridge approach slab condition

Figures 19 and 20 present the severity and extent categories considered for each distress type. Each severity level of a particular distress is recorded for a pavement section. In other words, an average severity for a segment is not used. Rather, the extent of pavement within a given segment experiencing each particular distress type and severity is recorded. No sampling of pavements is included in the rating, resulting in a 100 percent survey of the state's highway network every 2 years. Staff from Caltrans' central office perform the surveys.

Caltrans also measures the ride quality of its pavements as an input into its PMS. Ride quality ratings are measured and recorded for each segment using the following equation:

$$\text{RideScore} = \frac{\text{Summation of } 1/8\text{" road meter counts}}{\text{Length (miles) x 50 (constant)}}$$



Flexible pavement conditions are evaluated as shown in the following examples.

Example 1 — Given 20% length with Type A cracking, no patching. Repair strategy is to fill cracks.

Example 2 — Given 20% length with Type B alligator cracking, no patching. Repair strategy is base repair and patch plus thin AC overlay and local digouts.

Example 3 — Given 40% length with Type B alligator cracking, 10% area patched. Repair strategy is structural analysis (structural overlay based on measured deflections, or reconstruction).

FIGURE 18 Decision trees presenting rehabilitation strategies, Caltrans *(23)*.

Pavement Condition Evaluation System

A mainframe pavement condition evaluation system is used by the central office to correlate pavement problems to feasible repair strategies. Trigger values have been established for each severity/extent combination of each distress type to identify the time at which various rehabilitation strategies should be selected. For each lane of homogeneous road segment in the highway system, each distress type is considered independently, and a particular rehabilitation strategy is identified.

Once each of the homogeneous sections has been considered and each distress type has been evaluated, a comparison of all triggered strategies is completed. The strategy that will best address all of the problems identified for that segment, while providing an acceptable level of service, is then identified as the dominant strategy. This concept is illustrated in Figure 21. An example of the decision trees that are used to identify the strategies for each distress type was presented previously as Figure 18.

Service life and project costs are also assigned to each of the rehabilitation strategies considered by Caltrans. Costs and service life are assigned by the central office and reviewed periodically to represent current trends within the state.

Lists of candidate rehabilitation locations, indicated dominant repair strategies, strategy service lives, and estimated costs are compiled for each of the districts within the state. Any work conflicts or committed projects are resolved, and the

FLEXIBLE PAVEMENT CONDITION RATING SYSTEM

PROBLEM	SEVERITY		EXTENT
ALLIGATOR AND BLOCK CRACKING	TYPE		% LENGTH
	A	LONGITUDINAL CRACKING IN WHEEL PATHS (1)	1
			3
	B	ALLIGATOR CRACKING IN WHEEL PATHS (1)	33
	BLK	BLOCK CRACKING IN MAJORITY OF LANE WIDTH	99
	C	SPECIAL OR UNUSUAL ALLIGATOR CRACKING	DESCRIBE & EXPLAIN SEVERITY & EXTENT IN NOTES
LONGITUDINAL CRACKING	CRACK WIDTH		LENGTH/STA.
	< 1/8" (HAIRLINE)		≤ 100'
			200'
	1/8"-1/4"		300'
	> 1/4"		900'
TRANSVERSE CRACKING	CRACK WIDTH (MEAN)		NO. CRACKS/STA.
	< 1/8"		1
			2
	1/8"-1/4"		3
	> 1/4"		9
RAVEL AND WEATHERING	CONDITION	RATING	% OF LENGTH
	LOSS OF FINE AGGREGATE	FINE	1
			3
			33
	LOSS OF COARSE AGGREGATE	COARSE	99
RUTTING	DEPTH		% OF LENGTH (1)
	≥ 3/4"		1
			3
			33
			99
PATCHING	QUALITY	RATING	% AREA
	SOUND	GOOD OR FAIR	1
			3
			33
	UNSOUND	POOR	99
DRIP TRACK (RAVEL)	CONDITION		OCCURRENCE/SEC.
	EXISTS		1
			2
			3
			9

(1) ONE WHEEL PATH CRACKED OR RUTTED THE ENTIRE LENGTH OF SEGMENT = 50% OF LENGTH

FIGURE 19 Flexible pavement condition rating system, Caltrans *(23)*.

RIGID PAVEMENT CONDITION RATING SYSTEM

PROBLEM	SEVERITY		EXTENT	
SLAB BREAKUP	STAGE CRACKING (1)		% SLABS/SEGMENT	
	1ST. STAGE		1	
	2ND. STAGE		3	
	3RD. STAGE (2)		33	
			99	
CRACK SPALLING (3RD STAGE ONLY)	AVERAGE WIDTH	RATING		
	< 1/4"	NOM		
	≥ 1/4"-1 1/2"	MOD		
	≥ 1 1/2"	SEV		
PATCHING (FULL LANE WIDTH)	CONDITION	RATING	% AREA/SEGMENT	
	GOOD	GOOD	1	
	FAIR	FAIR	3	
	POOR	POOR	33	
			99	
FAULTING (STEP OFF)	CONDITION		% SLABS/SEGMENT	RATING
	VISABLE		≥ 25	YES
LANE/SHOULDER JOINT SEPERATION (RT. EDGE)	JOINT WIDTH		% LENGTH/SEGMENT	RATING
	≥ 1/4"		≥ 10	YES
LANE/SHOULDER DISPLACEMENT (RT. EDGE)	JOINT WIDTH		% LENGTH/SEGMENT	RATING
	≥ 3/4" UP		≥ 10	UP
	≥ 3/4" DOWN		≥ 10	DOWN
RIGHT SHOULDER CONDITION	OVERALL CONDITION	RATING		
	GOOD	GOOD		
	FAIR	FAIR		
	POOR	POOR		
BRIDGE APPROACH RIDE COMFORT	PCA RIDE RATING	RATING		
	ACCEPTABLE < 17	NUMBER		
	UNACCEPTABLE ≥ 17	NUMBER		

(1) SEE FIGURE I-3.

(2) ALSO CORNER CRACKING AND FRAGMENTED SLABS. EACH SEGMENT RATED FOR ALL THREE SEVERITIES AND ACCOMPANYING EXTENT.

FIGURE 20 Rigid pavement condition rating system, Caltrans *(23)*.

lists are presented to the districts for review. The districts select the final strategy based on the results of a field review, an analysis of funding constraints, or other factors. The individual projects are also prioritized by the districts, with consideration given to political constraints, traffic levels, and maintenance service levels.

System Applications

The Caltrans PMS, which is located in the Maintenance Division, is fully implemented and is used throughout the agency for various purposes. Some of the most beneficial aspects of the system include

- Meaningful pavement condition data for each lane throughout the entire state highway system,
- Reduction of lane miles with immediate rehabilitation needs,
- Reduced lane miles of rough pavement, and
- A structured process for evaluating pavement conditions and identifying the appropriate level of repair commensurate with the assigned level of service.

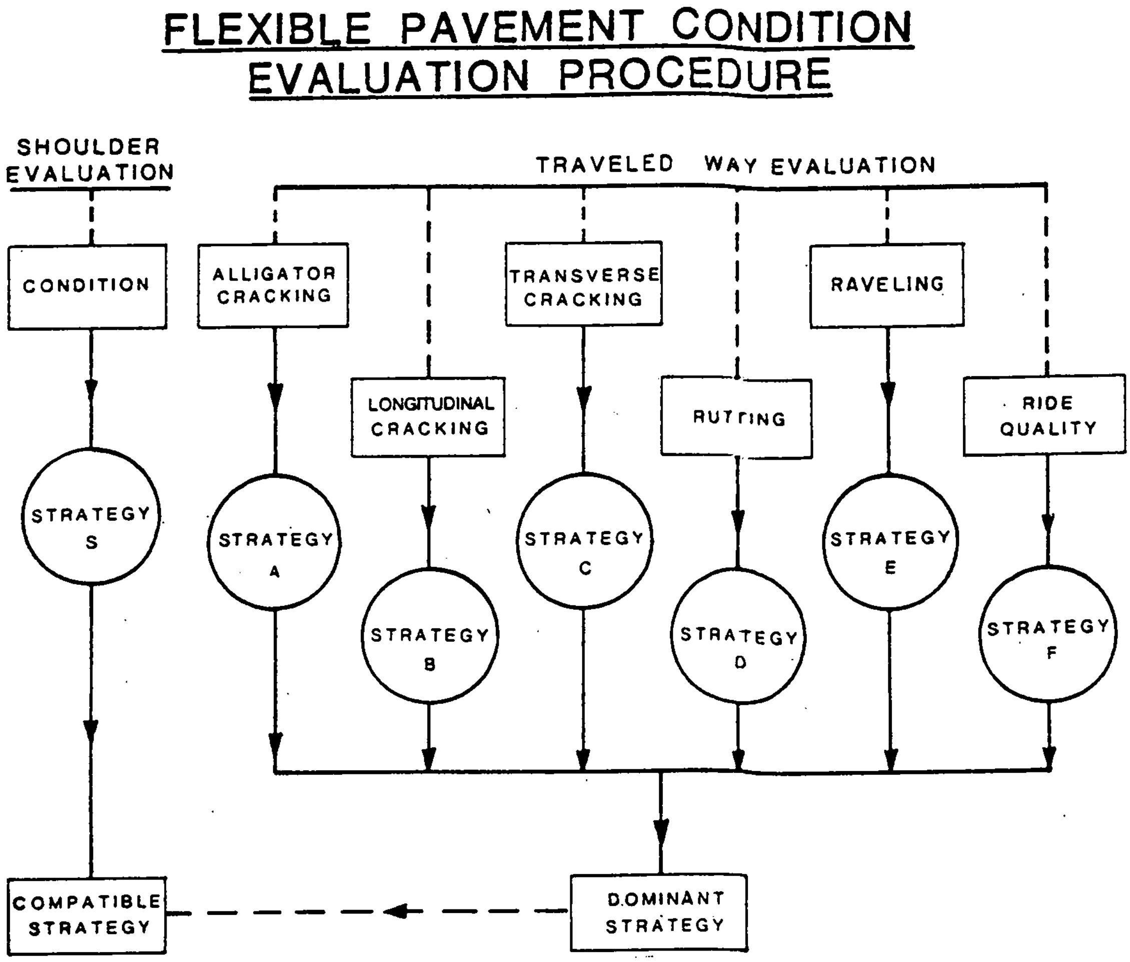


FIGURE 21 Flexible pavement condition evaluation procedure, Caltrans *(23)*.

Caltrans' headquarters uses the PMS in several ways. One of the primary uses is to develop a report that summarizes the level of effort that would be required to maintain the entire state highway system at a certain level of service. Project priorities can also be established using parameters available from the PMS. These priorities are established in conjunction with legislative, fiscal, and other controls that are imposed on the agency. Headquarters also reports that the PMS has aided in improved communications between the districts, headquarters, and FHWA, and has improved the consistency in decision making within the agency and in making project tradeoffs within and between districts.

The districts also use the system for a variety of reasons. The data stored in the PMS can be used to evaluate repair strategies and the cost-effectiveness of various strategies, determine project priorities, and provide repair cost estimates. The data are also used to assist in the distribution of discretionary funds for rehabilitation and as a basis for assessing the impact on maintenance workload when rehabilitation projects are postponed.

System Constraints

Due to a lack of funding and appropriate staffing levels, Caltrans has had little opportunity to enhance its system over the last 10 years. The agency plans to enhance its system in the next few years by adding predictive capabilities and some type of prioritization or optimization programming. These additions are expected to help Caltrans use new technology, meet the ISTEA requirements (now optional), and better control long-term network conditions and budget levels.

CASE STUDY 2: NORTH DAKOTA'S PRIORITY ASSESSMENT MODELS

In 1989, the North Dakota Department of Transportation (NDDOT) contracted with a consultant to develop analytical models that would supplement its pavement management database capabilities and enhance the program development process. The system that was implemented within the agency uses pavement performance models to predict future pavement condition and a benefit/cost analysis to help prioritize the selection of projects and rehabilitation treatments.

The North Dakota computer programs are housed in the Planning Division. NDDOT uses the system as a tool that can assist Planning and Programming Division leaders in making more informed decisions about project selection. NDDOT reports that the system does not drive the agency's decision process; the system is considered part of the decision process.

System Overview

At the time NDDOT enhanced its PMS capabilities, it had established an extensive computerized database that contained highway inventory and condition information. The agency inventories the condition of its pavement network on a routine basis and enters the results into the existing PMS database. Condition information is currently collected using semi-automated video equipment. Pavement distress type, severity, and quantity are evaluated, and deducts are assigned to each combination to determine a condition rating. In addition, structural information is collected with a falling weight deflectometer (FWD), and roughness is determined using a profilometer.

The agency uses pavement performance models to develop a multiyear prioritized program for pavement families with consistent deterioration patterns. Decision matrices were established to determine appropriate rehabilitation treatments for various functional classifications, condition levels, and geometric situations. A benefit/cost analysis is used to determine the timing and level of rehabilitation that provides the agency with the most cost-effective strategy over the analysis period. The PMS program is compared to the recommendations of the districts, and a final multiyear program is developed.

System Components

The database, condition ratings, and performance modes form the bases for the PMS.

Database

NDDOT's PMS database operates on a mainframe computer that facilitates the exchange of information between divisions. Pavement management related data are downloaded from the mainframe into a personal computer for analytical purposes. Database related reports can be generated from the system at the most basic level.

Condition Ratings

NDDOT collects three types of condition information for its highway network—distress, structural, and ride. The agency has developed a combined index that reflects the values of each of the three variables, but does the majority of its analysis using each of the three ratings separately.

Several years ago, NDDOT purchased automated equipment to improve the safety aspects of conducting the surveys. Videotapes are produced for the highway network, and distress information is obtained through the manual interpretation of the video, in accordance with North Dakota's condition rating. The interpretation includes identification of the type, severity, and extent of distresses on asphalt and concrete pavements in the first 152.5 m (500 ft) of each mile segment. Deduct values are assigned to each type, severity, and extent combination and subtracted from 100 to reflect the current condition of the pavement segment.

In addition, NDDOT collects FWD data and roughness data to provide additional ratings of the structural capability and ride quality of the pavement network. All three ratings are stored in the state's database.

Performance Models

Pavement deterioration models were developed for the state's highways based on historical condition information stored in NDDOT's database. Pavements were separated into families that were expected to have similar performance trends due to their similarities in construction, functional classification, surface type, cross section, traffic, and geographic location. Performance models were developed to model condition, structural, and roughness ratings. Forty-two pavement performance models were developed to reflect the state's deterioration trends. An example of North Dakota's performance model is shown in Figure 22.

Rehabilitation Decision Matrix

A rehabilitation decision matrix was also developed, the purpose of which was to identify the various rehabilitation treatments that were to be considered in the pavement management analysis program. Various rehabilitation strategies were considered at different times based on the functional classification of the pavement, the existing surface type, the traffic levels, geometric parameters, and structural condition. A portion of the decision matrix for asphalt pavements is shown in Figure 23. Life-cycle costs for each rehabilitation strategy are included in the matrix, as are the expected performance trends once the treatment is applied.

For a rehabilitation treatment to be considered in the pavement management analysis, each of the conditions reflected in the decision matrix must be met. In some cases, multiple treatments may be considered for one segment of pavement. The analytical software uses a benefit/cost analysis to recommend one project over another.

Analysis

As mentioned previously, project selection is conducted based on a benefit/cost analysis of the various strategies for each pavement section. In the North Dakota system, benefit is determined as the additional life that is provided by the application of a rehabilitation treatment. It is calculated as the area under the life expectancy curve for the given level of repair. The denominator (cost) is the life-cycle cost of the rehabilitation treatment. The program identifies the strategy selection for each year of the analysis at the anticipated budget levels. Multiple strategies can quickly be generated by altering any of the variables of the analysis, including budget levels, timing of rehabilitation strategies, and costs per treatment. The impact of each separate analysis can be viewed in terms of overall network condition or in a number of other ways, such as miles of backlogged pavement or weighted average condition by highway.

System Applications

The NDDOT PMS is housed in the agency's Planning Division. The computerized analytical system is used as a tool to

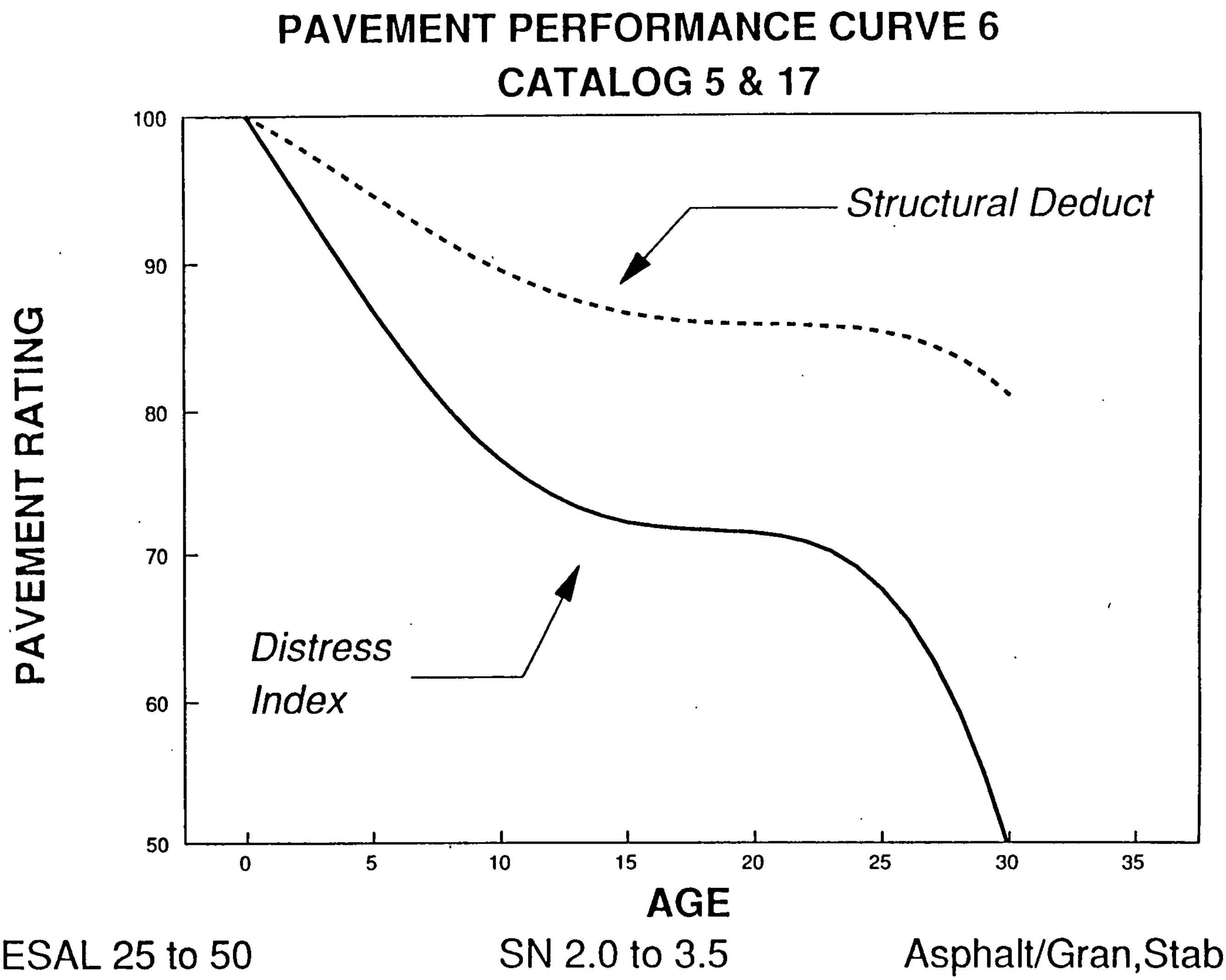


FIGURE 22 North Dakota pavement performance curves *(23)*.

Treatment Strategies	Committed Components		Surface Components		Operations Components						
	Combined Distress	Surface Type	Structural Condition (0-54 scale)	Ride (0-5 scale)	Functional Class	ESALs	Width	Pavement Thickness	ADT	SN	Rut Deduct
	High Low	Type	High Low	High Low	Number	High Low	Wide Narrow	Thick Thin	High Low	High Low	High Low
	Enter values representing ranges when these treatments are considered										
Thin OL (≤-2 1/2")	85 - 65	AC	35 - 15			74 - 0	≥27		≤750		
Thin OL	85 - 70	AC	30 - 15			74 - 0	≥33		2000 - 751		
Thin OL	85 - 70	AC	30 - 15			74 - 0	≥39		≥2001		
Thin OL	85 - 65	AC	25 - 15			100 - 75	≥27	≥4"	≤750		
Thin OL	85 - 70	AC	25 - 15			100 - 75	≥33	≥4"	2000 - 751		
Thin OL	85 - 70	AC	25 - 15			100 - 75	≥39	≥4"	≥2001		
Thin OL	99 - 0	AC		<2.5			≥39		≥2001		

FIGURE 23 Example from rehabilitation strategy matrix for flexible pavements, North Dakota *(23)*.

assist the agency in developing plans and programs. At the time a project is considered for the rehabilitation program, candidate treatments are assigned to ascertain the budget levels that will be necessary to fulfill the agency's goals. Prior to design, the project segments are evaluated closely to determine the actual treatment that will be applied.

The districts in North Dakota were collecting distress information for the highways in their pavement networks when the PMS was implemented. The information was compiled in the NDDOT central office and distributed back to the individual districts, which prioritized the list in terms of sections that they felt should be considered for the current rehabilitation program. The recommendations were reviewed by a panel of engineers and planners from the central office and compared to the recommendations of the computerized program. Differences in the program were reviewed, and the impact of changes was considered and analyzed until a final program could be generated.

System Constraints

At the present time, NDDOT's PMS is capable of prioritizing rehabilitation needs based on the current and forecasted condition in conjunction with other variables such as structural integrity, cost, benefit, geometrics, and traffic. The PMS is considered a tool that the agency uses for making informed decisions on project selection; it does not drive the decision process.

NDDOT listed two hindrances to the development or implementation of its methodology. The first is the concern that the decision-making prerogatives would be diminished with implementation of the methodology. In addition, the agency reported that there could be some loss of the human element in the selection process if the recommendations generated by the system are construed as being decisions.

CASE STUDY 3: KANSAS' NETWORK OPTIMIZATION MODELS

Kansas, Alaska, Colorado, and Arizona have used similar PMS that feature network optimization models. The systems implemented in each of these states have been developed by a consultant, who provides continued system enhancements as required. This case study features the methodology used by the Kansas Department of Transportation (KDOT).

The KDOT PMS consists of three components: a network optimization system (NOS), a project optimization system (POS), and a pavement management information system (PMIS). The PMIS provides the information necessary to run the NOS and POS analyses. The NOS has been operational since 1986; the POS is not fully implemented at this time.

System Overview

KDOT collects condition information for its highway network on an annual basis. The agency evaluates three distress types for each of the surface types used on the network, and rates extent and severity. KDOT monitors rutting on all pavement types, but this information is used primarily in safety evaluations; the agency also collects roughness data. The result of the annual survey is a summary of pavements in 1 of 27 distress states, which are used to simplify the assignment of feasible rehabilitation actions and costs and to predict performance.

Pavement actions are considered at several levels within this system. The major modification program is intended to improve the safety and service of the existing highway system. Work in this category includes reconstructing or rehabilitating pavements, but focuses primarily on widening traffic lanes, adding or widening shoulders, and eliminating sharp curves and steep hills.

Another level, called the substantial maintenance program, is used to protect the traveling public and its public investment in the highway system by conserving the condition of the network as long as possible. Resurfacing projects are included in this category.

The substantial maintenance program is developed through optimization goals established in the NOS. At this level, pavement rehabilitation and maintenance policies that would minimize the agency's total costs, subject to meeting desired performance standards or maximizing performance standards for a fixed budget, are set. The NOS outputs list the percentage of all miles in a given road category recommended for each of three categories of rehabilitation actions—routine maintenance, light rehabilitation, and heavy rehabilitation. The optimal policy for a given year is also provided in terms of condition states, the optimal action for each state, the proportion of the total mileage in each condition state, and the unit cost for each recommended action.

Project locations selected by the NOS are then investigated further as part of the POS analysis, and detailed site-specific data are collected for the candidate projects. At this level, deflection measurements, detailed distress data, and cores are used to identify the optimal rehabilitation action or initial design for each project. The POS analysis is specifically designed to address the engineering and technical decisions required in pavement rehabilitation using site-specific actions, costs, and engineering data.

System Components

The databases, condition evaluation, network optimization system (NOS), and project optimization system (POS) form the bases for the PMS.

Databases

KDOT uses two components in its pavement management analysis. The first, called CANSYS, is the database on the mainframe computer that supports the major modification program for safety improvements. The PMIS is the database on a minicomputer that contains the necessary information for the NOS and POS models to run. The PMIS database is a relational database to assist KDOT in responding to both standard and ad hoc queries. Information is uploaded and downloaded between the two databases.

Condition Evaluation

Mile-long highway segments are monitored yearly at the network level. Because of the computational requirements of

TABLE 4
SURFACE DISTRESS TYPES

Pavement Type	Distress Type
PCCP (Portland Cement Concrete Pavements)	Roughness Joint Distress Faulting
Composite	Roughness Transverse Cracking Block Cracking
FDBIT (Full-Depth Bituminous)	Roughness Transverse Cracking Block Cracking
PDBIT (Partial-Depth Bituminous)	Roughness Transverse Cracking Fatigue Cracking

the NOS linear programming algorithm, only three distress types are considered for each of the pavement types included in the network. The distresses selected for these surface types are presented in Table 4. Rutting is also measured on all flexible pavements. A current enhancement effort is underway to change the flexible pavement distress types to roughness, transverse cracks, and rutting.

The Markov optimization models in the NOS use condition states to evaluate the performance of various pavement sections and the costs associated with their repair. A total of 216 possible condition states are defined for the program to reflect the specific combinations of distress levels and levels of variables that influence the rate of pavement deterioration. The two primary influence variables are the indices to the appearance of the first distress and the rate of change in the distress. The results of the condition survey are used to determine the current condition state of each individual mile segment in the network.

Condition states are further divided into distress states, which are established for the three levels of each distress type. The system uses 27 distress states to simplify the assignment of feasible rehabilitation actions, costs, and the pavement performance models used in the analysis.

Projects that are evaluated at the project level (in the POS) receive more detailed investigations to assist in identifying the optimal rehabilitation action for an individual highway segment. Data collection includes deflection measurements from a Dynaflect, detailed distress data, and laboratory tests on cores and soil samples.

Network Optimization System (NOS)

The NOS uses linear programming to develop optimal policies to maintain an acceptable performance level for the state's highways at a minimum cost. Transitions between distress states are used to assess the current level of needs within the state, as well as to forecast future needs for a multiyear optimization. At the network level, pavement maintenance and rehabilitation policies are established to minimize the total costs to meet desired performance standards, or to maximize performance for a fixed funding level. Standards are developed for 23 road categories, which are established based on functional classification—pavement type, roadway width, and traffic loading. In 1994, the NOS was moved off the mainframe computer and installed on a Pentium: OS/2 platform.

The primary outputs of the NOS include the following: annual "minimum" rehabilitation budgets over a selected planning horizon, such as 5 years; locations of candidate rehabilitation projects; maximum performance achievable from a fixed budget; and optimal rehabilitation policies (Lytton, R.L., "Optimization Techniques," unpublished, May 1994).

Project Optimization System (POS)

Once a candidate portfolio of projects has been identified from NOS analysis, a detailed investigation of its condition is performed as described above. The data are evaluated in the POS, with the intent of identifying the set of initial designs for each project in the portfolio, which maximizes user benefits. Alternative rehabilitation actions are evaluated using site-specific information and mechanistic response variables in the POS performance prediction models. The budget for the portfolio and the performance for each of the individual project segments are constrained by the optimal policies identified by the NOS. At the present time, user benefits are evaluated in terms of a subjective rating that is related to pavement condition levels. This results in an optimization strategy that maximizes system mileage in a high-performance level over time, or minimizes the maintenance levels required by the state's forces. In 1994, the POS was also moved off the mainframe computer and installed on a Pentium: OS/2 platform.

System Applications

The development of the KDOT PMS began with a 1979 *Issue* paper (Lytton, R.L., "Optimization Techniques," unpublished, May 1994). Recommendations from that paper called for a system that contained formal performance prediction and optimization capabilities. A consultant was hired to assist in developing the system for the state using a Markov decision process to model the highway network.

A PMS steering committee was appointed to provide the overall direction for the PMS implementation within the agency. This committee represented the top management within the organization. A pavement management task force was also organized to supervise and assist the consultant in PMS development. Representatives from the bureaus of materials and research, construction and maintenance, planning development, and districts were participants in the task force.

At the present time, the PMS is located in the Division of Operations (materials and research). This division uses funding levels for rehabilitation, developed by the Division of Planning and Development, to establish a pavement rehabilitation program based on the PMS recommendations.

KDOT has realized significant benefits as a result of its PMS implementation. These include decision support from KDOT executive management and funding support from the Kansas Legislature. The agency also reports that the resource allocation for preservation projects is optimized.

System Constraints

KDOT has experienced several hindrances during PMS implementation primarily due to the complexity of its system, which requires sophisticated computer equipment and system analysts who understand the Markov process. At times, the system can be difficult to understand for those not familiar with its complexities; however, KDOT has had a successful experience overall with the system.

CASE STUDY 4: MICHIGAN'S USE OF OTHER METHODOLOGIES

Michigan has developed a methodology for managing its highway network that does not fit within any of the previous categories. This system is being developed under the direction of representatives from the state's planning and highway bureaus.

The state took a somewhat different approach to pavement management by separating it into two separate processes: planning and technical. Only the planning portion of the Michigan Department of Transportation (MDOT) system has been developed for implementation. It is referred to as the Roadway Quality Forecasting System (RQFS). A simple manual method for the RQFS has also been developed (*25*).

System Overview

In Michigan, the selection of projects and recommended preservation treatments is currently based on the respective results of a priority assessment model and project life-cycle cost analysis. The central office of MDOT annually conducts a call for projects in which preservation program development constraints are announced. In response, districts submit a list of proposed projects to the central office where they are ranked according to a model based on sufficiency, PMS, traffic, and economic data. The preservation treatment is usually based on district recommendations or life-cycle cost analysis. MDOT is now revising this process to conform to the ISTEA requirements (now optional) and to make use of the PMS analysis methods developed for Michigan in the mid 1980s.

To automate the PMS analysis, software systems were written for MDOT's mainframe computer. However, problems arose because most users did not know how to access the mainframe or how to use the information once it was made available to them. Since no formal user training was conducted, users did not understand the PMS analysis methods; thus, most of the PMS information was generally considered unreliable or unnecessary. With the conversion of mainframe programs to run on personal computers, access to the analysis was simplified and the program was made easier to use. The responsibility for the development of PMS analysis methods was also transferred from the materials and technology division to the design division.

The methodology for project and treatment selection is being revised to conform to the RQFS and to the needs of two separate processes used to develop network preservation programs: planning and technical. The planning process, which is the responsibility of the planning bureau, consists of a needs assessment, the long-range plan, and budget setting. The technical process, which is the responsibility of the highway bureau, consists of design, construction, maintenance, and research. Program development is the responsibility of a task force consisting of members from both of the above-mentioned bureaus.

The needs assessment provides technical data used for developing the long-range plan, which specifies the constraints to be met by the annual preservation programs. Typically, constraints consist of the program's budget level, lane-mile length, average design service life, and weighting value assigned for program benefits. The objective of the technical process is to aggregate projects and treatments that meet the constraints of the long-range plan and maximize program benefits.

The lane-mile length and average design service life of a program are referred to as the program strategy. Current and future network performance and budget requirements are controlled by the strategy that the annual programs conform to. The methodology for project and treatment selection requires that the projects and treatments selected for the annual program meet the budget, lane-mile length, and design service life requirements of the long-range plan. Usually, thousands of alternative programs can meet these constraints; the problem is to select the best program. This is accomplished by ranking programs according to their efficiency and the benefits they provide. The program that provides the best combination of efficiency and benefits is the best choice. Efficiency can be calculated as the ratio of the cost of the most cost-effective program that is technically possible compared to the cost of the proposed program.

For the needs assessment, networks are divided into sections having uniform performance. Project analysis is conducted for each of the uniform sections in the network. To do this, the districts complete fix guides, which provide basic pavement design information needed to estimate the cost, design service life, and benefits of each of the feasible preservation treatments. Pavement design files consist of the following items:

- Physical inventory of each network,
- Information from each district's fix guides,
- Cost equations for each treatment listed in the fix guides,
- Unit cost data,
- Inventory (based on type, severity, and extent) of each incidence of distress that occurs in each pavement segment, and
- Data needed to compute benefits derived from each feasible treatment.

These data are used to calculate the design service life, cost, cost effectiveness, and benefits of all feasible treatments.

Because of the large volume of project data generated by the automated project analysis system, it is necessary to summarize the data in the form of matrices that indicate for each specified range of cost effectiveness the lane miles and lane-mile cost of pavements available to move from each lower to each higher remaining service life category. A strategy analysis software program (now referred to as the RQFS) was developed to identify the relationship between any given funding stream, the resulting network performance, and the time in years required for the performance of the network to reach equilibrium.

Given the strategy analysis capability, the long-range planning process consists of selecting the program strategy that will achieve the desired network performance level within an acceptable time frame for the lowest total network life-cycle cost. It should be noted that in this instance, the term "performance" refers to a project's or network's condition and the rate at which its condition is changing. A project's condition is reported to either be acceptable or unacceptable. A network's condition is reported as the percent of the network's total length that is in unacceptable condition. A project's rate of deterioration is equal to the slope of its performance curve. A network's rate of deterioration is equal to its average remaining service life.

Because the needs assessment is based on project analysis of the entire network for all feasible preservation treatments, long-range planners, and the entire agency, have the information needed to determine what can technically be accomplished with the budget and strategy required by the long-range plan. Therefore, planners and executives involved in the planning process need not deal with individual projects, but rather with the efficiency and benefit ranking of alternative programs.

The link between the planning and technical processes are the long-range planning constraints and the efficiency of alternative programs. The technical process needs to include a technical analysis method that can be used to develop alternative programs that comply with long-range planning constraints. Michigan has not yet developed this analysis method. A pilot software system for the development of program analysis was initiated in the mid 1980s for use in the FHWA's 4R (restoration, resurfacing, recycling, and reconstruction) program. The system worked well but has not been revised to be compatible with the current RQFS. The pilot system consists of a file of the boundaries of projects proposed by the districts and the automated project analysis software system used for needs assessment. The user designates the budget, strategy, and ranking variable, and the software produces a ranked order list of alternative programs that meet these constraints. For each alternative program, the software prints out a ranked order list of each of its projects, respective treatments, and a summary of the project and benefit analysis results. The objective of program analysis is to provide a highly efficient program that maximizes program benefits while meeting long-range planning requirements. The objective of a technical project analysis method is to reduce the project's cost for its designated design service life or to increase its design service life for a given project budget.

While MDOT currently uses a priority assessment model to select projects and various other methods to select treatments, it is phasing into a new methodology that recognizes the two independent processes involved in network preservation, and in which the selection of projects and their treatments are based on requirements of the long-range plan.

System Components

Several elements make up the Michigan PMS—condition rating, performance prediction, evaluation of repair performance, and analysis.

Condition Rating

In addition to physical inventory, cost, and design data, the MDOT system requires continuous distress and longitudinal and transverse profile data to determine the remaining service life for each 0.1 mile pavement segment in the network. Condition is based on a distress index that is developed from distress data. For each segment, the distress type, severity, and extent of each distress occurrence is recorded and summarized. Surveys are conducted once every 2 years using a semi-automated procedure in which video images of one directional lane of the total system are produced. The images are then reviewed, and each occurrence of distress is recorded by type and severity by physically challenged individuals placed by a

Michigan Department of Education job placement agency. The total cost of the survey is approximately $50 per lane mile. A very comprehensive software system has been developed to input and manage the data.

The distress index is based on a threshold value above which the cost of reactive maintenance is no longer considered acceptable. Maintenance division engineers decide the extent of each distress type and severity level that defines the threshold of acceptability. For example, 20 high severity transverse cracks per segment may be considered as the acceptable threshold based on reactive maintenance costs. Since Michigan uses a threshold value of 50 distress points for the distress index, each severe transverse crack would have a distress point value of 2.5 in this example. Lesser severity levels are pro-rated between 0 (no distress) and 2.5 (high severity). For example, if there are only 3 categories (low, medium, and high), then the distress point value of low severity would be 0.83 and medium severity would be 1.66. This same procedure is repeated for each distress type.

A new pavement begins with a condition rating of zero (0), and distress points are added as evidence of distress accumulates. When 50 distress points have been accumulated in a segment, that segment is considered to be in unacceptable condition on the basis of the reactive maintenance it requires.

Performance Prediction

The MDOT system defines a pavement's design service life as the estimated number of years for the project to accumulate an average of 50 distress points. The number of years from the current year required for a particular pavement section to reach a distress index of 50 is referred to as the remaining service life (RSL) of the segment. Segments of approximately equal RSL are aggregated by statistical means into sections of uniform performance. The RSL of newly constructed pavements is equal to their design service life (DSL). Performance models must be based on the causes of deterioration as well as other factors. These models will require a feedback process that is difficult to design and necessitates the use of complex software programs. For these reasons, MDOT has not yet begun working on the feedback process needed to support performance model development. Performance of each segment is currently based on projections of distress data. For pavements with projected RSLs greater than the DSL, the RSL is truncated to its DSL. No pavement segment is left with an RSL greater than its DSL.

Evaluation of Repair Performance

MDOT uses fix guides (listings of information used for design analysis) consisting of 30 to 50 alternative preventive maintenance, repair, rehabilitation, and reconstruction treatments for each pavement type. There are three fix guides within each district, one for each of the following pavement types: rigid, composite, and flexible. For each treatment, the fix guide lists the information needed for the automated design analysis software system to combine fix guide recommendations and pavement condition data to compute project cost, DSL, cost effectiveness, and all the benefits provided by the treatment. Because distress is inventoried for each segment, the cost and improvement in distress condition, as well as profile condition, can be calculated for each treatment listed in the fix guide. However, at this time automated project analysis includes only distress condition. Software has been developed for longitudinal profile condition, but it has yet to be included in the automated project analysis software system. No decisions have been made regarding transverse profiles.

Analysis

Several analysis software programs are needed for the MDOT pavement preservation process. In general, these programs can be grouped into primary functions, as shown below.

- A needs assessment system that provides information needed for the long-range planning process. This system is operational, but is currently under revision.
- A strategy analysis (RQFS), which is an analysis tool for identifying the lowest network life-cycle cost program strategies that provide acceptable levels of network performance. This information is used to develop long-range plans and the constraints that proposed annual programs must comply with. This system is also operational.
- A program analysis system for identifying the combination of projects and treatments that meet the constraints of the long-range plan and maximize program benefits. A pilot study software system has been developed and used, but it has not been revised to be compatible with the RQFS.
- A project analysis system for minimizing project cost has not yet been addressed by the MDOT.

Most of the analysis methods such as the fix guides, automated project cost analysis, strategy analysis, and network life-cycle costs are presented in a TRB publication (*7*) and the FHWA *Advanced Course in Pavement Management Systems* (*4*).

An important aspect of the analysis methods used by MDOT is that both planning and technical processes communicate with each other on the basis of common terminology, which is presented below.

- Segment—a length of pavement 0.1 miles long.
- Uniform section—an aggregation of contiguous segments having approximately equal RSL.
- Project—one or more uniform sections with a designated beginning and ending point.
- Program—a collection of two or more projects and their designated treatments.
- Network—a collection of projects and programs having a specified functional class.
- Remaining service life (RSL)—the estimated number of years from the current year that the segment is projected to remain in acceptable condition. If two or more segments are aggregated into a section or project, the average RSL is reported.
- Design service life (DSL)—the estimated number of years required for a project to accumulate 50 distress points.
- Program strategy—the lane-mile length and average DSL of the annual preservation program.

- Project condition—classified as acceptable if its RSL is greater than zero and unacceptable if its RSL is equal to zero.
- Project rate of deterioration—the slope of its performance curve.
- Network condition—percent of the network length in unacceptable condition.
- Network rate of deterioration—the network's average RSL.
- Network performance—the percent of the network length in each RSL category.
- RSL category—0 to 2 years for category I, and then in 5-year increments (3 to 7 years for category II, 8 to 12 years for category III, and so on).

In the RQFS, various strategies are evaluated based on their impact on the network over a 40-year period. A strategy, for example, could be to move 1 percent of the network from an RSL of 0 to an RSL of 13 to 17 years, and another 2 percent of the network from an RSL of 0 to an RSL of 18 to 22 years. To determine the cost of this strategy, an average cost is determined from the needs assessment cost matrices for the designated networks. The new network RSL distribution is calculated, as is the efficiency of the strategy being evaluated. The cost effectiveness of a program strategy is evaluated on the basis of program cost and the area of improvement in average remaining life of the network when the program strategy is complied with for the full 40-year analysis period compared to the do nothing option.

A candidate program strategy provides a combination of low network life-cycle cost, acceptable network performance, acceptable reactive maintenance work load, and affordability, and it can be achieved with high efficiency preservation programs. To use the system, users enter the anticipated budget level and the RQFS plots the best possible network performance for the next 40 years and the program strategy to achieve it. Alternatively, users may input the desired network performance to determine the budget level that has the lowest network life-cycle cost and the program strategy that achieves it.

System Applications

The MDOT system has not been fully developed or implemented. It currently has no database system and must rely on flat files. This is one reason staff did not consider it to be user friendly. Benefits of this system when fully implemented include the following items.

- Planners can control future network performance and budgets.
- The agency can include any projects or treatments it wishes. The effectiveness of selections is based on the efficiency and the benefits provided by the proposed program. The efficiency of alternative programs is related to the cost of achieving long-range planning objectives. Hence, administrators can adjust programs to take into account the effect political and other factors have on program efficiency. The program only has to comply with the program strategy and budget constraints to meet long-range planning objectives. The use of more efficient programs means long-range plans can be complied with at lower budget levels.
- The feedback processes expected to be developed to support the planning and technical processes will be an organizational learning tool that will enable improvements to network performance and the benefits of preservation programs without increasing budget levels.

System Constraints

Implementation of the MDOT system has been an on-going problem, due in large part to a lack of user training and thus, a lack of understanding of the system and the complexity and volume of system data outputs. To some degree, these problems have been resolved by moving some of the analysis methods, such as the RQFS, to the personal computer and by developing a steering committee that has focused on output formats and requirements rather than analysis methods.

The MDOT approach has several practical constraints including the timing of when projects are actually let versus when they are planned to be let, and the availability of personnel to help with project scoping. In addition, communication and teamwork between the districts and the central office were mentioned as not being used to the fullest.

CHAPTER FIVE

CONCLUSIONS

States and provinces vary in the methodologies they use to select pavement management projects and their associated treatments for pavement preservation. The methodologies vary in level of sophistication and rely on different types of information as the basis for decision making. Most agencies use one of three basic methodologies: pavement condition analysis, priority assessment models, and network optimization models.

The primary objective of the agencies using these methodologies is to identify candidate projects (and their treatments) in an objective and consistent manner. Pavement management methodologies provide a means for justifying the decisions made within a highway agency and help an agency to provide a better transportation system for its users. As discussed earlier, the process of ranking projects systematically can result in significantly more benefit to the agency than selecting projects without planning. Additional benefits can be realized by using optimization technologies over ranking procedures. These benefits include longer pavement service life, better satisfaction of its intended function, and a greater number of users served. The use of these procedures is easily demonstrated as a cost-effective use of taxpayer's dollars.

Several general observations can be made regarding the use of standardized methodologies to select projects and recommend preservation treatments within highway agencies.

- No one methodology addresses the needs or objectives of every agency. In fact, each agency must carefully evaluate its pavement management goals and organizational constraints before selecting a methodology to use. The simplest methodology, pavement condition analysis, may be appropriate for an agency just beginning in pavement management, but will most likely not meet the long-range objectives of ISTEA. Although these objectives remain valid, compliance is optional with the passage of the National Highway System (NHS) legislation. To meet these objectives, agencies are expected to use priority assessment models and network optimization models to assist in the development of multiyear pavement preservation plans. These methods accommodate forecasted pavement condition and use various levels of sophistication to analyze the cost effectiveness of alternative preservation strategies.
- The results of this synthesis clearly show that most of today's highway agencies rely on the more simplistic approaches for managing pavement networks. This appears to be a result of the lack of understanding elements of higher level systems, the availability of staff and computers to perform the analysis, and the resistance of agency personnel to change.
- In many cases, the upgrade of pavement management capabilities to meet the now optional ISTEA requirements will result in a number of required changes in the way project and treatment selection is currently being performed. Current training programs being planned and developed by FHWA will be beneficial to agencies struggling with meeting the objectives.
- As computer technology advances, and the technology transfer efforts begin to take place, more sophisticated types of analysis will hopefully become more common in highway agencies.

Based on the responses provided to the questionnaire for this synthesis, several other specific conclusions can be made regarding the particular methodologies being used.

- The selection of a treatment for a particular project is most often done in conjunction with the project selection process. The next most common time for treatment selection is after project selection is completed.
- The selection of a treatment to address the project needs was most often cited as the basis for selecting a particular treatment. Life-cycle costs were not considered by many agencies at this time, but will most likely increase in importance due to the requirements (now optional) stated in the *Federal Register* and Executive Order 12893.
- Distress, roughness, and structural analysis are all being used to some degree to evaluate network conditions. The use of distress/condition data was most prevalent but also most variable. Ride condition was the next most common condition measurement, and it was also one of the most standardized procedures for condition evaluation. A number of methods were being used to perform a structural analysis, but this was primarily being done at the project level.
- Relatively few agencies extended their methodologies to roadways under city or county jurisdiction. Several agencies indicated that this situation is changing in light of the (now optional) ISTEA requirements.
- Agencies using a pavement condition analysis indicated that they were constrained by the lack of performance models and multiyear analysis, which they noted limited the value of their project selection process. They did not report that they were necessarily selecting projects that were most cost effective in the long run.
- Only 20 percent of the respondents were using fully automated pavement management systems (PMS). The majority of agencies that were semi-automated had only automated their data collection and database capabilities. Computer resources were greatly under utilized.
- Almost all of the survey respondents indicated that their pavement management functions were housed in either planning and programming or engineering and materials divisions. Although these divisions must interact on project and treatment selection issues, different aspects are emphasized depending on where pavement management is housed.
- None of the methodologies could account for the complex political issues that frequently influence overall funding and project/treatment selection. Respondents reported that their ability to use the pavement management analysis to its

greatest benefit was constrained by the limited resources available to implement the recommendations.

- The system requirements (now optional) outlined in the *Federal Register* are impacting the approaches being used by agencies for project and treatment selection. Some of the changes include adding multiyear analysis, incorporating life-cycle costs in the analysis, expanding the system to include additional miles, and considering alternate strategies.

One of the most obvious deficiencies in the pavement management field became evident during the evaluation for this synthesis. There appears to be little standardization in pavement management terminology, resulting in conflicting responses within an agency or inconsistencies in the data reported. Even the three primary methodologies, as defined in the *AASHTO Guidelines for Pavement Management Systems*, were not clearly understood by the participants of this study. Future efforts in the area of standardization of pavement management terminology would greatly benefit the transfer of technologies among agencies and pavement management coordinators by providing the following:

- The ability to summarize condition of pavements . . . across political and geographic boundaries,
- The ability to forecast and report performance trends of both projects and networks,
- The ability to combine resources for the research and development of technology and software needed for both project- and network-level analysis, and
- Assistance in establishing national standards or goals for performance of pavements.

It also became evident that, after more than 20 years of development of pavement management concepts, many agencies are still using fairly simplistic systems that do not take advantage of the computer technology available today. In fact, only 20 percent of the respondents indicated that their methodologies were fully automated. Better training, coupled with the availability of more computer and personnel resources, would greatly help in this area.

The largest number of hindrances affecting the implementation of a pavement management methodology were found to be related to a lack of support by policy and decision makers. A continued focus on institutional or organizational issues that affect the success of a pavement management implementation are also critical if pavement management is to be fully integrated within an organization. The proceedings from the Third International Conference on Managing Pavements feature a number of papers on this topic.

Additional training is also required to enable agencies to use more sophisticated technologies and the interrelationships between policy and pavement management. Few practicing engineers comprehend the probability and mathematical programming methods that are used in optimization. Without an understanding of these topics, it will be some time before pavement management emerges as a more sophisticated analysis tool. Integration of the six management systems that were previously required by ISTEA may force this increase in sophistication more rapidly than has been evident in the last 10 years.

Research efforts to explore the ways in which the results of the six management systems can be integrated are also needed. This will require the development of an interrelationship between the technical information and strategies obtained from each of the management systems, with the long-range planning process at the network level. The successful integration of these technical and planning processes is key to implementing procedures that result in an overall improvement in network performance for any given funding level.

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APPENDIX A

Questionnaire

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Project 20-5, Topic 24-05

Pavement Management Methodologies to Select Projects and Recommend Preservation Treatments

Questionnaire

1. Indicate what methodology best describes how your agency selects projects and treatments.

   a. Pavement Condition Analysis(1) ☐
   b. Priority Assessment Models(1) ☐
   c. Network Optimization Models(1) ☐
   d. Systematic Methodology(2) ☐
   e. Other(2) ☐

(1) As outlined in the AASHTO Guidelines for PMS.

(2) Submit a brief outline and diagrams that indicate the general basis for and describe your agency's project and treatment selection methodology.

2. Is this methodology fully implemented within your agency?

   a. Yes ☐
   b. No ☐

3. Indicate all variables that are used to establish the worth of candidate preservation projects.

		Currently	Planned
a.	Distress Condition	☐	☐
b.	Roughness	☐	☐
c.	Rut Depth	☐	☐
d.	Longitudinal Profile	☐	☐
e.	Transverse Profile	☐	☐
f.	Surface Friction	☐	☐
g.	Project's Cost	☐	☐
h.	Project's Design Service Life	☐	☐

i.	Project's Benefits (list each)	☐	☐
	______________	☐	☐
	______________	☐	☐
	______________	☐	☐
	______________	☐	☐
	______________	☐	☐
j.	Other (List each)	☐	☐

____
____
____

4. If your project and treatment selection methodology is based on priority assessment, which methods are used to prioritize?

   a. Condition Ranking ☐
   b. Initial Cost Ranking ☐
   c. Cost and Timing Ranking ☐
   d. Life Cycle Cost Ranking ☐
   e. Benefit/Cost Ranking ☐
   f. Other ☐
   Please list ______________
   ____
   ____

5. If your project and treatment selection methodology is based on optimization, which methods are used to optimize?

   a. Linear Programming ☐
   b. Non-linear Programming ☐
   c. Dynamic Programming ☐
   d. Integer Programming ☐
   e. Heuristic Methods ☐
   f. Other ☐
   Please list: ______________
   ____
   ____
   ____

6. If your project and treatment selection methodology is based on optimization, indicate all constraints used for the selection process.

   a. Budget Level ☐
   b. Network Condition Level ☐
   c. Network Rate of Deterioration ☐

3

d. Network Remaining Service Life ☐
e. Time to Meet Planning Objectives ☐
f. Benefits ☐
Please list benefits used or explain how benefits are used as constraints.
____
____
____
____

g. Other ☐
Please list: ____________________
____
____
____

7. Indicate all levels at which optimization methods are used and what is optimized at level.

a. Network ☐
What is optimized?
(1) Network Condition ☐
(2) Network Rate of Deterioration ☐
(3) Network Remaining Service Life ☐
(4) Budget Level ☐
(5) Other ☐
Explain: ____________________
____
____

b. Program Development ☐
What is optimized?
(1) Network Condition ☐
(2) Network Rate of Deterioration ☐
(3) Network Remaining Service Life ☐
(4) Program Benefits ☐
(5) Lane Miles Preserved ☐
(6) Other ☐
Explain: ____________________
____
____

c. Project Development ☐
What is optimized?
(1) Design Service Life ☐

4

(2) Project Cost ☐
(3) Benefits Provided ☐
(4) Other ☐
Explain: ____________________
____
____
____

8. The project selection process takes place when?

a. Before Budget Setting Process ☐
b. As a Part of the Budget Setting Process ☐
c. After the Budget Setting Process ☐

9. Treatment selection process takes place when?

a. As a Part of the Project Selection Process ☐
b. After the Projects have been Selected ☐
c. Other ☐
Explain: ____________________
____
____
____

10. On what basis are treatments selected? Indicate the two most important.

a. To Meet Project Needs ☐
b. Benefits provided by the treatment ☐
c. Heuristic Methods ☐
d. Project Life Cycle Cost ☐
e. Decision Trees ☐
f. Decision Matrices ☐
g. To Meet Network Needs ☐
h. Other: ☐
Please list: ____________________
____
____

11. What factors are used to evaluate alternative treatments? Indicate all that apply.

a. Total Cost ☐
b. Design Service Life ☐
c. Remaining Service Life ☐

d. Current Pavement Condition ☐
e. Traffic Load ☐
f. Functional Class ☐
g. Cost of Available Materials ☐
h. Benefits Provided ☐
Please list benefits: ____________________

i. Constraints ☐
Please indicate what constraints must be complied with:
____

j. Pavement Type ☐
k. Life Cycle Cost ☐
l. Other ☐
Please indicate what other factors are used for evaluating treatment alternatives: ____________________

12. The condition of networks are reported in terms of what variables? Please list:
____

13. The condition of projects are reported in terms of what variables? Please list:
____

14. About how many candidate treatments are considered for each project selected for the annual preservation program? Check the best answer.

a. 1 to 2 ☐
b. 3 to 4 ☐
c. 5 to 6 ☐
d. 7 or more ☐

15. Does your project and treatment selection methodology provide for the control of long-term network condition and budgets?

a. Controls long-term network condition. Yes ☐ No ☐
b. Controls long-term budget levels. Yes ☐ No ☐

16. If your methodology controls future network condition or budget levels, what is the time frame of your analysis period?

a. One to two years ☐
b. Three to five years ☐
c. Six to ten years ☐
d. Eleven to twenty years ☐
e. Greater than twenty years ☐

17. Please provide a complete list of candidate treatments for each pavement type included in your management system.

18. What demonstrated and potential benefits does your pavement management methodology for selecting projects and treatments provide your agency? Please list them and specify which benefits have been demonstrated.
____

19. Have there been hindrances to the development or implementation of your project and treatment selection methodology? Indicate all that apply.

a. Lack of Funds ☐
b. Lack of Personnel ☐
c. General Negative Attitude Toward Pavement Management ☐
d. Lack of Support From:
   (1) Policy and Decision Makers ☐
   (2) Planners ☐
   (3) The FHWA Division Office ☐
   (4) Technical Staffs ☐
   (5) Other ☐
e. Complexity of the Methodology ☐
f. Fear that Decision Making Prerogatives Would be Diminished ☐
g. Lack Computer Programming and Systems Analysis Personnel ☐
h. Other, Please Indicate ☐
____

20. Indicate all the types of highway networks your methodology is applicable to:

    a. Interstate ☐
    b. Freeways ☐
    c. Primary ☐
    d. Secondary ☐
    e. Main Arterials ☐
    f. Collectors ☐
    g. County Roads ☐
    h. City Streets ☐
    i. Other, Please List ☐

    ____
    ____

21. What are the practical and theoretical constraints of your methodology? Please provide a brief overview of what these constraints are.

    ____
    ____
    ____

22. List other factors that influence the selection of projects and treatments like political, demographic, etc.

    ____
    ____
    ____
    ____

23. List any resource requirements (data, computer, personnel, equipment) which are specifically required to utilize this methodology.

    ____
    ____

24. Will the ISTEA Legislation influence your project and treatment selection methodology? Yes ☐ No ☐
    Please briefly explain your answer. ______________
    ____
    ____

25. What portion of your methodology is automated?

    a. All ☐
    b. Some ☐
       Please identify which portions are automated. ________
       ____
    c. None ☐

26. Is the methodology used in Headquarters or Districts?

    a. Headquarters ☐
    b. Districts ☐
    c. Both ☐

    Please provide any available material which summarizes your methodology and its use within the agency.

27. In what section is Pavement Management located?

    a. Planning ☐
    b. Programming ☐
    c. Research ☐
    d. Engineering ☐
    e. Other ____________ ☐

28. Was your PMS approved by FHWA?

    a. Yes ☐
    b. No ☐
       If no, why? ______________________
       ____

Thank you for your assistance.

Please Respond To:

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FAX: (217) 356-3088

If you have questions, please call at (217) 356-4500

We would appreciate your response by October 29, 1993

APPENDIX B

Summary of Survey Responses

All state responses are alphabetized, and Canadian provinces follow states. Standard postal abbreviations are used for states. Abbreviations for Canadian provinces are as follows:

ALB:	Alberta	NS:	Nova Scotia
BC:	British Columbia	ONT:	Ontario
MAN:	Manitoba	PEI:	Prince Edward Island
NB:	New Brunswick	QB:	Quebec
NF:	Newfoundland	SSK:	Saskatchewan

Some respondents stated that their answers were based on a planned pavement management system, and others included responses for both a current and a planned system. These have been noted wherever possible. Some respondents also included extra comments, and these have been noted.

1. Indicate what methodology best describes how your agency selects projects and treatments.

a. Pavement Condition Analysis

AL	KY	OK	VA
CA	MD	OR	WA
CT	MO	PA	WV
DC	NE	RI	WI
HI	NH (see document)	TX	BC (currently)
ID	NJ	UT	MAN
IL	NC	VT	ONT
IA (3R and 4R)			

b. Priority Assessment Models

DC	NE	SD	WY
IN	ND	TN	SSK
MN	OK		

c. Network Optimization Models

AK	KS	ALB	NS (planned)
AZ	LA	BC (new PMS will do this)	PEI
AR	MA		
CO	MN		

d. Systematic Methodology

MT
OK (see attachment)
QB

e. Other

IA (Primary Const.)	MI (see attachment)	NY (see comments)	NB (see attached)
ME (see attachment)	NV (see attachments)	OH	NS (current)

f. No System

MS
NF

2. Is this methodology fully implemented within your agency?

a. Yes

AL	KS	NJ	WA
AK	KY	NY	WY
AZ	ME	NC	MAN
CA	MD	ND	NS (current system)
CO	MA	OH	ONT
CT	MI (variances in each district)	OK	PEI
DC	MT	PA	QB
HI	NE	SD	SSK
IL	NV	UT	
IA		VA	

b. No

AR	NH	WV
ID	OR	WI
IN	RI	ALB
LA	TN	BC
MN	TX	NS (planned PMS)
MO	VT	

3. Indicate all variables that are used to establish the worth of candidate preservation projects.

C=currently used
P=planned

State	Distress Condition	Roughness	Rut Depth	Long. Profile	Trans. Profile	Surface Friction	Project Costs	Project Design Service Life	Project Benefits	Other
AL	C	C	C	C	C	C	C	C		
AK	C	C	C	C			C	C	C Future condition	
AZ	C	C	C							
AR	C	C	C	P	P			P		
CA	C	C								
CO	C	C	C	C	P		P			
CT	C	C	P	P	P			C		
DC	C	C	C			C	C		Savings in agency cost	Functional class
HI	C	C								
ID	C	C	C	P	P	C	C	C	P Network optimization	ITD has a network optimization model, but it is not currently being used to select projects
IL	C	P	C	P	P	C	C	P		
IN	C	C	C			C	C	C		
IA	C			C		C	C	C		Age, structural adequacy, age of last life (ACC), annual and total 18K (ESAL's) agg. durability
KS	C	C	C	C			C	C		
KY	C	C	C			C	C			Traffic volume, travel speed, appearance
LA	C	C	C			P	C	C	P user costs (by implication from area under the condition performance curve; i.e., the greater the area given by a strategy, the less the user cost	
ME	C	C	C				C	C	C serviceability, reduced maintenance cost	
MD	C	C	C	C	C	C	C	C		
MA	C	C	C	C	C	C	C	C		

State	Distress Condition	Roughness	Rut Depth	Long. Profile	Trans. Profile	Surface Friction	Project Costs	Project Design Service Life	Project Benefits	Other
MI	C	C	P			P	C	C	C Improved ride quality, decreased maintenance costs, related safety improvements, capital avoidable costs, user savings	C Shoulder upgrading from gravel to bituminous, addition of turning lanes, drainage upgrading, public officials & citizens comments & complaints, route classification
MN	C	C	C	C		C	C	C	C Effectiveness (area under curve)	
MO	C	C	C	P	P	C	C	C		
MT	C	C	C			C	C	C	C (ADT)	
NE	C	C	C	C	C	C	C	C		
NV	C	C	C	C		P		P		Excessive maintenance costs, pavement related accidents
NH	C	C	C			C	P	P		
NJ	C	C	C				P	P		
NY	C	P	?			C	C	C	C (Reduction of wet-weather accidents, reduction of demand maintenance)	
NC	C	P	C	P		P		P		
ND	C	C	C				C			
OH	C	C				C				
OK	C, P	P	P	C	C	P	P	P	P (Benefit/cost ratio)	C, P (ADT); C (Congestion variables)
OR	C	P	C	P		C	C	C		
PA	C	C	C	C		C			P (Benefit/cost ratio)	
RI	C,P	P	C,P	P	P	P	P	P		
SD	C,P	C,P	C,P	C,P	C,P	C,P	P	P		C, P Roadway strength (FWD), drainage adequacy
TN	P	P	P	P						
TX	C	C	C	P					C Improved distress and ride scores over treatment life	
UT	C	C	C	P	C	C	C	P	P Cost savings to motorists.	
VT	C	C	C			P	P	P		
VA	C	C	C			C	C	C		
WA	C		C							
WV	P	C	C	C	C	C	C	C		

State	Distress Condition	Roughness	Rut Depth	Long. Profile	Trans. Profile	Surface Friction	Project Costs	Project Design Service Life	Project Benefits	Other
WI	C	C	C				C	P	C PDI gain, PSI gain	
WY	C	C	C	C	C	C	C	C		
ALB	C	C					C	C	Effective maximization for programming purpose; cost minimization for planning purposes	Structural adequacy as determined by deflection testing
BC	C, P	C, P	C, P				C, P	C, P	P Overall quality or performance as a function of ride quality, distress structural adequacy	
MAN	P	C, P	C, P	C,P	C, P		P	C, P	C, P Safety, rideability, traffic volume capacity, loading capacity, regional development	C, P Construction planning: Continuity of construction, readiness of work
NB	C	C	C	P					Reduced maintenance costs	
NS	C, P	C, P	C, P				C, P	C, P	P Present worth initial & future rehab strat., present worth periodic maintenance costs, user delay due to rehab activities, salvage values	C, P Pavement strength
ONT	C	C	P			P	C	C		Refer to the Pavement Performance Record and Action Plan Fact Sheet pertaining to a typical pavement section (attached)
PEI	C	C	P				C	C		Composite Pavement Quality Index
QB	C	C	P							Local considerations; AADT
SSK	C, P	C, P	C, P				C, P	C, P	P Road user costs	C Traffic volume

4. If your project and treatment selection methodology is based on priority assessment, which methods are used to prioritize?

State	Condition Ranking	Initial Cost Ranking	Cost and Timing Ranking	Life-Cycle Cost Ranking	Benefit-Cost Ranking	Other
AK						Linear Programming Markov Chain
AR	X			X		
CA	X					
CO	X					
DC					X	
HI	X					
ID	X					
IL	X					
IN	X			X	X	
IA	X					NOTE: Highway System plan target values
KY						Condition, traffic volume and travel speed
MI	X					NOTE: In the central office we have a priority assessment as a second phase of project selection. It includes nine variables: surface condition by work type, ride quality, PMS score, cost/VMT/yr, cost/lane mile/yr, district priority, maintenance savings, and user savings.
MO	X					
MT						District Engineers are consulted to determine and to update the priorities based on need and level of maintenance.
NE	X					
NV						See attachment A
NH	X		X		X	
NY	X			X		
NC	X					

State	Condition Ranking	Initial Cost Ranking	Cost and Timing Ranking	Life-Cycle Cost Ranking	Benefit-Cost Ranking	Other
ND	X		X	X	X	
OH	X					
OK	X		X		X	
PA	X					NOTE: Current actual field practice uses condition data to rank projects within their subsystem
SD	X					
TN	X					
TX						NOTE: Incremental benefit/cost ranking.
UT	X		X		X	
VT	X					
VA	X			X		
WV	X					
WY	X	X		X	X	
ALB					X	
BC					X	NOTE: We will optimize on benefit/cost ranking. All of the above may be considered as well as optimization. Presently, condition ranking and initial cost are used for situation before major reconstruction Pavement Management Programs are a tool and cannot replace Engineering Judgement in complex situations.
MAN	X					
NB	X					
ONT	X				X	
QB	X					NOTE: User needs, local considerations
SSK					X	

5. If your project and treatment selection methodology is based on optimization, which methods are used to optimize? (**Bold** indicates responses used in summarizing responses to Question 1.)

State	Linear Programming	Non-linear Programming	Dynamic Programming	Integer Programming	Heuristic Methods	Other
AK	X		X			
AZ	X					
AR	X					
CO	X					
CT	X					
DC						Priority assessment (benefit/cost)
ID						Decision tree
IN					X	Incremental benefit-cost technique
KS	X					
LA	X					Incremental benefit-cost optimization
MA					X	
MN						Marginal cost-effectiveness (developed by PMS, LTD.)
NH					X	
TX	X					
UT						Incremental cost/benefit
WY					X	
ALB	X					
BC		X				
NS					X	(planned PMS)
ONT					X	
PEI			X			
QB						NOTE: LP optimization under development (Markovian decision process); questions 6 & 7 refer to process in development

6. If your project and treatment selection methodology is based on optimization, indicate all constraints used for the selection process. (**Bold** indicates responses used in summarizing responses to Question 1.)

State	Budget Level	Network Condition Level	Network Rate of Deterioration	Network Remaining Service Life	Time to Meet Planning Objectives	Benefits	Other
AK	X	X					NOTE: Select overall rehab budget to give specified average condition.
AZ		X					
AR	X	X	X	X			
CO		X					
CT	X						Max/min mileage for annual treatments
IN	X					Benefit maximized - Area under deterioration curve as indicator of benefit	
KS	X	X					
LA	X						
MA	X	X	X			Overall serviceability of system as a function of budget	
MN	X	X				Effectiveness (area under PQI curve)	
NH	X	X	X				
RI						1.Area-under-the -curve benefits calculated by a user defined composite condition index 2.Savings in user cost 3.Savings in maintenance cost	
TX	X						
UT	X	X	X		X	X	
VA	X	X	X	X			
WY	X						

State	Budget Level	Network Condition Level	Network Rate of Deterioration	Network Remaining Service Life	Time to Meet Planning Objectives	Benefits	Other
ALB	X						X System is used for planning purpose to identify required budget to maintain the network at a standard level. In this instant optimization is done to minimize the cost.
BC	X	X					
NB	X	X	X				
NS	X	X					(planned PMS)
ONT	X	X			X		
PEI	X	X		X		Maximize effectiveness of improvements	
QB	X	X					

7. Indicate all levels at which optimization methods are used and what is optimized at level.

State	Network Level[a]	Program Development Level[b]	Project Development Level[c]
AK	1, 4		
AZ	1		
AR	1, 2, 3, 4	1, 2, 3	
CA	1	1	
CO	1	3	1
CT	5 (minimize user-costs)		
IL		5	2
IN		4, 6 (Optimization function is to select projects to maximize benefit at fixed budget levels)	
IA	1	1	1, 2
KS	1, 4		2, 3
KY		1	1, 2
LA	3, 4	3	
MD	1, 4		
MA	1, 4	1, 5	1, 2
MO		6 (Worst first)	
NH	1, 4	1	1, 3
ND	4	4, 5	1, 2, 3
TX	5 (We analyze by project but summarize by network. We summarize dollars needed and lane miles treated)	6 (same as 7a, but no direct summary by program. We do have IH, NHS, Rehab, and Prev. Maint., so we could summarize for IH Rehab, as an example)	4 (benefit/cost ratio)

State	Network Level[a]	Program Development Level[b]	Project Development Level[c]
UT	1	1	1, 2, 3
VA	1, 3	1, 3, 5	1, 2, 3, 4 (manually optimized)
WV	1	1	1
WY	1		4 (benefit/cost ratio)
ALB	1, 4	4	
BC	1, 4		1, 2, 3
MAN			1, 2
NB	1, 2, 4		
NS (all responses for planned PMS)	1, 4, 5 (maximum delay, to limit the number of years a project may be delayed)	4	1, 3
ONT	1	1	2
PEI	1, 4	1, 4	
QB	4	6 HPMS is used to generate program alternatives	1, 3

[a]1=Network condition; 2=Network rate of deterioration; 3=Network remaining service life; 4=Budget level; 5=Other.
[b]1=Network condition; 2=Network rate of deterioration; 3=Network remaining service life; 4=Program benefits; 5=Lane miles preserved; 6=Other.
[c]1=Design service life; 2=Project cost; 3=Benefits provided; 4=Other.

8. The project selection process takes place when?

State	Before Budget Setting Process	As Part of Budget Setting Process	After Budget Setting Process
AL			X
AK	X		X
AZ			X
AR	X (planned)		X (current)
CA		X	
CO	X		
CT		X	
HI			X
ID			X
IL		X	
IN			X
IA			X
KS			X
KY	X		
LA			X
ME			X
MD	X		
MA	X		
MI	X (by districts)		X (by committee)
MN			X
MO			X
MT	X		
NE			X
NV		X	
NH	X		
NJ	X		
NY			X
NC			X
ND		X	
OH			X
OK		X	
OR			X

State	Before Budget Setting Process	As Part of Budget Setting Process	After Budget Setting Process
PA			X
RI		X	
SD			X
TN			X
TX			X
UT		X	X
VT	X		
VA	X		
WA		X	
WV			X
WI			X
WY		X	
ALB		X	X
BC		X (current)	X (will be an option when new PMS is implemented)
MAN	X		
NB		X	
NS		X (planned)	X (current)
ONT		X	
PEI	X		
QB			X
SSK	X		

9. Treatment selection takes place when?

State	As Part of Project Selection	After Projects Have Been Selected	Other
AL	X		
AK	X		
AZ	X		
AR	X (plan)	X (current)	
CA	X		
CO	X		
CT		X	X With exception to the 100% State funded Vendor-In-Place Resurfacing Program, the treatment--typically a 2 inch overlay--is specified before project selection.
DC			Treatments are assigned during Network Condition Analysis.
HI		X	
ID	X		
IL	X		
IN	X		
IA		X	
KS	X		
KY		X	
LA	X		
ME			Prior to project selection.
MD	X		
MA		X	
MI	X		NOTE: On rare occasion, the central office recommends a revised fix during the statewide selection process. A fix could be revised during the design stage as well.
MN		X	
MO		X	
MT		X	NOTE: However, when project is nominated, there is a tentative treatment proposed.
NE			Maintenance projects programmed at same time as other construction program.
NV		X	
NH	X		NOTE: The six Districts prioritize their choices and submit their programs to headquarters; the budget is "consulted" and final choices are made fairly for each District and types of treatment.
NJ		X	
NY		X	
NC		X	
ND	X		
OH	X		
OK		X	NOTE: Will be improved with new pavement management system.
OR		X	
PA			The current PMS matrix provides treatments for each segment (±½ mile) of roadway for the entire 41,000 miles. Costs are then computed for the highest treatment group.

State	As Part of Project Selection	After Projects Have Been Selected	Other
RI	X		
SD	X		
TN		X	
TX	X		NOTE: And this is done at District offices, then summarized and approved by State office.
UT	X	X	
VT		X	
VA	X		
WA		X	
WV		X	
WI			Before selection process.
WY	X		
ALB	X		
BC	X		
MAN	X		
NB	X	X	
NS	X (plan)		Currently treatments are determined prior to a project's inclusion in the current program.
ONT	X		
PEI	X		NOTE: Tentative treatments identified at project development, subject to project specific engineering.
QB		X	
SSK	X		

10. On what basis are treatments selected? Indicate the two most important.

State	To Meet Project Needs	Benefits Provided by Treatment	Heuristic Methods	Project Life-Cycle Costs	Decision Trees	Decision Matrices	To Meet Network Needs	Other
AL	X		X					
AK								Markov chain linear programming
AZ	X						X	
AR	X			X	X			NOTE: "e" is planned, others are current
CA	X				X			
CO	X							
CT				X			X	
DC		X				X		
HI	X	X						
ID	X			X				
IL	X	X						
IN		X				X		
IA	X	X						
KS		X					X	
KY	X							
LA	X	X						
ME	X				X			
MD	X	X		X				
MA	X						X	
MI	X							X Michigan Dept. of Transp. guidelines and AASHTO guidelines
MN	X	X						
MO	X			X				
MT	X						X	
NE	X						X	
NV	X	X						
NH	X	X				X		
NJ	X							
NY	X			X				
NC	X			X				
ND	X	X						
OH	X			X				
OK					X	X		NOTE: Based on condition (distress present), roughness, environmental distress, load distress, and structural number

	To Meet Project Needs	Benefits Provided by Treatment	Heuristic Methods	Project Life-Cycle Costs	Decision Trees	Decision Matrices	To Meet Network Needs	Other
OR	X							
PA					X	X		NOTE: Each treatment triggered by a condition is then evaluated through a decision-making process of superseded treatments and a final overall treatment group is then called out.
RI		X				X		
SD				X			X	
TN	X	X						
TX	X				X			
UT				X			X	
VT	X							NOTE: Cost of treatment in light of budget and miles of deficient surfaces.
VA		X					X	
WA	X	X		X				
WV	X						X	
WI		X		X				
WY				X	X			
ALB					X			
BC	X			X	X			
MAN	X			X				
NB	X	X						
NS	X	X	X		X			NOTE: "a" and "c" are current, "b" and "e" are planned
ONT	X	X						
PEI		X			X			
QB	X	X						
SSK	X			X				

11. What factors are used to evaluate alternative treatments? Indicate all that apply.

State	Total Cost	Design Service Life	Rem Serv Life	Current Pvmt Cond	Traffic Load	Funct. Class	Cost of Available Methods	Benefits Provided	Constraints	Pvmt Type	Life-Cycle Cost	Other
AL	X	X		X	X							
AK	X	X		X	X	X	X		Budget			Presence of permafrost, frost susceptibility, environmental region
AZ	X	X		X						X		
AR	X	X		X	X							NOTE: "d" is planned, others are current
CA	X	X		X		X			District-level budget constraints			
CO	X											
CT	X	X		X	X	X			X	X	X	
DC	X			X		X		X				
HI		X		X	X		X			X		
ID	X	X	X	X	X		X		Budget constraints, public input & opinion as well as environmental constraints		X	
IL	X		X	X	X	X		Increased ACOL thickness for special sections	Budget	X		
IN				X	X	X		Area under deterioration curve function of life of treatment, ADT & amount of improvement	Budget amount	X	X	
IA				X	X	X					X	Constructability, traffic interference
KS	X	X	X	X	X	X	X			X		
KY	X				X	X				X	X	
LA	X		X	X	X	X		User costs (area under condition perfor-mance curve)		X	X	

State	Total Cost	Design Service Life	Rem Serv Life	Current Pvmt Cond	Traffic Load	Funct. Class	Cost of Available Methods	Benefits Provided	Constraints	Pvmt Type	Life-Cycle Cost	Other
ME		X		X	X	X						
MD	X	X	X	X	X	X	X		Monies available for particular projects	X	X	
MA	X	X		X	X	X			Budget		X	Performance
MI	X	X	X	X	X	X		Retain existing curb or guardrail instead of replace, maintaining traffic convenience to the public during construction, longer term fixes in high traffic volume areas, a good location for promising experimental treatments	District $ targets, overall transportation budget, investment plan targets for preservation VS improve/ expand and other categories such as bridge safety, etc.	X		Existing pavement mix design and historical performance of certain types of pavement, eligibility and applicability for highway pre-ventative maint-enance program.
MN	X	X		X				Area under curve (effectiveness)		X	X	
MO	X	X		X	X		X				X	
MT	X	X		X	X			skid resistance, better drainage, increased strength	Alternative must be skid resistant and durable for the climate			Availability, applicabilty and having contractor who can do the work
NE		X	X	X	X	X	X		ADT and truck ADT	X		
NV	X	X		X	X						X	NOTE: Life-cycle cost analysis is presently only used to justify selecting PCC over AC.
NH			X	X			X					
NJ	X			X	X	X	X			X		
NY	X	X		X	X					X	X	
NC	X	X		X								
ND	X	X			X					X		
OH				X	X						X	

State	Total Cost	Design Service Life	Rem Serv Life	Current Pvmt Cond	Traffic Load	Funct. Class	Cost of Available Methods	Benefits Provided	Constraints	Pvmt Type	Life-Cycle Cost	Other
OK	X			X	X	X	X	Future projected conditions	Budget, proper engineering treatment selection	X		Costs, future projected conditions
OR	X	X		X	X	X	X			X	X	
PA				X	X	X		Traffic volumes are an intrinsic part of the matrix.				Condition data, traffic volumes, functional class, IRI, etc.
RI		X	X	X	X	X		Most cost-effective strategy for a section and budget			X	
SD	X	X	X	X	X	X				X	X	
TN	X			X		X					X	
TX	X	X		X	X	X	X	Improved ride quality and reduced surface distress.	Total available funding	X	X	District experience, contractor availability, material availability
UT	X	X	X	X	X	X	X	X	Corridor plans - section consistency	X	X	
VT	X			X	X					X		
VA	X	X	X	X	X	X		X	Traffic interruption	X	X	
WA	X				X	X				X	X	
WV	X	X		X	X	X	X			X		
WI	X							X			X	User inconvenience
WY	X	X		X	X	X		Incremental benefit/ cost ratio		X	X	
ALB	X	X		X	X			Treatment which is the most cost-effective	Width of pavement, expected service life	X		
BC	X	X	X	X	X	X	X	Low cost, long life, low user cost, high performance (ride, distress, structure), meets short-term needs, meets long-term needs	Limited funds, optimization of investment, specified short- or long-term life	X	X	Potential of innovative method if supported by laboratory and field tests.

State	Total Cost	Design Service Life	Rem Serv Life	Current Pvmt Cond	Traffic Load	Funct. Class	Cost of Available Methods	Benefits Provided	Constraints	Pvmt Type	Life-Cycle Cost	Other
MAN	X	X		X	X	X	X	Increased service life and reduced future maintenance expenditures	Budget, traffic handling (availability of detours), availability of materials	X	X	Available right of way if a thick overlay is an alternative
NB	X	X		X	X	X		Reduced maintenance costs, safety	Clearance at overpasses, retaining shoulder widths	X		
NS	X	X	X	X	X	X		Under present process alternative treatment evaluations are empirically derived.		X	X	
ONT	X	X	X	X	X	X				X	X	
PEI	X	X		X	X	X		X				
QB	X	X	X	X	X	X	X	Safety, comfort, reduction of maintenance costs	Geometry, traffic flow, weather	X		
SSK				X	X				Funding level	X		Structural adequacy

12. The condition of networks are reported in terms of what variables? Please list.

AL:	pavement condition
AK:	rutting, roughness, fatigue cracking and patching. converted into a relative benefit from 0 to 1
AZ:	ride, cracking
AR:	pavement distress, roughness, rutting
CA:	roughness with lane miles, priority by lane miles - distress categories
CO:	smoothness (IRI), rutting, cracking distress (longitudinal crack, transverse crack, block cracking, alligator cracking, load associated cracking)
CT:	distress score, roughness score
DC:	Pavement Condition Index (PCI)
HI:	Pavement Serviceability Index (PSI)
ID:	miles of deficiencies in cracking, roughness, rutting, and deficient width
IN:	Pavement Quality Index (PQI); $PQI=W_1$ x distress index + W_2 x ride index - W_3 rut index
IA:	pavement condition ratings
KS:	distress condition, roughness, rut depth, longitudinal profile, project cost, project design service life
KY:	ride and pavement condition index (based on roughness measurement)
LA:	remaining service life
ME:	pavement condition rating, mileage geometrically deficient, mileage structurally deficient
MD:	overall condition category, present serviceability
MA:	distress index (DI) - weighted pavement types of distress (scale 0-5), pavement serviceability rating (PSR) - roughness measurement (scale 0-5), pavement serviceability index (PSI) equal to the lower value of either the DI or PSR (i.e., if DI $\leq$ PSR, then PSI = DI; if DI $>$ PSR, then PSI = PSR). PSI is the reported variable for both network and project.
MI:	average remaining service life, remaining service life categories, pavement type, surface condition rating (sufficiency), surface age categories, ride quality categories
MN:	Pavement Quality Index (PQI), Present Serviceability Rating (PSR), Surface Rating (SR). PSR=0-5 scale, SR=0-4 scale, PQI=square root of PSR x SR
MO:	annual change in roughness and overall condition (PSR)
MT:	pavement serviceability, rutting and skid resistance; pavement nondestructive deflection files are being developed (flexible pavement)
NE:	pavement condition index, NSI; Present Serviceability Index, PSI
NV:	four condition categories: preventive maintenance, corrective maintenance, overlay, and reconstruct
NH:	riding comfort, surface distress, and rutting.
NJ:	average ride quality/distribution of ride quality distress, skid, rutting for Interstate, State, and total network
NY:	percentage of pavements rated poor, and fair; average surface rating
NC:	Percentage falling below an acceptable level of service
ND:	pavement condition, riding quality, age
OH:	distress condition, roughness, surface friction
OK:	roughness, condition index, overall combined score
OR:	% of fair or better pavement (determined by type and amount of distress, i.e., cracking and rutting)
PA:	Many of the network analysis is performed using SAS programs which can vary depending on the users preference. There is no systematic methodology outlined for network analysis using PMS data.

RI:	mileage, yearly budget, and overall pavement condition
SD:	PSR, roughness
TN:	roughness, rutting, distress
TX:	distress score, ride score, condition score, % of "substandard" mileage, maintenance levels of service (rutting, alligator cracking, ride quality)
UT:	ride, friction, structural, rut, distress
VT:	roughness, 60%; cracking, 25%; rutting, 15%
VA:	a visual condition survey of surface distresses; ride quality
WA:	PSC (Pavement Structural Condition), a cracking index; PRC (Pavement Rutting Condition), a rutting index
WV:	PSR
WI:	PSI, PDI
WY:	rutting, roughness, remaining service life, skid
ALB:	overall pavement quality index (PQI); Percent of length of pavement falling below the acceptable PQI
BC:	Ride Quality (RCI or IRI) Ride Quality Index, Distress (13 types, severity & density) Pavement Distress Index, Structural Adequacy Index, *Pavement Quality Index--most common overall index
MAN:	none. A project is being planned to report in terms of distress condition, roughness, loading capacity and depreciated value.
NB:	Riding Comfort Index (RCI), Surface Distress Index (SDI), Strength Readings
NS:	Presently the network condition is not routinely nor systematically evaluated and reported on. The planned PMS will report network condition in terms of cracking, surface deformation and defects, roughness and structural adequacy.
ONT:	Pavement Condition Index (PCI)
PEI:	Ride Comfort Index (0-10), Surface Distress Index (0-10), Structural Adequacy Rating (0-10)
QB:	IRI, distress condition, diagnostic of cause of problem
SSK:	roughness, age

13. The condition of projects are reported in terms of what variables? Please list.

AL:	pavement condition, pavement structural number
AK:	rutting, roughness, fatigue cracking and patching, converted into a relative benefit from 0 to 1 on a mile by mile basis
AZ:	ride, cracking, rutting, flushing, friction
CA:	priority value calculated from ride quality and structural distress
CO:	smoothness (IRI), rutting, cracking distress (longitudinal crack, transverse crack, block cracking, alligator cracking, load associated cracking), falling weight deflections
CT:	distress score, roughness score, amounts of critical distress, remaining service-life
DC:	distress, 5 structural related, roughness
HI:	ranking
ID:	cracking, roughness, rutting, structural, width deficiencies, capacity, vertical or horizontal alignment problems
IL:	condition rating, 0—9, with distresses listed
IN:	Ride = PSI, Pavement Serviceability Index; Rut = RI, Rut Index; Distress = PCR, Pavement Condition Rating
KS:	distress condition, roughness, rut depth, longitudinal profile, project cost, project design service life
KY:	distress condition, ride, rut depth; For interstates and toll roads, also trend graphs for each item.
LA:	condition indices: roughness and distress
ME:	pavement condition rating, structural/geometric adequacy, IRI
MD:	pavement condition--distress, rutting, roughness, drainage, structural adequacy
MA:	distress index (DI) - weighted pavement types of distress (scale 0-5), pavement serviceability rating (PSR) - roughness measurement (scale 0-5), pavement serviceability index (PSI) equal to the lower value of either the DI or PSR (i.e., if DI ≤ PSR, then PSI = DI; if DI 〉 PSR, then PSI = PSR). PSI is the reported variable for both network and project.
MI:	remaining service life, age, distress points, surface condition, ride quality, base condition, drainage condition, friction, soil or base condition, surface width and type, and shoulder width, type, and condition
MN:	Pavement Quality Index (PQI), Present Serviceability Rating (PSR), Surface Rating (SR). PSR=0-5 scale, SR=0-4 scale, PQI=square root of PSR x SR
MO:	roughness, physical distresses, rutting
MT:	pavement roughness or serviceability, cracking, faulting, and spalling (rigid pavement)
NE:	Pavement condition index, NSI; Present serviceability index, PSI; independent evaluation of cracking, rut, ride, and thermal cracking for AC; faulting, joint conditions, panel conditions, and ride for PCC
NV:	severity and extent of cracking, rut depth, bleeding, raveling and roughness (longitudinal profile).
NH:	riding comfort (IRI, profile)
NY:	very detailed specific pavement distress symptoms (see attachment 2)
NC:	cracking, rutting, ride, spalling, joint seal, raveling, bleeding
ND:	pavement condition, geometrics, riding quality, maintenance effort required
OH:	distress condition, roughness, surface friction
OK:	roughness, condition index, overall combined score
OR:	crack index, rut index, high, low, and average friction number
PA:	see #12

RI:	cost and age
SD:	PSR, roughness
TN:	roughness, rutting, distress, structural strength
TX:	distress score, ride score, condition score, % of "substandard" mileage, maintenance levels of service (rutting, alligator cracking, ride quality)
UT:	ride, friction, structural, rut, distress
VT:	roughness, cracking, rutting, structural strength
VA:	a visual condition survey of surface distresses; ride quality; drainage and subsurface conditions are explored if needed
WA:	PSC (Pavement Structural Condition), a cracking index; PRC (Pavement Rutting Condition), a rutting index
WV:	PSR, roughness
WI:	PSI, PDI
WY:	rutting, roughness, skid, surface distress
ALB:	pavement performance; i.e., Pavement Riding Comfort Index (RCI), Structural Adequacy Index (SAI), and Visual Condition Index (VCI), and the overall Pavement Quality Index (PQI)
BC:	ride quality, distress (13 types), structural adequacy, and Pavement Quality Index, all of which would be commonly used at the project level
MAN:	Surface Condition Rating, current maintenance expenditures
NS:	Presently the pavement condition of projects is reported in terms of visual assessments, roughness, and strength. The planned PMS will provide similar information.
ONT:	PCI, Distress Manifestation (DM), Ride Condition Rating (RCR), PavementCondition Subjective Rating (PCR), Change in PCI in three years (ΔPCI)
QB:	roughness, deflection, detailed distress, structural condition, drainage
SSK:	Pavement Rating Number, roughness

14. About how many candidate treatments are considered for each project selected for the annual preservation program? Check the best answer.

a. 1 to 2

AR (current)	MT	OK	WI
CA	NE	PA	NB
HI	NJ	SD	NS (current)
IN	NC	TX	

b. 3 to 4

AL	LA	OR	ALB
AZ	MD	TN	MAN
AR (planned)	MA	UT	NS (planned)
CO	MI	VA	ONT
IL	MN	WA	PEI
IA	MO	WV	SSK
KS	NY (see comments)	WY	
	ND		

c. 5 to 6

CT	VT
ME	BC
NH	QB

d. 7 or more

AK	OH
RI	ID
DC	KY

15. Does your project and treatment selection methodology provide for the control of long-term network condition and budgets? NOTE: Only "yes" responses listed.

a. Controls long-term network condition

AK	MA	WA (if fully funded)
AZ	MN	ALB
AR	OH	BC
DC	OK	NS (planned)
IN	RI	ONT
IA	SD	PEI
KS	UT	
LA	VA	

b. Controls long-term budget levels

AK	NY (see comments)	ALB
AR	OK	BC
DC	UT	PEI
RI	VT	ONT
MA	VA	
MN	WA (if fully funded)	

16. If your methodology controls future network condition or budget levels, what is the time frame of your analysis period?

State	1-2	3-5	6-10	11-20	>20
AL		X			
AK			X		
AZ		X			
AR	X	X	X		
CO		X			
DC			X		
IN				X	
IA				X (ACC)	X (PCC)
KS			X		
LA		X			
ME	X				
MD			X		
MA		X			
MI					X (when RQFS is used)
MN		X			
NH		A 5-year plan exists in at least one District			
NY[1]					
OH	X				
OK	X	X	X	X	X
RI[2]					
TX[3]	X	X	X		
UT					X
VT		X			
VA			X		
WA			X		
ALB			X		
BC	X	X	X		
NB	X	X			
NS					X (planned)
ONT		X			
PEI			X		
QB		X			

[1]NY: See comments.
[2]RI: Planned system has flexible analysis period defined by user from 1 to 20 years.
[3]TX: User-definable. These are outputs only.

17. Please provide a complete list of candidate treatments for each pavement type included in your management system.

AL: N/A at this time, still under development

AZ: routine maintenance, seal coat, ACFC/ACSC, Asphalt-Rubber ACFC/ACSC, 2" AC + Asphalt Rubber OR 3" AC + ACFC, 4.5" AC + ACFC and other heavy actions

CT: Provided separately.

DC: emergency repair (routine maintenance), slurry seal, spot resurfacing, light cover, regular cover, reconstruction

HI: flexible pavement repair strategies

1. 2-1/2" AC overlay
2. 1-1/2" AC overlay & reconstruction
3. 1-1/2" overlay & reinforcing fabric
4. 1-1/2" AC overlay
5. fog seal
6. routine maintenance

rigid pavement visual defects

1. grind slab
2. routine maintenance
3. 3-1/2" AC overlay
4. 1-1/2" AC overlay
5. remove & replace slab
6. fill cracks

IN: asphalt surfaced pavements: interstate & prin. arterials

- thin overlay
- thick overlay (4R treatment)
- replace jointed concrete
- overlay
- patch
- crack & seat
- replace

KS: Provided separately.

KY: AC pavements

- thin overlays (1 or 1 ½ inches)
- milling and overlays
- milling and inlays
- stress absorbing membrane interlayer and thin overlays (1 or 1 ½ inches)

PCC pavement

- full and partial-depth repairs
- join resealing
- edge drain retrofitting
- diamond grinding
- AC overlays (3 inches or 3 ½ inches)

LA: Provided separately.

ME: crack sealing, minor maintenance, major maintenance, 5/8" HMA overlay, 3/4" HMA overlay, 1 ½" HMA overlay, 3" HMA overlay, pavement rehab, highway rehab, reconstruction

MA: routine maintenance, surface treatment, structural overlay, reconstruction (asphalt)

MI: Provided separately. These are from our pavement management system, but reflect the range of treatments used by our districts and may be adjusted by the districts.

MO: grinding, sealing, thin overlay, thick overlay, thin bond PCCP, unbonded PCCP, replacement.

MT: The present PMS treatments produce excessive maintenance costs. Therefore, they constitute another reason for getting a different PMS.

NE: fog seal, slurry seal, armor coat, resurfacing

NV: Provided separately.

NH: Provided separately.

NJ: overlay (with or without milling)

NY: Provided separately.

NC:	In the process of revising a decision tree that has been in place for 12 years. Project level treatments determined on a case-by-case basis.
ND:	Provided separately.
OH:	routine maintenance, seal coat, crack seal--underseal, concrete pavement restoration, non-structural overlay, non-structural overlay with repairs, structural overlay, structural overlay with repairs, crack & seat, PCC structural overlay, reconstruction with flexible, reconstruction with rigid, reconstruction with composite
OK:	completely user defined up to 20 treatments per pavement type, load group, and functional class
OR:	AC: inlay, overlay, recycle, reconstruct with AC or PCC PCC: overlay, patching, undersealing, slab replacement, reconstruct
PA:	Provided separately.
RI:	Provided separately.
TN:	asphalt • overlay 1 ½-3" • mill and overlay • recycle in-place • micro-surface overlay • slurry overlay concrete • crack & seat then overlay with asphalt 6-7" • unbonded overlay with concrete • micro-surface overlay
TX:	NN (needs nothing), PM (prev. maint.), LRhb (light rehab), MRhb (med. rehab), HRhb (heavy rehab/reconstruction)
UT:	responsive maintenance, preservation (scheduled), rehabilitation, reconstruction
VT:	functional overlay, structural overlay, reclaim, cold planing, microsurfacing, stone seal
WA:	no automatic (listed) rehabs
WV:	PCC pavement a) concrete repair b) asphaltic concrete overlay with 1) crack and seat 2) saw and seal 3) plain AC pavement a) asphalt overlays b) asphalt removal with overlay
WY:	evolving system
BC:	(flexible pavements) virgin hot mix overlay, remote recycling, hot-in-place recycling, cold-in-place recycling, seal coat or graded seal microsurfacing, mill-fill overlay and various combinations.
MAN:	Provided separately.
ONT:	Provided separately.
PEI:	Provided separately.
SSK:	asphalt concrete surfaces: 1) structural rehabilitation--overlay, recycle 2) non-structural rehabilitation--mill & replace, mill & replace plus overlay sealed granular surfaces 1) structural rehab--overlay (AC), granular overlay & seal 2) non-structural rehab--overlay (AC), granular overlay & seal, rework base & reseal

18. What demonstrated and potential benefits does your pavement management methodology for selecting projects and treatments provide your agency? Please list them and specify which benefits have been demonstrated.

AL:	demonstrated-consistent measurement of pavement distresses and evaluation of condition of roadways; potential-best treatment based on condition of roadway
AK:	Reduced pavement design life. Compared to previous 10 years before PMS, saves 8 million dollars annually on a $32 budget. We don't do projects that don't need to be done.
AZ:	Realistic estimates of budget needs.
CA:	Reduction of lane miles with immediate rehabilitation needs. Reduced lane miles of "rough" pavement.
CT:	Consistent and systematic process to evaluate pavement conditions. Consistent and systematic process to identify and recommend treatments.
DC:	System just got implemented. System selects projects objectively.
HI:	Standardized the candidate selection process
ID:	Has the potential for improving overall network condition at less cost.
IN:	Have shown thin overlay with milling is a viable treatment when done early to keep interstate at high service level. Cannot afford to let pavement deteriorate & do more extensive treatments.
IA:	Smoother, stronger & better condition pavements - increase pavement structure to obtain an additional 15 years of life.
KS:	KDOT executive management decision support (demonstrated), KDOT budget allocation by Kansas legislature (demonstrated), optimal resource allocation for preservation projects
KY:	Equalizing pavement conditions statewide (demonstrated), uniform application of treatments.
LA:	can't answer at this time - not enough history of PMS implementation.
ME:	increased objectivity, ability to assess effectiveness of TIP as measured by network performance
MA:	optimum pavement design, project priorities, budget requirements, treatment selection - all demonstrated
MI:	Demonstrated both subjective and objective review of projects; experienced personnel (knowledge gained and experience applied); low ranking projects are not selected, are delayed or receive added scrutiny; allows flexibility and response to the public and local and state officials; sensitive to realistic, current conditions in the field.
MN:	Potential--most cost effective strategies are selected. I'm not sure how to quantify this.
MO:	Three year program for project development (priorities) support data for type of treatment.
MT:	Eventually we hope to use PMS to select and prioritize projects.
NE:	Selection of projects in "need," improvement of average condition and remaining service life.
NV:	1) minimize political intervention, 2) support for increasing revenue, and 3) better pavements - lower cost
NY:	Standardized methodology used by all eleven regions which assures consideration of several state-of-the-art treatment strategies as part of the LCCA.
NC:	An objective basis to select interstate rehab projects - demonstrated; an objective basis to select primary and secondary projects, more cost effective rehab treatments
OH:	Allocation of funds to areas where need is greatest (greater benefit derived from available funding)
OK:	(expected) least cost for meeting defined condition levels, user overrides for unique conditions, integration of minor maintenance and major maintenance (MR&R)
OR:	On the interstate the percent of fair or better pavements has been improving
PA:	The current system allows us to develop priorities based on network or on any variable we desire based on cost.

RI:	1. Prioritize a list of treatment strategies based on the benefit-cost ratio. 2. An effective rehabilitation program that will work within yearly budget constraints.
SD:	Objective, not subjective. Most of the politics are removed from the process. Based on statewide, not regional needs.
TN:	We expect our PMS, when implemented, to provide selection of projects based on actual rather than perceived condition. We also expect that we will be better equipped to project future pavement conditions.
TX:	Attached.
UT:	System analysis and monitoring. Measures to chart progress and to establish goals with.
VT:	Extends useful life of the infrastructure, restores the structural and functional characteristics.
VA:	Provides a priority listing based on pavement condition.
WA:	Ability to target "low life cycle cost" time to rehab/ Ability to track conditions with time
WV:	Aids in project selection--interstates only evaluates budget adequacies
WI:	flags trouble spots, respond in a consistent manner to pavement condition data
WY:	Basis for pavement program. Demonstrated improvement over subjective approach in the past.
ALB:	Check the standards of the overall network (PQI), and provide advance needs for budget adjustment and consequences for reduced budget.
BC:	Optimal Pavement Performance at lowest cost. Presently implementing PMS (will be fully implemented in three years).
MAN:	Has provided the means to maintain the system at a relatively good condition without increasing the annual maintenance and rehab expenditures.
NB:	Allows us to evaluate subjective district priority projects using objective data.
NS:	The present method of pavement management does not objectively prioritize pavement rehabilitation needs across the province nor place them along a time scale for implementation. The planned PMS will permit the Department to take advantage of these opportunities.
ONT:	Objective evaluation of pavements (demonstrated); co-ordinated maintenance and rehabilitation (demonstrated); accurate pavement performance prediction (potePEIal).
PEI:	Improved cost effectiveness, reduction in the pace of network deterioration.
QB:	uniformity in managing pavements throughout province; accountability; reduced long term cost; increased efficiency and effectiveness
SSK:	Saskatchewan's existing methodology is easily understood and accepted by district management.

19. Have there been hindrances to the development or implementation of your project and treatment selection methodology? Indicate all that apply.

State	Lack of $	Lack of Staff	Gen Neg Attitude Toward PMS	Lack of Support*	Complex Approach	Fear that Decision-Making Perogatives Would Diminish	Lack of Comp Prog. and Systems Analysis Staff	Other
AK								With extensive use of tech. committees as well as director level mgmt. committees at both regional and HQ level, all fears and negativity were addressed and implementation of results was quickly embraced.
AZ	X	X			X		X	
AR		X						Available time
CA	X	X					X	
CO	X	X		1				
CT		X						Reluctance by some in the dept. to accept pavement mgmt. concepts and changes which may result.
ID		X	X	1, 4	X			
IL		X	X	1	X	X		Reluctance to abandon old systems and methods.
IN		X					X	
IA	X	X						
KS					X		X	
LA		X		1	X			
ME	X	X	X			X	X	
MD	X							
MA		X					X	
MI	X	X	X		X		X	PMS system was not user friendly, was paper-based, and provided much more information than most users needed. Graphics were not directly available. This has been resolved at the network strategy analysis level, but not at the project analysis level; Communication issues between districts and central office personnel and between engineers and planners
MN		X			X	X	X	
MO	X	X	X	1, 2		X	X	
MT	X		X	1			X	Our Caltrans PMS is not user-friendly and is being replaced.
NE		X			X	X		Lack of control during project selection procedures.

State	Lack of $	Lack of Staff	Gen Neg Attitude Toward PMS	Lack of Support*	Complex Approach	Fear that Decision-Making Perogatives Would Diminish	Lack of Comp Prog. and Systems Analysis Staff	Other
NV		X					X	Lack of flexible computer architecture. Antiquated system runs in batch mode. New system with relational database is being installed.
NH	X	X	X[1]	1, 2, 4		X		
NY								Over the years, turf wars have hindered the development of a PMS.
NC	X		X	1		X	X	
ND						X		Reliability based on just "hard coded" data, loss of human elemselectionelction process (relates to "f")
OH		X						
OR	X		X	1, 2		X	X	
PA	X	X	X					
RI			X	4				
SD					X	X		Decision makers are comfortable with existing system, afraid of changes a new system might bring
TN		X				X		
TX		X		1		X	X	Lengthy review, justification, and delays in buying computer equip.
UT	X	X			X			
VT	X	X	X					
VA	X	X	X	1			X	
WI			X	1, 2	X	X		
WY	X	X			X		X	
ALB	X							
MAN	X	X			X		X	Former lack of support from decision makers.
NB	X							
NS	X	X			X	X	X	
ONT		X	PEI				X	
PEI		X		5		X		(under D5 wrote "politicians")
QB					X	X	X	lack of pavement knowledge and experience

[1]NH: General "footdropping" and lack of support started to disappear in late 1992. Some fears on decision making still exist.
* 1) From Policy/Decision-Makers; 2) From Planners; 3) From FHWA Division Office; 4) From Technical Staff; 5) From Others

20. Indicate all the types of highway networks your methodology is applicable to:

State	Interstate/ Interprov.	Frwys	Prim.	Sec.	Main Art.	Coll.	Cnty Roads	City Roads	Other
AL	X	X	X	X	X				
AK	X	X	X	X	X	X	X	X	
AZ	X	X	X	X					
AR	X	X	X	X	X	X		X	
CA	X	X	X	X	X	X			
CO	X	X	X	X					
CT	X	X	X	X	X	X			
DC	X	X	X	X	X	X		X	
HI	X	X	X	X	X	X			
ID	X	X	X	X	X	X			
IL	X	X	X	X	X	X			
IN	X	X	X	X	X	X			
IA	X	X	X	X	X	X			
KS	X	X	X						
KY	X	X	X	X	X				
LA	X	X	X	X	X	X	X	X	NOTE: g and h are NHS only
ME	X	X	X	X	X	X			
MD	X	X	X	X	X				
MA	X	X	X	X	X				
MI	X	X	X	X	X	X	X	X	Any network could be defined on the state trunkline system including by route or district boundary--could be extended to local systems.
MN	X	X	X						
MO							X	X	X
MT	X		X	X	X	X			Other state maintained roads, frontage roads, crossovers or unders, etc.
NE	X	X	X	X	X	X			
NV	X	X	X	X	X	X			
NH									All State maintained highways
NJ	X	X	X	X	X				
NY	X	X	X	X	X	X			NOTE: see comments
NC	X	X	X	X	X	X	X		
ND	X	X	X	X					
OH	X	X	X	X	X	X			
OK	X	X	X	X	X	X	X	X	
OR	X								NOTE: will soon be applicable to b-e too.
PA	X	X	X	X	X	X			

State	Interstate/ Interprov.	Frwys	Prim.	Sec.	Main Art.	Coll.	Cnty Roads	City Roads	Other
RI	X	X	X	X	X	X			System includes all functionally classified routes except for rural minor collectors.
SD	X	X	X	X	X	X			
TN	X	X	X	X	X				
TX	X	X	X	X	X	X			
UT	X	X	X	X	X	X	X	X	
VT	X		X	X	X	X	X	X	
VA	X	X	X	X	X	X	X	X	
WA	X	X	X	X	X	X			NOTE: local agencies are adopting PMS for g, h
WV	X	X			X				
WI	X	X	X	X	X	X			
WY	X		X	X	X	X		X	
ALB				X	X				
BC	X	X	X	X	X				
MAN		X	X	X	X	X			
NB					X	X			
NS		X	X	X	X	X	X		
ONT		X	X	X	X	X			
PEI			X	X	X	X	X		
QB		X	X	X	X	X			
SSK			X	X	X	X			

21. What are the practical and theoretical constraints of your methodology? Please provide a brief overview of what these constraints are.

AL:	practical constraints-size and variability of highway system-lack of sufficient mileage of certain types of roads to provide data for analysis
AK:	The system is constrained in the sense that it is a network system dealing in one mile increments and category average performance for rehabilitation and crack sealing. Individual designs are still required and spot maintenance may be required above PMS recommendations.
AZ:	Too complicated for small road systems; Network results are difficult to translate into project specific results
AR:	none
CA:	Flexible pavement is rated by sampling--prone to human error and sampling error. Process has been somewhat subjective. Repairs roads in worst condition first--no optimization.
CO:	none
CT:	Output is based on current needs and current conditions, does not tell us what timing is best. The optimization model, when implemented will tell us the best timing and best treatments.
DC:	none
HI:	Defect surveys are made through the windshield.
ID:	The primary constraint of our pavement management system is internal resistance to change, although this barrier is eroding over time.
IL:	Projects below a certain CRS value are rehabilitated. Borderline projects are selected on project by project basis.
IN:	Uses averages.
IA:	Lack of data on county roads and city streets.
KS:	Change in pavement condition between the annual spring survey and final project location/treatment determination in the spring of the following year
KY:	Budget
LA:	The accuracy of the indices and performance curves weighs heavily on the correctness of the benefit/cost ratio.
ME:	none
MD:	Analysis method does not lend itself to multi-year prioritization.
MA:	budget, personnel
MI:	Practical: Actual project letting years vs planned time and personnel available for thorough project scoping; number of variables with good data for prioritization at central office. Theoretical: Future program size, teamwork and communication between districts and central office is not utilized to its fullest extent.
MN:	none
MO:	Practical dollars, resources, etc. has to come first over theoretical needs.
MT:	Our project and treatment methodology does not optimize for effect on the network.
NE:	Cannot account for complex political issues which impact overall funding of projects.
NV:	single year programming; insufficient pavement condition sample size (10 ft × 100 ft per mile)
NH:	none
NJ:	manpower and data collection equipment
NY:	Budget cutbacks will adversely affect both project and treatment selection. Further, our treatment selection process assumes adequate funding for maintenance activities determined on the LCCA.
NC:	Acceptance by area engineers, not having historical data to perform life cycle cost.
ND:	none
OH:	Available funds, available manpower to produce necessary plans.
OK:	no optimization at this time, just prioritization
OR:	It is hard to convince people to look for network optimization strategies when there is not enough money to deal with the existing poor pavements.
PA:	The current matrix only analyzes based on a set condition or treatment strategy. It is based on a maintenance philosophy which is 10 years old.

RI:	Not finalized.
SD:	Does not consider project optimization, only considers the "worst first" which is not the most cost effective way to select projects.
TN:	Budgetary & political influence always influence project choices. Until a sufficient history database is built the decision process will be something less than purely scientific.
TX:	We project condition in terms of each distress type - we don't project a single index. This makes analysis very difficult and imprecise.
UT:	Deterioration curve, trigger values, performance prediction after treatment.
VT:	Does not assist us to develop a long term network level strategy. Data not currently loaded to allow us to do cost projections. Use of resources not optimized.
VA:	none
WA:	Limited funding and manpower prevents truly optimum results.
WV:	Ability to gather data
WI:	none
WY:	Budget
ALB:	none
BC:	Must prepare a detailed and complete database describing geometric, structural, environmental, and loading aspects of all provincial paved highways. Must also have a standard distance system.
MAN:	Lack of adequate distress information, information technology and an optimization methodology. These fundamental constraints are anticipated to be overcome in the intermediate term due to senior management requirements for more comprehensive information and to accommodate corporate planning.
NB:	There are no optimization techniques. Priorities are based on current and projected conditions.
NS:	The present method of pavement management does not objectively prioritize pavement rehabilitation needs across the province nor place them along a time scale for implementation. The planned PMS will permit the Department to take advantage of these opportunities.
ONT:	Methodology applicable to only flexible pavements; process to incorporate other types of pavements (i.e., rigid pavements and surface-treated pavements, etc.) underway.
PEI:	The most relevant constraint is that the overall deteriorated state of the network limits potential for constructive decision making.
QB:	no explicit benefit estimation; no long term condition projections (reliability); computer availability
SSK:	Limited to treating only pavements near the end of their service life as identified by district staff.

22. List other factors that influence the selection of projects and treatments like political, demographic, etc.

AL:	political, engineering judgement, environmental
AK:	The optimized PMS project list is considered with all other types of projects so that only 80% of PMS projects are actually programmed.
AZ:	Balance work between districts, Individual bias of personnel in different areas that have "ownership" interest in projects.
AR:	none
CA:	Prioritization of individual projects is performed by districts, in consideration of political constraints, traffic, maintenance service level, (functional class). Low volume roads may be rehabilitated only by exception.
CO:	none
CT:	Geographical boundaries.
DC:	Political, citizens requests (vibration, drainage problems, etc.)
HI:	none
ID:	Political influence and public concerns are always a problem to be dealt with as with any public agency. What the motoring public sees as a major concern may not be at the top of our priority list.
IL:	Political, location, expected traffic growth, geometric constraints.
IN:	Political; geographic (distribution of projects); continuity (do sections back-to-back to limit disruption & variability); design capability (getting plans ready)
IA:	Equalize condition throughout the entire state.
KS:	Engineering judgement at the district level
KY:	Factors not incorporated in the evaluation schemes, such as roads importance to tourism or economic development.
LA:	Public input; although we do not want this to change our procedure unless such input points out to us that some appropriate consideration was overlooked
ME:	none
MD:	System preservation is key factor.
MA:	project locations, environmental, political, traffic
MI:	District balance and overall district pavement condition; improve/expand budget vs preservation budget; funding needs for bridges, roadsides, traffic operations and safety upgrading; maintenance history and expenditures; public observations and letters; political interest.
MN:	Political, balance work load within districts, corridor--other work planned on adjacent sections, manpower constraints in districts.
MO:	none
MT:	Politics somewhat
NE:	Political and demographic
NV:	High traffic volumes in some urban areas inhibits performing some maintenance strategies (chip seals, sand seals, etc.); Coordinating with local government projects.
NH:	Political influence will be a factor until the system is fully implemented and has proved itself.
NJ:	none
NY:	Project selection is influenced by demographics. For example, some care must be taken by our regional offices to distribute project benefit among all counties.
NC:	Ultimate project selection by Board of Transportation (political). Treatment of lower classification highways is still determined by area engineers, not necessarily PMS
ND:	Political, funding
OH:	Locally available materials, contractor presence within a given area
OK:	district, residency jurisdictional divisions; user overrides for considering other factors; unit costs
OR:	Public input, climate
PA:	Due to decentralization of the District offices, much of the projects are selected by the District. It is usually performed using various factors such as condition functional class, ADT, priorities, politics, demographics, etc.

RI:	Political, budget, coordination with other scheduled infrastructure improvement projects
SD:	Public input solicited. FHWA regulations also hinder the process since all projects must be identified and placed in the STIP. Projects that quickly crop up must wait until FHWA mandated planning process is fulfilled.
TN:	Political, budget, product knowledge
TX:	Political--intervention of Commissioners, Legislators, public delegations, FHWA mandates.
UT:	Corridor plan - adjoining section treatment
VT:	Politics (of course), future reconstruction projects, district maintenance, FHWA requirements, emergency projects.
VA:	none
WA:	Final selection is made by Engineering and Program managers in each District and Preliminary Budget and manpower balances are made.
WV:	Geographical distribution
WI:	political, capacity, safety, multimodal
WY:	Geometrics, safety.
ALB:	political commitment, constructional improvements, widening
BC:	Time before major reconstruction, strategic importance, functional importance
MAN:	Political, regional, timeliness
NB:	Political
NS:	none
ONT:	Jurisdictional, political, proportional "slice" of budget to all regions (demographic)
PEI:	Local political intervention, requirement to spread work geographically
QB:	budget distribution; available materials; local considerations (socio-economical)
SSK:	Maintenance requirements, federal cost-shared programs.

23. List any resource requirements (data, computer, personnel, equipment) which are specifically required to utilize this methodology.

AL:	none
AK:	South Dakota Profiler, mini-computer-, 1 engineer, ½ time assistant, 2 seasonal technicians, part-time computer programmer, mainframe database.
AZ:	Network data, field crews, ride meter, computer
AR:	PC-based system
CA:	Mainframe computer, pavement management software, MIS personnel, ride van, personal (laptop) computers.
CO:	none
CT:	Need a dedicated unit for Pavement Management (at least 5 engineers, 2 programmers), numerous personal computers, software, etc.
DC:	Street inventory data, high speed PC, data collection team, roughness collection equipment, skid trailer.
HI:	none
ID:	HPMS data, deficiency data, PC networks and mainframe, numerous programs, testing equipment such as South Dakota Profiler.
IL:	Rating panels to drive the highway system to rate the pavements and a computer to store the ratings.
IN:	Use software developed by Deighton &Assocs.
IA:	none
KS:	network annual condition data, cost data, minicomputer (UNIX) andPCSs, 2 engineers, 3-4 eng. tech, 1 programmer, 2 MDR4090s and 2 MDR4010s (data collection equipment
KY:	Personnel, data acquisition and analysis.
LA:	inventory data, condition data, personal computer(s), software (database, analysis, and graphical), 2 engineers, 3 technicians
ME:	inventory data, history data, condition data, maintenance & PC
MD:	Condition surveys, life cycle cost, construction history, pavement deflections
MA:	personnel with database management experience and pavement management experience; 486/66MHZz, 640 RAM - 100 MG, minimum; field equipment - ARAN, FWD, skid tester
MI:	District experts in maintenance, construction, project development, traffic & safety; Application programsto runn prioritization and pavement management system; Computers for storage of potential projects ID and background data; Computers for access to PMS,dataa from sufficiency, materials & technology division.
MN:	Data--see #3, computer--PC, highly trained operator (NOT user-friendly)
MO:	Pavement condition data and the computer resources to analyze it.
MT:	none
NE:	Pavement condition measurement equipment, mainframe and personal computers, personnel, and division interaction.
NV:	data, computer, personnel, equipment, funding
NH:	Automatic Road Analyzer (ARAN) for ride, distress & rut; skid trailer; software for processing ARAN data; software at District level for creation of 5 year resurfacing program (6 Districts); Personnel: ARAN (3), skid (2), Programs (6)
NJ:	ARAN, computer software, 6 persons, ASTM skid trailer
NY:	All listed are necessary.
NC:	Relational database
ND:	Pavement data, FWD, District knowledge of pavement performance maintenance data
OH:	Mainframe computer, PC, field and office personnel
OK:	none - extraordinary
OR:	Very fast PC, data collection personnel, skid vehicle, ride vehicle, pavement raters, engineers to analyze
PA:	System uses a large IBM mainframe for the PMS. The matrix and analysis at the Segment level including the SAS programs work off the mainframe system.

RI:	Pavement evaluation workstation, PC for database & analysis software, specially equipped vehicle
SD:	Computer & data files; personnel for data collection, processing, and verification.
TN:	Computer, road condition measuring devices, data storage devices, plotters.
TX:	Mainframe and microcomputer equipment. Distress, ride, skid, and deflection testing equipment. Electronic and mechanics shops.
UT:	Data, computer, trained personnel, pavement condition equipment.
VT:	Vendor data collection of roughness, cracking, and rutting; computer equipment/software
VA:	none
WA:	PCS must be available to all users of our PMS
WV:	Personnel and data
WI:	Data, computer, personnel, equipment
WY:	Data, computer, personnel, equipment
ALB:	Updated accurate inventory, trained personnel for data management and efficient equipment for pavement evaluation, knowledge of computer
BC:	Database: geometric, environment, structural, load, etc; personnel commitment on a regional basis; standard information engineering or computer format; regional and headquarters commitment.
MAN:	Personnel, computer and data
NB:	none
NS:	The present system requires the use of qualitative pavement condition data, specialized test equipment on which rehabilitations design is based and personnel.
ONT:	Mainframe and microcomputers, expert personnel (head office and regions), ARAN, PURD, ASTM Pavement Skid Friction Tester, etc.
PEI:	There is a need for personnel trained in the use of complex mathematical systems.
QB:	PC, data collection program, trained personnel
SSK:	Rating panel consisting of head office and district staff.

24. Will the ISTEA Legislation influence your project and treatment selection methodology? NOTE: Not applicable to Canadian Provinces.

State	Y	N	Comments
AL		X	Probably not, though we have not fully reviewed the Interim Final Rule
AK		X	We had already implemented PMS as required by ISTEA.
AZ	X		Some revisions will be needed to conform to portions of ISTEA.
AR	X		Different funding resources always influence budgets.
CA	X		Predictive ability is currently under development, that will allow introduction of optimization subject to budget or road condition constraints.
CT	X		Pavement Management System must be expanded to include locally maintained roads which are eligible for federal aid.
DC	X		System was designed around (based on) ISTEA requirements.
HI		X	
ID	X		Will over time allow more public involvement bringing us to a point where we will have to choose projects based on our optimization model in order to prove to the public we are spending funds in an efficient & equitable manner.
IL		X	The method was previously in place. However, ISTEA may influence some modifications.
IN		X	Too soon to tell: don't feel it will influence much.
IA	X		We will consider county roads and city streets in project selection
KS		X	Not for current state highway system network
KY		X	
LA	X		Our PMS is in the process of taking over for our present "condition" based project selection
ME	X		will incorporate LCCA
MD		X	
MA		X	ISTEA expands the number of miles to be evaluated, we will be combining projects with MPOs
MI	X		Our PMS will be used at both the network and project levels throughout the department. The basic methodology will not change, however, additional input and output variables will be included as well as interfacing with other management systems and county and city systems.
MN		X	Other than to expand on to more roads (local)
MO	X		Forced use of rubber AC mixes to comply with ISTEA.
MT	X		There will be an increase in the use of ground tire rubber in pavements. Also, ISTEA requires projects be selected in consultation (or cooperation) with the public, depending on the system.

State	Y	N	Comments
NE		X	Not that restrictive
NV		X	Follows AASHTO and FHPM 6-2-4-1
NH	X		With the added requirements of data both in scope and amount, we expect a review of our PMS before full implementation.
NJ	X		The expansion of PMS to MPO (county and municipalities) will greatly increase treatment and project selection
NY	X		The ISTEA regulation may require additional data be collected and used as part of the project selection process. ISTEA will not affect treatment selection.
NC	X		Will enable us to get computer technology essential for W.C. to perform requirements of ISTEA
ND	X		To some degree. Obviously, the requirements stated in the bill will cause compliance and possibly persuade the treatment selection process to continue in an altered course.
OH		X	Methodology complies except for extent of system--we will have to expand
OK	X		Depending on final rules, we may need to add optimization methods
OR	X		Expanding analysis capabilities and abilities to look at alternate strategies at network level will hopefully improve project selection and treatment selection
PA	X		Currently the research project for performance curves and optimization models was developed to comply with ISTEA requirements.
RI		X	ISTEA does not provide any guidance in this area. Our project and treatment methodology will be based on what is best for the state.
SD		X	We meet nearly all of the mandates using the current methodology but we are enhancing our system for our own benefit.
TN	X		We are implementing a more objective project selection process.
TX		X	Not initially. It might later on, as we become more familiar with it.
UT	X		Expand coverage to include roads not on state system
VT	X		Currently evaluating PMS software to meet ISTEA requirements and pavement program needs
VA	X		We will enhance our PMS to include those analysis required by ISTEA
WA		X	Uncertain, however, no changes appear necessary
WV	X		PMS requirements
WI		X	
WY	X		Still reviewing impact on pavement management

25. What portion of your methodology is automated?

State	All	Some	Comments	None
AL		X	data analysis, mapping	
AK		X	Project recommendations require interpretation and strip charts of pavement condition require interpretation. All else is automated.	
AZ		X	Budget determination	
AR	X		(planned)	
CA	X			
CO		X	Smoothness & rutting data collection.	
CT		X	Pavement rating, analysis, tentative project/treatment selection	
DC		X	Condition data collection using laptop, data transfer, analysis through project selection.	
HI		X		
ID		X	Everything except surface condition rating is automated.	
IL		X	Distress data collection, (rutting, roughness)	
IN		X	Selection of candidate sections and treatments - actual programming of projects is manual.	
IA		X	Data storage and condition analysis	
KS		X	All portions are computer-assisted manual processes.	
KY		X	Data management	
LA	X			
ME	X			
MD		X	Ranking pavement sections by category	
MA	X			
MI		X	Submission of projects & related information; statewide analysis of project priority; Project and network analysis for PMS is automated and in the process of being made user-friendly	
MN	X			
MO		X	Identification of potential projects.	
MT		X	Sufficiency--assists in prioritization.	
NE		X	Profile measurement. Prioritization and reporting are semi-automated.	
NV		X	All except pavement condition surveys	
NH		X	Processing and reporting of ARAN data, District Level resurfacing program, and Treatment "Tree" process	
NJ		X	roughness/distress/rutting/skid data collection	
NY		X	Network pavement condition survey, project-level data collection, life-cycle cost analysis	

State	All	Some	Comments	None
NC		X	determination of pavement distress rating	
ND		X	Data collection	
OH		X	Data analysis	
OK	X		condition surveys, roughness, and rut depth measurements	
OR		X	Skid & ride testing, network condition analysis, prioritization of interstate projects, ranking of interstate projects based on paving needs	
PA		X	condition data analysis through matrix	
RI		X	Data collection, optimization techniques, condition index calculations	
SD		X	Project prioritization	
TN		X	All but distress measurement	
TX		X	Treatment selection, project identification, optimization, impact analysis	
UT	X		Data gathering, storing, manipulating, retrieving, analysis, reporting	
VT		X	Data collection and annual program selection are automated	
VA				X
WA		X	Predictions of low-life-cycle timing	
WV		X	Database management and RSL analysis	
WI		X		
WY		X	Field data collection, data manipulation, project selection	
ALB	X			
BC		X	Subsystems database, rehab, feedback, maintenance, project level	
MAN		X		
NB		X	Data collection, storage, final generation of 5 year listing	
NS				X
ONT		X	Pavement roughness and PCI calculation and repoPEIng	
PEI	X			
QB	X			
SSK		X	Ride measurement, cost-effectiveness analysis	

26. Is the methodology used in Headquarters or Districts?

State	Headquarters	Districts	Both	Notes
AL			X	
AK			X	projects selected on a statewide basis.
AZ	X			
AR	X			
CA			X	
CO	X			
CT	X			
DC	X			not available
HI	X			
ID	X			
IL			X	
IN	X			
IA			X	
KS			X	
KY			X	
LA	X			
ME	X			
MD		X		
MA	X			
MI			X	
MN	X			
MO	X			
MT			X	
NE			X	
NV	X			
NH			X	
NJ	X			
NY		X		
NC	X			
ND	X			
OH	X			

State	Headquarters	Districts	Both	Notes
OK	X			
OR	X			
PA			X	
RI	X			
SD	X			
TN			X	
TX			X	
UT			X	
VT	X			
VA			X	
WA			X	
WV	X			
WI			X	
WY			X	
ALB	X			
BC		X (replaced "districts" with "regions")		presently under development
MAN	X			
NB	X			
NS			X	
ONPEI			X	
PEI	X			
QB			X	
SSK	X			

27. In what section is Pavement Management located?

State	Planning	Programming	Research	Eng.	Other	Comments
AL			X			
AK				X	Headquarters Materials	
AZ					Material Group	
AR		X				
CA					Maintenance	
CO	X			X		
CT				X		
DC				X		
HI					Materials	
ID	X					"Planning & Programming Section"
IL	X	X			Design	
IN	X					
IA					Committee	
KS					Operations (Materials & Research)	
KY				X		
LA	X					
ME			X			
MD					Materials	
MA				X		
MI	X		X			
MN				X		Materials
MO	X					
MT				X		
NE	X					
NV	X					
NH	X					
NJ					Construction/ maintenance	
NY					Operations (see comment)	
NC				X		
ND	X					Planning division, PM section
OH	X					
OK	X					
OR				X		
PA				X		Bureau of Maintenance

State	Planning	Programming	Research	Eng.	Other	Comments
RI					Program development (includes former planning division)	
SD	X					
TN				X		
TX					Design	
UT	X	X			Materials	
VT					Construction & Maintenance	
VA					Maintenance Division	
WA					Materials Laboratory	
WV	X					
WI					Construction	
WY				X		
ALB				X		
BC				X		"Geotechnical and Materials Engineering Branch"
MAN		X				"Programming Branch & Pavement Design Section"
NB	X					
NS	X				Presently no central focal point	"a" is planned
ONT				X		
PEI	X					
QB	X			X		under "d" added support
SSK	X					

28. Was your PMS approved by FHWA? NOTE: Not applicable to Canadian Provinces.

State	Yes	No	Comments
AL	X		
AK	X		
AZ	X		
AR	X		
CA	X		
CO	X		
CT	X		
DC	X		
HI	X		
ID	X		
IL	X		
IN	X		
IA	X		(responder replaced "approved by" with "found acceptable")
KS	X		
KY	X		
LA	X		
ME	X		
MD	X		
MA	X		
MI	X		
MN	X		
MO	X		
MT		X	We are in the process of acquiring a different PMS.
NE	X		With limits based on future ISTEA resolutions
NV		X	see attachment D; we are developing system to comply
NH	X		
NJ	X		
NY			(responder answered "c," DON'T KNOW)
NC	X		
ND	X		
OH	X		
OK			in process now
OR	X		for 1993 requirements
PA	X		for 1993 requirements
RI	X		
SD	X		
TN		X	It is not yet implemented
TX	X		2/19/93
UT		X	Lack of adequate construction history.
VT		X	We are in the process of upgrading our PMS to meet ISTEA and gain FHWA approval.
VA	X		
WA	X		
WV	X		
WI	X		
WY	X		

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