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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE

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PAVEMENT MANAGEMENT PRACTICES

TRANSPORTATION RESEARCH BOARD
National Research Council

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Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

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The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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The Transportation Research Board evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

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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 highway 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 pavement designers, maintenance engineers, and others responsible for the management of highway pavements. Information is presented on pavement management systems—the established, documented procedures used to treat all activities involved in providing and sustaining pavements in an acceptable condition.

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.

As highway agencies focus more attention on maintenance and rehabilitation of highway networks, the use of some form of a pavement management system becomes increasingly important. This report of the Transportation Research Board describes the features, applicability, and uses of a pavement management system and recommends five general steps for implementing a new pavement management system or improving an existing system.

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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George W. Ring, Engineer of Design, Transportation Research Board, assisted the NCHRP Project 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 PRACTICES

SUMMARY

As highway agencies have shifted from construction of new pavements to maintenance and rehabilitation, more attention is being focused on ways to better manage the huge investment in paved highways. Pavement management is not new; highway agencies have been making decisions about pavements for as long as there have been pavements. The emphasis in recent years, however, has shifted from perceived needs and best judgments to a systematic approach.

Pavement management is the effective and efficient directing of the activities involved in providing and sustaining pavements in an acceptable condition at the lowest life-cycle cost. A pavement management system (PMS) is an established, documented procedure that treats all of the activities involved in pavement management in a systematic and coordinated manner. A PMS usually includes condition surveys, a data base of pavement-related information, analysis scheme, decision criteria, and implementation procedures.

Pavement management can be applied at the network level or at the project level. At the network level, pavement management is concerned with information related to the entire highway network; as such it involves policy and programming decisions. Network-level pavement management is used to establish programs, set policy, and estimate budget needs. At the project level, pavement management is concerned with detailed technical information on specific pavement sections and can be used for activities such as establishing priorities for maintenance and rehabilitation.

Of 53 agencies responding to a survey, 35 have some form of pavement management system or process and 11 have a partial system or are developing a system. The agencies reported that the most effective method for developing a PMS was for the chief administrative officer to initiate the effort and a steering committee or task force to guide the development. Almost all of the pavement management processes include some form of pavement evaluation or monitoring. Outputs from the PMS covered a wide range of information including pavement condition, deficiencies, priority listings in various categories (e.g., repair needs), predictions of remaining life, strategies and treatments, and costs.

The agencies use the information from their PMS for such activities as establishment of priorities for overlays, maintenance, and allocation of funds; budget preparation; development of rehabilitation strategies; and identification of problem areas. Most survey respondents believe their PMS is cost-effective. Benefits cited were cost savings, better budgeting and allocation of funds, improved priority listings of projects, better selection of projects, ability to evaluate alternative strategies, improved data collection and thus knowledge of pavement condition, and more uniform, consistent, and accurate information from location to location and from year to year. Some areas where improvements are needed include life-cycle costing, optimization models, prediction capability, data collection and processing, and intradepartmental coordination.

Development of a pavement management system involves the following steps: (a) commitment from top management, (b) establishment of a task force or steering committee to guide development, (c) selection or development of a system that meets the needs of the agency, (d) demonstration of the system on a limited scale and revisions as needed, (e) full-scale implementation, and (f) follow-up and improvements.

In general, the following components are recommended for inclusion in a pavement management system: (a) a means for monitoring or evaluating pavement condition (may include measures of distress, roughness, friction, structural capacity), (b) a data base (including costs, pavement history, traffic volume and loads over time, and inventory data), (c) methods for analyzing data and generating reports (at both network and project level), and (d) an updating capability.

CHAPTER ONE

INTRODUCTION

Construction of new highways, including the Interstate system, has been the primary emphasis of highway agencies since the 1950s with many new miles of pavements being added to the various systems. During the 1960s and 1970s, construction of the Interstate system was the largest public works project in history. Many of the pavements constructed then have reached or soon will reach the end of their design lives. The highway systems are now basically complete, and the emphasis has changed from new construction to system preservation consisting of maintenance and rehabilitation.

There are nearly four million miles of public highways or roads in the United States. Over 50 percent of these miles are either flexible or rigid pavements with the remaining either gravel surfaced or unsurfaced. The highway system supports an estimated economic activity of more than $400 billion annually or nearly 20 percent of the gross national product. The highway system is also dedicated to the needs of national defense (*1*).

Lamm, in his comments at the North American Pavement Management Conference in Toronto, said, "The network of highways, roads, and streets across America has always been one of our Nation's most important assets. All Americans are affected, directly or indirectly, by highway transportation. It is the lifeline over which nearly all consumer and industrial goods are transported at some point in their journey" (*2*). The costs of transportation affect the price of virtually every product used by the consumer. Good roads are beneficial to industry and thus to the consumer through cost savings in vehicle operations. Good roads benefit industry by helping to maintain competitiveness and increase productivity. Evidence has shown that better roads are important for the regeneration and development of industry (*3*).

There has been a steady increase in vehicle miles of travel per year in the United States from 1955 through 1985, with the exception of a slight drop in 1974 and again in 1979 and 1980. This is illustrated in Figure 1 (*4*). Motor fuel consumption paralleled vehicle miles of travel through 1978 (Fig. 1) after which there was a drop in fuel consumption caused by energy-conservation measures.

A comparison of the growth in volumes and loadings on the rural interstate system from 1970 through 1985 using three-year moving averages revealed that the percent increase in daily traffic load as measured in equivalent single-axle loads (ESAL) has been increasing faster than the percent increase in total daily traffic. This is illustrated in Figure 2 (*4*). From 1970 through 1985 trucks with five or more axles increased from 9 to 17 percent of total daily traffic, which is nearly a 100 percent increase in 15 years. On many pavements, 25 to 30 percent of the daily traffic volume consists of trucks with 5 or more axles. By contrast, twenty-year traffic forecasts made in the 1950s and 1960s included 10 to 15 percent heavy trucks for rural Interstate highways. Trucks with 5 or more axles produced 69 percent of the ESALs in 1970 whereas in 1985, because of the increase in their percentage of the total traffic, they produced 92 percent of the ESALs on the rural Interstate (*1, 4*). Data from the Highway Performance Monitoring System (HPMS) indicate that a substantial portion of Interstate-system pavements are in poor condition (Table 1) (*1, 4, 5*).

The Interstate system contains one percent of the total mileage in the United States and carries 20 percent of all vehicle miles (*2*). In 1983, more than 6,000 miles of the pavements on the Interstate were in poor condition and needed improvement (*1*). In 1985, 4,700 miles were reported in poor condition according to the HPMS (*4*). Lamm (*2*) reported at the North American Pavement Management Conference that America's other arterial routes were in worse condition than the Interstate system.

> These roads account for 9 percent of all roads in the United States, but receive nearly 50 percent of all highway travel. Approximately 45 percent of the pavement mileage on these roads either needs now, or will soon need, some level of restoration. Over 11 percent of this mileage demands major improvements immediately. . . . On our rural collector systems (21 percent of our road mileage and 18 percent of total vehicle miles of travel), 2 out of 3 miles are in poor condition or are approaching poor condition and in need of attention (*2*).

Considering the Interstate, arterial, and collector systems, nearly 170,000 miles of pavement are in need of attention throughout the country. In addition, there are many thousands of miles of state and local roads. From 1980 to 1982, the rate of pavement deterioration was reported to be increasing twice as fast as the rate that improvements were being made to correct the deficiencies (*1, 5*). A comparison of 1983 and 1985 data based on the HPMS showed that there were 16 percent fewer miles of pavements in poor condition in 1985 than in 1983 (*4, 5*). This would indicate that in this time period at least, pavement improvements were moving ahead of pavement deterioration. Some of this, however, may be caused by variations in the data within the HPMS. A further comparison between 1983 and 1985 showed that there was not a corresponding increase in pavement miles in the PSR range of 3.5 to 5.0 as there was a decrease in miles in the poor category. The increase showed up in the range of 2.1 or 2.6 to 3.4, which may indicate that the improvements made were minor in nature (*4, 5*).

With the poor condition of many pavements and cost increases caused by inflation, highway agencies have been faced with an almost overwhelming problem. In 1976, the U.S. Congress es-

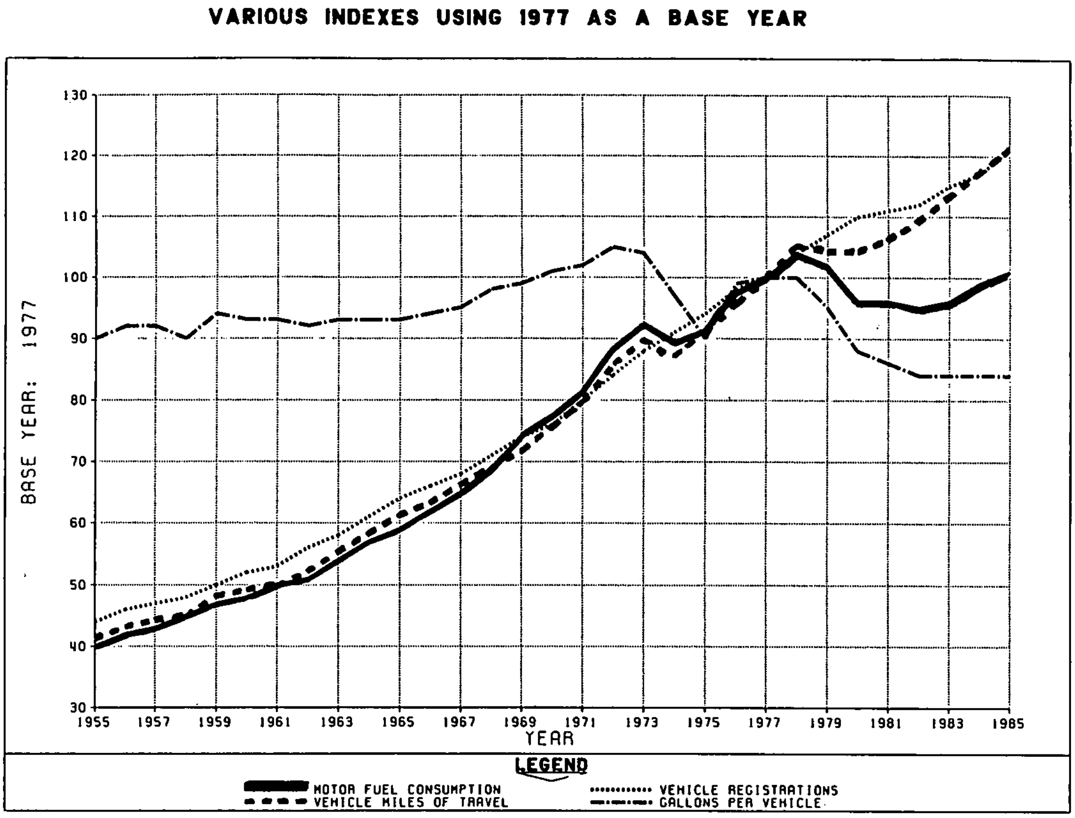


FIGURE 1 Motor fuel consumption and vehicle miles of travel in the United States from 1955 to 1985 (*4*).

tablished the 3-R program consisting of resurfacing, rehabilitation, and restoration to provide funds for the preservation of the Interstate system. Reconstruction was added in 1981 to change the program to 4-R, and this expanded program exceeded $4 billion in 1983. Table 2 shows the estimated costs for maintaining the existing conditions on the primary, secondary, and urban systems and including the 4-R Interstate needs through the year 2000. In addition to those costs shown in the table, it has been estimated that it will require $15 billion to complete the construction of the Interstate and $45.8 billion to take care of the bridge deficiencies (*1*).

Pavements now represent the single greatest investment highway agencies have in their systems and as such they deserve considerable care and attention. Larson (*6*) stated at the North American Pavement Management Conference:

> The central issue for our industry is to serve the public well enough that we continue to gain public support. And of course the circularity here is obvious. Unless we have money, unless we have good systems we can't serve. And unless we serve we will have even less money. So we've got to break out of this downward spiral and my sense is that the states, the federal government, are in fact doing that, but unevenly and with considerable amount of effort required. We must control costs, we must give good products, and pavement management systems are tools to do that job. Pavements are highly visible to our public. I have said many times in Pennsylvania that two things count: pavements free from potholes, and having a license and title delivered on time. These are the things that motorists care about and they care about these things passionately and continually. We can't stop where we are with the state of our knowledge or with the state of our technology. From any perspective, unless we can have a stream of innovations that will take the generally shrinking buying power available to us and produce equal or even better services to the public, we will cease to be competitive and our profession will suffer. More importantly, society will suffer so our challenge is very clear.

Much of the current interest in pavement management has been brought about because highway agencies realized that managing the tremendous investment of billions of dollars in paved roads requires the exercise of sound judgment. The task is large

TABLE 1

PERCENTAGE OF INTERSTATE HIGHWAY PAVEMENTS IN VARIOUS CONDITIONS

Type	Year	Condition (1)			PSR < 2.5 (4,5)
		Poor	Fair	Good	
Rural	1981	9.0	53.3	37.7	-
	1982	13.5	55.9	30.6	-
	1983	13.1	55.1	31.8	13.5
	1985	-	-	-	10.9
Urban	1981	10.0	50.8	39.2	-
	1982	16.3	49.3	34.4	-
	1983	17.5	52.4	30.1	17.0
	1985	-	-	-	11.2

and the funds available have been relatively limited. Formalized pavement management provides the tools that a highway agency can use in making the most beneficial and cost-effective use of funds in rehabilitating and reconstructing pavements. This provides the highway manager with the capability for properly evaluating all possible alternatives in the process of selecting the best.

BACKGROUND

The management of pavements is not new because highway managers have been making decisions about pavements for as long as there have been pavements. Decisions have been relatively routine and part of normal operations regarding such things as what pavements will be constructed or maintained, what materials will be used, and when the work will be done. These decisions may be motivated by public pressure or may be based on the knowledge and experience of the individuals involved. Questions such as what, where, and when have been basic, but the solutions used have not always been the best or the proper ones. They were generally based on a perceived need and on the best judgment. Initially, there were not as many

TABLE 2

ESTIMATED COSTS FOR MAINTAINING EXISTING CONDITIONS ON VARIOUS SYSTEMS THROUGH YEAR 2000 (*1*)

	1983-2000 Costs (billions)	
Maintain System	Total	Pavements
Interstate 4-R	$64.3	$35.6
Primary	93.3	53.8
Secondary	.48.6	26.3
Urban	72.7	47.1
	278.9	162.8

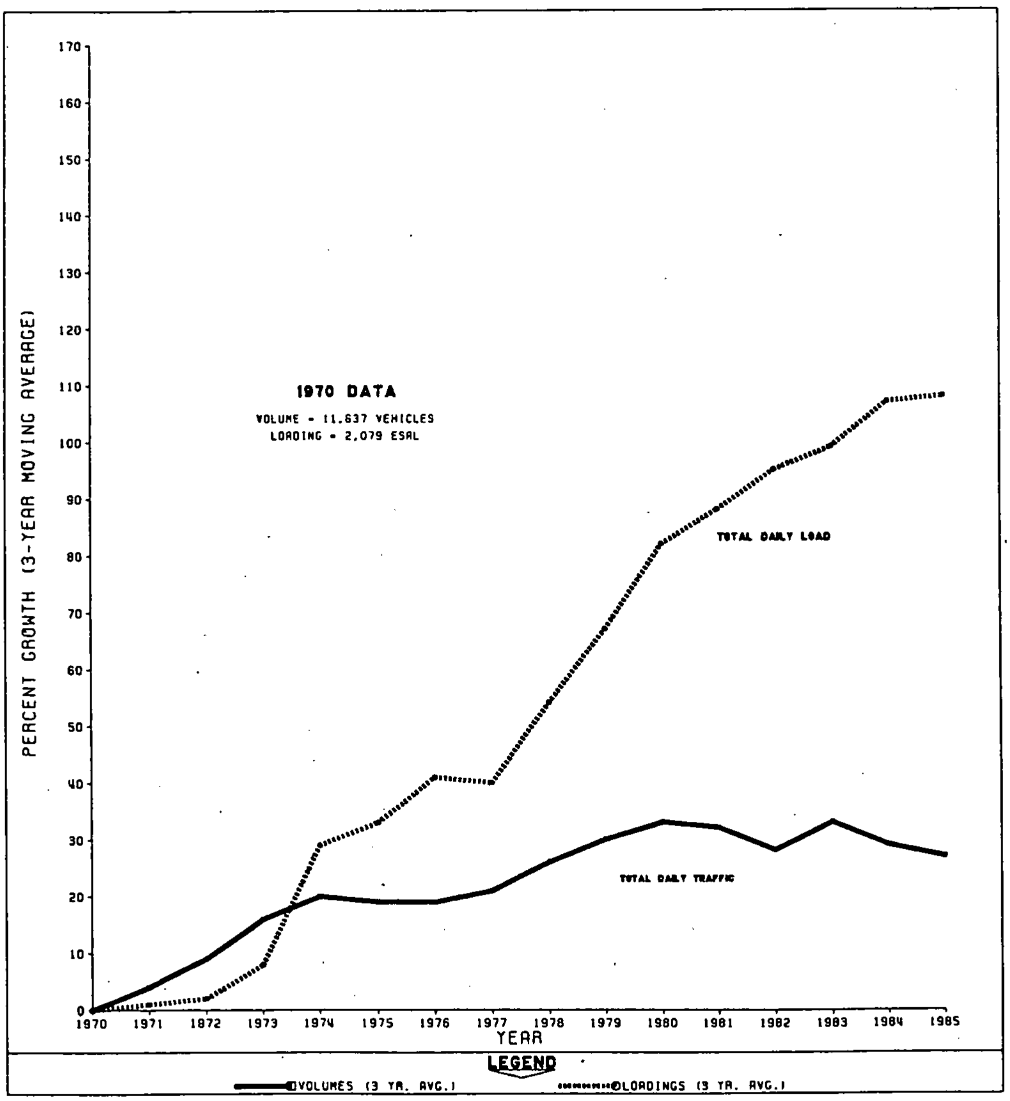


FIGURE 2 Comparison of growth in volumes and loadings on the rural Interstate system at truck weight sites (*4*).

pavement miles and the bulk of the work was new pavement construction with new geometrics and routine maintenance. Then the situation began to shift from new construction toward mostly system preservation. The various processes for managing pavements have evolved over the years in response to needs that existed. As stated earlier, pavements have always been managed to one degree or another; the recognition of pavement management as a unique process or system has only come about in recent years.

Major research in the areas of pavement design and performance were started in 1920 at the time the Highway Research Board was organized. The research was a mixture of theoretical and empirical studies (*7*). After World War II, there was an increase in allowable truck weights and administrators began to recognize the need to allocate roadway costs among different vehicle classes. Various road tests were used as the basis for setting or changing the cost distribution among different vehicle classes. The WASHO Road Test was conducted from 1952 to 1954 in Malad, Idaho and the AASHO Road Test was conducted from 1958 to 1961 in Ottowa, Illinois. The AASHO Road Test was the most comprehensive ever conducted and contained 836 test sections and 169 different pavement combinations. The Road Test was designed to provide information needed by engineers for pavement-design purposes. The procedures developed from the Road Test results are still in use by many agencies. One significant result from the Road Test was an increased awareness of the value of pavement serviceability and performance monitoring (*7–9*).

At the completion of the AASHO Road Test a program of satellite studies was proposed to verify or modify the results from the Road Test for conditions and materials different from those that existed at the test site. Unfortunately, few states took advantage of this program. In 1966, AASHO, through the National Cooperative Highway Research Program, initiated a study on pavement design. These efforts evolved into a systematic approach to the design, construction, and maintenance of pavements (*7, 10*).

In the late 1960s and early 1970s, the term "pavement management system" came into use as the means of describing the range of activities that are involved in providing serviceable pavements; it was based on a systems engineering approach to the problem of economical design, construction, and maintenance of pavements (*7, 11*). In the early 1970s many states were beginning to use a form of objective rating of pavement condition as a way of prioritizing rehabilitation projects with more funds being allocated to preserving pavements (*8, 12*). Similar research efforts were being accomplished in Canada as well as the United States.

The California Department of Transportation began the development of a pavement management system in 1977 in order to meet their pavement needs. Their new system was implemented in 1979 (*13, 14*). Arizona started with a pavement evaluation program in 1974 and then expanded to a management system (*15–17*). The State of Washington began in the late 1960s with priority planning using biannual pavement condition surveys (*18*). Several other agencies such as Utah, Kentucky, Florida, Pennsylvania, Texas, Ontario, Saskatchewan, and New York started at about the same time with pavement monitoring programs (*10*). Pavement evaluation is considered to be the foundation for pavement management, and for many agencies devising rating schemes was their first formalized effort at managing pavements. The Air Force developed a pavement management system known as PAVER in the 1970s (*19*).

The Federal Highway Administration has emphasized the use of pavement management and has encouraged state and local highway agencies to improve techniques and programs for the preservation of the highway system (*9*). NCHRP Report 215 (*12*) identifies a number of factors that provided impetus to the interest in and development of a pavement management system (Table 3). There was an extensive pavement building boom in the late 1950s and 1960s and many pavements constructed then have reached or soon will reach the end of their design lives. As a result of the accelerated pavement construction during this period, agencies have a large number of pavement miles that are now in need of maintenance or resurfacing. However, buying power has eroded because of inflation and fuel-conservation measures. Deteriorating pavements, insufficient funds to provide adequate maintenance, and excessive user costs have been receiving increased publicity. The realization of the need to maintain a safe, serviceable network of highways has contributed to the development of systematic procedures for managing the resources needed for pavements.

PROBLEM

An important mission of a highway agency is to provide serviceable pavements through design, construction, and maintenance for the benefit of the highway user. This is an enormous challenge given the great number of miles of pavement that are either currently in need of treatment or those that will soon be so. This is a particularly difficult situation because pavements often are deteriorating faster than they are being corrected. Effective management of the system is essential in these challenging times.

Considerable effort has been made over the last decade in the development and implementation of procedures and practices for managing pavements. The various highway agencies are organized in different ways in their efforts to address pavement management needs with the placement of pavement responsibilities varying from agency to agency.

The state of development of pavement management within agencies varies from no program at all to those that are very sophisticated. Some agencies are in the process of developing pavement management processes while others are planning the approach they will be using to develop such a process. Many agencies are looking for guidance to assist them in their efforts to develop pavement management within their organization.

Conditions such as climate and materials vary within a state and between states. Practices that may be successful in one area may be total failures in another. Pavement management must be able to take into consideration and properly evaluate local factors that may influence performance of a pavement.

There is a considerable variation in the types of information generated in existing pavement management systems and in the use of that information. There are also similarities in some of the information types. There is a need to identify the different types of pavement management outputs that can and are being obtained and used. A description of the types of outputs that can be obtained and the beneficial application of each would be helpful to many agencies.

TABLE 3

FACTORS PROVIDING IMPETUS TO PAVEMENT MANAGEMENT SYSTEM INTEREST AND DEVELOPMENT (*12*)

YEAR 1950 1960 1970 1980	FACTOR
	1. Road building boom of 1950's and 1960's
	2. Developments in pavement technology, systems methods, information growth, data handling capabilities, computers, etc.
	3. Direct application of systems analysis to design component of pavement management
	4. Increased emphasis on management of existing network; i.e., rehabilitation and maintenance needs
	5. Recognition of direct effect of pavement condition on user costs
	6. Increased emphasis and capability in pavement monitoring as a management tool
	7. General growth in management methods and awareness
	8. Increased maintenance costs with decreased availability of funds (inflation)
	9. Energy and material shortages

The technology used and available for use in pavement management systems has advanced considerably over the last several years. Equipment for monitoring pavement performance and for storing and processing the large amounts of data has shown extensive advancements, making it possible to manage pavements more effectively.

Agencies learn from the experiences of each other. An evaluation of the current practices of the various agencies in managing pavements can be helpful to those beginning to develop or those in the process of developing a pavement management program. Because of the variable nature of organizational structures, it is necessary to customize procedures within each organization.

There is a need to properly answer the "what if" questions regarding pavements. Some of the types of what if questions are:

1. What if no maintenance is performed on a section of pavement or if the maintenance is delayed?
2. What if preventive maintenance is performed?
3. What if one pavement is rehabilitated before another one?
4. What if the budget is reduced?
5. What if the weight limits are increased for trucks?
6. What if a pavement fails prematurely?

A well-designed pavement management program or system can effectively help an agency answer these questions plus many others. For example, it can help in identifying and selecting alternative procedures for rehabilitating pavements and it can assist an agency in its efforts to justify more funds through a legislature. There is a need to identify the existing and potential applications of pavement management.

Pavement management can assist an agency in dealing with changes that come about from day to day and year to year. Some of the conditions that have changed over the years that bear on the management of pavements are:

- Escalation of highway construction costs
- Decrease in fuel tax revenues
- Increased vehicle miles of travel
- Increase in numbers and sizes of trucks and changed configurations of trucks
- Unexpected pavement failures
- Pavements deteriorating at a faster rate than they are being restored
- Higher tire pressures
- Different vehicle suspension systems
- Development of new or improved rehabilitation techniques and materials

There is a need to better understand the pavement management process and the tools available to be able to effectively manage the pavements to compensate for any changes that may come about or to minimize the effect of a proposed change or even prevent it from occurring.

RESEARCH APPROACH

Most of the information for this synthesis was obtained through a survey of practice sent to highway and transportation departments in the United States and Canada and through an extensive literature search. Approximately 250 different documents and reports were reviewed. Pavement management practices of a large number of states and provinces were reviewed and evaluated. The processes used by a number of agencies in developing a pavement management program or system were studied. The information was then prepared in synthesis form.

CHAPTER TWO

WHAT IS PAVEMENT MANAGEMENT?

Pavement management is a continuous ongoing activity that has always existed in highway and/or transportation agencies, and it crosses over the various organizational boundaries within each agency. It has always been practiced in one form or another in the process of making decisions about pavements but it has not always been known as pavement management. Within an agency, it can be a very systematized process or it can be very simple and informal. Pavement management is generally classified into two levels: the network level or the project level; these will be discussed later in this chapter.

An important mission of a highway or transportation department is to design, build, and preserve pavements. Some of the primary objectives of pavement management are to furnish answers to questions such as:.

- What needs to be done for a given pavement?
- When are improvements needed in order to prevent failure and extend pavement life?
- Where or in what order should potential projects be done?
- How should improvements be undertaken given a wide range of potential materials or techniques?

Pavement management is concerned with doing the right thing, at the right place, using the right type of materials, with the right thicknesses, with the right design details, and all for the lowest total cost (*2*). Pavement management is the means of "organizing, coordinating, and controlling all of the various activities that may have an effect on the cost and life of a pavement. It is the exercise of management control over any activities related to pavements" (*20*).

AASHTO defined some of the terms associated with the management of pavements in their publication, *Guidelines on Pavement Management* (21). These were prepared to foster a common understanding of the various terms associated with the management of pavements.

> *Pavement Management* (PM) is the effective and efficient directing of the various activities involved in providing and sustaining pavements in a condition acceptable to the traveling public at the least life cycle cost. Examples of these activities include, but are not limited to, the following as they relate to pavements:
>
> - planning
> - budgeting and programming
> - design
> - construction
> - monitoring
> - research
> - maintenance
> - rehabilitation
> - reconstruction
>
> A *Pavement Management System* (PMS) is an established, documented procedure treating many or all of the pavement management activities listed above in a systematic and coordinated manner. It consists of five essential elements structured to serve decision-making responsibilities at various management levels.
>
> 1. Pavement surveys related to condition and serviceability.
> 2. Data base containing all pavement related information.
> 3. Analysis scheme.
> 4. Decision criteria.
> 5. Implementation procedures.
>
> The difference between the practice of pavement management and a pavement management system is the establishment and documentation of each of these components to formally treat one or more of the pavement activities in a coordinated and objective process. Feedback on these activities is an important part of both PM and a PMS.
>
> A *Pavement Management Information System* (PMIS) is an established and documented procedure for collecting, storing, processing, and retrieving the information required in a pavement management system. It represents a foundation for PMS since all pavement decisions must be based on a common, integrated source of information derived from reliable, good quality data (*21*).

There are a number of other definitions for pavement management and pavement management system that have been developed over the years (*7, 12, 22, 23*). Figure 3 illustrates how a simplified pavement management system might be structured. Some flow charts become very complex as all components are fit together.

There are different management systems that exist with highway or transportation agencies. Some of these systems may be rather narrow in scope whereas others may be very broad and far reaching. For example, a highway or roadway management system may contain some information on pavements as well as geometrics, bridges, drainage, and other roadway characteristics. The pavement information may consist of dates constructed or improved and ride or serviceability data. A maintenance management system may include information on the maintenance of all items such as pavements, bridges, drainage structures, signs, shoulders, guard rail, etc. A pavement maintenance management system would cover just the maintenance activities on pavements. Accident data or information may also be relevant to specific pavement sections.

The most important characteristic of any management system is the information gathered, stored, and available for use. Some of the information obtained to satisfy the needs of one area or system may also be valuable to another system within the same agency. To minimize costs, multiple access and use of certain data would be very beneficial and would assist others to meet

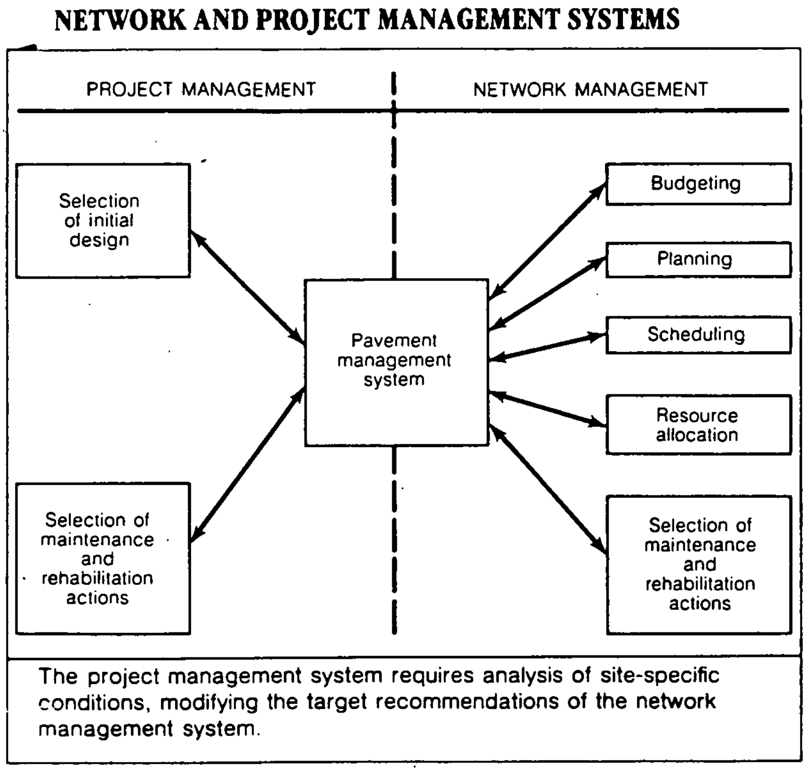


FIGURE 3 Simplified pavement management system flow chart including network and project levels (*23*).

some of their needs. Common terms and units for use by all (where certain data may have multiple application) would be cost-effective. A careful and coordinated developmental effort by all potential users is essential.

OBJECTIVES OF PAVEMENT MANAGEMENT

Some of the objectives of pavement management are to obtain the best possible value for the available public funds and to provide a transportation system that is safe, economical, and comfortable. Further objectives are to improve the efficiency of the decision-making process, to provide feedback on the consequences of decisions, and to ensure the consistency of decisions that are made irrespective of where they are made within a given organization (*24, 25*). Effective pavement management should be able to determine the relative significance of local factors that may contribute to pavement deterioration. Some of these factors are climate variability, poor or variable aggregates, inadequate asphalt mixture design, deficient load-transfer devices, etc.

There are a number of features that are essential to a good pavement management system. Some of these are:

1. Easily updated or modified using better models or new information as they become available.
2. Useful for identifying and evaluating alternative strategies.
3. Applicable to decision making based on rational procedures with quantified attributes, criteria, and constraints.
4. Utilizes feedback information from the consequences of decisions (*12*).
5. Contains systematic techniques or methods for collecting and storing data for making decisions.
6. Includes an objective and repeatable system for evaluating the condition of pavement.
7. Contains procedures for retrieving and analyzing data for network, project, and project management level decisions.
8. Useful for conducting research on questions regarding policy and technical matters.
9. Includes procedures for updating the data base (*25*).

NETWORK LEVEL AND PROJECT LEVEL

Pavement management activities and system components are usually characterized at two different administrative levels that are referred to as network and project levels. A possible separation of these two levels in pavement management is shown in Figure 3.

Network Level

Pavement management at the *network level* deals with summary information related to the entire highway network. As such, it involves policy and programming decisions, frequently made by upper management. An example of network-level pavement management is the use of graphic representations to establish rehabilitation programs, set policy, and justify budget requests. These graphic representations might consist of:

- The current condition of the highway network.
- The performance trend of the network with past history and future needs.

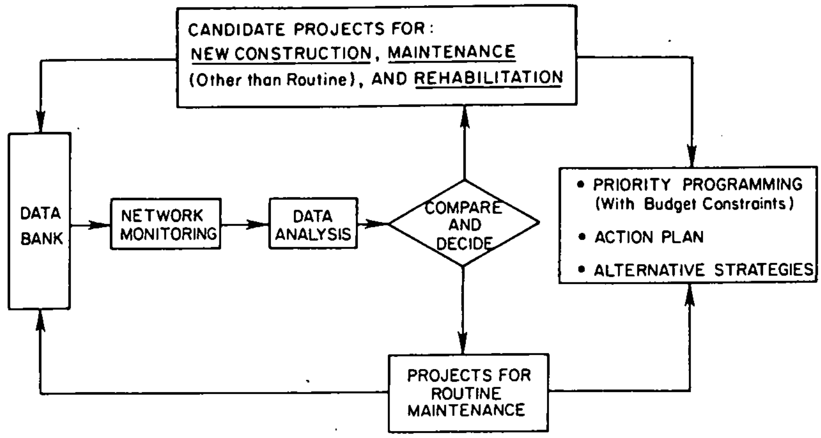


FIGURE 4 Elements in a network-level management system (*22*).

- A projection of future needs.
- The estimated impacts of alternative funding plans on future pavement condition (*21*).

Network-level decisions are generally always made for large groups of projects or for an entire highway network. It is used for estimating overall budget needs and is very helpful in answering the "what if" policy questions. Figure 4 is illustrative of the elements contained in a network-level management system. Data collection is an essential part and is identified as network monitoring in the figure.

Some of the characteristics or applications of a network-level system are:

- Identifying candidate projects for improvements considering rate of deterioration, type of distress, etc.
- Prioritizing the candidate projects considering the performance characteristics, traffic, user costs, and other local factors.
- Generating budget requirements for the short- and long-range needs of the agency.
- Supporting funding needs and requests.
- Assessing the present condition of the system and forecasting future conditions based on funding or level of effort applied (*1, 25*).

Project Level

Pavement management at the *project level* deals with detailed and technical information related to a specific pavement section. As such, it involves decisions made by middle or lower management. Examples of project-level pavement management include the following as they relate to specific pavement sections:

- Establishing priorities for maintenance, rehabilitation, and reconstruction based on criteria set by top management.
- Obtaining feedback relative to pavement performance to provide input into pavement design, construction, and maintenance activities.
- Applying life cycle cost analysis when considering alternatives.
- Considering major design parameters such as foundation strength, number of projected axle loads, materials specifications, climate, etc., when designing a pavement structure (*21*).

Project-level pavement management is concerned with management decisions that are more technical and more specific for individual pavement sections. It provides a more detailed analysis on selected highway segments than is possible or needed in network-level analysis. Figure 5 illustrates the elements contained in a project-level management system.

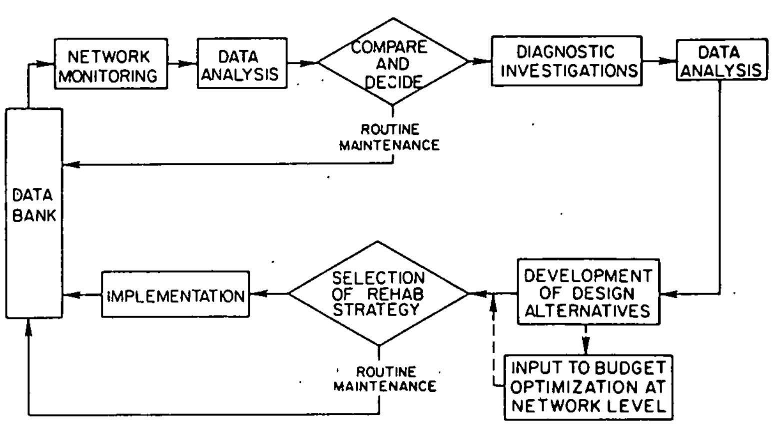


FIGURE 5 Elements in a project-level management system (*22*).

Some of the characteristics of a project-level analysis are:

- Diagnosis of the problems with each pavement through evaluating distress, load-carrying ability, pavement friction, and engineering judgment.
- Analysis of life-cycle costs of the alternative strategies being considered for the pavement.
- Assessment of the benefits associated with improvement in pavement condition, extending pavement life, etc.
- Estimation of costs for various methods or materials that can be used.
- Design of the rehabilitation or reconstruction improvement to be done (*25*).

Project-level management allows for a detailed analysis of pavements scheduled for improvements and includes a detail diagnosis of the actual deficiencies, the probable cause for those deficiencies, and alternative corrective methods. It may include a preliminary design that would contain a description of what needs to be done and when it needs to be done. The most cost-effective strategy can be determined (*1*).

PAVEMENT MANAGEMENT COMPONENTS

There are a number of different roles within a highway or transportation agency that affect pavements. Many of these roles are defined as the responsibility of different units or sections within an agency. This section of the synthesis will not deal with units or sections but with the functions or activities as they relate to pavements. Chapter 3 will discuss specifically how different states or agencies are organized and how they operate in their efforts to manage pavements. The order with which the various activities will be discussed in this section is not necessarily the order that they may occur within an agency. Figure 6 (*26*) illustrates many of the functions or activities that may be involved in managing pavements. How particular agencies structure their pavement management processes and how the information may flow within the agency is given in Chapter 3.

Planning Activity

The planning function within an agency is generally concerned more with performance of the network rather than with individual projects, and as such identifies which roads should be constructed or improved and when. Planning assesses deficiencies in the network, identifies improvement needs, establishes priorities to eliminate or minimize the identified deficiencies, and develops a scheduled program and corresponding budget.

The emphasis has changed in recent years from system extension through additional or new routes to system preservation within existing corridors through 4-R-type activities. There has been a continuing transition to rehabilitation of old or existing highways rather than building new (*1, 7*).

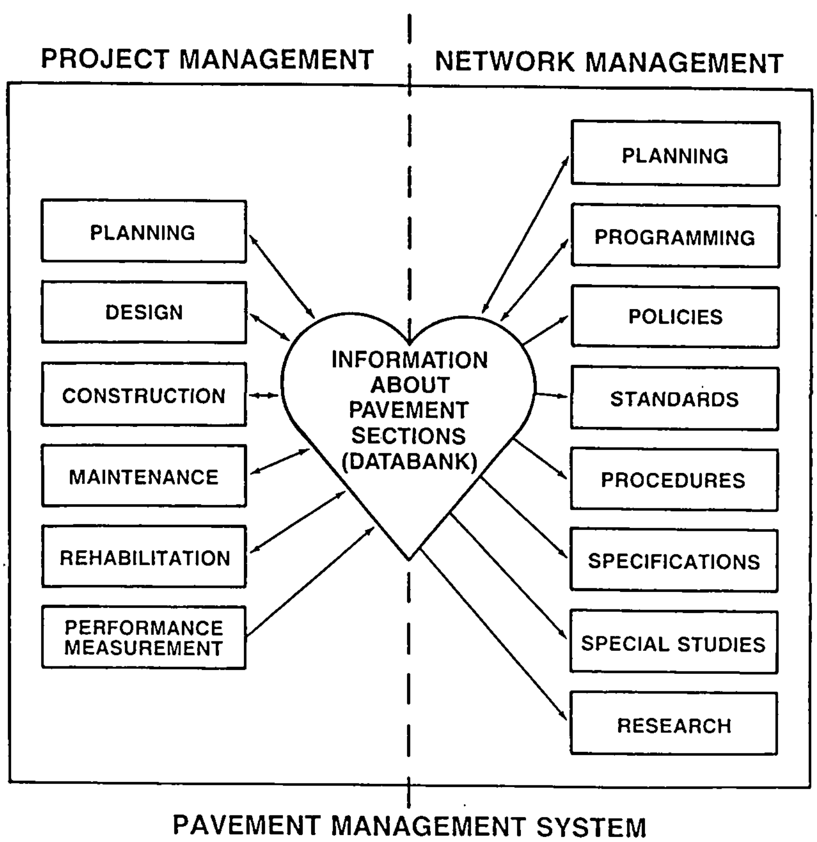


FIGURE 6 Functions or activities involved in managing pavements (*26*).

Programming Activities

Programming is responsible for developing actual programs for the construction of new roads or the rehabilitation of existing pavements. The program is developed within budgetary constraints and from recommendations made from the various areas or divisions in the department. Programming lists the projects that are to be done, the sources of funds, and the time frame. Good reliable data are essential in programming projects (*1*).

Design

The design phase converts each selected project from a programmed item to a set of plans and specifications. Design includes selecting the pavement type, the materials, the structural section or layer thickness, and the design life. A variety of input information is used including projected traffic loads, materials characteristics, site conditions, etc. The AASHTO Design Guides or some variation from them are the most common procedures used in designing pavements.

With the advent of more rehabilitation projects of the 4-R type, a number of new variables and information needs have been added to the design process. Some of these include detail evaluation of the existing pavement condition, more materials and techniques options, and greater variation in design life. The process includes generating a number of feasible alternative design strategies, analyzing the alternatives, and selecting the best strategy (*1, 7*).

Construction

The construction process translates the design recommendations for new or rehabilitated pavements into reality. Construction must be in accordance with the plans and specifications using quality materials and workmanship. Advances and innovation have been made in recent years in construction equipment and techniques that are particularly beneficial for rehabilitation-type projects (*1, 7*). Information from construction is an essential part of pavement management and needs to be input into the system.

Traffic Loads

Reasonably accurate traffic load information for the various highway sections is needed in order to properly design pavements and evaluate their performance. Highway agencies need to know the accumulative effect of actual loads that are being applied to pavements. It is important that the weights of traffic loads that are being reported are accurate. There is a problem of documenting illegal loads on the highway system and there is continuing pressure being applied to highway agencies to allow bigger and heavier legal loads (*27*). Agencies need to know what the probable impact might be before the heavier loads are allowed on the system (*1*). Many agencies are obtaining weigh-in-motion systems to assist them in enforcing truck weight laws and in obtaining more accurate load information (*28*).

Environmental Conditions

Environmental conditions such as moisture and temperature have a significant effect on the design and performance of a pavement. There is an interaction between the environment and traffic in that as environmental conditions become more severe, the effect of a given number of traffic loads increases and pavement deterioration tends to accelerate (*1*).

Maintenance

Proper and timely maintenance of pavement sections is essential to attaining the planned performance of a pavement over its design life. There are variations in how maintenance is defined but generally it consists of such activities as patching, crack sealing, and seal coating. There are two general types of maintenance: corrective and preventive. Corrective maintenance is performed after failure occurs; preventive maintenance is performed before failure and is intended to prevent or delay failure. Patching is corrective because there is a pavement failure that is repaired or corrected. Seal coating is a form of preventive maintenance.

Timing is part of good pavement management and consists of taking proper action when needed. Preventive maintenance before failure is much more cost-effective than corrective maintenance and involves doing the right thing at the right time. It is important that maintenance be done properly using correct procedures, the right materials, and trained personnel. One main problem in pavement management information is the lack of good, reliable unit-cost data that can be tied to specific pavement sections (*1*).

Materials

The properties of materials used in construction, rehabilitation, and maintenance are very important in the performance of a pavement. Materials variability and specification conformance are critical factors. Materials vary naturally, which will be carried over into their use in the construction of a pavement; therefore, quality control of materials is critical to performance of the pavement. Inspection and testing on construction needs to be done by competent personnel.

There are many new and innovative materials that are now available for use in rehabilitating pavements. Some exotic materials increase costs and may or may not increase pavement life or improve performance. Knowledge of the properties of these new materials is very helpful in selecting the right material for use (*1*).

Monitoring

Monitoring of pavement performance consists of measuring pavement characteristics such as structural capacity, roughness, distress, and friction on a periodic basis. Distress normally includes cracking, rutting, patching, etc. The results from monitoring pavement performance provide a number of useful products or benefits, some of which are:

- Assistance in determining which improvements might be needed and when they should be done.
- Descriptions of how various pavements are performing through rates of change in performance level or condition and by the amount of life remaining until failure.
- Generation of priority listings for future improvement needs.
- Development of maintenance programs and identification of future rehabilitation needs and corresponding potential strategies.
- Improvements in the technology for design, construction, and maintenance of pavements (*1, 7*).

Because of the importance of pavement monitoring in the process of managing pavements, a subsection titled Evaluating Pavement Performance is included later in this chapter.

Research

Research is the process of finding solutions to existing problems and in seeking better and more cost-effective materials and methods (*1*). Research should be a continuing process in pavement management to ensure that all component parts are always up-to-date and effective in getting the most from pavements.

Cost Records

Accurate, up-to-date cost data for initial construction, maintenance, and rehabilitation are needed in making the most cost-effective decisions. These cost data should be tied to specific identifiable pavement sections. Cost data are useful for estimating future expenditures and needs for pavements at both network and project levels, for developing and defending budgets and for demonstrating how the funds are being spent (*1*).

Data Management

A pavement management system has the potential of generating a considerable quantity of data from all of the component parts as identified above. Much of the data has been gathered and stored but has not always been easily accessible. Sometimes the data have been fragmented with different divisions within an agency keeping data of particular interest or use to them resulting in some gaps and overlaps in information. Computers have made it possible to store and analyze very large quantities of data, to perform complex analysis, and to provide output summaries or reports. The data records for each project consisting of construction as built, maintenance activities, costs, traffic volume and loads, and performance history can be saved for future use. A good data bank is the heart of a pavement management system.

EVALUATING PAVEMENT PERFORMANCE

How well a pavement performs under traffic is a primary concern in managing pavements. Pavement performance is a measure of the accumulated service provided by a facility and the adequacy with which the pavement fulfills its mission based on all of the various indicators or measurements (*29*). As such, it is most important to both the highway manager and user. Pavement performance in general is illustrated in Figure 7 with the higher values on the vertical scale indicating better performance (*30*). As loads are applied to a pavement, the performance level (pavement condition) deteriorates resulting in a curve decreasing over time (*1, 7, 25, 30*).

There are four primary measures of pavement condition: (a) roughness or ride, (b) distress, (c) structural capacity, and (d) pavement friction. There are variations in the measures used by different agencies but they all have essentially the same overall purpose, which is to have some means of determining how well pavements are performing or serving their intended purposes.

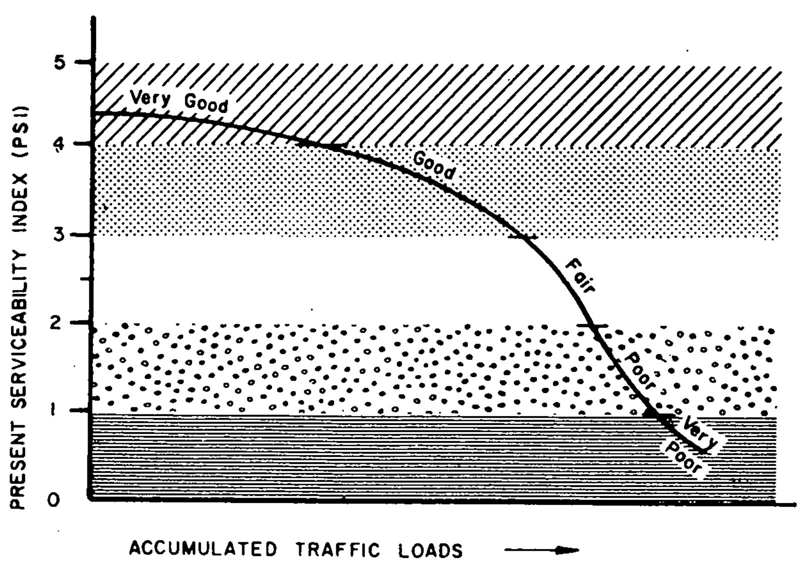


FIGURE 7 Pavement performance curve (*30*).

Roughness

Roughness of the pavement surface, sometimes identified as riding comfort, is probably of the greatest concern to the highway user of all the different measures of performance. Many agencies combine roughness with distress factors of cracking, patching, and rutting to produce a numerical index referred to as Present Serviceability Index or PSI. The change in this index with traffic and time produces a performance curve. As a pavement becomes rougher, it becomes less serviceable to the public and increases user costs.

There are various roughness or ride measuring systems that have been developed and that are in use. These include roughometers, ridemeters, profilographs, profilometers, etc. The International Roughness Index (IRI) has been developed to provide a common scale of measuring roughness regardless of what type of equipment is being used (*31*). The IRI is a standardized roughness measurement related to those obtained by response-type road roughness measurement systems. It is based on a mathematical model described in NCHRP Report 228 (*32*).

Distress

Evidence of distress is generally of considerable concern to maintenance personnel and generally shows up through such characteristics as rutting, cracking, patching, spalling, potholes, etc. Once visible signs of distress appear, then the more expensive corrective maintenance would be required. Distress is quantified or evaluated visually. Some forms of distress require early action to prevent further, more severe deterioration. For example, cracks left unattended can lead to spalling, ravelling, potholes, and softening of the support. Timing is important. Automated equipment is now available for gathering information about some forms of distress (*33*).

Structural Capacity

The structural capacity of a pavement is the load-carrying ability of the pavement. As loads are applied to a pavement, the pavement structure gradually weakens until the system eventually fails. As the system fails, distress manifestations begin to develop. Deflection measurements are the most common techniques used to assist in evaluating the structural capacity of a pavement. The Benkleman beam, Dynaflect, Road Rater, and the falling weight deflectometer are the more common ways of measuring deflection, which can be used to determine the load-carrying ability of a pavement (*33*). Deflection characteristics are different for flexible and rigid pavements.

Pavement Friction

Pavement friction is more closely associated with safety than the other types of measurements that are made. Pavements with low friction numbers may constitute a safety hazard for motorists. Measuring pavement friction on a periodic basis provides a means of identifying hazardous or potentially hazardous pavements that may require corrective action.

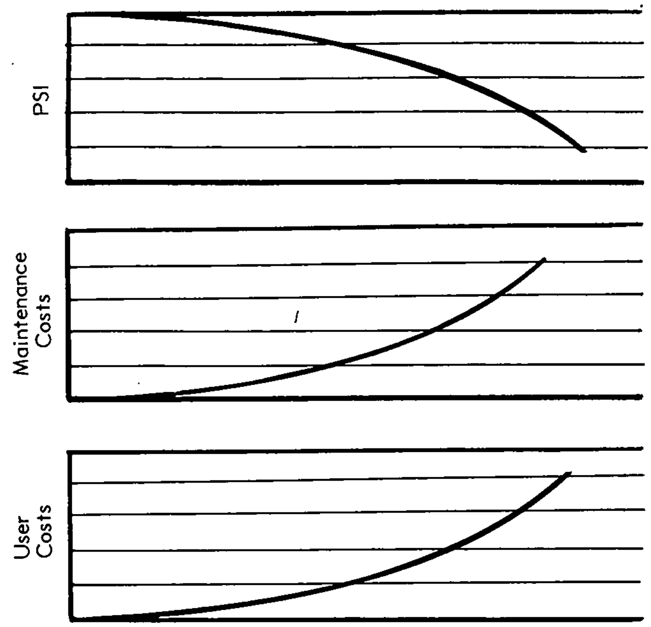


FIGURE 8 Increase in maintenance and user costs caused by pavement deterioration (*1*).

Factors Influencing Performance

As pavements deteriorate by one means or another, maintenance and user costs increase. This is illustrated in Figure 8. Performance of a pavement is influenced by such factors as construction quality, materials, traffic loads, environment, design, maintenance activities, and timely and proper rehabilitation.

Construction quality can and does significantly affect how a pavement performs and how long it will last (Figure 9). A poorly constructed pavement can have a significantly shorter life than one that is well built in accordance with the design and specifications.

Materials vary in nature and fluctuations may occur in the process of producing a mixture or final product. There are a very large number of material types and combinations that have been used in constructing new pavements or in rehabilitating existing pavements. Figure 9 indicates how materials of inferior quality might affect the performance of a pavement. It may not

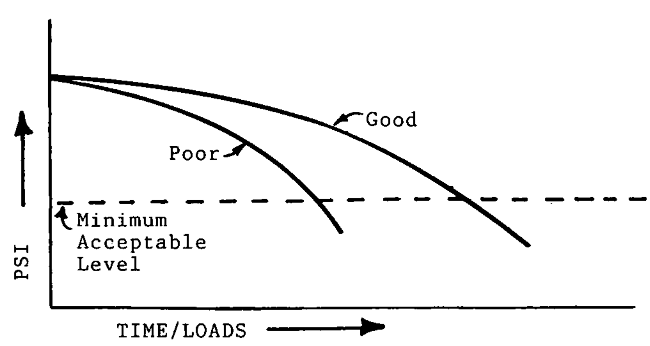


FIGURE 9 Effect of construction or materials quality on pavement performance (*1*).

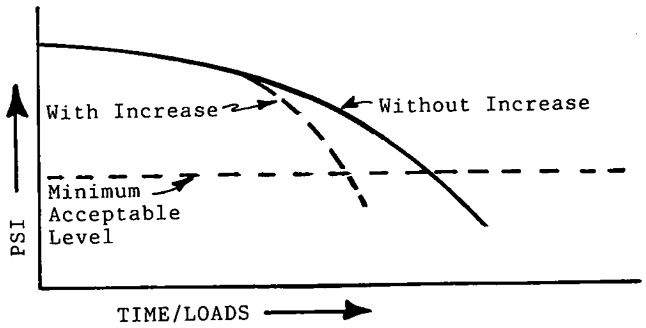


FIGURE 10 Effect of truck weights on pavement life (*1*).

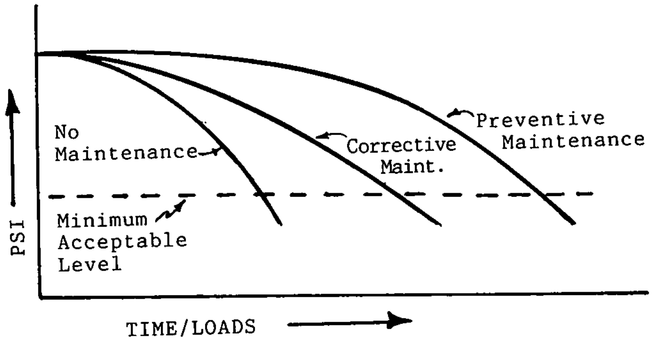


FIGURE 12 Effect of maintenance on pavement performance (*1*).

be a good buy to use a reduced quality, lower cost material if the pavement does not last as long.

Heavier traffic loads will reduce the life of a pavement when compared with lighter loads. As axle weights increase, either because of change in limits or because of illegal overweights, pavement life is affected. This is illustrated in Figure 10.

The environmental conditions at a site can affect pavement performance. Some of the local conditions that can affect pavement life are moisture, temperature, freezing and thawing, and expansive soils. Environmental conditions in addition to traffic loads do have an affect on pavement life.

Variations in the structural design of a pavement also have a significant affect on pavement performance and life. Pavements are sometimes underdesigned as part of stage construction, or they may be underdesigned or overdesigned unintentionally because of inaccurate or uncertain design data. The affect of design on pavement performance is given in Figure 11.

Pavements require proper and timely maintenance in order to achieve the intended performance and life. Many times, maintenance has been too little and too late resulting in shortened pavement life and increased agency and user costs. How maintenance may affect the performance and life of a pavement is presented in Figure 12. Preventive maintenance is not a solution or alternative to underdesign.

The appropriate rehabilitation strategy accomplished at the right time can significantly increase the life of a pavement and alter the performance curve. Pavements rehabilitated before failure can reduce costs by about one-fourth of what they might have been had the pavement failed before corrective action (*25, 30*). The affect of rehabilitation on performance is illustrated in Figure 13. The timing of rehabilitation will have a significant effect on pavement costs with rehabilitation before failure being much more cost-effective (*30*).

PAVEMENT MANAGEMENT OUTPUTS

The outputs generated by a pavement management system vary from agency to agency. The most common types are those presenting pavement evaluation results (inventory of pavement condition) and those with priority rankings. The types of outputs being produced and their application will be discussed in detail in Chapter 3.

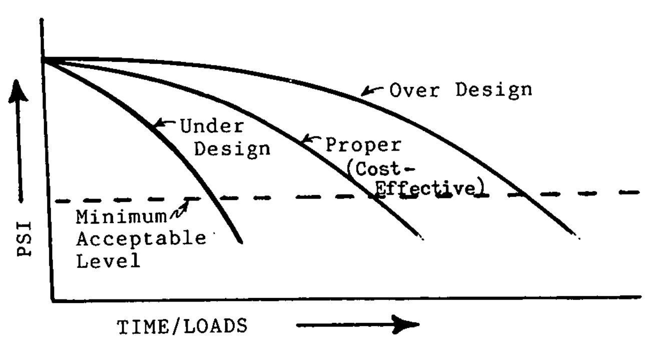


FIGURE 11 Effect of design on pavement performance (*1*).

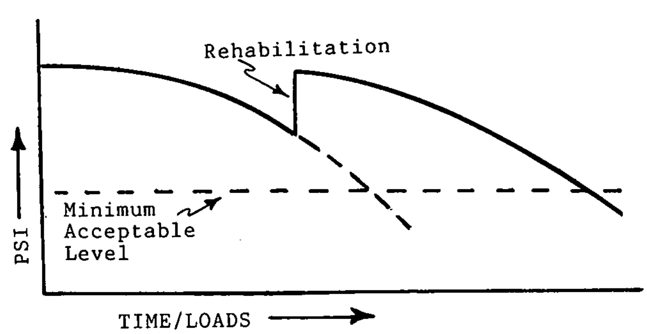


FIGURE 13 Effect of rehabilitation on pavement performance (*1*).

CHAPTER THREE

CURRENT PRACTICE

This chapter covers the current practices in pavement management by various states, provinces, and other agencies as obtained from replies to a survey of practice in 1986 and an extensive literature review. Responses were provided by 46 states, the District of Columbia, five Canadian provinces, and one county; 45 of these agencies included copies of reports or procedures in addition to completing the survey form. Thirty-six agencies furnished copies of their organization charts. The survey form and details of responses are contained in Appendix A.

MANAGING PAVEMENTS BY THE VARIOUS AGENCIES

The survey of practice included a request as to whether the agency had a pavement management system or process and if not, how pavements were managed. Of the 53 total responses, 35 agencies indicated they had a pavement management system or process, 11 agencies said they had either a partial system or they were in the process of developing a system, and 7 agencies stated they had no process or system. These seven agencies with no pavement management process said they plan to develop one. Figure 14 illustrates the status (1986) of pavement management in various agencies.

Based on the survey of practice, agencies that currently do not have a pavement management process or system indicated that they select projects for improvement through recommendations from their district offices or from maintenance.

The most common name used for the process of managing pavements by the different agencies is Pavement Management System or PMS with 24 agencies using this name. Seven other agencies include pavement management as part of the title such as Pavement Management, Pavement Management Process, and Pavement Management Program. Three refer to their process as an information system and two as an evaluation or performance system. Two agencies use "roadway" rather than "pavement" in the title. Appendix A (Table A-1) contains details on what the various states or agencies are doing.

PAVEMENT MANAGEMENT ORGANIZATIONAL RESPONSIBILITY AND STRUCTURE

The survey of practice contained information on the position or division within the agency that is responsible for pavements or managing pavements. Table 4 provides a breakdown on management responsibility within the agencies.

Appendix A (Table A-2) contains greater detail on the management responsibility for pavements within each state or agency. Seven of the agencies indicated that they had a pavement management section, unit, or bureau with some of these falling under the direction of other divisions. Two agencies stated that management responsibility was under the direction of a pavement management engineer, two said a pavement management coordinator was responsible, and two stated that their program was directed by a pavement management committee.

Examples of some typical organization charts are contained in Appendix B. Examples of applicable policies as developed by some of the agencies on pavement management are contained in Appendix C. Those policies included are from Indiana, Kansas, and Utah.

HOW PAVEMENT MANAGEMENT DEVELOPED

The various agencies were asked in the survey of practice how they developed or established pavement management within their organization and under whose direction it was accomplished. Table 5 presents the primary methods or means used to develop or establish pavement management, and Table 6 identifies the position or group that directed or initiated its development within an organization. Further details are available in Appendix A (Table A-3).

Generally, the most effective means for developing pavement management within an organization has been for the Chief Administrative Officer to initiate the effort and for a steering committee or task force made up of individuals with different pavement responsibilities within the agency to guide the effort. Some examples of agencies using this approach include California (*34*), Kansas (*35*), New Hampshire (*36, 37*), Pennsylvania (*38*), Tennessee (*39*), Utah (*40*), and the District of Columbia (*41, 42*). Some agencies borrowed ideas or systems from other agencies modifying them to fit their own needs. Some examples of this are (a) Colorado used the Arizona system as a model, (b) Idaho borrowed from Utah and modified for their own use, and (c) Hawaii modified the California system.

PAVEMENT MANAGEMENT COMPONENTS

Each agency was asked in the survey of practice what elements or activities were contained in their pavement management process, if it was formalized, and if it was computerized. A large number of elements or activities were identified by the various agencies as being part of their pavement management system

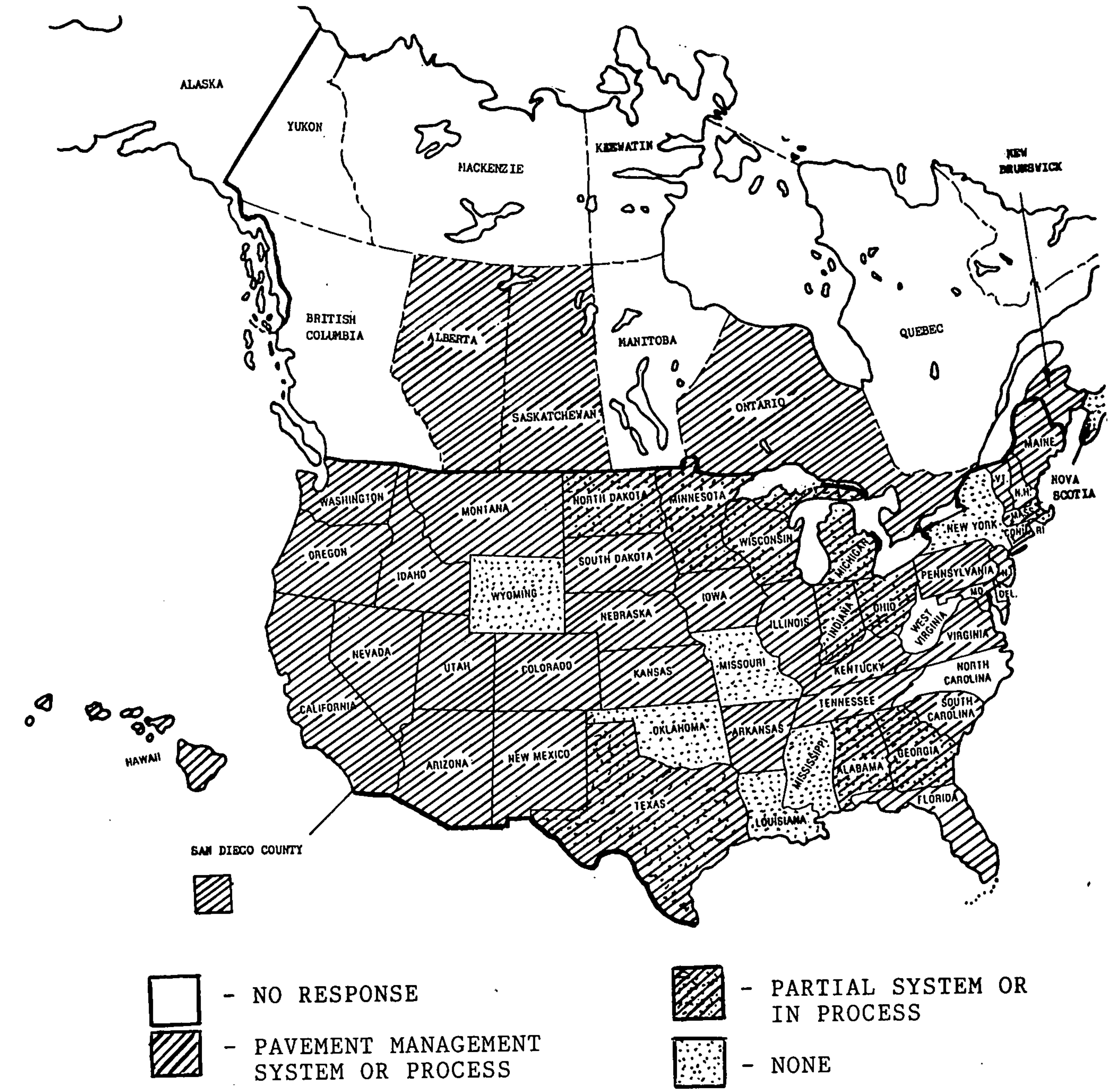


FIGURE 14 Status of pavement management programs in North America (1986).

or process. The most frequently identified activity or element was some form of pavement evaluation or monitoring with virtually every agency evaluating pavement condition in some manner. Ride, distress, friction, and deflections are the characteristics most frequently monitored. Table 7 presents a listing of components as identified by the agencies in order of frequency with the first item identified most often by the agencies.

In addition to those listed in Table 7, several different systems or system components, such as pavement information and needs system and pavement management system index, were identified. Further details on the elements or activities contained in the pavement management system as identified by each of the agencies are contained in Appendix A (Table A-4).

Table 8 gives a summary of the status of pavement management systems in the agencies; more details are contained in Appendix A (Table A-4).

OUTPUTS GENERATED FROM PAVEMENT MANAGEMENT

The states or agencies that indicated they had a pavement management system or process in their response to the survey of practice were asked what types of outputs were obtained from their process and where and how they were used. Appendix A (Table A-5) provides details from the agencies.

Output Types

A very large number of different outputs were identified by the responding agencies. To better understand the various types that were developed by the agencies, the outputs were placed into a number of categories. The following subsections provide narrative descriptions of the different types of outputs.

Pavement Condition

Many agencies have summaries on pavement condition. These may be broken into listings covering roughness, distress, skid resistance (pavement friction), or deflections or they may be a composite listing or index. A knowledge of pavement condition

TABLE 4

PAVEMENT MANAGEMENT RESPONSIBILITY

DIVISION OR POSITION	NUMBER OF AGENCIES
Pavement Management Branch, Unit, Section	3
Pavement Management Engineer, Systems Coordinator	2
Pavement Management Committee	2
Pavement Design Engineer, Pavement Design Section	3
Pavement Management Unit or Section in Planning Division	4
Pavement Management Section or Pavement Systems Unit in Materials Division	2
Pavement Management Section in Roadway Design	1
Roadway Management Division	1
Program Development Division	1
Technical Services Division, Pavement Management Section	1
Technical Services Bureau	1
Planning Division	3
Maintenance Division	5
Materials Division	4
Planning and Maintenance	1
Maintenance and Materials	1
Maintenance and Design	1
Maintenance, Design, and Construction with one of the following: Research, Materials, Planning	3
Maintenance, Design, Construction, Planning, and Technical Services	1
Maintenance, Design, Materials, and Program Development	1
Maintenance, Design, Planning, Programming, Geotechnical, and Research	1
Maintenance, Materials, and Operations Analysis	1
Maintenance, Planning, Research and Training	1
Maintenance, Operations, Surfacing, and Research	1
Planning, Program and Project Development, Design	1
Planning and Development, Operations	1
Highways, Planning and Programming	1
Field Operations, Principal Civil Engineer	1
Engineers and Superintendents	1
Several Divisions have Joint Responsibility	1
TOTAL	51

TABLE 5

METHODS USED BY AGENCIES TO DEVELOP PAVEMENT MANAGEMENT

METHOD(S) USED TO ESTABLISH PAVEMENT MANAGEMENT	NUMBER OF AGENCIES USING METHOD
Steering Committee	7
Task Force, Study Group	8
Borrowed from Another Agency	6
Evolved from Needs or Studies	5
By Consultant	3
In-House - By a Division, By an Engineer, Etc.	9
Authorized by Chief Administrative Officer	2
In House plus University	1
Under Pavement Management Engr. or Coordinator	3
Pavement Management Unit	1
Totals	45

is invaluable to an agency managing pavements. Figure 15 contains an example of a pavement condition output summary (*43*).

Pavement Performance

Pavement condition generally relates to the present whereas pavement performance adds a time dimension. Some agencies provide tables or graphs illustrating pavement performance or history. These help the user to quickly ascertain what has been happening to a pavement over the years and to predict what may happen in the future. Pavement performance can be tracked for individual characteristics, such as roughness, or for a combined index, such as present serviceability index. An example of an output from pavement performance is contained in Figure 16.

Deficiencies

Some agencies provide listings of pavements that may be deficient in one or more categories. These are pavements where a given performance characteristic or other measurement has fallen below some threshold or acceptable level. This type of listing identifies critical pavement sections that are in need of immediate attention. A listing of pavements that are deficient in pavement friction is useful to the agency in eliminating hazardous or potentially hazardous locations. Figure 17 is an example of a pavement deficiencies summary (*44*).

TABLE 6

THE POSITION OR GROUP DIRECTING THE DEVELOPMENT OF PAVEMENT MANAGEMENT

WHO DIRECTED THE DEVELOPMENT OF PAVEMENT MANAGEMENT	NUMBER OF AGENCIES
Chief Administrative Officer, State Highway Engineer, Director, Superintendent, Secretary of Transportation	13
Steering Committee or Pavement Management Committee	5
Pavement Management Engineer or Coordinator	2
Other	3

TABLE 7

LISTING OF PAVEMENT MANAGEMENT COMPONENTS

PAVEMENT MANAGEMENT COMPONENTS IDENTIFIED BY AGENCIES	FREQUENCY IDENTIFIED
CONDITION RATING OR PAVEMENT MONITORING	29
ROUGHNESS OR RIDE	14
DISTRESS	12
SKID	8
DEFLECTIONS	4
TRAFFIC	9
PRIORITIZATION OR RANKING	9
MAINTENANCE	6
FUTURE NEEDS OR REQUIRED IMPROVEMENTS	6
PREDICTIONS OR PROJECTIONS	6
CONSTRUCTION AND REHABILITATION	6
DESIGN	6
RESEARCH	5
DATA BASE	5
MATERIALS	4
PROGRAMMING	4
PLANNING	4
BUDGETING	3
COST AND ESTIMATING COSTS	3
MAINTENANCE COSTS	3
OPTIMIZATION	2
AGE	1
GEOMETRICS	1
TREATMENT TYPE	1
LIFE CYCLE ANALYSIS	1
CLIMATE	1
ACCIDENTS	1

Prioritized Listings

Prioritized listings of one type or another are fairly common among the agencies that manage pavements. Some types of priority listings in use are: (a) pavement condition ratings, (b) candidate 3-R projects, (c) rehabilitation projects, and (d) repair needs. The priority listings can be on a state-wide basis, on a system basis, or within a district. An example of a priority listing is contained in Figure 18 (*45*).

Predictions

A few agencies make predictions of the remaining life of a pavement or when it is expected to fall below some minimum acceptable performance level so that improvement work can be accomplished before failure. This requires the development and use of prediction models that many agencies do not yet have. Agencies that do have the capability find it to be very useful in planning their improvement programs and minimizing costs. Some of the agencies that have some type of performance prediction capability as identified in the survey of practice are Arizona, Arkansas, Iowa, Kansas, Maine, Montana, and Washington.

Strategies

Some of the agencies are now developing strategy summaries or listings including types such as project planning, repair, recommended rehabilitation, and preferred and alternative strategies. These strategy summaries are useful in the final process

TABLE 8

STATUS OF PAVEMENT MANAGEMENT

Status	Number of Agencies
Formalization	
Fully	25
Mostly	4
Partly	5
In development	4
Not formalized	3
Computerization	
Fully	32
Partly	7
In development	5

of selecting the best strategy for each pavement section proposed for improvements.

The World Bank (*46*) has developed the Highway Design and Maintenance Standards model (currently HDM-III) to evaluate policies, standards, and programs of highway construction and maintenance. The model simulates total life-cycle conditions and costs and provides economic decision criteria for multiple alternatives for a road, a group of roads, or an entire network. Versions of HDM-III are available for mainframe and personal computers.

Treatments

Some agencies generate listings of proposed or potential treatments for sections planned for improvements. These may be either maintenance or rehabilitation and may include the year when improvements are needed. Figure 19 (*38*) contains a listing of proposed treatments.

Costs

For either budgeting purposes or for allocation of funds, it is necessary to know what it will cost to undertake the needed work. This type of listing can also be helpful for justifying budget requests and in efforts to obtain needed funds. Figure 20 (*47*) is an example of a cost summary for one agency.

History

A few agencies maintain a history on each pavement in their system of the type shown in Figure 21. This history can be stored in the computer and updated as additional information becomes available. The information can be extracted at any time and used as the basis for planning needed improvements.

Summary Reports

A wide variety of summary reports are available in a variety of formats. Many of these are designed for use by administrators or legislators in understanding the current status of pavements and changes that are taking place. For example, is the pavement system getting better or worse and how much money is needed to keep pace with the deterioration of the system. Examples of summary reports used by two different agencies in describing their system are contained in Figures 22 (*48*) and 23 (*49*).

Where and How Outputs Are Used

The agencies with some type of pavement management system identified different ways they were using the outputs from their system or process. A general summary of their responses follow.

CONDITION OF STATE HIGHWAY SYSTEM PAVEMENTS
1984

Roadway Condition Rating	Principal Arterials: Interstate Miles	Principal Arterials: Interstate %	Principal Arterials: Non-Interstate Miles	Principal Arterials: Non-Interstate %	Minor Arterials Miles	Minor Arterials %	Collectors Miles	Collectors %	Highway System Miles	Highway System %
Very Good	62	9	303	12	149	6	22	1	536	7
Good	287	40	408	16	464	18	153	9	1,312	18
Fair	279	39	705	28	873	33	520	31	2,377	32
Poor	83	12	941	38	909	35	789	48	2,722	36
Very Poor	0	--	143	6	206	8	180	11	529	7
TOTALS	711	100	2,500	100	2,601	100	1,664	100	7,476	100

FIGURE 15 Example of pavement condition output summary (Oregon) (*43*).

PAVEMENT PERFORMANCE RECORD

DISTRICT: 8
HIGHWAY : 2

LHRS	OFFSET	LENGTH	DIRECTION	FACILITY	CLASS	LANES	AADT	TRUCK %
10550	2.7	10.0	B	A	Q	2	4500	9.0

FROM: COLLINS BAY RD(FRONTENAC RD2)
TO : (LENNOX/ADDINGTON RD6)

OVERALL PAVEMENT PERFORMANCE HISTORY

YEAR	75	76	77	78	79	80	81	82	83	84	85	86
AGE				4		6	7			10		
PCR				90		91	78			78		
PCI				88		89	81			76		
RCR				9.0		8.0	8.0			7.5		
DM				24		2	30			44		

SEVERITY OF DISTRESS CODES

1. VERY SLIGHT
2. SLIGHT
3. MODERATE
4. SEVERE
5. VERY SEVERE

DETAILED PAVEMENT PERFORMANCE HISTORY

		1978		1980		1981		1984	
SEV.=SEVERITY, EX.=EXTENT,%		SEV.	EX.	SEV.	EX.	SEV.	EX.	SEV.	EX.
C. AGG. LOSS & RAV.		1	35			2	65	2	65
FLUSHING		3	5			3	5	3	5
RIPPLING AND SHOVING									
WHEEL TRACK RUTTING								1	15
DISTORTION		2	5			2	5	2	5
LONGITUDINAL	SING. & MULT.	3	5			3	5	3	5
(WHEEL TRACK)	ALLIGATOR								
CENTRE LINE	SING. & MULT.					3	35	3	35
	ALLIGATOR							3	5
PAVEMENT EDGE	SING. & MULT.							3	5
	ALLIGATOR								
TRANSVERSE	HALF,FULL & MULT.	2	90	2	5	3	35	3	90
	ALLIGATOR	2	15						
MEANDER AND MIDLANE		2	5			2	5	3	15
RANDOM									

MAINTENANCE TREATMENT (EXTENT%)

	EVALUATION YEAR	1986
PAVEMENT	MANUAL PATCHING	
	SPRAY PATCHING	
	ROUT & SEAL CRACKS	
SHOULDER	MANUAL PATCHING	
	MACHINE PATCHING	
	ROUT & SEAL CRACKS	
	CHIP SEAL	

MAJOR MAINTENANCE HISTORY

YEAR>	1986		
ITEM	I	II	III
TYPE(CODE)			
EXTENT %			
COST			

SHOULDER PERFORMANCE HISTORY FOR TREATED OUTER SHOULDERS

YEAR>	1986	
	SEV.	EX.
CRACKING		
PAV. EDGE/CURB SEPARATION		
EDGE CURLING		

DISTRESS COMMENTS: COMFORTABLE RIDE WITH A FEW AREAS OF SLIGHT DISTORTION.
OTHER COMMENTS : PREVENTATIVE MAINTENANCE CANDIDATE

FIGURE 16 Example of pavement performance output (Ontario).

Prioritization

Many agencies said that they use the output from their system as a means of establishing priorities within their respective organizations. Some of the applications include (a) overlay priorities, (b) allocation of funds, (c) resurfacing, (d) Interstate 4-R program, and (e) maintenance.

Funding

One of the needs of a highway agency is determining the amount of money required for maintaining and rehabilitating pavements and, if there are not enough funds available, then justifying the need for more money. Some of the uses for outputs identified in the area of funding were: (a) budget preparation and justification, (b) amount of funds required, (c) allocation of funds, (d) increase in department funding, and (e) maintenance costs by districts.

Legislature

A few agencies said that they use the output from their pavement management system in preparing and presenting information to their state legislatures.

Programming

Pavement information has become a key element in programming maintenance and rehabilitation activities within an agency. Some of the programs are being developed as far ahead as five or six years into the future. Programming 3-R and 4-R activities is becoming the most important part of the work in this area.

Strategies and Alternatives

The outputs from pavement management systems or processes are now being used to develop rehabilitation strategies at both the network and project levels. Evaluating various treatment and design alternatives is part of this process of selecting the best or optimum strategy.

Problem Identification

One of the most frequent uses of pavement management outputs is the process of identifying problem areas and needs within the system. It is useful from that standpoint in planning maintenance activities and nominating rehabilitation projects. It may be useful in helping to identify potentially hazardous locations.

DISTRICT: 5 ROUTE: I-96 DIRECTION: WEST BOUND DATE SURVEYED: 85- 4-15

* SECTION 1 : RIGID PAVEMENT (BEGINNING MILE POST: 0.00 LENGTH: 0.07 NUMBER OF SEGMENTS: 1)

SEGMENT NUMBER	BEGINNING MILE POST	PAVT RATING	CODE & REMARKS	JOINT OR CRK DETERIORATION	HOLES & FAULTING	SUBSURFACE DRAINAGE	MILL SURFACE	ANALYTICAL SURVEY	JOINT SURVEY
(1)	0.00	5 A	.. ..	......	......	......	......	......	......

* SECTION 2 : FLEX. PAVEMENT (BEGINNING MILE POST: 0.07 LENGTH: 0.23 NUMBER OF SEGMENTS: 2)

SEGMENT NUMBER	BEGINNING MILE POST	PAVT RATING	CODE & REMARKS	SURFACE CRACKING	TRANSVERSE CRACKING	SURFACE ROUGHNESS	CRACK MAINT.	ANALYTICAL SURVEY	******
(2)	0.07	2	.. ..	......	......	......	ACTION		
(3)	0.19	3 B	.. ..	......	......	......	ACTION		

* SECTION 3 : BEGINNING MILE POST: 0.30 LENGTH: 0.03 NUMBER OF SEGMENTS: 1 (SEGMENT NOS. 4 - 4)

* NO DATA PROVIDED FOR THIS PORTION OF THE ROADWAY *
*BRIDGE *

* SECTION 4 : FLEX. PAVEMENT (BEGINNING MILE POST: 0.32 LENGTH: 0.25 NUMBER OF SEGMENTS: 3)

SEGMENT NUMBER	BEGINNING MILE POST	PAVT RATING	CODE & REMARKS	SURFACE CRACKING	TRANSVERSE CRACKING	SURFACE ROUGHNESS	CRACK MAINT.	ANALYTICAL SURVEY	******
(5)	0.32	2	.. ..	......	......	......	ACTION		
(6)	0.38	2	.. ..	......	......	......	ACTION		
(7)	0.47	2	.. ..	......	......	......	ACTION		

* SECTION 5 : FLEX. PAVEMENT (BEGINNING MILE POST: 0.57 LENGTH: 0.19 NUMBER OF SEGMENTS: 2)

SEGMENT NUMBER	BEGINNING MILE POST	PAVT RATING	CODE & REMARKS	SURFACE CRACKING	TRANSVERSE CRACKING	SURFACE ROUGHNESS	CRACK MAINT.	ANALYTICAL SURVEY	******
(8)	0.57	3 B	.. ..	......	......	......	ACTION		
(9)	0.66	5 B	.. ..	......	......	......	ACTION		

* SECTION 6 : FLEX. PAVEMENT (BEGINNING MILE POST: 0.76 LENGTH: 0.28 NUMBER OF SEGMENTS: 3)

SEGMENT NUMBER	BEGINNING MILE POST	PAVT RATING	CODE & REMARKS	SURFACE CRACKING	TRANSVERSE CRACKING	SURFACE ROUGHNESS	CRACK MAINT.	ANALYTICAL SURVEY	******
(10)	0.76	2	.. ..	......	......	......	ACTION		
(11)	0.85	2	.. ..	......	......	......	ACTION		
(12)	0.95	2 A	.. ..	......	......	......	ACTION		

* SECTION 7 : FLEX. PAVEMENT (BEGINNING MILE POST: 1.04 LENGTH: 0.28 NUMBER OF SEGMENTS: 3)

SEGMENT NUMBER	BEGINNING MILE POST	PAVT RATING	CODE & REMARKS	SURFACE CRACKING	TRANSVERSE CRACKING	SURFACE ROUGHNESS	CRACK MAINT.	ANALYTICAL SURVEY	******
(13)	1.04	4 C	.. ..	......	......	......	ACTION		
(14)	1.14	2	.. ..	......	......	......	ACTION		

FIGURE 17 Example of summary of pavement deficiencies (Michigan) (*44*).

Decision Making

Pavement management outputs are used either directly or indirectly by many administrators and by various divisions or districts in making decisions about pavements.

Information

The information generated in a pavement management system or process is useful in research studies, monitoring trends in pavement performance, and providing material for public distribution.

EFFECTIVENESS AND WEAKNESSES

Each agency with a pavement management system or process was asked how effective it is within their organization, whether it is cost-effective, and what weaknesses it has.

Pavement Management Effectiveness

Of the agencies that said they had a pavement management system or process, nine said theirs was highly or very effective, six said theirs was effective, and 10 said their system was moderately or somewhat effective. Six said their system was developing or emerging and nine agencies said they did not know or it was too early to evaluate at this time. Comments were provided by some of the agencies regarding the effectiveness of their system. Some of these are:

- Success and acceptance beyond expectations.
- Being used to make decisions.
- More effective as program develops.
- In use since 1980, good support.
- Used by top management.
- Good for establishing resurfacing needs and priorities.
- Provides insights to changes within the system.

Cost-Effectiveness

Eighteen agencies said their system or process was definitely cost-effective. Four said theirs was probably cost-effective and

10 said they did not know. No one said their system was not cost-effective. One comment of particular note in the responses to the survey of practice was the one from California where they said, "Pavement Management System costs about 0.25 percent of total annual rehabilitation budget."

Weaknesses

When asked what weaknesses existed in their pavement management system or process, the various agencies identified several weaknesses in their responses on the survey of practice. These were categorized according to subject matter and are summarized in this subsection. Further details are available in Appendix A (Table A-5).

Life Cycle

One of the weaknesses identified by several agencies is that life-cycle costs are not currently included. The main problem has been either that there is a lack of data to perform life-cycle cost analysis or that procedures are not yet available within the organization. Synthesis 122 (*50*) should be of some help to an agency in developing the capability to perform life-cycle cost analysis, as would the World Bank model (*46*).

Optimization

Some agencies indicated that the inability to optimize was a weakness. They were not sufficiently advanced to optimize pavement expenditures or the models were too complex and difficult to understand.

Prediction

The ability to predict the performance of an individual pavement (project level) or the system as a whole (network level) is an important part of managing pavements. Some of the weaknesses in this area included: (a) lack of sufficient data base for project pavement life, (b) the need to refine prediction models, and (c) the need for better information on pavement performance.

Data Collection

Data of all types are necessary to adequately manage pavements. The weaknesses identified in data collection were generally associated with pavement condition or monitoring. Some of those identified by the agencies were: (a) time and labor intensive, (b) need to modernize and update pavement condition survey techniques to increase quality of the data and reduce

CONDITION RANKING OF PAVEMENTS IN NEED OF IMPROVEMENT IN 1985

CONDITION RANKING	ROUTE (COUNTY)	LOCATION	LENGTH (MILES)	PAVEMENT TYPE	CONDITION SURVEY DIR.	RI	POINTS	TREATMENT
1	I-71 (Jefferson)	From: MP 1.60, 0.15 mi. S of Zorn Ave. To: MP 5.44 (Exclude from MP 4.18 to 4.92 in southbound lane)	3.84 NB 3.10 SB	PCC	NB SB	3.2 3.2	17 16	Break, Seat & Overlay
	I-264 (Jefferson)	From: MP 22.65 To: MP 23.24, I-71	0.59	PCC	EB WB	2.7 -	14 13	Break, Seat & Overlay
2	I-264 (Jefferson)	From: MP 0.00, I-64 EB To: MP 0.48	0.48	PCC	EB WB	3.0 2.7	15 13	Break, Seat & Overlay
	I-64 (Jefferson)	From: MP 0.72, E. end of Ohio Rv. Bridge To: MP 1.34, Beginning of structure	0.62	PCC	EB WB	2.8 2.4	13 10	Break, Seat & Overlay
3	I-75 (Madison)	From: MP 83.20 NB From: MP 84.64 SB To: MP 87.32, KY 876	4.12 NB 2.68 SB	PCC	NB SB	3.4 3.3	18 17	Break, Seat & Overlay
4	I-275 (Kenton)	From: MP 0.00, I-75 To: MP 0.62, 0.62 mi. N (CW) of I-75	0.62	CRCP	NB SB	2.0 1.9	14 12	Overlay
	I-275 (Kenton-Boone)	From: MP 0.62, 0.62 mi. N (CW) of I-75 To: MP 4.06, 0.09 mi. N (CW) of KY 212	3.44 (Northbound)	CRCP	NB	2.6	13	Overlay
5	I-65 (Barren-Hart)	From: MP 55.00 NB From: MP 53.50 SB To: MP 57.63, KY 218	2.63 NB 4.13 SB	PCC	NB SB	3.7 3.9	16 13	Break, Seat & Overlay
6	I-75 (Rockcastle)	From: MP 50.77, Laurel County Line To: MP 55.80, US 25	5.03 (Northbound)	AC	NB	3.7	15	Mill & Overlay
7	I-75 (Rockcastle-Madison)	From: MP 68.31, KY 1505 To: MP 75.52, KY 21	7.21	PCC	NB SB	2.9 3.1	18 17	Break, Seat & Overlay

FIGURE 18 Example of prioritized listing (Kentucky) (*45*).

SYSTEMATIC TECHNIQUE to ANALYZE and MANAGE PENNSYLVANIA PAVEMENTS (STAMPP)

TREATMENT SUMMARY

CENTRE COUNTY
L.R. 27
FROM STATION 1399+11 TO STATION 1689+87
LENGTH - 5.51 MILES
1983 DATA (FILE NAME 'CENDAT83')

TREATMENT NUMBER

STATION to STATION (MILEPOST)	(MILEPOST)	LANE	FLEXIBLE PAVEMENT 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	PAVED SHOULDER 0	1	2	3	4	5	6	7	8	9	UNPAVED SHOULDER 10	11	12	13
1399+11	1430+00	WA	I	I	I	I	I															I										
1430+00	1466+74	WA	I		I		I																				I					
1466+74	1484+00	WA	I		I	I	I													I												
1484+00	1505+00	WA	I	I	I	I	I																						I			
1505+00	1544+55	WA	I		I	I	I																									
1544+55	1575+00	WA	I	I	I	I	I																						I			
1575+00	1611+00	WA	I		I	I	I																						I			
1611+00	1641+02	WB	I		I	I	I		I		I																					
1641+02	1665+03	WA	I	I	I	I	I		I		I								I							I						
1665+03	1689+87	WA	I	I	I	I	I															I										

FLEXIBLE PAVEMENT TREATMENT
(0) ROUTINE MAINTENANCE
(1) CRACK SEAL
(2) SKIN PATCH
(3) MANUAL PATCH
(4) SEAL COAT
(5) MECHANIZED PATCH
(6) BASE REPAIR
(7) SURFACE TREATMENT - 1 in. PLANT MIX
(8) LEVEL & SEAL COAT
(9) JOINT REPAIR
(10) MILL, LEVEL & SEAL COAT
(11) WIDEN, LEVEL & SEAL COAT
(12) LEVEL & RESURFACE
(13) MILL, LEVEL & RESURFACE
(14) WIDEN, LEVEL & RESURFACE
(15) RECONSTRUCTION

SHOULDER TREATMENT
(0) ROUTINE MAINTENANCE
(1) JOINT SEAL
(2) SKIN PATCH
(3) SEAL COAT
(4) SHOULDER CUTTING
(5) SURFACE TREATMENT
(6) WEDGE & SEAL
(7) CUT OUT & SEAL
(8) MANUAL PATCH
(9) RECONSTRUCT
(10) ROUTINE MAINTENANCE
(11) GRADING
(12) CUTTING
(13) RESTABILIZE

FIGURE 19 Example of listing of proposed treatments (Pennsylvania) (*38*).

1985 CONSTRUCTION SEASON WORKALL MILES
STATE MILEAGE AND COST SUMMARY BY FUND

(DOLLARS IN $1,000)

TREAT TYPE	MAINT MILES	MAINT $COST	PRES MILES	PRES $COST	SIX-YR MILES	SIX-YR $COST	TOTAL MILES TREATED	TOTAL $COST
PATCH	115.03	911.0	45.60	762.0	.00	.0	160.63	1,673.0
SEAL	42.85	187.0	344.94	5,818.0	54.71	1,344.0	442.50	7,349.0
OIL MAT	20.11	251.0	48.71	971.0	16.70	381.0	85.52	1,603.0
THIN OLAY	.80	55.0	107.24	11,922.0	28.67	13,853.0	136.71	25,830.0
OVERLAY	.00	.0	5.72	355.0	110.89	37,114.0	116.61	37,469.0
RECONST	.00	.0	.78	170.0	68.83	125,067.0	69.61	125,237.0
CONSTRUCT	.00	.0	.00	.0	17.42	30,604.0	17.42	30,604.0
OTHER	20.80	50.0	.00	.0	6.60	13,802.0	27.40	13,852.0
FINAL TOTALS	199.59	1,454.0	552.99	19,998.0	303.82	222,165.0	1,056.40	243,617.0

RECORDS TOTALED

FIGURE 20 Example of cost summary (Oregon) (*47*).

ACTION PLAN FACT SHEET

DISTRICT: 8
HIGHWAY : 2

LHRS	OFFSET	LENGTH	DIRECTION	FACILITY	CLASS	LANES	AADT	TRUCK %
10550	2.7	10.0	B	A	D	2	4500	9.0

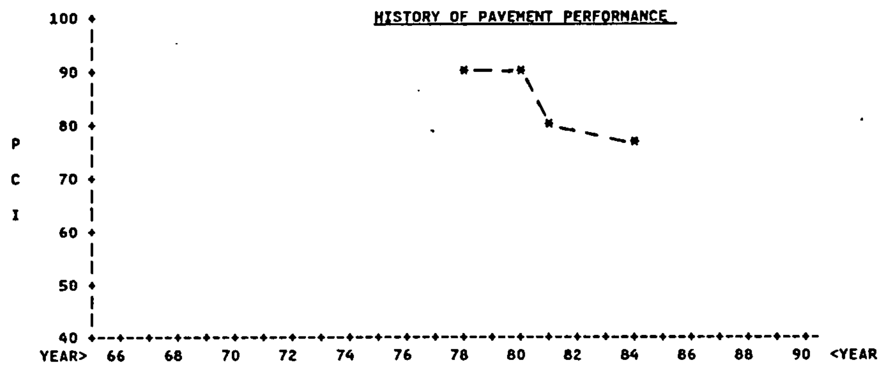
FROM: COLLINS BAY RD. (FRONTENAC RD 2)
TO : LENNOX/ADDINGTON RD 6

	REHABILITATIONS			
STRUCTURE	1	2	3	4
CONTRACT NO.	54306	74135		
SURFACE TYPE (CODE)		H4		
TOTAL SURFACE THICKNESS, MM				
ADDED OVERLAY THICKNESS, MM		40		
MILL / REPLACE THICKNESS, MM				
BASE TYPE (CODE)				
BASE THICKNESS, MM				

SUBBASE TYPE (CODE) :
SUBBASE THICKNESS, MM :
SUBGRADE TYPE (CODE) : 4

STRUCTURAL COMMENTS : CONTRACT 74135 INCLUDED PAVEMENT WIDENING 300MM ON EACH SIDE.

HISTORY OF PAVEMENT PERFORMANCE



URBAN SECTION,% : 0.0
PAVEMENT WIDTH,M : 13.4
SHOULDER TYPE : GRAV
LOAD RESTRICTION : NONE
YEAR OF LAST SKID TEST : -
OTHER DEFICIENCIES : -

PAVEMENT CONDITION:	YEAR	PCI	RCR	DM
	1984	76	7.5	44

ESTIMATED CHANGE IN PCI AFTER 3 YEARS > <

PREFERRED AND ALTERNATIVE STRATEGIES

	PART	DESCRIPTION	CODE	PROG YEAR	EXTENT %	COST/KM ($1000)	PCI AFTER	LIFE YEARS
PREFERRED STRATEGY	I	Rout and seal cracks	RS	86	100	2	74	4
	II							
HOLDING STRATEGY	I							
	II							
DEFERRED STRATEGY	I							
	II							

STRATEGY COMMENTS:

PREPARED BY:
DATE: NOV. 15, 85

FIGURE 21 Example of pavement history (Ontario).

expense, (c) field testing problems, (d) lack of structural inventory, (e) need improvements in evaluating surface distress, (f) need improved data for better assignment of strategies, and (g) lack of a common data base.

Data Processing

Data processing was listed as a weakness by some agencies. Some of the problems are: (a) personnel needs for data processing is greater than the available supply, (b) automation, software development, and staffing are the weakest areas, (c) length of time required to computerize portions of the system, and (d) sophisticated computer resources needed.

Cost Data

There has been a general lack of good cost data, in particular maintenance, and a good economic model for evaluating strategies, although the World Bank model (*46*) may be a solution to the latter problem.

Staffing and Equipment

The need for more staffing and equipment was listed by some agencies.

Coordination

The lack of adequate intradepartmental coordination within some organizations was identified as a weakness. Some of the difficulties included: (a) need to integrate better with maintenance management, (b) lack of effective coordination between divisions, (c) PMS strategies not correlated very well with actual activity, and (d) present system lacks a common referencing scheme.

COSTS NECESSARY TO PRESERVE THE EXISTING SYSTEM

Based on the 1985 Pavement Management Report
Costs Shown in Millions of Dollars

Inflation Rate = 2.5%
Revenue Growth = 5.0%

	Resurfacing, Restoration and Rehabilitation Work (3R)							Normal - Heavy Maintenance Work				
	"A"	"B"	"C"	"D"	"E"	"F"	"G"	"H"	"I"	"J"	"K"	
F.Y.	Def + Infl.	System Deter Costs	Total 3R Needs	State Funds	Fed Funds	Prop 3R Expend	Accum Deficit	Norm Maint Costs	Backlog 3R Maint Costs	Total Maint Needs	Prop Maint Expend	F.Y.
							324.10					
1986	332.20	58.99	391.19	18.30	24.43	42.73		11.67	6.13	17.80	17.80	1986
							348.46					
1987	357.17	60.46	417.63	21.98	25.00	46.98		11.96	6.59	18.55	18.55	1987
							370.65					
1988	379.92	61.98	441.89	33.32	26.44	59.76		12.26	7.01	19.27	19.27	1988
							382.13					
1989	391.68	63.53	455.21	35.43	27.97	63.40		12.57	7.22	19.79	19.79	1989
							391.81					
1990	401.60	65.11	466.72	48.75	29.58	78.33		12.88	7.41	20.29	20.29	1990
							388.39					
1991	398.09	66.74	464.84	51.95	31.29	83.24		13.20	7.34	20.54	20.54	1991
							381.60					
1992	391.14	68.41	459.55	63.94	33.09	97.03		13.53	7.21	20.75	20.75	1992
							362.52					
1993	371.58	70.12	441.70	68.20	35.00	103.20		13.87	6.85	20.72	20.72	1993
							338.50					
1994	346.97	71.87	418.84	72.75	36.96	109.71		14.22	6.40	20.62	20.62	1994
							309.13					
1995	316.85	73.67	390.52	77.62	39.03	116.65		14.57	5.84	20.42	20.42	1995
							273.87					
1996	280.72	75.51	356.23	82.83	41.22	124.05		14.94	5.18	20.11	20.11	1996
							232.19					
1997	237.99	77.40	315.39	88.39	43.52	131.91		15.31	4.39	19.70	19.70	1997
							183.48					
1998	188.07	79.33	267.40	94.33	45.96	140.29		15.69	3.47	19.16	19.16	1998
							127.11					
1999	130.29	81.32	211.61	100.51	48.54	149.05		16.09	2.40	18.49	18.49	1999
							62.56					
2000	64.12	83.35	147.48	96.22	51.26	147.48		16.49	1.18	17.67	17.67	2000
							.00					

FIGURE 22 Summary report (Nevada) (*48*).

Other

A few weaknesses identified by some agencies were considered to be of enough importance to be mentioned here so that they may be useful to others. Some of these are: (a) low-volume roads never receive priority, (b) there is a lack of time to develop and implement final stages, (c) decision criteria used in the program is not well documented, (d) there is a lack of roadway functional classifications, and (e) the process developed in stages results in a large number of programs with each performing a specific function.

BENEFITS FROM A PAVEMENT MANAGEMENT SYSTEM

The agencies with pavement management systems or processes were asked in the survey of practice what benefits they had obtained from their system. A large number of individual benefits were identified by the agencies but, to simply review, they have been grouped in this section by subject matter. Further details are available in Appendix A (Table A-5). The following subsections provide a summary of the identified benefits.

Dollar Savings

Reduction in costs and potential dollar savings were reported as benefits to the agency through the use of a pavement management system. Savings in personnel was also reported. Proper decisions made now with respect to pavements can mean millions of dollars savings in future years. A better perception or understanding of highway benefit/cost relationships is also a benefit.

Budgeting—Funding Allocation

Numerous items were identified by the agencies relating to benefits through budgeting and allocation of funds. Some of these are:

- Better means of allocating funds.
- Knowledge that rehabilitation and maintenance funds are expended in a consistent manner state-wide.
- Enables the agency to achieve condition goals at lowest cost.
- Agency can now forecast condition level that will result from current budgets.

- Justification for increase in state funds.
- Background data for budgets and increasing funding for resurfacing and for pavement rehabilitation.
- Network-level analysis has proven to be an excellent tool for quantifying the department's needs for additional funding of pavement maintenance and 3-R programs.

Legislature

Some agencies reported that their pavement management system assisted them in dealing with their state legislatures. New Hampshire obtained a gas tax increase in 1981 for pavement resurfacing. Tennessee reported that they were able to get a fuel tax increase for improving the level of maintenance. Utah received a fuel tax increase for rehabilitation. Statements made by some agencies were:

- Invaluable in keeping the legislature informed concerning the condition of the roads in their jurisdiction.
- Integral part of funding request package to the legislature.
- Department has gained credibility with public and with the legislature.

Prioritization

The ability to prioritize pavements by some rational means was reported as a benefit by some agencies. A few of the statements obtained from the survey of practice are:

- Better prioritized resurfacing programs.
- Rational prioritization of projects and a sound basis on which programming decisions can be made.
- Optimum use of available funds owing to prioritization of the road system.
- Accomplishing higher priority work first.

Improved Project Selection

It was reported that the process of selecting projects has improved. A few statements made by the agencies were: (a) better project selections and improved ability to assess the trend of network condition, (b) can now determine the mix of short-, medium-, and long-term fixes that will enable achieving goals at lowest cost, and (c) generally lowest rated pavements are resurfaced.

Rehabilitation Strategies

One benefit identified for pavement management systems was improved strategies. A few specific comments are:

- Pavement management allows the department to evaluate alternative strategies and to change direction and emphasis.
- The use of pavement management enables an agency to measure the effects of alternative strategies and to plan for these effects when the strategy is implemented.
- Getting people to think in terms of life-cycle cost when comparing rehabilitation alternatives.
- Development of long-term strategies, which can be produced through analyzing performance data for various pavement designs and conditions.

Improved Data Collection—Pavement Condition

Some agencies reported that their data collection process has been strengthened, which has benefited other component parts of pavement management. Pavement condition data is the most important information gathered for managing pavements. A few of the benefits listed by different agencies are:

- Highway system conditions have shown overall improvements during the last five years.

COLLECTIVE PAVEMENT
PRIORITIZED STRATEGY LIST
(MACRO ANALYSIS)

STRATEGY IDENTIFICATION				TOTAL COSTS (Present Worth)			BENEFIT/COST ANALYSIS			D.O.T. EXPENDITURE	
TRIAL NUMBER	PAVEMENT NUMBER	CONDITION & STRATEGY CODE	STRATEGY DESCRIPTION	TOTAL REHABILITATION COST† (X $1,000)	TOTAL BENEFIT (X $1,000)	BENEFIT/ COST RATIO	ANNUAL COST (X $1,000)	ANNUAL BENEFIT (X $1,000)	ANNUAL INCREMENTAL BENEFIT/COST RATIO	INCREMENTAL TREATMENT EXPENDITURE (X $1,000)	ACCUMULATED TREATMENT EXPENDITURE (X $1,000)
1	13	2A*	Lane-level(Maint.)	14.3	1,495.3	104.6	2.4	251	104.6	11	11
2	3	3B*	Lane-level & 2" overlay	81.8	7,582.9	92.7	10.9	1,011	92.7	118	129
3	7	10B	Plan & 2" overlay	89.2	7,269.8	81.5	12.7	1,035	81.5	155	284
4	4	53A*	2" overlay	77.5	4,309.0	55.6	11.9	662	55.6	111	395
5	3	3K	Lane-level & 5" overlay	233.1	16,107.2	47.2	22.5	1,558	69.1	149	544
6	3	41B*	SAMI & 2" overlay	144.1	5,879.3	40.8	19.2	784	40.8	197	741
7	4	53B*	3" overlay	126.7	6,119.6	30.8	16.9	816	48.3	55	796
8	6	12A*	2" overlay	418.3	12,549.0	30.0	102.0	3,061	30.0	659	1,455
9	6	12B*	SAMI & 2" overlay	692.8	20,091.2	24.9	128.8	3,728	29.0	276	1,731
10	8	41D	SAMI & 3" overlay	206.4	7,616.2	23.3	24.7	912	36.9	69	1,800
11	2	52B*	SAMI & 2" overlay	459.7	9,469.8	20.6	70.5	1,453	20.6	751	2,551
12	5	1B	5" overlay	1,143.4	23,439.6	20.5	175.9	3,598	20.5	1,140	3,691
13	10	9C	4" overlay	690.1	11,041.7	16.1	91.6	1,472	16.0	907	4,678
14	9	1A	5" overlay	451.4	6,771.0	15.0	56.9	852	15.0	580	5,258
15	12	2A**	Lane-level(Maint.)	38.2	577.1	15.1	5.9	89	15.1	**	5,258
16	2	52D	SAMI & 3" overlay	701.6	12,980.3	12.0	93.7	1,731	18.5	269	5,527
17	13	2B	Plane & 2" overlay	74.8	2,678.5	10.5	9.0	320	35.8	120	5,647
18	4	53F	5" overlay	237.2	7,828.9	10.5	28.4	937	33.0	111	5,753
19	6	12F	5" overlay	1,482.7	31,879.2	9.9	211.0	4,539	21.5	715	6,473
20	1	62A	2" overlay	268.9	2,232.4	8.3	41.3	343	8.3	465	6,938

* A higher benefit/cost strategy follows for this pavement.
** Rehabilitation not recommended-refer to Maintenance Division.
† Total Rehabilitation Cost includes cost of treatment, plus cost of traffic delays during construction, minus the salvage value at the cycle end.

FIGURE 23 Summary report (Utah) (*49*).

- Removing subjectivity from pavement rating.
- Documentation of pavement data.
- Better inventory of pavements and their condition.
- Identification of condition trend of the highway network and the relative condition of pavements in each district.
- Ability to analyze pavement performance since 1978. Value increases as history lengthens.

Understanding the System with Up-to-Date Information

Several agencies believed it was very beneficial to them to more fully understand their system and what was happening to it as demonstrated by current up-to-date information. This allowed them to have an overall perspective of network condition and to better analyze their operating policies and procedures. They were able to assess pavement condition in a quantitative manner and to have immediate access to current road condition information.

Data Storage and Analysis

Some agencies reported that they were benefited through improved data storage and analysis. They said that computerization is an absolutely decided advantage over previous methods. It permitted them to easily retrieve historic data and to evaluate pavement performance over time. The linking of several information systems to a common data base was listed as a benefit.

Uniformity, Consistency, and Accuracy

One very important benefit through a properly functioning pavement management system is the ability to provide results that are uniform, consistent, and accurate from location to location and from year to year. It was reported that (a) all state highways are evaluated using the same criteria, (b) there is a consistent selection of resurfacing needs, (c) PMS provides the same up-to-date, accurate pavement performance data on all sections, and (d) planning and programming are more rational. The use of a common location reference system is very important in maintaining consistent accurate information.

Improved Communications

Several agencies reported in the survey of practice that pavement management helped them improve communications within their agency. Communications were improved between the various divisions and districts, and there was an increased awareness of the pavement management process on the part of upper management. Internal disagreements were reduced.

Other

There were several other benefits that were identified by different agencies. A few that were considered significant are listed here.

- Selecting locations for improvements because of high accident experience when the proper interface exists with accident records.
- Provide for federal data reporting requirements.
- Long-term planning and programming of rehabilitation projects.
- Determining the effect of deferred or delayed action and reacting accordingly.

BENEFITS IDENTIFIED FROM OTHER SOURCES

The previous listed benefits from the use of a pavement management system were based on the responses from the various agencies to the survey of practice. The following benefits were obtained from documents other than from the survey of practice (*1, 23, 25, 51, 52*).

- A greater understanding and knowledge is available regarding the condition or health of the pavement network and individual pavements within that network.
- The agency now has the ability to know if the condition of the pavement network is improving or deteriorating over time.
- It is possible to predict the future condition of pavements more accurately.
- The ability to establish priorities for pavement improvements is improved.
- A PMS helps provide realistic and cost-effective performance standards so that maintenance or rehabilitation projects can be selected through the use of a systematic, consistent, and documentable engineering basis.
- The ability to develop accurate long-term needs and plans and policies for maintenance and rehabilitation is improved.
- The ability to assess various funding levels and to justify the level selected is enhanced. The system would provide the facts for presentations to the legislature.
- A PMS provides the ability to identify the consequences of inadequate funds for rehabilitation and maintenance in relationship to excess user costs and inconvenience.
- The funding backlog for projects in need of maintenance and rehabilitation can be identified.
- Rehabilitation and maintenance strategies can be identified and evaluated.
- Life-cycle costs for various types of construction and rehabilitation can be evaluated and the cost-effectiveness for different types of maintenance can be determined.
- An objective and consistent means for evaluating the condition of all pavements within the state or agency is available through a PMS.
- The probability for improved pavement performance is enhanced.
- Access to accurate factual information for use in dealing with materials suppliers and other pressure groups is easily accessible.
- Advancements in the state of the art in the design, construction, maintenance, rehabilitation, and evaluation of pavements have been made.
- The ability to assess the potential effect of any proposed changes in axle and gross truck weights is available through PMS information.

• Assurance that the best pavement for the dollar expended and the highest level of service at a minimum of cost are being obtained are part of the benefits available.

• Improvement in the productivity of those responsible for managing pavements is obtained.

NATIONAL ACTIVITIES

Pavement Seminar

In the late autumn of 1985, two Pavement Seminars for Chief Administrative Officers were held in the United States (*1, 53*). One seminar was held in Florida for the eastern part of the country and a second one was held in California for the western part of the United States. The seminars were prepared and conducted through the joint efforts of the Federal Highway Administration and the American Association of State Highway and Transportation Officials. The seminars were planned for the Chief Administrative Officers of the various state highway or transportation departments with the following objectives (*53*):

> First to encourage a review of current organizational needs in light of the shifting emphasis from pavement system expansion to pavement system modification and preservation.
>
> Second, to review the current state of the art in pavement management.

The following items were addressed in the two seminars (*53*):

- What does a comprehensive pavement management process look like, as found in several states?
- What are the problems we face in pavement management?
- What tools do we have?
- What are some good strategies, and what has not worked?
- What research has been done? What do we need to know? Where does the Strategic Highway Research Program fit in?

The states were asked in the survey of practice if anyone from their agency had attended the "Pavement Seminar for Chief Administrative Officers" and if so, what effect, if any, it had on the agency. Thirty-nine of the states said they did participate and seven said they did not. Of the 39 participating, 34 said the program was beneficial to them and 4 said it provided little or no benefit. One state did not indicate whether it was worthwhile or not. Some of the comments from the states regarding the effect the seminar had on their organization are:

Alabama: "Better awareness of need for systematic pavement management."

California: "California well advanced in Pavement Management; should make even more use by managers."

Delaware: "Pavement Management Engineer position created in January."

Kansas: "Agency procedures were reviewed and implementation and development of the network and project level system has resumed without modification. Review consisted of developing answers for 16 typical management questions facing Chief Administrative Officers. Kansas DOT was satisfied that its Pavement Management and priority optimization system provided answers to most of them."

Massachusetts: "Commissioner has directed that a Task Force establish a Pavement Management system by April 1, 1986."

Nevada: "Pavement Management has been of highest priority at Nevada DOT for past 6 years and will continue to do so."

Oklahoma: "Reaffirmed the need to develop and implement a program."

Texas: "Task Force created to direct development and implementation of Pavement Management System."

Virginia: "Better understanding of Pavement Management objectives by top management."

The 16 pavement management questions asked of the Chief Administrative Officers at the Seminar are contained in Appendix E.

Strategic Highway Research Program

AASHTO, FHWA, and the National Research Council have undertaken the Strategic Highway Research Program (SHRP) as a means of increasing the productivity and safety of the highway system in the United States through research. Six priority problem areas were identified for the program: asphalt, long-term pavement performance, maintenance effectiveness, bridge component protection, cement and concrete, and snow and ice control (*54*). Long-term pavement performance is the study area that is most closely tied to pavement management. The standardization and improvement in pavement data collection that will result from the long-term pavement performance study should be of great benefit in advancing the state of the practice of pavement management.

National Cooperative Highway Research Program

The National Cooperative Highway Research Program (NCHRP) operates under the Transportation Research Board and is established through a contract between FHWA, AASHTO, and TRB. A number of research projects and syntheses have been developed over the years that have a direct bearing on pavements and on the management of pavements. Several of these reports and syntheses are referenced as part of this synthesis.

Federal Highway Administration

The Federal Highway Administration (FHWA) has taken an active interest in pavements and the materials used for their construction for many years. In more recent times they have taken an active role in promoting pavement management. Through research, they have provided useful documents to assist states in improving their management of pavements. Most recently, they put together with the cooperation of AASHTO the "Pavement Seminar for Chief Administrative Officers" (*1, 53*), which was previously discussed in this chapter.

CHAPTER FOUR

APPLICATION OF THE PAVEMENT MANAGEMENT SYSTEM

The purpose of this chapter is to discuss how a pavement management system can be applied or utilized in the various divisions or areas of an agency. Chapter 2 provided a description of pavement management including the basic parts or elements normally contained in the system. The information or data from each of these basic elements is stored in the data management element or the heart of the system. This chapter discusses how the information that is stored and available through a pavement management system can be used in the various divisions of an agency in getting the most for the pavement dollar. Developing strategies and evaluating alternatives while considering life-cycle costs is part of this general effort.

APPLYING PAVEMENT MANAGEMENT WITHIN AN AGENCY

Not all agencies can accomplish the work described in this subsection because only a limited number have all of the data necessary. Agencies lacking some of the required information within their own organization can work toward obtaining the additional data. During the interim, they can utilize information from other sources or make their best estimate of values relying on the experience and knowledge of department employees.

Maintenance

Data from pavement management systems or processes has been used as input for maintenance programs. Montana uses information from their pavement management system for reference in selecting projects for maintenance (*55*). Nevada employs their system to assist in the allocation of resources and to make the best use of available funds. They use two repair strategy categories: preventive and corrective maintenance (*48*). The number of centerline miles for each highway system is summarized for the various repair strategies and the costs are determined. Pavements can be placed in priority arrays for either preventive or corrective maintenance. Corrective maintenance is basically working on the worst pavements first, whereas preventive maintenance requires predicting when failure might occur so that some treatment can be placed early enough to prevent failure and extend pavement life. A comprehensive pavement management system should have information stored in the data base on all potential maintenance treatments along with their chances of success for various conditions. Costs should also be part of the stored information. Adequate maintenance cost data have been generally lacking for most agencies, and this area needs further work. Prediction models also need further refinement.

Rehabilitation

Rehabilitation of pavements is of great importance to all highway agencies in these times when preservation of the system has come to the forefront. Rehabilitation (like maintenance) can either be corrective or preventive and thus requires reliable performance data and good prediction capability. Rehabilitation can benefit significantly from a comprehensive pavement management system. There are so many variables introduced in a rehabilitation project that it is a real challenge to identify and select the best, most cost-effective solution for the project (*56*). There are a very large number of materials and techniques available, and the pavement is undergoing continual change over time. A design made one year, based on conditions existing at that time, may no longer be adequate the following year when the project is done, owing to changes in the condition of the pavement. A pavement management system offers the best answers to dealing with the challenges of system preservation through rehabilitation.

Planning

With the changing emphasis from system extension to system preservation, planning has need for more pavement data. Pavement condition information at a network level is of particular use in planning. Past performance of the different systems within the various districts or areas, rates of change in condition, and predicted future condition are types of useful information for planning that can be obtained through a pavement management system. Cost information is also needed and can be part of the system. Planning also uses pavement performance data in preparing reports required by the Federal Highway Administration.

Programming, Budgeting, and Scheduling

Programming develops the actual program for the construction of new or rehabilitated pavements based on input from other divisions or areas. The primary source of information for programming and scheduling rehabilitation projects is pavement performance data from a pavement management system. Prioritized arrays of pavement needs are helpful in establishing the sequence with which pavements will be improved. If cost data are contained in the pavement management data base, then priority arrays can be developed including the estimated costs for each project. Pavement scheduling for future years can be enhanced if life prediction capability exists within pavement management.

Construction

Construction of rehabilitated pavements can be benefited considerably through a pavement management system as discussed above. Knowledge gleaned from information stored on construction materials and techniques can be of significant assistance in obtaining quality durable pavements.

Design

Design faces many new challenges with the shifting emphasis from constructing new highways to the preservation of existing pavements and with the need to make the most cost-effective use of available funds. Many more factors and levels are introduced that must be evaluated to guarantee a suitable final product that will perform as designed. Further discussion will be provided later in this chapter on some of the newer methods that can be applied in the pavement design process. These include decision analysis, optimization, design alternatives, and life-cycle cost analysis. These all can be built into a pavement management system and thus be part of the input to the design process.

Pavement Performance

Pavement performance is a measure of the changes in pavement condition under accumulated service and, as such, requires that pavements be monitored using different types of measurement over extended time periods. Pavement performance becomes the vehicle for tracking pavement condition over the years, predicting future performance, and developing priority rankings. Pavement monitoring and traffic loadings are important inputs through a pavement management system in evaluating performance.

Research

A fully integrated pavement management system provides a tremendous pool of current and historical information covering all aspects of a pavement. As such, a wide variety of special studies, both long term and short term, can be undertaken. For example, it is possible to study the relationship between the pavement structure and maintenance costs or the effect of pavement condition on accidents. One important research area could consist of developing the best combination and timing of maintenance and rehabilitation with the objective of getting the best pavements at the lowest life-cycle cost. Because data would already be available in storage, for the most part, it would only require the processing of existing data to satisfy the needs of the special study and then preparing a report. Study and analysis of data collected has the potential for very large payoffs in the management of pavements.

Truck Size and Weight

A pavement management system is a helpful tool for an agency to use in evaluating the effect of potential changes in truck size and weight. Knowledge of truck weights on various routes coupled with pavement performance on those same routes provides the basic information. It can also be used to determine the relative effect of trucks on different routes where the weights are known.

STRATEGIES

Strategy has been defined as "a plan or method for dealing with all aspects of a particular problem" (*12*). Tennessee (*39*) considers four major strategies in their program: (a) routine maintenance, (b) repair distress and/or place seal coat, (c) overlay or recycle, and (d) major rehabilitation or reconstruction. Nevada (*48*) uses four similar strategies: (a) preventive maintenance, (b) corrective maintenance, (c) overlay, and (d) reconstruct. Pavement maintenance strategies are defined as "plans of action embodying the continuing application of pavement maintenance techniques that are designed to improve or maintain the condition of a pavement segment above some predetermined minimum requirement" (*29*).

Decision Analysis

A method referred to as decision analysis is used on occasion by different individuals and agencies in dealing with uncertainty (*57–61*). The use of decision trees and cost-decision analysis was discussed by Alexander (*60*), who assigned probabilities to the chances of success for a given treatment. The Markovian decision process was used by Woodward-Clyde on Arizona's Pavement Management System in order to establish probabilities for different pavement conditions (*59*). The Markovian process is useful for decisions in pavement management where multiple pavement condition variables are incorporated and where there are a large number of alternative actions.

Curtayne and Servas (*61*) of South Africa discussed economic considerations and the use of decision theory in the design of pavement rehabilitation. They stated that rehabilitation treatments will always be under some degree of uncertainty and that decisions are made on a probabilistic basis. They illustrated their strategies and the potential outcomes with decision trees. Figure 24 shows a decision tree developed by them giving possible outcomes of alternative maintenance strategies. Curtayne and Servas further pointed out that because of "the inherent variability of pavement properties and the uncertainties about their behavior, these decisions have to be analyzed in terms of probability theory" (*61*).

Optimization

An optimum strategy is "that strategy among the alternatives considered which is expected to maximize the realization of

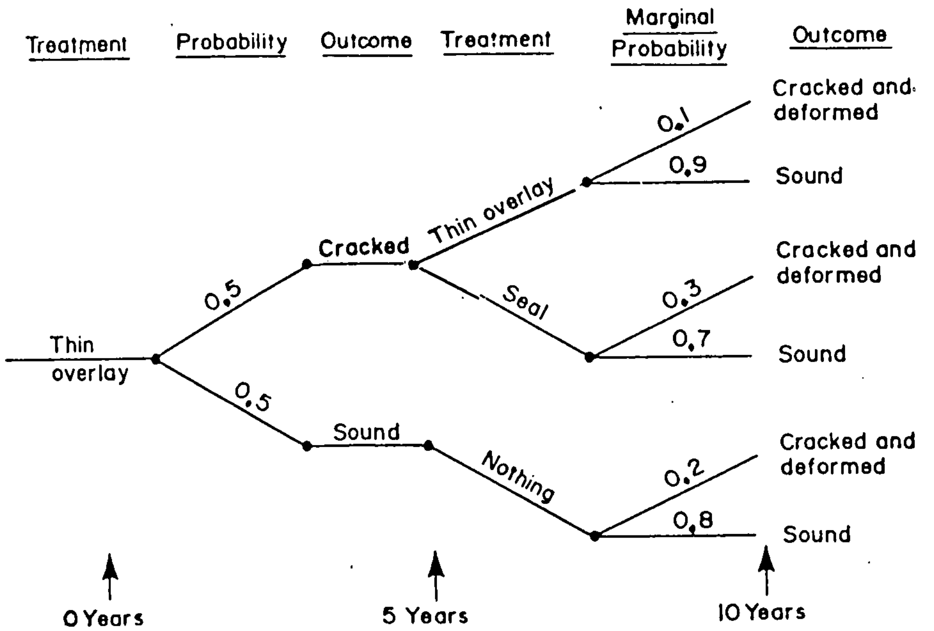


FIGURE 24 Typical branch of a decision tree giving possible outcomes of alternative maintenance strategies (*61*).

management goals subject to the constraints imposed" (*12*). An optimization model is "a mathematical description or algorithm designed to compare alternative strategies and to identify the relative merits of each strategy according to assigned decision criteria, such as safety, cost, etc." (*12*). The basic objective is to identify the strategy that is optimal among the large number of options or alternatives that are designed to achieve a specific goal. "Using optimization procedures helps evaluate a large number of alternative solutions to a specific set of conditions and to obtain an optimal solution, which would be impossible by traditional techniques of enumeration" (*52*). A network optimization system helps to answer questions such as:

1. If I specify the desired condition (level of service) of the pavements in the network, how much funding would be required to achieve and maintain that condition for an indefinite period?
2. If I increase the level of service of the pavements in the network by a specific amount, what would be the effect on budget requirements?
3. If funding over the next five years is limited to "x" dollars, what is the best level of service to expect (*52*)?

Optimization at a project level would concentrate on site-specific conditions on location where additional information can be easily obtained for a more detailed engineering analysis. The objective at the project level is to identify an alternative solution that does not exceed the target costs for the project at the required performance level. Materials, conditions, and experience at the site can be described more accurately at the project level because the emphasis is on a specific project at a given location.

Optimization can be based on need, on economics, or on a combination of the two. Some highway agencies have found it more economical to take care of potential problem pavements with little or no distress and to treat the worst cases last (*30, 56*). Maintenance and rehabilitation can both be classed as preventive or corrective. Corrective maintenance has been defined as the "type of maintenance used to take care of day-to-day emergencies and repair deficiencies as they develop. May include both temporary and permanent repairs; sometimes referred to as remedial maintenance" (*29*). Corrective maintenance or rehabilitation is undertaken after distress is very evident and failure has occurred or is very near. Preventive maintenance (or rehabilitation) is, "the type of maintenance intended to keep the pavement above some minimum acceptable level at all times. It is used as a means of preventing further pavement deterioration that would require corrective maintenance. It may include either structural or nonstructural improvements to a pavement surface" (*29*). Corrective rehabilitation being done after failure develops in a pavement may cost four or more times more than preventive rehabilitation, which would have been done before failure (*30*).

Evaluating Pavement Design Alternatives

Alternatives have been defined as "the various choices of treatments available for providing a solution to a pavement deficiency or problem" (*29*) and as "different courses of action or systems that will satisfy objectives and goals" (*62*).

If there is only one alternative available as a solution for a particular problem, then there is no decision. However, in practice there are a considerable number of choices to be made. Time is a variable along with numerous potential treatments and techniques and design sections. With all of these variables, there are also differences in performance characteristics, future maintenance needs and costs. Figure 25 illustrates some alternative choices for a given payment. Figure 26 (*63*) shows a simplified repair matrix for flexible pavements.

Recommendations were developed in NCHRP Synthesis 122 (*50*) regarding procedural steps for selecting the preferred design

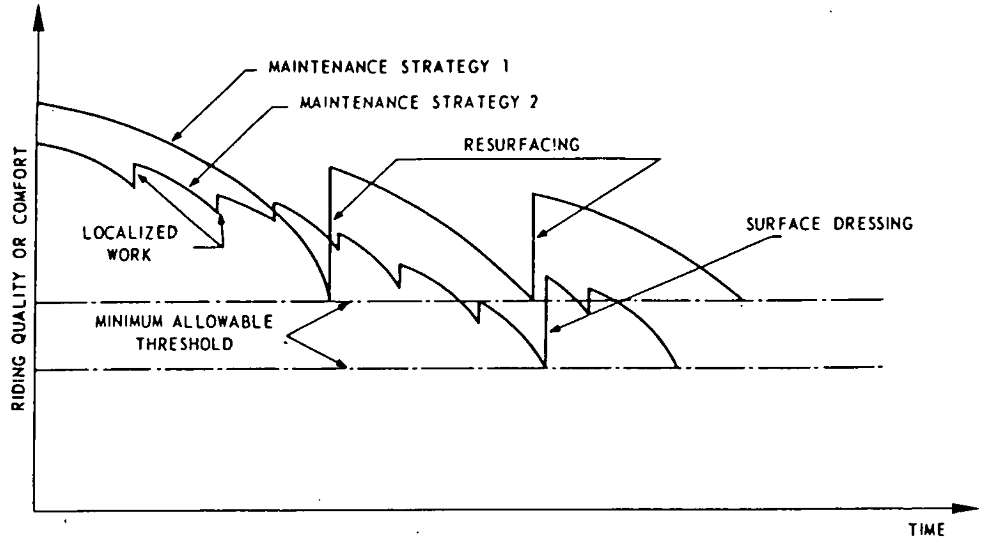


FIGURE 25 Alternative maintenance strategies for a pavement (*29*).

alternatives for new or rehabilitated pavements. There were twelve suggested steps:

1. Determine the site characteristics and other input data that may influence the design.
2. Identify various pavement management strategies that might be used to achieve the life requirements for the project.
3. Identify all feasible alternatives that might satisfy the needs for the project.
4. Remove from further consideration any item or items that are common among all alternatives.
5. Select the analysis period to be used.
6. Select a suitable discount rate.
7. Predict the performance characteristics of the different alternatives being considered.
8. Make cost estimates for each alternative being considered.
9. Calculate present worth of costs for the alternatives.
10. Make a sensitivity analysis on items or factors that may

MAINTENANCE MATRIX

Pavement Surface Defects / Methods Of Treatment	Reconstruct	Thick Overlay	Thin Overlay	Stress Absorbing Interlayer W/ Overlay	Heater Scarifyer Rejuvenator & Overlay	Hot Recycle	Cold Recycle	Surface Planing	Cover Aggregate	Rejuvenator	Lane Level	Remove & Replace	Crack Filling
Roughness			X		X		X	X			X	X	
Structural												X	
Skid Resistance			X				X	X	X			X	
Linear Cracking												X	X
Block Cracking					X					X		X	X
Alligator Cracking					X					X		X	
Rutting								X			X	X	
Corrugation							X				X	X	
Raveling			X						X	X		X	

FIGURE 26 Flexible pavement repair matrix (Utah) (*63*).

be subject to variation to ensure the selection of the proper alternative.

11. Evaluate the alternatives against other potentially overriding factors.

12. Select the most promising or preferred new pavement design or rehabilitation design based on all the factors that were evaluated.

A comprehensive, well-integrated pavement management system should be able to provide the information required to make the best decision for pavement design alternatives. In the event all of the information is not available, then managers would need to use their best judgment in filling the gaps.

Life-Cycle Cost Analysis

Life-cycle costing is defined as "an economic assessment of an item, area, system or facility and competing design alternatives considering all significant costs of ownership over the economic life, expressed in terms of equivalent dollars" (*64*). One of the major difficulties in using life-cycle cost analysis to date has been the general lack of accurate cost data, particularly in the maintenance area. Life-cycle costing was included as part of the outlined steps in the previous subsection and can be reviewed in greater detail in NCHRP Synthesis 122 (*50*). A pavement management system has the potential for providing the input needed in analyzing pavement alternatives using life-cycle costing procedures.

EXAMPLES OF PAVEMENT MANAGEMENT APPLICATIONS

California Department of Transportation (Caltrans) (*13, 14, 34, 65, 66*)

Caltrans began the development of a pavement management system in 1977 to: (a) relate rehabilitation expenditures to actual needs rather than to influence by individuals, (b) use logically determined strategies as basis for repair of the most appropriate road segments, (c) improve capabilities in programming, and (d) serve the public better. The development of the pavement management system (PMS) was initiated by the Caltrans Chief Engineer with the formation of a steering committee to provide guidance and policy direction and a task force to perform the actual development and implementation. The PMS was to be easily understood and would: (a) identify rehabilitation needs and establish a state-wide ranking, (b) ensure that the most appropriate repair strategies were used to satisfy the needs, and (c) be operational within two years (by 1979). The California pavement management system was developed as directed and it has been in use since 1979 on California's highway system of 15,000 centerline miles or 48,000 lane miles.

The California system was designed to provide answers to three questions: (a) Is the pavement in need of repair? (b) What general repair category is the most appropriate? and (c) In what order of priority should repairs be undertaken? Surveys of pavement condition are conducted on a biennial basis with data collected during the six-month period beginning in March of each odd-numbered year. A 100 percent sample of all 48,000 lane miles on the state highway system is done. The survey records the extent and severity of each of several different forms of distress and ride quality. Figure 27 illustrates the condition rating systems used by California for flexible and rigid pavements. A PCA ride meter as developed by Caltrans is used to measure ride quality. A state-wide pavement friction inventory is accomplished with a towed test trailer conforming with applicable ASTM standards.

Caltrans uses a relatively simple engineering logic system as a means of determining what to do with pavements in need of repair. Different systems are used for flexible and rigid pavements. Figure 28 illustrates a decision tree as developed by Caltrans engineers based on their experience with flexible pavement repairs. Using this or similar decision trees, engineers can select an appropriate solution for each pavement situation.

California provides an array of 14 priority categories by combining ride score, distress ratings, and average daily traffic in different ways. Four different reports are generated from the pavement management system:

1. Pavement Condition Inventory—A computer printout of existing conditions based on survey results.
2. Listing of Corrective Strategies for All Triggered Lanes—Shows inventory condition or problem, appropriate repair strategy, dominant strategy, and annual maintenance costs (Fig. 29).
3. Candidate Locations Sorted by Program—Separate listings for maintenance program and for rehabilitation program containing dominant strategy, cost estimate, ADT, expected service life and annual maintenance costs (Fig. 30).
4. Priority Order for listings contained in the third report above.

The pavement management system is not intended as a design system in California. The responsibility for project development and design rests with the district offices that use the "Candidate Locations Priority List" to develop the projects. The District establishes the project priority number by taking the weighted average of the individual segments that make up the entire project. The priority lists for each district are submitted to the PMS staff at Caltrans headquarters for the compilation of a state-wide priority list. A computer is used to analyze the data, select candidate rehabilitation and maintenance locations, and generate the appropriate reports.

The Pavement Rehabilitation Branch in the Division of Maintenance is responsible for the Caltrans Pavement Management System.

Caltrans engineers have identified a number of benefits from their system:

1. The PMS has given them confidence in knowing where their pavement problems are state-wide. California is a large state with widely differing climatic conditions.
2. They can prioritize, quantify, and justify needs and trends for rehabilitation programs. This ability has resulted in a doubling of the rehabilitation budget in California since PMS was implemented. They can now provide the facts to influence change in the program.
3. They believe that they are now getting a more consistent level of pavement performance state-wide. They also believe that productivity in their rehabilitation program has never been better.
4. The California PMS has produced information that has

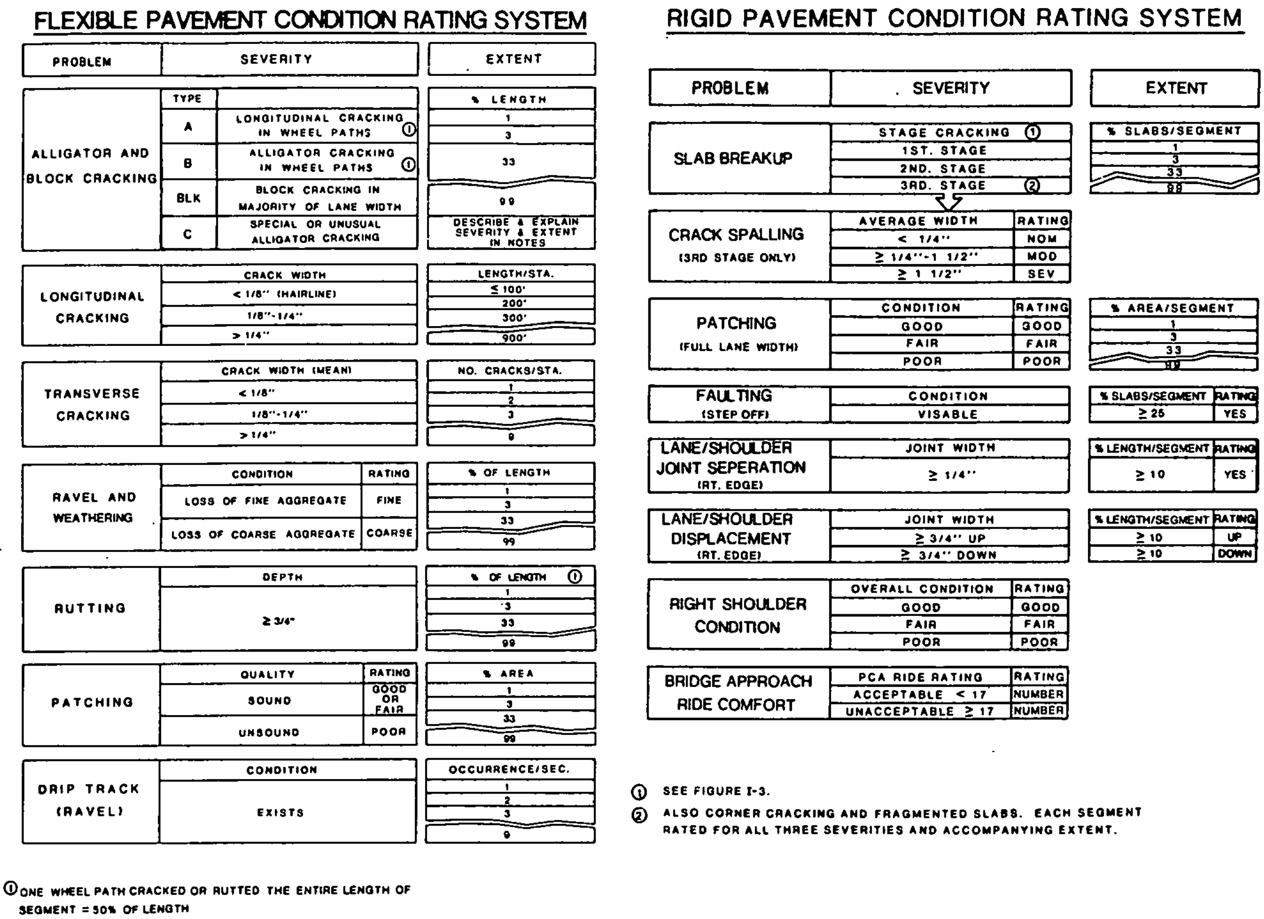


FIGURE 27 Condition rating systems (California) (*14*).

been used in preparing items for legislative purposes. The PMS was helpful in obtaining legislative approval to increase funding for rehabilitation work.

Iowa Department of Transportation (*67–72*)

In 1979 the Highway Division Director of the Iowa Department of Transportation formed a pavement management committee with members from the offices of Road Design, Materials, and Data Processing. The committee was enlarged in 1980 to include a member from the Planning and Research Division. A representative from the Federal Highway Administration was invited to attend the meetings. A pavement management coordinator was assigned from the Office of Materials to oversee the implementation of the objectives identified by the committee. In 1986, members of the Field Review Team from the Office of Roadway Design joined the committee. The objectives as formulated for the committee are as follows:

1. Provide current data base for all offices concerned with pavements.
2. Annually update the physical condition status of the rural state highway network.
3. Provide management with consolidated matrix information from which rational prioritization of projects and programming decisions can be made.
4. Provide a method of evaluating the performance of highways under different design, maintenance, and construction strategies (*68*).

A commitment from top management was requested and approved to develop Iowa's Pavement Management System (IPMS).

Iowa has been one of the participating states in the Long-Term Monitoring (LTM) pilot program under the direction of the Federal Highway Administration. This program has been beneficial to Iowa in initiating a formal pavement management process.

A data base was established for the Pavement Management System that includes: construction history, design parameters, material source locations, ride values, deflection testing data, condition survey data, traffic data, friction numbers, rut depths, and accident history. Eighteen thousand pound equivalent single-axle loads and maintenance costs are to be added to the data base. The data base is organized so that each office in the department that may be concerned with pavements can easily access all available information through the use of a computer terminal. Access to the data base is accomplished by inputting the county, system, route number, and beginning milepost for the pavement section of interest.

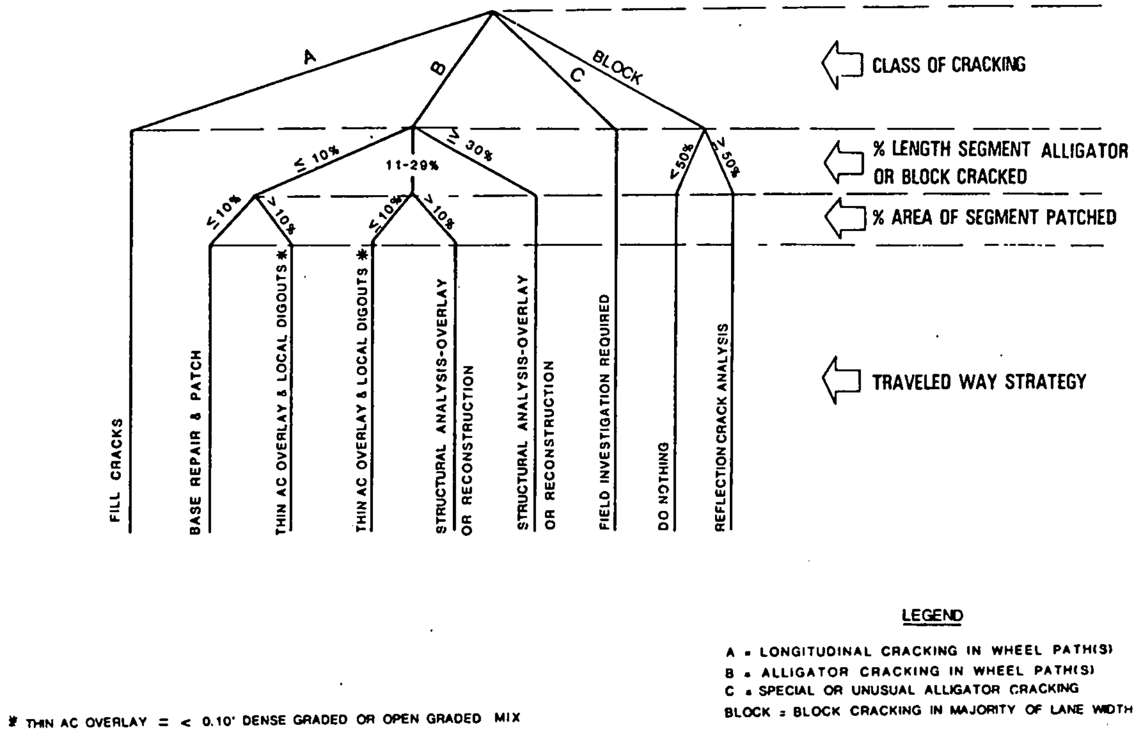


FIGURE 28 Decision tree for alligator and block cracking in flexible pavements (California) (*14*).

PMS 230-6 DIST = 03
RUN DATE 02/17/84
CALIFORNIA DEPT OF TRANSPORTATION DIVISION OF MAINTENANCE

PAVEMENT MANAGEMENT SYSTEM
CORRECTIVE STRATEGIES FOR ALL TRIGGERED LANES (FLEXIBLE)
PMS HIGHWAY PROGRAM HA22 BASED ON 83/84 SURVEY

DISTRICT 03 ROUTE 070 COUNTY BUT

* DOMINANT STRATEGY FOR PROJECT CONCEPT

PM 6.4 TO PM 7.9 TOTAL LANES: 2

	LANE	PROBLEM	REPAIR STRATEGY
ROAD TYPE: FLEX. TWC LANE	L1	ALLIG. A CRACK	FILL CRACKS
		ALLIG. B CRACK	*STRUCTURAL ANALYSIS/RECYCLE
ADT: 7,400		ALLIG. C CRACK	FIELD INVESTIGATION REQUIRED
COST CENTER: 633	R1	ALLIG. A CRACK	FILL CRACKS
		ALLIG. B CRACK	*STRUCTURAL ANALYSIS/RECYCLE
ANNUAL MAINT. COST/MILE: LAST FY $3,940		ALLIG. C CRACK	FIELD INVESTIGATION REQUIRED
LAST FY-1 $100			
LAST FY-2 $5,290			

PM 7.9 TO PM 9.1 TOTAL LANES: 2

	LANE	PROBLEM	REPAIR STRATEGY
TOAD TYPE: FLEX. TWC LANE	L1	ALLIG. A CRACK	FILL CRACKS
		ALLIG. B CRACK	*STRUCTURAL ANALYSIS/RECYCLE
ADT: 7,400			
	R1	ALLIG. A CRACK	FILL CRACKS
COST CENTER: 633		ALLIG. B CRACK	*STRUCTURAL ANALYSIS/RECYCLE
ANNUAL MAINT. COST/MILE: LAST FY $670			
LAST FY-1 $100			
LAST FY-2 $3,010			

FIGURE 29 Listing of corrective strategies for all triggered lanes (California) (*14*).

```
PMS219-B                                          PAVEMENT MANAGEMENT SYSTEM
RUN DATE: 02/23/84                             CANDIDATE LOCATIONS PRIORITY LIST
CALIFORNIA DEPT OF TRANSPORTATION            PRIORITY SORT - DISTRICT ROUTE COUNTY PM ORDER
DIVISION OF MAINTENANCE                      HIGHWAY PROGRAM HA22         BASED ON 83/84 SURVEY

DIST     ROUTE     COUNTY        PM  TO  PM     DIST PRIORITY    62    ST PRIORITY 03-0994   PMS PRIOR NUMB:  7.01041
 03       065       PLA          4.3     5.3       COST CENTER 664      ADT          10,000   ROAD TYPE: FLEX. TWO LANE
 PMS STRATEGY:  STRUCTURAL ANALYSIS/RECYCLE        PROGRAM HA22         COST     $104,100     SERVICE LIFE:  10 YEARS
DIST STRATEGY:                                     PROGRAM              COST                  PROGRAMMED:            BUDGETED:
C/L MILES   1.0    LANE MILES     2.0    ANNUAL MAINT. COST/MILE: LAST F.Y.     $280  LAST F.Y.-1     $50  LAST F.Y.-2     $30

DIST     ROUTE     COUNTY        PM  TO  PM     DIST PRIORITY    78    ST PRIORITY 03-1112   PMS PRIOR NUMB:  7.01554
 03       070       BUT          3.4     4.2       COST CENTER 633      ADT           6,700   ROAD TYPE: FLEX. TWO LANE
 PMS STRATEGY:  STRUCTURAL ANALYSIS/RECYCLE        PROGRAM HA22         COST      $83,300     SERVICE LIFE:  10 YEARS
DIST. STRATEGY:                                    PROGRAM              COST                  PROGRAMMED:            BUDGETED:
C/L MILES    .8    LANE MILES     1.6    ANNUAL MAINT. COST/MILE: LAST F.Y.  $10,020  LAST F.Y.-1    $650  LAST F.Y.-2    $700

DIST     ROUTE     COUNTY        PM  TO  PM     DIST PRIORITY    70    ST PRIORITY 03-1075   PMS PRIOR NUMB:  7.01406
 03       070       BUT          4.2     5.7       COST CENTER 633      ADT           7,400   ROAD TYPE: FLEX. TWO LANE
 PMS STRATEGY:  STRUCTURAL ANALYSIS/RECYCLE        PROGRAM HA22         COST     $156,100     SERVICE LIFE:  10 YEARS
DIST. STRATEGY:                                    PROGRAM              COST                  PROGRAMMED:            BUDGETED:
C/L MILES   1.5    LANE MILES     3.0    ANNUAL MAINT. COST/MILE: LAST F.Y.  $16,750  LAST F.Y.-1    $650  LAST F.Y.-2  $2,570

DIST     ROUTE     COUNTY        PM  TO  PM     DIST PRIORITY   146    ST PRIORITY 03-1999   PMS PRIOR NUMB:  9.01660
 03       070       BUT          5.7     6.4       COST CENTER 633      ADT           7,400   ROAD TYPE: FLEX. TWO LANE
 PMS STRATEGY:  THIN OVERLAY & LOCAL DIGOUTS       PROGRAM HA22         COST      $86,000     SERVICE LIFE:  10 YEARS
DIST STRATEGY:                                     PROGRAM              COST                  PROGRAMMED:            BUDGETED:
C/L MILES    .7    LANE MILES     2.1    ANNUAL MAINT. COST/MILE: LAST F.Y.  $12,900  LAST F.Y.-1    $340  LAST F.Y.-2  $1,580
```

FIGURE 30 Candidate locations sorted by program (California) (*34*).

Available system outputs include the following:

1. Pavement Status (List of Test Sections between specified beginning and ending mileposts).
2. Pavement Control Sections (Display of the current condition of a pavement section including location, pavement condition, and service level).
3. Section Matrix Values (A display of pavement status matrix values including 18 kip percent remaining life, structural adequacy, pavement width, rut depth, PSI decrease per year on a six-year basis, PSI deduction, etc.).
4. Matrix Limits (A display of the matric factor limits for the same items contained in No. 3 above).
5. Project History Plot (A visual display of construction project limits and locations).
6. Project History Screen (Identifies materials source locations; shoulder and pavement width, types, and dimensions; steel placement; joints; etc.).
7. Four Matrix Reports (Attributes arranged in a pavement management matrix array).
8. PSI Trend Table and Graphs.
9. Network Level Rehabilitation Modeling Maps (Under development).
10. Optimization Listings (Under development).

Project history data can be obtained and viewed for any selected segment of any primary route within the pavement management system and the data reports can be printed. Figure 31 illustrates a display of projects within a road segment. The top portion of the figure provides a schematic representation of the projects as they occur with respect to one another within the road section requested. Figure 32 shows a printout of the project history report for a given project.

The status of a given pavement can also be obtained through the system. The display illustrated in Figure 33 presents a listing of all control sections that lie within the range requested. Figure 34 is a sample pavement status report for a selected pavement section. The Iowa Pavement Management System also has the capability of generating plots of pavement performance.

Programs for project optimization and rehabilitation modeling based on historical data and the projection of future pavement performance are under the process of development in Iowa.

The Iowa Department of Transportation has utilized life-cycle costs to analyze various highway projects in their system. They have only used the process to date to identify the construction costs of the initial and the rehabilitation projects that are ex-

```
    ROUTE   COUNTY   SYS   BEG MPST   END MPST  DIR ::::::::::::::::::::::::
     030      23     01    295 . 00   305 . 00      | PROJECT HISTORY  H.2|

7777777777777777779988888888888888.A11111111444442222555555555533335555555555
//////////////////////////////////./A000000400000400500000000000555500000666
//////////////////////////////////.//AAAAAA0AAAAA0AA0AAAAAAAAAAA0000AAAAA0000
//////////////////////////////////.////////A/////A//A//////////AAAA/////AAAA
//////////////////////////////////.//////////////////////////////////////////
//////////////////////////////////.//////////////////////////////////////////
*_____:_____:_____:_____:_____:_____:_____:_____:_____:_____:_____*
295.00                                                            305.00

 SEQ  PROJECT NUMBER                DATE OPEN  LENGTH   BMPST   EMPST  DIR
  1   FN-30-9(16)--21-23              0769      03023   299.77  300.77
  2   FN-30-9(16)--21-23              0769      03023   301.55  301.99
  3   FN-30-9(16)--21-23              0769      03023   303.36  303.81
  4   FN-30-9(14)--21-23              1168      13058   300.77  301.55
  5   FN-30-9(14)--21-23              1168      13058   301.99  306.36
  6   UN-922*(1)                      1257      02094   304.60  305.14

IF THERE ARE MORE THAN 6 PROJECTS TO DISPLAY, THE FIRST PROJ. # ON THIS PAGE
WILL BE HIGHLIGHTED.  TO SELECT A PAGE OF PROJECTS, TYPE X, Y, OR Z AND ENTER.
THEN, FOR A DETAILED PROJECT HISTORY, ENTER THE PROJECT SEQ NO.==>
PF1/13-HELP  PF5/17-MAIN MENU  PF2/14-PRINT  PF4/16-H.1   PF3/15-EXIT
```

FIGURE 31 Display of projects within a roadway segment (Iowa).

```
                 IOWA PAVEMENT MANAGEMENT SYSTEM
                 P4163102 PROJECT HISTORY REPORT
                            12/05/85

ROUTE     COUNTY   SYS   BEG MPOST    END MPOST DIR  CO/CITY RTE
 030        23     01    299.77       300.77

                                          SURFACE  BASE
PROJECT NUMBER                      LANE    MIX     MIX       LENGTH
FN-30-9(16)--21-23                         6.00%   6.00%      03.023

FROM: 1.0 MI. W. OF CALAMUS, E. TO 2.2 MI. W. OF DEWITT @ VARIOUS LOCA.

           TYPE DEPTH  WIDTH       SIZE   COARSE AGGREGATE SOURCE
SHOULDER GSH   02.00  003.00      00.75  BEHR
WIDENING       00.00  000.00      00.00
SPRINKLE       00.00  000.00      00.00
SUBBASE        00.00  000.00      00.00
BASE      AAC  01.00  024.00      00.50  BEHR
SURFACE   AAC  01.00  024.00      00.38  SHAFFTON

SURFACE COARSE AGG.:CRUSHED LIMESTONE BED:         FRIC:    DUR:

FINE AGGREGATE SOURCE              CODE    CEMENT SOURCE              OPEN
BEHR                               A23504  SINCLAIR OIL               0769

TRANS. JOINT   SPACE   LONG.  JOINT   REINF

COMMENTS:
SEQ. PROJ.. USE SAME KEY DATA: SUBSTITUTING SEQ 1-5 TO VIEW
REST OF PROJECT.
```

FIGURE 32 Printout of a project history report.

pected over the life of the pavement. Present worth of future funding needs or the user costs associated with the various projects have not been considered, although they have been used to determine how good the decisions have been. Iowa learned that life-cycle costs provide the decision maker with another objective tool for use in evaluating rehabilitation alternatives.

The primary benefit of the pavement management system as identified by Iowa is that the system provides the same accurate and up-to-date pavement performance information on all pavement sections, making it possible for the rational prioritization of projects and a sound basis on which programming decisions can be made. The development of long-term rehabilitation strategies is a less tangible but possibly greater benefit that can be developed from analyzing performance data for various pavement designs and conditions. Proper decisions made now can result in a savings of millions of dollars in the future.

Maine Department of Transportation (*73–83*)

The Chief Administrative Officer of the Maine Department of Transportation in November 1980 directed that a study be undertaken to determine whether they should develop a formal pavement management system (PMS). Pavement management was given top priority with one of the early objectives stated as: "The early goal of our PMS study will be to provide information that will serve as a basis for future decisions" (*73*). About one year after the study began, it was concluded that the formal implementation of a systematic approach to managing pavement investments should be initiated by the department. The study also concluded that a permanent PMS office with staff should be established.

Guidelines were developed for the PMS group covering such areas as organization, structure, and ultimate objectives; these were accepted by top management. Management adopted the following criteria for the program.

1. Needs would be evaluated statewide for each of its systems; for example, Interstate and Primary.
2. The announced policy for this first effort was that existing average system conditions would be maintained, as would the distribution of conditions.
3. Methodology to address and identify these needs would be based on PMS information and project selection methodologies would reflect newly provided information (*73*).

The pavement management system in Maine was placed in the Technical Services Division (formerly Materials and Research) and is under the direction of the Pavement Management Engineer in the Research and Development Section.

The present PMS framework in Maine contains three levels: the *Program Level,* the *Project Selection Level,* and the *Project Level.* These are all integrated into the system as shown in the framework illustrated in Figure 35. The Program Level, commonly referred to as the network level, provides information on the number of miles needing attention with the amount of money required. This is used in the budgeting process and by top management. The Project Selection Level provides information of sufficient detail to identify the highway segments that should be included in the final prioritization process. This is used by the Programming Section and the Maintenance Department in the final prioritization and project selection. Output from the Project Level is used in the Bureau of Project Development to determine the optimum treatment for each priority section. All three levels are now functioning in Maine.

Pavement condition in Maine is determined through a distress survey, which is accomplished as part of the ongoing PMS effort. The survey covers the entire highway system in the field where cracking, rutting, patching, and cross section characteristics are noted. This information is then coverted to a pavement condition rating (PCR) on a scale from 0 to 5 with 0 being impassable and 5 being perfect. The results from the survey are analyzed

```
  ROUTE   COUNTY   SYS   BEG MPST   END MPST      !!!!!!!!!!!!!!!!!!!!!!!
   030      23     01    295 . 00   305 . 00      ! PAVEMENT STATUS  S.2!

  SEQ  DIR                           BMPST   EMPST
  1    0 ---------------------      293.86  299.75
  2    0 ---------------------      299.75  311.06
  3      ---------------------         .       .
  4      ---------------------         .       .
  5      ---------------------         .       .
  6      ---------------------         .       .
  7      ---------------------         .       .
  8      ---------------------         .       .
  9      ---------------------         .       .
  0      ---------------------         .       .
  A      ---------------------         .       .
  B      ---------------------         .       .

THIS IS A LIST OF TEST SECTIONS WHICH FALL WITHIN RANGE OF YOUR BEGINNING AND
ENDING MILEPOSTS.  TO VIEW THE PAVEMENT STATUS OF ANY INDIVIDUAL SECTION, JUST
ENTER THE CORRESPONDING SEQ. NUMBER FOR THE SECTION HERE        ==>

PF1/13-HELP  PF5/17-MAIN MENU   PF6/18-S.1   PF3/15-EXIT
```

FIGURE 33 Display listing of control sections in an area (Iowa).

```
                 IOWA PAVEMENT MANAGEMENT SYSTEM
                 P4163102 PAVEMENT STATUS REPORT
                            12/05/85

LEVEL   ROUTE      COUNTY   SYS   BEG MPOST    END MPOST   CONT.
  B      030         23     01    293.86       299.75       0

      SURF   PAVE    SHOULDER            EN        WS          MATRIX
DIR   TYPE   WIDTH   WIDTH        PSI    FN-YR     FN-YR       RATING
 0    PC     24      07           2.80   39 0783   39 0783     5.18

STR        80%     K     RUT     IJK    PSI
RATING     STR     VAL   DEPTH   RIDE   DEDUCT      ADT     %TRKS
04.46      03.79   102   0.03    3.06   0.26        04555   08.2

18KIP              D-     6YR
YEAR               CRACK  PSI     YR PSI    YR PSI    YR PSI
1984                 1    0.01    84 2.80   81 3.47   78 2.86

============ NB/EB 18KIP ===========   ============ SB/WB 18KIP ===========
CONS RSRF POSTCONS POSTRSRF            CONS RSRF POSTCONS POSTRSRF
YEAR YEAR    ACCUM    ACCUM  PREDICT   YEAR YEAR    ACCUM    ACCUM  PREDICT
1956 0000 03554416 00000000 05500000   0000 0000 00000000 00000000 00000000

=========== MAINTENANCE COST SUMMARY  FOR SURFACE AND SHOULDER ==========
 MCOST    3YR AVERAGE COST   POST-CONST CUM COST   POST-RESURF CUM COST
 YEAR    SURFACE  SHOULDER    SURFACE  SHOULDER     SURFACE  SHOULDER
  85    000002389 000002276  000009587 000009848   000009587 000009848
```

FIGURE 34 Status report for a selected pavement section (Iowa).

and presented in tabular and graphical form. Table 9 shows the pavement condition on the various highway systems in Maine in 1984. The existing pavement condition is further presented in a three dimensional chart shown in Figure 36.

Maine predicts future pavement condition based on their understanding of deterioration rates, which is illustrated by the curve shown in Figure 37. Use of this information coupled with the application of pavement management principles for different highway improvement techniques enables them to predict future condition of pavements after improvements are made. Maine thus develops a recommended capital improvement program intended to maintain the average condition of the system through the application of improvements in a timely manner. The summary in Table 10 shows the needs that were identified for the various systems along with proposed improvement types.

Maine uses a computer to store and analyze data developed in the pavement management system. Figure 38 presents a computer-generated summary from the Network Analysis System showing projected pavement condition rating (PCR) loss.

Some of the benefits identified by Maine from their PMS as listed in the survey of practice are:

1. Justification for increase in state funds.
2. Ability to transfer federal funds from Interstate 4-R to primary systems as justified by needs.
3. Ability to distribute funds for state projects to district based on needs rather than allocating funds equally among the districts.

Maine considers their system to be cost-effective.

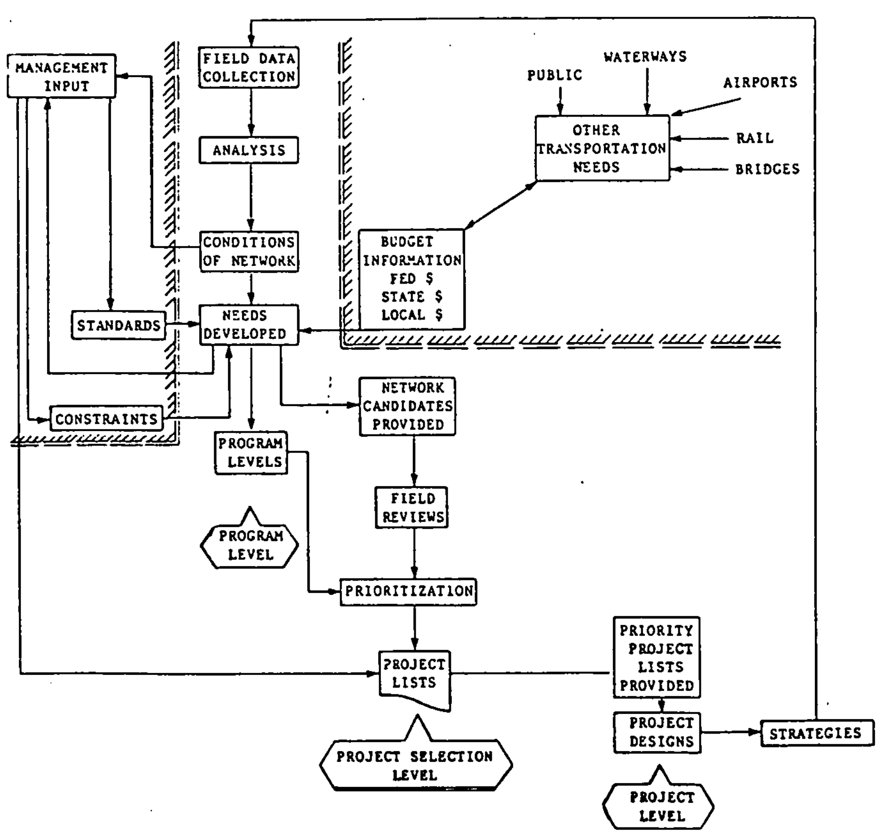


FIGURE 35 Pavement management system framework (Maine).

TABLE 9

PAVEMENT CONDITION IN MAINE

EXISTING (1984) PAVEMENT CONDITION (MILES)

Highway System	Very Poor 0.0-1.5	Poor 1.6-1.9	Poor-Fair 2.0-2.3	Fair 2.4-2.7	Fair-Good 2.8-3.1	Good 3.2-3.5	Very Good 3.6-5.0	Average Pavement Condition(PCR)
Federal-Aid Interstate*	0	0	0	38	74	67	335	3.9
Federal-Aid Primary (Rural)	56	76	178	228	305	302	680	3.4
Federal-Aid Primary (Urban)	2	9	1	29	45	14	79	3.4
Federal-Aid Secondary (State Highway)	93	123	143	272	224	230	390	3.1
Federal-Aid Secondary (State-Aid)	29	117	169	259	266	115	302	3.1
Federal-Aid Urban	36	23	30	104	176	126	189	3.2
Non-Federal Aid (State-Highway)	0	9	18	27	14	18	45	3.2
Non Federal Aid (State-Aid)	95	196	317	446	492	276	840	3.2
TOTAL	311	553	856	1403	1596	1148	2860	3.3

*Interstate Mileage is doubled since Northbound and Southbound are rated independently.

Pennsylvania Department of Transportation (*38, 84–88*)

The Pennsylvania Secretary of Transportation named a special eight-member task force to develop and implement a pavement management system in the department. The representatives on the task force included the Director of Operations, a District Engineer, an Assistant District Engineer-Maintenance, a District Pavement Management Engineer, the Division Manager for the Bureau of Strategic Planning, the Bureau of Design Pavement Management Engineer, a representative from the Office of Research, and the Division Chief of the Bureau of Management Information Systems. The members of the Special Task Force were relieved of their normal duties and sequestered for the duration of the project.

The Special Task Force identified five objectives for use in the development of a Systematic Technique to Analyze and Manage Pennsylvania's Pavements (STAMPP) (*38*):

1. To provide a uniform statewide condition evaluation which would improve decision making.
2. To provide management with the information and tools to monitor the condition of the network, assess future needs, establish county condition rankings and optimize investments.
3. To provide condition information to fulfill the requirements of Act 68 (1980), which requires the allocating of maintenance funds to the individual counties based on needs.
4. To provide information for monitoring the performance of various pavement designs, rehabilitation and maintenance techniques.
5. To provide information for identifying candidate projects for maintenance and betterment programs.

These objectives were used to provide the framework for developing a pavement management system and as the basis for further developments in the area. The 43,000-mile state highway system was too large for beginning a pavement management system so they started with 12,000 miles of Interstate and Priority Commercial Network Highways.

Pennsylvania then developed a Roadway Management System (RMS) to improve management control over their large highway network. RMS was designed as the primary management system for controlling inquiries, and for updating and reporting of all department roadway data including pavement conditions,

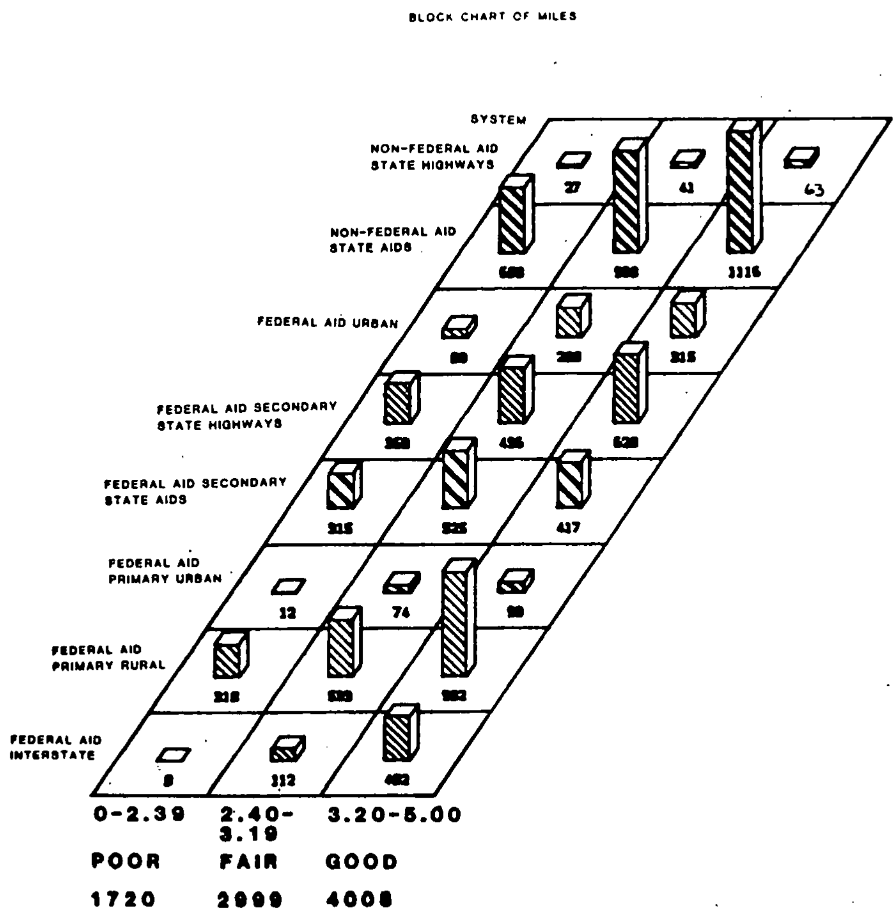


FIGURE 36 Three-dimensional chart of pavement condition (Maine).

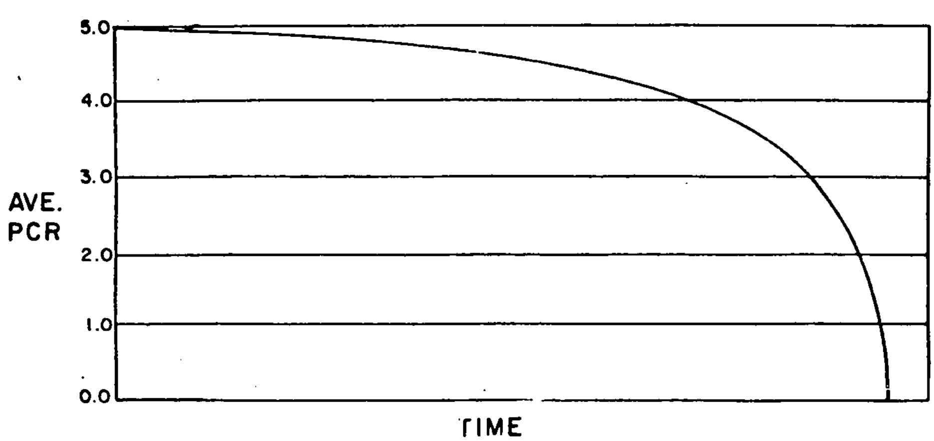


FIGURE 37 Illustrative pavement deterioration curve (Maine).

DIVISION 5

FEDERAL-AID PRIMARY RURAL PROJECT SUMMARY

PAVEMENT MANAGEMENT NETWORK ANALYSIS SYSTEM

GRP	PJN	LENGTH	PCR	SDEV	YR	RIDE	AADT	PROG	COND	PCR2	BEN	PT	ST	TT	GNPCR	GAINP	COSTP	MF	MF1	GAINS	COSTS	GAINT	COSTT
A1																							
	71	4.56	3.23	0.37	65	2	2876		10	3.10	55	DONO			8	0	0	.	.	.	.	.	.
	45	0.31	3.26	.	62	2	2679		10	3.13	54	DONO			1	0	0	.	.	.	.	.	.
	44	4.80	3.36	0.33	80	2	2679		10	3.23	51	DONO			8	0	0	.	.	.	.	.	.
	70	1.14	3.39	1.05	58	2	2876	D5	10	3.26	50	DONO			2	0	0	.	.	.	.	.	.
	53	1.34	3.50	0.24	69	2	1921		10	3.38	44	DONO			2	0	0	.	.	.	.	.	.
	51	1.14	3.58	0.16	77	1	1921		7	3.45	42	DONO			2	0	0	.	.	.	.	.	.
	65	0.30	3.61	.	57	2	2194	D10	10	3.48	42	DONO			0	0	0	.	.	.	.	.	.
	39	1.12	3.74	0.00	67	2	1969		10	3.61	37	DONO			1	0	0	.	.	.	.	.	.
	42	0.60	3.74	.	76	2	1969		10	3.61	37	DONO			1	0	0	.	.	.	.	.	.
	50	1.27	3.74	.	81	2	1921		10	3.61	37	DONO			2	0	0	.	.	.	.	.	.
	52	0.70	5.00	.	83	1	1921		7	4.88	0	DONO			0	0	0	.	.	.	.	.	.

TOTAL PROJECTED PCR LOSS FOR THIS ANALYSIS GROUP = 3

TOTAL PROJECTED LOSS IN SEVICE FOR THIS ANALYSIS GROUP = 6

GRP	PJN	LENGTH	PCR	SDEV	YR	RIDE	AADT	PROG	COND	PCR2	BEN	PT	ST	TT	GNPCR	GAINP	COSTP	MF	MF1	GAINS	COSTS	GAINT	COSTT
A2																							
	105	1.72	2.58	0.38	61	2	2678	P4	11	2.25	75	FALR	HMM		4	22	89	2.5	.	9	19	.	.
	69	1.36	2.68	0.60	58	2	2876	D5	11	2.35	72	FALR	HMM		3	18	71	2.5	.	7	15	.	.
	93	3.19	2.70	0.30	48	2	2973		11	2.37	72	FALR	HMM		7	44	166	2.5	.	17	36	.	.
	66	2.42	2.72	0.50	57	2	2278	D10	11	2.39	69	FALR	HMM		6	25	126	2.5	.	10	27	.	.
	67	1.30	2.86	0.26	57	2	2876	D5	11	2.53	67	FALR	HMM		3	16	68	2.5	.	6	15	.	.
	94	2.92	2.89	0.17	47	2	2973		11	2.56	66	FALR	HMM		6	37	152	2.5	.	15	33	.	.
	100	2.34	2.89	0.17	68	2	2713		11	2.56	65	FALR	HMM		5	27	122	2.5	.	11	26	.	.
	68	0.50	2.96	.	57	2	2876	D5	11	2.63	64	FALR	HMM		1	6	26	2.5	.	2	6	.	.
	49	3.62	2.86	0.23	64	2	1921		11	2.53	63	FALR	HMM		8	30	188	2.5	.	12	41	.	.
	23	0.88	2.77	.	75	2	1181		5	2.44	62	HMM	DONO		2	5	10	.	.	0	0	.	.
	92	4.32	2.99	0.16	57	2	2088		11	2.66	60	FALR	HMM		9	36	225	2.5	.	15	49	.	.
	41	1.80	3.02	0.03	76	2	1969		11	2.69	59	FALR	HMM		4	14	94	2.5	.	6	20	.	.
	106	8.59	3.10	0.81	59	2	2678		11	2.77	59	FALR	HMM		16	87	447	2.5	.	35	97	.	.
	40	2.84	3.08	0.31	78	2	1969		11	2.75	57	FALR	HMM		5	21	148	2.5	.	9	32	.	.
	43	2.75	3.10	0.14	76	2	1969		11	2.77	56	FALR	HMM		5	21	143	2.5	.	8	31	.	.

TOTAL PROJECTED PCR LOSS FOR THIS ANALYSIS GROUP = 14

TOTAL PROJECTED LOSS IN SEVICE FOR THIS ANALYSIS GROUP = 32

FIGURE 38 Computer-generated summary showing projected pavement condition rating (Maine).

traffic volumes, construction and maintenance costs, and accidents. The RMS was the result of years of planning and development and is intended to assist department personnel in predicting pavement performance and to plan needed maintenance and rehabilitation before failure.

Pennsylvania's Roadway Management System contains ten major functions (Fig. 39). The RMS is computerized and is designed with on-line processing capability.

The first function in RMS is the main menu or Application Selection where the user can select any roadway-related system or RMS application. Function two provides access to many of the 24 data bases contained within Roadway Information Data Base (RIDB). Function three is the Pavement Management function and is one of the largest and most complex in the Roadway Management System. This function replaces and enhances the former STAMPP system and contains six subfunctions. The fourth function is Roadway Information Management, which is one of the largest functions containing five subfunctions. Function five is Special Processes and contains four subfunctions.

Function six is Reference Table Management and function seven is Standard Application Inquires. Function seven contains eight different screens: (a) planned and approved projects, (b) accident details, (c) accident summary, (d) planned maintenance activities, (e) ADT and pavement conditions, (f) planned and approved projects affecting a structure or accident details by structure, (g) ADT and pavement condition ranking, and (h) state route sequential listing.

Function eight is Straight-Line Diagram (SLD) and has the capability for both vertical SLD and horizontal SLD in either black and white or in color.

Function nine is Ad Hoc Query Language and function 10

TABLE 10

PROPOSED IMPROVEMENTS BY SYSTEM (MAINE)

1986-1987 HIGHWAY IMPROVEMENT NEEDS
(Millions of Dollars & Miles of Improvement)

SYSTEM	5/8" Mulch	State Light Resurf.	Federal Light Resurf.	1 1/2" Overlay	Overlay& Widening	Structural Overlay	State Rehabil.	Rehabil./ Reconst.	Complim. Projects	TOTAL
Federal-Aid Interstate						40 ($6.6)			$ 6.4	$13.0 (40 mi.)
Federal-Aid Primary(rural)			326($21.4)	82($13.0)		9 ($1.8)		23 ($17.8)	$15.8	$69.8 (440 mi.)
Federal-Aid Primary(urban)				16($ 3.4)	2($1.6)			1 ($ 1.0)	$ 1.3	$ 7.3 (19 mi.)
Federal-Aid Secondary(SH)	210($2.0)		145($ 9.4)			2 ($0.5)		14 ($ 9.8)	$ 6.8	$28.5 (371 mi.)
Federal-Aid Secondary(SA)	345($3.4)		35($ 2.7)					18 ($ 5.7)	$ 0.6	$12.4 (398 mi.)
Federal-Aid Urban				24($ 5.3)	4($3.6)			1 ($ 0.8)	$ 4.7	$14.4 (29 mi.)
NFA State Highway	45 ($0.6)	5($0.3)					3 ($ 0.4)		-	$ 1.3 (53 mi.)
NFA State-Aid	634($6.2)	84($2.8)					40($5.0)	6 ($ 1.5)	$ 1.4	$16.9 (764 mi.)
SPECIAL PROGRAMS:									$14.0	$14.0
TOTAL	1234($12.2)	89($3.1)	506($33.5)	122($21.7)	6($5.2)	51($8.9)	43($5.4)	63($36.6)	$51.0	$177.. (2114 mi.)

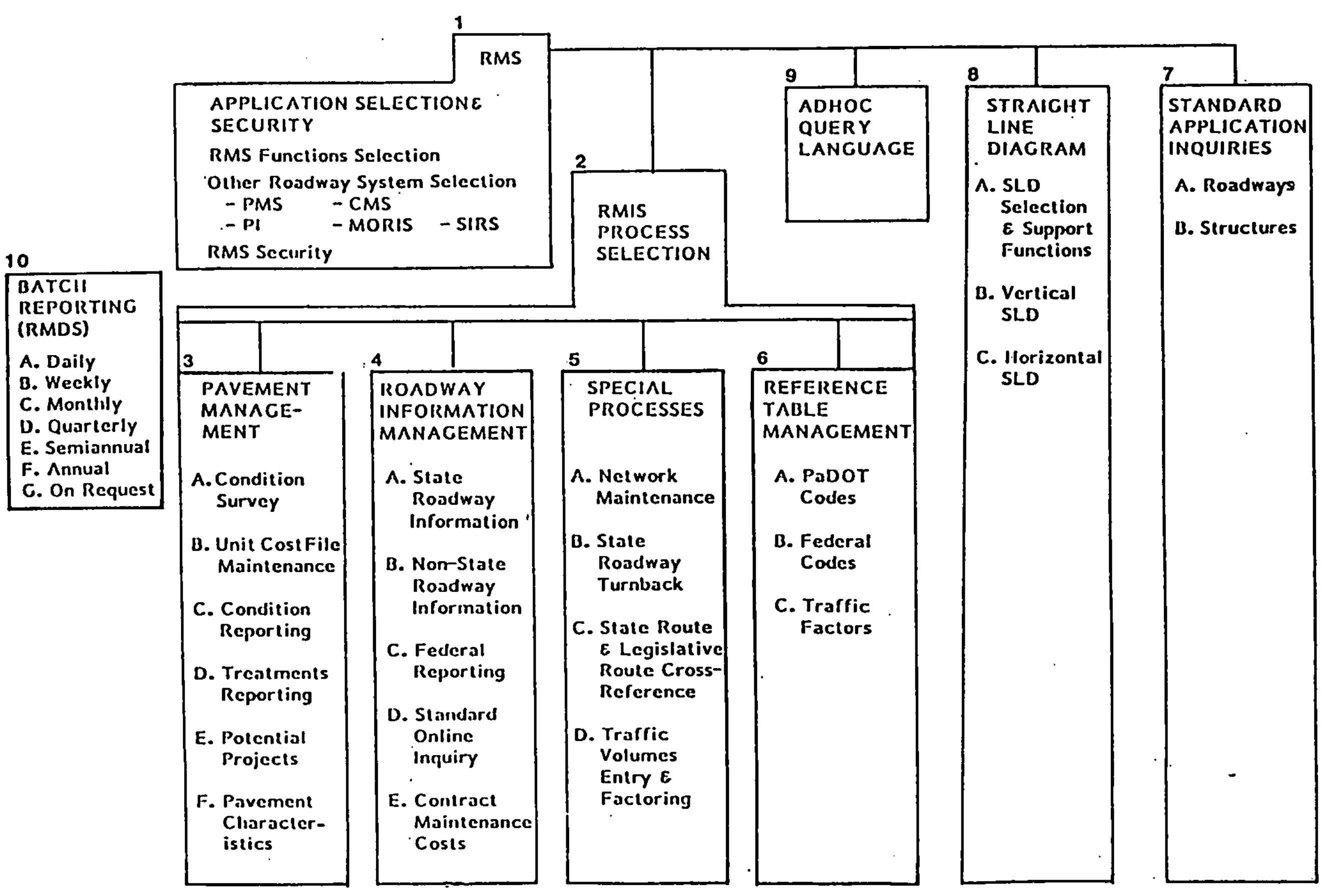


FIGURE 39 Roadway management system functional overview (Pennsylvania) (*88*).

RIGID PAVEMENT TREATMENT STRATEGIES

		LOW			MEDIUM			HIGH		
		1	2	3	4	5	6	7	8	9
A	JOINT SEAL FAILURE	X	1	2	1	2	2	1	2	2
B	LONGITUDINAL JOINT SPALLING	1	2	3	4	4	4	4	4	4
C	TRANSVERSE CRACKING	X	X	X	2	3	3	9	(9)	9
D	TRANSVERSE JOINT SPALLING	X	1	3	4	4	4	5	5	5
E	FAULTING	X	6	6	7	8	8	9	9	10
F	BROKEN SLAB	6	6	6	9	9	9	9	9	9
G	BITUMINOUS PATCHING	9	9	9	9	9	9	9	9	9
H	SURFACE DEFECTS	4	4	4	9	9	9			
K	RUTTING	10								

(X) ROUTINE MAINTENANCE
(1) SPOT JOINT SEAL
(2) JOINT SEAL
(3) JOINT REHABILITATION
(4) JOINT SPALL REPAIR
(5) JOINT REPLACE
(6) SUBSEAL
(7) SUBSEAL & SLABJACK
(8) SUBSEAL & SLABJACK & GRIND
(9) SLAB REPLACE
(10) OVERLAY

COMBINATIONS FOR OVERLAY:

>30% PATCHING

OVERLAY REPAIR RECOMMENDATIONS:

ADTT	REPAIR
0 - 1000	3-1/2" BITUMINOUS
1001 - 2000	6" BITUMINOUS
2001 - 3000	CONCRETE OVERLAY
ABOVE 3000	RECONSTRUCT

EXPLANATION OF TREATMENT STRATEGIES

NUMBERS ACROSS THE TOP OF THE STRATEGY GRID (1 THRU 9) REFER TO MARKS ON THE CONDITION SURVEY INPUT FORM. ---->

EXTENT: NONE	1	2	3	SEVERITY
0	1	2	3	L
	4	5	6	M
	7	8	9	H

LETTERS DOWN THE SIDE (A THRU K) REFER TO CORRESPONDING CONDITIONS. FOR EXAMPLE, A SECTION HAVING SEVERE TRANSVERSE CRACKING OVER 20% OF ITS SLABS IS CODED C8. C8 CONDITION ALONE INDICATES TREATMENT #9 - SLAB REPLACE.

ANY COMBINATION OF CONDITIONS THAT REQUIRE >30% PATCHING WILL INDICATE TREATMENT #10 - OVERLAY.

BITUMINOUS SURFACE PAVEMENT TREATMENT STRATEGIES

		LOW			MEDIUM			HIGH		
		1	2	3	4	5	6	7	8	9
A	EXCESS ASFHALT	X	X	X	X	X	X	X	X	X
B	RAVELING/ WEATHERING	2	2	4 (7)	2	4 (5)	4 (7)	5	8 (5)	8 (12)
C	BLOCK CRACKING	2	2	4 (7)	1	1+8 (5)	1+8 (7)	1+5	1+8 (1+5)	10 (13)
D	TRANSVERSE AND LONGITUD.CRACKING	X	X	X	1	1	1	1+2	1+2	10 (13)
E	ALLIGATOR CRACKING	2	2	2	2+3	2+3 (5)	3+8 (3+12)	6	6	6+8 (6+12)
F	EDGE DETERIORATION	X	2	2	3	2+3	2+3	3	5	11
G	BITUMINOUS PATCHING	X	X	X	3	5	5	3	3+5	10 (13)
H	POTHOLES	3	3	3	3	3	3	3	3	6
I	WIDENING DROPOFF	X	2	2	X	5*	5*	3	10* (13)*	10* (13)*
J	PROFILE DISTORTION	6 OR 9#	6 OR 9#	6 OR 9#						
K	RUTTING	X	8 (13)							

* ASSUME 6' WIDTH FOR COST

( ) URBAN AREA

(X) ROUTINE MAINTENANCE
(1) CRACK SEAL
(2) SKIN PATCH
(3) MANUAL PATCH
(4) SEAL COAT
(5) MECHANIZED PATCH
(6) BASE REPAIR
(7) SURFACE TREATMENT - 1" PLANT MIX
(8) LEVEL & SEAL COAT
(9) JOINT REPAIR
(10) MILL & LEVEL & SEAL COAT
(11) WIDEN
(12) LEVEL & RESURFACE
(13) MILL (RECYCLE) & LEVEL & RESURFACE
(14) RECONSTRUCTION

\# TYPE SURFACE:
30/40/50 FLEXIBLE - (6) BASE REPAIR
60/80/90 RIGID BASE - (9) JOINT REPAIR

```
COMBINATIONS FOR SEAL COAT (4):          COMBINATIONS FOR WIDEN (11):
     C8 + E3 + >ADT 2000 + RURAL             >2' NARROWER THAN DESIGN
     C8 + E5 + >ADT 2000 + RURAL                 MANUAL PART2 CRITERIA

COMBINATIONS FOR (8):                    COMBINATIONS FOR RESURFACING (12):
     SEAL COAT (4) +  K1                     E8 + B8 + >ADT 2000
     B5 + B7 + RURAL
     C2 + C8 + RURAL

COMBINATIONS FOR  ----- (9 + 13) -----   OR   ----- (8 + 9) -----
    >D7 +>I7 + J3 +     (URBAN)          OR          (RURAL)
     D9 + I9 +          (URBAN)          OR          (RURAL)
          I9 + J3 +     (URBAN)          OR          (RURAL)

COMBINATIONS FOR  ----- (13) -----            ----- (10) -----
  K1 + B9 +       (>ADT 2000 OR URBAN)   K2 + (<ADT 2000 + RURAL)
  K1 + C6 +              "               K2 +         "
  K1 + C9 +              "               K2 +         "
  K1 + E6 +              "               K2 +         "
  K1 + E8 +              "               K2 +         "
  K1 + E9 +              "               K2 +         "
  K2 + B6 + B8 + (>ADT 2000 OR URBAN)    OR   (<ADT 2000 + RURAL)
  K2 + C5 + C8 +         "                            "
 >E7 + C5 +              "                            "
 >E7 + C6 +              "                            "
 >E7 + C8 +              "                            "
  C9 + E6 +              "                            "
  C9 + E8 +              "                            "
  C9 + E9 +              "                            "
  G6 + G5 +              "                            "

COMBINATIONS FOR  ----- (12) -----       OR   ----- (8) -----
  E9 + B9 +       (>ADT 2000 OR URBAN)   OR   (<ADT 2000 + RURAL)
  E8 + B9 +              "                            "
  E9 + B8 +              "                            "
```

FIGURE 40 Treatment strategies for rigid pavement and bituminous surfaces (Pennsylvania) (*38*).

is Batch Reporting. There are seven batch reporting cycles: daily, weekly, monthly, quarterly, semi-annual, annual, and on-request.

Field data are gathered through use of special condition survey input forms. There is one form for rigid pavements and one for bituminous surface pavements. The evaluation includes both extent and severity of the various defects.

Strategies were developed for rigid pavements, for flexible pavements, and for shoulder treatments. The strategies were in the nature of preventive and corrective and for maintenance and rehabilitation of pavements. The treatment strategies for rigid pavements and for flexible pavements are shown in Figure 40.

CHAPTER FIVE

DEVELOPING OR IMPROVING A PAVEMENT MANAGEMENT SYSTEM

The first step in developing or improving a pavement management system is making the decision to do just that. The previous chapters presented information on what pavement management is, what various agencies are using and how they are applying it within their organization, and what benefits they are obtaining. The purpose for this chapter is to identify steps or guidelines that can be used to assist any agency desiring to either develop a new pavement management system or to improve an existing one.

DEVELOPMENT STEPS

Management can be defined as the process of: (a) defining the problem, (b) setting goals, (c) planning and organizing, (d) directing and implementing, and (e) following up. These same items can be applied to the process of improving pavement management within an agency (*1*). The following expanded steps are illustrative of that process.

Commitment to Pavement Management

The first and most important step is making the decision to start either improving an existing pavement management system or developing a new one. To be successful, strong support and backing from the top administrators within the agency are essential. If it is understood by all concerned that top management is behind the effort, it will then be much easier to obtain full support from the various divisions within the agency that may be involved in any changes, improvements, or development. A new or modified pavement management system may require changes in how things are being done in the agency and in who is involved. The fear of what may happen with something new often creates uncertainty, which in turn may result in apprehension. Any change that has the potential of changing the status quo may affect people who are involved, thus generating human resistance.

Pavement management to succeed must have a strong beginning with top management making the commitment that they want to get the most from their pavement system and that they want the potential benefits that can come from a formalized pavement management system.

Use of Task Force or Steering Committee

Once the decision has been made to improve an existing pavement management system or to develop a new one, the next step is to organize a task force or steering committee to provide guidance or direction. This group should include top-ranking personnel from the various divisions or offices from within the organization who have an interest in pavements. Top management should clearly define the responsibilities and goals for the advisory group including time frames for accomplishing various tasks or achieving certain objectives. Some of the responsibilities of such a group might be:

- Define the objectives of the proposed system and what is expected over the short and long term.
- Define and evaluate the status of present practice for managing pavements within the agency including what information is currently available.
- Identify needed outputs or what information is needed by the various divisions or offices to effectively manage pavements.
- Identify data needs to ensure that the necessary information is generated and that calculations are as accurate as reasonably possible.
- Recommend appropriate changes or improvements in present practice.
- Identify the location for the permanent management or staffing for pavement management. A pavement management engineer or coordinator with staff support should be appointed early in the work of the steering committee or task force to perform the necessary research or legwork in accomplishing the objectives.

System Selection or Development

Once the objectives and recommendations have been developed by the steering committee and approved by top management, then a system should be developed, selected, and/or modified to meet those needs. The selection process includes identifying and evaluating a number of components that will be needed for the system to function properly. Costs of development and/or implementation along with future operation are important considerations along with the following points:

- The equipment and methodology for monitoring pavement condition must be considered. Obtaining field data can be expensive and labor intensive.

• Access to all of the data required for the system to properly function is essential. In many agencies, much of the needed data is already gathered and stored. The problem is often one of getting the information to where it will be used in the form required. The data storage and analysis segments are very important to the success of a pavement management system. This too can become very expensive if allowed to go unchecked. Knowledgeable care should be exercised in selecting hardware and in developing, adopting, or modifying software.

• The pavement management system should have the capabilities discussed in previous chapters of this synthesis and that are highlighted later in this chapter.

• The system should be understandable by those who will be operating and managing it and beneficial to those depending on its outputs.

• The system should be flexible or changeable as the state of the art and technology advances.

Demonstrating the Process

Once a system has been developed or modified to the point where it can be tried in actual practice, it is suggested that it be tested on a relatively small scale. This can accomplish three benefits to the using agency:

1. It provides an opportunity for the bugs to be worked out in the data collection and analysis processes.
2. It provides an opportunity for those resisting change from existing practices to observe or to be involved in a new or improved process and be of assistance in full-scale implementation. If skeptics can see how they can be helped in their assignments, then they may become supporters.
3. It allows top management and members of the steering committee to observe the process and recommend changes or improvements before final adoption for the entire highway network. This provides an opportunity to verify if the final product meets the objective as initially established.

Full-Scale Implementation

Once the system has been tried on a limited basis and adjusted as needed, it is then ready for full-scale implementation. The careful selection of individuals to be involved in the implementation process is very important. Prepublicity through newsletters and presentations or discussions may be helpful in completing this step. A training plan should be identified and involved in the implementation process.

Follow Up

Once the process is fully implemented, it should be reviewed periodically to observe if the system is achieving the objectives initially set. Follow up should also provide opportunities for improving the system. New technology is constantly being developed and, when beneficial to the system and its operation, should be considered for inclusion (*1, 25*).

PERSONNEL

One item of great importance in highways in general and in pavements specifically is obtaining and retaining qualified personnel. Engineers who have the necessary skills and training to deal with the complex and technical issues associated with pavements are needed. A study conducted by the Transportation Research Board on transportation professional needs (*89*) found that some transportation agencies will have a shortage of trained professionals between 1985 and 1995. A significant increase in retirements will be the case for many agencies. For example, in five states, more than one-third of all professional employees will be eligible to retire with full benefits between 1985 and 1989 (*89*). The average age for engineers in state highway or transportation agencies is approximately 45 years. More than 10 percent of the engineers are over 60 in four states, and in nearly half of all of the states 10 percent of the engineers are between 56 and 60 years of age.

There is a continuing problem of engineering personnel attrition, which further compounds the problem of acquiring more engineers with specialized pavement training. Because of the very large nationwide pavement rehabilitation program and the tremendous investment in pavements, qualified, experienced engineers are needed. Some agencies such as AASHTO and the FHWA and selected universities are providing training in pavements. More are needed (*1, 89*).

SUGGESTED PAVEMENT MANAGEMENT SYSTEM STRUCTURE

Much has been discussed in this synthesis on pavement management systems or processes. There are differences between agencies in how their systems are structured and how they operate. There are differences in how the various agencies are organized and in local conditions that exist. There are also similarities. It is therefore difficult to recommend one specific system for use by everyone because it would not fit everyone's situation or conditions. There are however, certain functions or activities that should be part of each system. The following characteristics are suggestions only and are not intended as firm recommendations.

Pavement Monitoring

The condition of pavements along with their performance characteristics is an essential part of any pavement management system. It is extremely difficult to manage pavements if it is not known what the present condition is or what the performance history has been. There is a difference in how the various agencies monitor the condition of their pavements. The important things are that the procedure be repeatable and that it measure characteristics that are important in the process of managing pavements. The most common methods used are distress (rutting, cracking, patching, etc.), roughness, pavement friction, and structural deflections.

Data Base

The potentially large quantities of data that are gathered and stored lend themselves to the use of computers. The data are of little benefit if they cannot be easily retrieved for use. There are certain types of information that are very helpful in managing pavements and that should be accessible through a data base. Some of these are:

- Cost data for construction, maintenance, and rehabilitation are essential.
- Pavement history is needed including as-built construction and other major improvements. Information on the types of maintenance performed and when it is done is also very beneficial. This component should be continually updated as improvements are made.
- Traffic data including volumes and loads over time are very beneficial in evaluating a pavement compared with design and in projecting remaining life.
- Inventory data including other features of the highway are useful. Included in this area are drainage, geometrics, utilities, etc.

Analysis Methods

The program should be set up in such a way that the pavement network as a whole or by road class or system can be evaluated. A network-level analysis is useful to the administrator in managing the entire pavement system. This can be used in planning and supporting budgets, prioritizing pavement needs, and forecasting future pavement condition based on action or inaction taken now.

The project-level analysis provides sufficient detail for each project to allow preliminary designs and for the identification and evaluation of alternative rehabilitation or maintenance strategies.

Updating

The system must be flexible so that it can be updated and improved over time if warranted by changing conditions or improved technology.

Research

Much benefit can be obtained through special research projects associated with a pavement management system and its data (*1, 25*).

CHAPTER SIX

CONCLUSIONS, RECOMMENDATIONS, AND RESEARCH NEEDS

CONCLUSIONS

The following conclusions were reached in this synthesis:

1. The emphasis of highway agencies has changed from new construction to system preservation, with maintenance and rehabilitation activities becoming very common. Pavements constructed since 1960 have or soon will reach their design life.
2. Pavements have been deteriorating at a rapid rate and in some cases faster than they are being improved. A high percentage of pavement miles are now in need of upgrading or soon will be.
3. Engineering technology is not as far developed for pavement rehabilitation as it is for the design and construction of new pavements.
4. A number of conditions, as they change, can directly affect how pavements perform. Some of these are increased size and weights of trucks, axle configuration, tire pressure, and suspension systems. Other conditions, such as inflation, escalating construction costs, and decreases in fuel tax revenues, will have an indirect effect through changes in construction and maintenance practices.
5. Managing pavements is not new as decisions in one form or another have been made for years regarding pavements. The what, when, where, and how are basic questions; however, the answers have not always been consistent. The recognition of pavement management as a distinct process has only come about in recent years.
6. Pavement monitoring or evaluation is generally the first area developed by agencies in a pavement management process. Other areas or components include planning, budgeting and programming, design, construction, maintenance, rehabilitation, and research.
7. Each highway agency is organized differently in dealing with pavements. Physical characteristics and background vary from agency to agency and from area to area; therefore, pavement management systems need to be customized.
8. Pavement management systems have proven beneficial and cost-effective to those agencies that have them. Some of the more notable benefits include money savings, better pavements, and better information with which to operate the system.
9. A pavement management system provides the agency with the ability to answer the "what if" types of questions such as: what if heavier trucks are allowed, what if no maintenance is done, what if rehabilitation is delayed, and what if the budget is cut. A pavement management system gives the agency the information needed to do the right thing at the right place using the right materials at the right time for the lowest life-cycle cost.
10. Of the 53 agencies responding to the survey of practice, 35 have some form of a pavement management system or process and 11 have either a partial system or they are in the development process. The seven agencies that do not have a pavement management system and are not in the process of developing one all said they plan to establish one.
11. The agencies with the greatest success in establishing a pavement management system are those where the chief administrative officer takes an active interest and directs that one be developed. A steering committee is also very helpful.
12. Some of the more common pavement management system outputs that are useful to the agency are: pavement condition, prioritized listings, deficiencies, strategies and treatments, and estimated costs.
13. Some of the weaknesses in present pavement management systems as identified by some of the agencies are: organization, life-cycle costs, ability to predict performance, and the integration of pavement management systems with other data systems within the agency. The Research Needs section of this chapter discusses this item further.

RECOMMENDATIONS

The recommended steps for developing a pavement management system or process are:

1. Commitment to pavement management by key agency personnel including the chief administrative officer.
2. Establish a task force to guide the development and adoption of a pavement management system. A pavement management engineer or coordinator should be assigned to work with the task force. Pavement management should not be subordinate to a division but should report as high as possible within the organization.
3. Select or develop a pavement management system that will meet the needs of the agency and will provide the information necessary to effectively manage the pavements.
4. Demonstrate the pavement management system on a limited scale so that it can be fine-tuned and modified before full-scale application.
5. Implement the system on a full-scale operational basis.

A pavement management system should have the means for monitoring or evaluating pavement condition, it should have a coordinated and accessible data base, it requires methods for processing and analyzing the data and for generating useable outputs, it needs to be easy to update, and it should be beneficial to research.

RESEARCH NEEDS

There are five areas of research needs that were identified from weaknesses in existing pavement management systems as identified by various agencies.

1. Better models are needed for optimizing pavement expenditures to ensure that the agency receives the greatest benefit from available funds.
2. Improved prediction models are needed for both project and network levels for predicting future condition or performance of pavements if nothing is done or if different strategies or treatments are used.
3. Improvements are needed in the data collection process to obtain better quality data and to reduce costs. Survey techniques used to determine pavement condition need to be modernized and updated.
4. Improvements are needed in data processing software, equipment, and staffing. There appears to be a general shortage of qualified personnel in the area.
5. There is a need for more and better cost data, particularly in maintenance, and for better economic models for evaluating strategies.

GLOSSARY

alternatives The various choices of treatments available for providing a solution to a pavement deficiency or problem (*29*).

analysis period A specified interval of time (or accumulated number of load applications) over which alternative strategies are to be evaluated. This is generally on the order of 20 years; i.e., a complete life cycle (*12*).

corrective maintenance Type of maintenance used to take care of day-to-day emergencies and repair deficiencies as they develop. May include both temporary and permanent repairs; sometimes referred to as remedial maintenance (*29*).

cost-effectiveness The situation that exists when the benefits exceed the costs for a given treatment, strategy, or improvement or when the benefit-cost ratio is greater than one (*29*).

deficiency Any indication of poor or unfavorable pavement performance or signs of impending failure; any unsatisfactory performance of a pavement, short of failure (*29*).

dominant strategy The strategy that will correct all problems and provide an acceptable level of service (*29*).

economic model a mathematical description of the expected costs, benefits, or both, associated with the elements of various strategies, for a specified analysis period (*12*).

failure Unsatisfactory performance of a pavement or portion such that it can no longer serve its intended purpose (*29*).

friction number (skid number) The number that is used to report the results of pavement friction tests conducted in accordance with ASTM Standard E 274 (*90*).

life-cycle costing An economic assessment of an item, area, system, or facility and competing design alternatives considering all significant costs of ownership over the economic life, expressed in terms of equivalent dollars (*50*).

maintenance Anything done to the pavement after original construction until complete reconstruction, excluding shoulders and bridges (*29*).

network level The level at which key administrative decisions that affect programs for road networks or systems are made. Sometimes referred to as the program level (*29*).

optimization model A mathematical description or algorithm designed to compare alternative strategies and to identify the relative merits of each strategy according to assigned decision criteria, such as safety, cost, etc. (*12*).

optimum strategy The strategy among the alternatives considered that is expected to maximize the realization of management goals subject to the constraints imposed (*12*).

optimum treatment The treatment that will correct the deficiencies of a pavement in the most cost-effective manner (*29*).

pavement condition The present status or performance of a pavement (*29*).

pavement maintenance techniques Methods used to accomplish strategy or correct deficiency in pavement segment (*29*).

pavement management (PM) Pavement management is the effective and efficient directing of the various activities involved in providing and sustaining pavements in a condition acceptable to the traveling public at the lowest life-cycle cost (*21*).

pavement management information system (PMIS) An established and documented procedure for collecting, storing, processing, and retrieving the information required in a pavement management system. It represents a foundation for PMS since all pavement decisions must be based on a common, integrated source of information derived from reliable, good quality data (*21*).

pavement management strategy A carefully arranged, systematic program of action applied to any area of pavement activity (*21*).

pavement management system (PMS) An established, documented procedure treating many or all of the pavement management activities ... in a systematic and coordinated manner. It consists of five essential elements structured to serve decision-making responsibilities at various management levels.

1. Pavement surveys related to condition and serviceability.
2. Data base containing all pavement-related information.
3. Analysis scheme.
4. Decision criteria.
5. Implementation procedures.

The difference between the practice of pavement management and a pavement management system is the establishment and documentation of each of these components to formally treat one or more of the pavement activities in a coordinated and objective process. Feedback on these activities is an important part of both PM and a PMS (*21*).

pavement optimization A procedure for obtaining the greatest life-cycle benefits for the lowest cost. Within the practice of pavement management, optimization might best be described as a process of obtaining the highest state of pavement performance over the pavement's life cycle with the least social and economic impact (*21*).

pavement performance The assessment of how well the pavement serves the user over time. The engineer often associates pavement condition with an arbitrary, but quantifiable, value relating to pavement roughness, pavement distress, or pavement strength. Performance is the measured change of condition and/or serviceability over increments of time (*21*).

prediction model A mathematical description of the expected values that a pavement attribute will take during a specified analysis period (*12*).

present serviceability The current condition of a pavement (traveled surface) as perceived by the traveling public (*90*).

Present Serviceability Index (PSI) An index derived from controlled measurements of the roughness in the wheeltracks designed to correlate with panel ratings (PSR), which may include pavement conditions not causing vibratory inputs (*90*).

Present Serviceability Rating (PSR) A mean rating of the serviceability of a pavement (traveled surface) established by a rating panel under controlled conditions. The accepted scale for highways is 0 to 5, with 5 being excellent (*90*).

preventive maintenance The type of maintenance intended to keep the pavement above some minimum acceptable level at all times. It is used as the means of preventing further pavement deterioration that would require corrective maintenance (*29*).

project level The level at which technical management decisions are made for specific projects or pavement segments (*29*).

rehabilitation The act of restoring the pavement to a former condition so that it can fulfill its function (*29*).

rehabilitation strategy A complete set of activities and decisions that make up one rehabilitation action (*29*).

rideability A measure of the smoothness of a pavement (traveled surface) as perceived by the public traveling in a vehicle at a speed appropriate for the particular surface (*90*). Note: Rideability is limited to the vibratory input felt by the riding public. Present serviceability includes rideability and other surface conditions not causing vibratory inputs (*90*).

Rideability Index (RI) An index derived from controlled measurements of the longitudinal profile in the wheel tracks and correlated with panel ratings of rideability.

routine maintenance The day-to-day maintenance activities, generally consisting of permanent and emergency patching. Usually considered corrective (*29*).

skid number *see* **friction number.**

skid resistance The retarding force generated by the interaction between a pavement and tire(s) under a locked condition (*90*).

strategy A plan or method for dealing with all aspects of a particular problem. For example, a rehabilitation strategy is a plan for maintaining a pavement in a serviceable condition for a specified period of time (*12*).

treatments Materials and methods used to correct a deficiency in a pavement surface (*29*).

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APPENDIX A

SURVEY OF PRACTICE SUMMARY

Agency________________________

NCHRP PROJECT 20-5
TOPIC 17-10

"PAVEMENT MANAGEMENT PRACTICES"

SURVEY OF PRACTICE

Pavement Management is defined in the 1985 AASHTO Publication "Guidelines on Pavement Management" as follows:

"Pavement Management (PM) is the effective and efficient directing of the various activities involved in providing and sustaining pavements in a condition acceptable to the traveling public at the least life cycle cost. Examples of these activities include, but are not limited to, the following as they relate to pavements: Planning, budgeting and programming, design, construction, monitoring, research, maintenance rehabilitation and reconstruction.

All respondents please answer questions in the A and C Sections of this Survey. Only those with some form of pavement management need answer the questions in Section B.

SECTION A

A-1. Do you have a pavement management process, system, program, etc. in your agency?______________________If not, please briefly describe how pavements are managed in your agency__________________________

____

____

A-2. What position(s), division(s), section(s), etc. are responsible for pavements or pavement management?___________________________
Please provide a copy of your appropriate organization chart(s) highlighting the position(s) or area(s) responsible.

A-3. Did someone from your agency attend the "Pavement Seminar for Chief Administrative Officers in the fall of 1985?______________________

If so, what effect if any has it had on your agency or do you expect it to have?____

____

____

A-4. If you do not have pavement management in your agency at this time, do you plan to do so?______________________________If so, what time frame?____

SECTION B

B-1. What is the name of your pavement management system, process, program, etc.____________________

B-2. How was it developed or established and under whose direction?________

____

B-3. What elements or activities are contained in pavement management in your agency?____________________

____

B-4. Is your pavement management process formalized?____________________

____________________Is it computerized and if so to what extent?

____

____

B-5. What types of outputs are obtained from your pavement management process?____________________

Provide examples if possible.____________________

____

Where and how are the outputs used?____________________

____

B-6. How effective is pavement management in your organization?__________

____________________Is it cost effective?__________

____________________What weaknesses, if any does it have?____________________

____

B-7. What benefits have you obtained from having a pavement management process? Please provide specific examples if possible.____________________

____

____

____

SECTION C

C-1. Please provide copies of the following documents or types of documents related to pavements or pavement management.

(a) Organization chart(s) with locations of pavements or pavement management highlighted.

(b) Any applicable policy or procedural statements.

(c) Reports related to how pavement management was developed and how it functions.

(d) Instructional Manuals or guidelines.

(e) Reports documenting types of outputs obtained and how used.

(f) Reports documenting any benefits obtained from managing pavements.

C-2. Person completing survey.

Name________________________________

Title________________________________

Address______________________________

____

____

Phone________________________________

C-3. Please return completed survey with any supporting documents to:

Dale E. Peterson

TABLE A-1 PAVEMENT MANAGEMENT PROCESS OR SYSTEM

AGENCY	DOES AGENCY HAVE A PAVEMENT MANAGEMENT PROCESS OR SYSTEM	IF NOT NOW, HOW ARE PAVEMENTS MANAGED	WHAT IS THE NAME OF THE PAVEMENT MANAGEMENT PROCESS OR SYSTEM	IF NO PAVEMENT MANAGEMENT NOW	
				PLAN TO DO SO?	IN WHAT TIME FRAME
State of Alabama	Yes, System is in final stages of development. Final reports not out.	- - - - -	Pavement Management Program	- - - -	- - - - -
Arizona Department of Transportation	Yes	- - - - -	Pavement Management	- - - -	- - - - -
Arkansas State Highway and Transportation Dept.	Yes	- - - - -	APAMS - Arkansas Pavement Management System	- - - -	- - - - -
California Department of Trans. (CALTRANS)	Yes	- - - - -	Pavement Management System	- - - -	- - - - -
Colorado Department of Hwys	Yes, Network Level	- - - - -	Network Optimization System (NOS)	- - - -	- - - - -
Connecticut Department of Transportation	Yes, limited	The Office of maintenance performs annual windshield survey, and has responsibility for selecting sections each year to be included in a 500 mile per year overlay program	No acronym currently used.	Yes	A network level system on-line with in 1-3 years; to be followed by project level system 3-5 yrs.
Delaware Department of Transportation	Yes	- - - - -	Pavement Management	- - - -	- - - - -
Florida Department of Transportation	Yes	- - - - -	Pavement Management in the Florida DOT is not a single office, rather it is an amalgamation of a number of processes including practically every office within the department.	- - - -	- - - - -
Georgia Department of Trans.	Yes	Part of the system is in place, part under development. System is considered an Information System rather than a Management System	Road Information System	- - - -	- - - - -
Hawaii Department of Trans.	Yes	- - - - -	Hawaii Pavement Management System	- - - -	- - - - -
Idaho Dept. of Trans.	Yes	- - - - -	Pavement Performance Management Information System (PPMIS)	- - - -	- - - - -
Illinois Department of Trans.	Yes	- - - - -	Illinois Pavement Feedback System (IPFS)	- - - -	- - - - -

TABLE A-I (Continued)

AGENCY	DOES AGENCY HAVE A PAVEMENT MANAGEMENT PROCESS OR SYSTEM	IF NOT NOW, HOW ARE PAVEMENTS MANAGED	WHAT IS THE NAME OF THE PAVEMENT MANAGEMENT PROCESS OR SYSTEM	IF NO PAVEMENT MANAGEMENT NOW	
				PLAN TO DO SO?	IN WHAT TIME FRAME
Indiana Dept. of highways	No formal operating Process	Div. of planning prepares a Hwy. Improvement Program with input from: 1) Each dist. submits a prioritized list of candidate proj. 2) Div. of Research and Training submits a prioritized list of roughness sects. in 4 ADT ranges	- - - - -	Yes	2-3 years - have completed a Phase I with consultant for recommendations. Present work centers on preparing a conceptual design
Iowa Dept. of Trans.	Yes	- - - - -	Iowa Pavement Management	- - - -	- - - - -
Kansas Dept. of Trans.	Yes	NOTE: PMS consists of a network optimization System (NOS) and Project Optimization System (POS) and several support systems & programs NOS complete & being implemented POS complete in about one year	Kansas Pavement Management System including NOS, POS, and support systems.	- - - -	- - - - -
Kentucky Dept. of Trans.	Yes	- - - - -	Pavement Management Process	- - - -	- - - - -
Louisiana Dept. of Trans. and Development	No	- - - - -		Do not have a true pavement management section at this time.	Begun to put information
Maine Dept. of Trans.	Yes	- - - - -	No formal name	- - - -	- - - - -
Maryland Dept of Trans.	Yes	- - - - -	Maryland Pavement Management	- - - -	- - - - -
Massachusetts Dept. of Public Works	Informal	Mays roughness numbers for candidate proj., deflection Analysis/Field Insp. for Proj. Design. Informal lines of communication Between programming, maint. design, planning, research construction	- - - - -	Yes	Commissioner directed a Task Force establish PMS by Apr. 1, 1986
Michigan Dept. of Trans.	Revising Process	Each Dist. submits a prioritized list of proj. to a screening committee that develops a statewide program. A pavement management system is being developed & impl. in districts & in future is to be incrementally implemented as part of the pavement management process.	Michigan DOT's Pavement Management System	Such plans have not been promulgated	
Minnesota Dept. of Trans.	Yes, but parts are still under development	- - - - -	Pavement Management System	- - - -	Anticipate implementing final portion in 1988

TABLE A-I (Continued)

AGENCY	DOES AGENCY HAVE A PAVE-MENT MANAGE-MENT PROCESS OR SYSTEM	IF NOT NOW, HOW ARE PAVEMENTS MANAGED	WHAT IS THE NAME OF THE PAVEMENT MANAGEMENT PROCESS OR SYSTEM	IF NO PAVEMENT MANAGEMENT NOW	
				PLAN TO DO SO?	IN WHAT TIME FRAME
Mississippi State Hwy Department	NO	Through maintenance standards and programmed overlays or reconstruction	- - - - -	Yes	Indefinite
Missouri Highway and Transportation Dept.	NO	Generally, decisions for pavement improvements are based on the riding quality and maintenance cost	- - - - -	Yes	Within the next 12 months
Montana Dept. of Highways	Yes	- - - - -	The Montana Pavement Management System	- - - -	- - - - -
Nebraska Dept. of Roads	Yes	- - - - -	Nebraska Pavement Management System	- - - -	- - - - -
Nevada Dept. of Trans.	Yes	- - - - -	Pavement Management System	- - - -	- - - - -
New Hampshire Dept. of Trans.	Yes, but just beginning	In past, resurfacing needs were prioritized by Division Engrs. and screened by State Maint. Engr. for state wide prioritization	Pavement Management System	- - - - -	- - - - -
New Jersey Dept. of Trans.	Yes	- - - - -	Pavement Management System	- - - -	- - - - -
New Mexico State Hwy Department	Yes	- - - - -	Pavement Management System	- - - -	- - - - -
New York Dept. of Trans.	No	Maint. Engr. (67) recommend candidate projects for maint. and rehab. These projects are reviewed at the region and main office levels in order to select proj. for the construction program.	- - - - -	Yes	Over next several years phased in, Beginning with Interstate Networks
North Dakota State Hwy Department	Under development	- - - - -	ND PMS	- - - -	- - - - -
Ohio Dept. of Trans.	Partial PMS	Annual priority ranking process based on current pavement conditions (pavement distress, pavement roughness and skid) no predictive capability	Maintenance Urgency Category (MUC)	Yes, a consultant has been hired	One year for 1300 miles of interstate Three years for 19000 miles of State Hwy.
Oklahoma Dept of Trans.	No	- - - - -	- - - - -	Yes	- - - - -

TABLE A-I (Continued)

AGENCY	DOES AGENCY HAVE A PAVEMENT MANAGEMENT PROCESS OR SYSTEM	IF NOT NOW, HOW ARE PAVEMENTS MANAGED	WHAT IS THE NAME OF THE PAVEMENT MANAGEMENT PROCESS OR SYSTEM	IF NO PAVEMENT MANAGEMENT NOW	
				PLAN TO DO SO?	IN WHAT TIME FRAME
Oregon State Hwy Division	Yes	- - - - -	Pavement Management System (PMS)	- - - -	- - - - -
Pennsylvania Dept. of Trans.	Yes	- - - - -	Roadway Management System	- - - -	- - - - -
South Carolina Dept of Hwy and Public Trans.	Yes	- - - - -	Pavement Management System	- - - -	- - - - -
South Dakota Dept. of Trans.	Yes	- - - - -	Pvmt Management Accomplished through the use of needs analysis and project analysis programs, project ranking programs, costing programs and data listings.	- - - -	- - - - -
Tennessee Dept. of Trans.	Yes	- - - - -		Program is presently being Impl.	
Texas Dept. of Hwys and Public Trans.	No, but have an Evaluation System	Currently, Pavement projects are selected by each of 24 Field Districts	Pavement Evaluation System (PES)	Yes	A task force is in the making
Utah Dept. of Trans.	Yes	- - - - -	Pavement Management Unit	- - - -	- - - - -
Vermont Agency of Transp.	Yes	- - - - -	Pavement Management System	- - - -	- - - - -
Virginia Dept of Highways and Transp.	Yes	- - - - -	Virginia Pavement Management System	Have Pavement Management Program	- - - - -
Washington State Dept of Transp.	Yes	- - - - -	Washington State Pavement Management System	- - - -	- - - - -
Wisconsin Dept of Transp.	Not a formal system	Wis. DOT has most of the elements of a pavement management system but these are not integrated within a single unit or section.	- - - - -	No timetable for establishing an integrated P.M. System	- - - - -
Wyoming State Hwy Dept.	No	At this time, the District Engineers decide which pavement sections require improvement based on experience and knowledge	Pavement Management System (PMS)	Yes	Now in process of programming Logic for first version of Wyö's PMS Hope to make program. Recommendations in Oct.

TABLE A-I (Continued)

AGENCY	DOES AGENCY HAVE A PAVE-MENT MANAGE-MENT PROCESS OR SYSTEM	IF NOT NOW, HOW ARE PAVEMENTS MANAGED	WHAT IS THE NAME OF THE PAVEMENT MANAGEMENT PROCESS OR SYSTEM	IF NO PAVEMENT MANAGEMENT NOW	
				PLAN TO DO SO?	IN WHAT TIME FRAME
District of Columbia Dept of Public Works	Yes	- - - - -	D.C. Pavement Management System	- - - -	- - - - -
Alberta Transp.	Yes	- - - - -	Alberta Transportation Pavement Management System (PMS)	- - - -	- - - - -
New Brunswick Dept. of Transp.	Yes	- - - - -	NBDOT Pavement Management System	- - - -	- - - - -
Nova Scotia Dept. of Transp.	No	Formal planning process applied supplemented with Pavement evaluation data.	- - - - -	Yes	5 years
Ontario Ministry of Transp. and Communication	Yes	- - - - -	Pavement Management System	Yes	1987
Saskatchewan Hwys and Transp.	Yes	- - - - -	Pavement Information System	Plan to formalize & increase Automation in next 18 mo.	- - - - -
San Diego County California	Yes	- - - - -	Pavement Management	- - - -	- - - - -

TABLE A-2 PAVEMENT MANAGEMENT ORGANIZATIONAL STRUCTURE AND RESPONSIBILITY

AGENCY	WHAT POSITION(S) OR DIVISION(S) ARE RESPONSIBLE FOR PAVEMENTS OR MANAGING PAVEMENTS	ORGANIZATIONAL CHART OR STRUCTURE	APPLICABLE POLICY OR PROCEDURAL STATEMENTS
State of Alabama Highway Department	Research Division of Materials and Tests Bureau	The Pavement Management Section in the Research Division of the Bureau of Materials and Tests.	- - - - -
Arizona Department of Transportation	Pavement Management Branch	The Pavement Management Branch under Pavement Services of the Materials Section	- - - - -
Arkansas State Highway and Transportation	Pavement Management Section in Roadway Design	Roadway Design is under Assistant Chief Engineer Design who is under Chief Engineer	- - - - -
California Department of Transportation (CALTRANS)	Division of Maintenance Pavement Rehabilitation Branch	Pavement Management and Rehabilitation Branch under Office of Highway Maintenance, under Division of Maintenance, under Deputy Director Maintenance and Operations, under Chief Deputy Director	- - - - -
Colorado Department of Highways	Network Level - Program Section of Planning Division. Project Level not formalized	Program Management Branch under Division of Transportation Planning under Deputy Director	- - - - -
Connecticut Department of Transportation	Current - Office of Maintenance Future - P.M. Division?	- - - - -	- - - - -
Delaware Department of Transportation	Pavement Management	- - - - -	- - - - -
Florida Department of Transportation	Many Offices participate in Pavement Management Process. The activities are coordinated through the State Pavement Design Engineer	An office with title "Pavement Management" does not exist in the Department, rather practically every office is integrated into the Depts. Pavement Management Program, coordination is through State Pavement Design Engineer	- - - - -
Georgia Department of Transportation	Operations Maintenance	- - - - -	"Pavement Management and Road Information System (PMRIS) Notice" (91)
Hawaii Department of Transportation	Soil Engineering and Pavement Design Section	Soils Engineering and Pavement Design Section under Materials Testing and Research Branch under Highways Division	- - - - -
Idaho Transportation Department	PMS Coordinator - Management Services Section	Pavement Management under Transportation Systems Analysis under Transportation Services under Director	- - - - -
Illinois Department of Transportation	Highways, Planning and Programming	Office of Planning and Programming under Assistant Secretary of Transportation.	- - - - -
Indiana Department of Highways	Divisions of Planning, Research, and Training, and Maintenance	P.M. Committee Members, Division of Planning, Division of Research & Training, Division of Computer Services, Division of Maintenance Engineering and Management Services Chief Engineer	"PVMT Management Committee" Policy 6-6 (92) "Highway Inventory & Systems" Policy 8-3 (93) "Resurface Program" Policy 15-4 (94) "Division of Planning-Preface" (95)

TABLE A-2 (Continued)

AGENCY	WHAT POSITION(S) OR DIVISION(S) ARE RESPONSIBLE FOR PAVEMENTS OR MANAGING PAVEMENTS	ORGANIZATIONAL CHART OR STRUCTURE	APPLICABLE POLICY OR PROCEDURAL STATEMENTS
Iowa Department of Transportation	In 1979 a Pavement Management Committee was formed and given the task of developing a pavement management system. The committee establishes objectives and provides support and manpower for the attainment of these objectives. The original committee consisted of representatives from Road Design, Materials, and Data processing, along with the Highway Division Director. A Pavement Management Coordinator was assigned from the Office of Materials to research existing data and pavement evaluation practices, and to coordinate activities for the establishment of an accurate and concise data base through computer programming and accessing of existing records. In 1980 the committee was expanded to include a member of the Planning & Research Division and FHWA representatives were invited to attend the meetings. Members of the Field Review Team (Office of Road Design) joined the Pavement Management Committee in 1986. The achievement of Pavement management objectives is accomplished through the combined effort and cooperation of the Pavement Management Committee members as described above. The attached organizational charts are highlighted to indicate the positions of these members.	P.M. Committee Members - Hwy Division Director, Road Design, Materials, Data Processing, Planning and Research Division, Members Field Review Team, Pavement Management Coordinator from Office of Materials	- - - - -
Kansas Department of Transportation	Division of Planning and Development, Division of Operations	Policy Development Task Forces & Office of Project Selection under Director of Division of Planning & Development; Bureau of Materials & Research under Director of Division of Operations. All under State Transportation Engineer	"Standard Operating Manual: Pavement Management System" (96)
Kentucky Department of Highways	Pavement Management Unit	Pavement Management Unit under Assistant State Highway Engineer for Operations	"Chapter 40-15: Pavement Management." (97)
Louisiana Department of Transportation and Development	Pavement and Geotechnical Design Section	- - - - -	- - - - -
Maine Department of Transportation	Pavement Management Engineer Presently pavement management is located in the Bureau of Planning. The pavement management unit provides a departmental wide service crossing Bureau lines and thus requires input and technical services from all Bureaus within MeDOT. To ensure this relationship, a PMS Technical Advisory Council (TAC) has been established to which the unit reports periodically. The Advisory Council's primary functions are as follows: 1. Provide advice and direction to the PMS unit. 2. To ensure departmental wide coordination and cooperation. 3. To ensure success in the meeting of recognized goals. Composition of the council is as follows: Chief Engineer Chairman * Engineer of Design ** Engineer of Materials & Research (2) Engineer of Construction Director of Computer Service * Director of Bureau of Planning * Director of Maintenance and Operations Director of Office of Policy Analysis Asst. Director of Bureau of Finance and Administration * District Engineer ▼	P.M.S. Activities under Roadway Section, under Technical Services Division, under Bureau of Project Development, under Deputy Commissioner of Highways	- - - - -

TABLE A-2 (Continued)

AGENCY	WHAT POSITION(S) OR DIVISION(S) ARE RESPONSIBLE FOR PAVEMENTS OR MANAGING PAVEMENTS	ORGANIZATIONAL CHART OR STRUCTURE	APPLICABLE POLICY OR PROCEDURAL STATEMENTS
Maine Department of Transportation (CONT)	Associate non voting members include a representative of the FMWA division office and six (6) senior managers from sections noted with an (*). The majority of technical support originates from the Research and Development Section Pavement evaluation teams consist of technicians originating from Design, Materials & Research, Construction, Planning and District Maintenance & Operations.		
Maryland Department of Transportation	Office of Materials and Research	Pavement Management Section under Bureau of Soils and Foundations Field Data Collection under Developmental Research under Bureau of Research	- - - - -
Massachusetts Department of Public Works	Maintenance, Design, Construction, Research	Highway Maintenance under Chief Maintenance, Pavement Design under HDWY & Structures, Engineering under Chief Engr. Research and Materials under Planning Director, Construction	- - - - -
Michigan Department of Transportation	PMS is being developed in the Materials and Technology Division of the Highway Bureau	PMS/BMS Section under Division Administrator in Materials and Technology Division	- - - - -
Minnesota Department of Transportation	Tech. Ser. Division, Res. & Dev. & Pvmt. Mgt. Section	Pavement Management Section under Office of Research and Development under Assistant Division Director in Technical Services Division	- - - - -
Mississippi State Highway Department	Maintenance, Construction, Design, Materials	- - - - -	- - - - -
Missouri Highway and Transportation Department	Planning and Maintenance. A Pavement rating team made up of representatives from Planning, Surveys & Plans, Materials, and Maintenance checks and rates the riding quality each year of the worst 1,000 miles of pavement sent in by the districts	- - - - -	- - - - -
Montana Department of Highways	District Engrs. are responsible for all plant in their area including pvmts. The Program Development Div. in Helena operates the pvmt. mgt. sys which collects data and is used to aid in making decisions regarding pavements.	Pvmt. Mgt. Sect. under Bureau Chief of Projects, Analysis under Administrator of Program Development Div., under Deputy Director	- - - - -
Nebraska Department of Roads	Program Management Division	Program Management Division under Deputy Director Planning under Director State Engineer.	- - - - -
Nevada Department of Transportation	Materials; Maintenance: Operations Analysis	Maintenance, Materials and Testing and 3 Districts under Assistant Director Operations, and Operations Analysis all under Deputy Director	- - - - -
New Hampshire Department of Transportation	Pavement Management Section in the Planning and Economics Division of Dept. of Public Works and Highways	Pavement Management under Transportation Planning and System Management under Administration, under Assistant Commissioner	- - - - -
New Jersey Department of Transportation	Bureau of Maintenance	Maintenance under Assistant Engineer Const. & Maint. under Const. & Maint. Engr. under Deputy State Highway Engr. also Design under Deputy State Highway Engr.	- - - - -

TABLE A-2 (Continued)

AGENCY	WHAT POSITION(S) OR DIVISION(S) ARE RESPONSIBLE FOR PAVEMENTS OR MANAGING PAVEMENTS	ORGANIZATIONAL CHART OR STRUCTURE	APPLICABLE POLICY OR PROCEDURAL STATEMENTS
New Mexico State Highway Department	Pavement Management Engineer	Pavement Management unit under Maintenance Section under Engineering/ Operations Division	- - - - -
New York Department of Transportation	Planning, Facilities Design, Highway Maintenance, Construction, Technical Services	Areas identified as having responsibilities relating to pvmt. mgt. are Highway Maint., Planning, Facilities Design, Construction, Technical Services, Program Planning & Management and Regions.	- - - - -
North Dakota State Highway Department	Planning, Program & Project Development, Design	- - - - -	- - - - -
Ohio Department of of Transportation	Bureau of Technical Services	Bureau of Technical Services under Systems Planning Admin. under Division of Planning and Design under Assistant Director of Transportation for Highways	- - - - -
Oklahoma Department of Transportation	- - - - -	- - - - -	- - - - -
Oregon State Highway Division	Pavement Management Unit, Planning Section	Pvmt. Mgt. Group in Planning Section under Admin. Branch under State Highway Engr. Principal participants in Pvtm. Mgt. are planning Sections, Road Design Section, Traffic Design Section, Const. Section, Maint. Section and Regions	- - - - -
Pennsylvania Department of Transportation	Roadway Management Division	- - - - -	- - - - -
South Carolina Department of Highways and Public Transportation	Maintenance	Maintenance under Engineering Division with State Highway Engr.	- - - - -
South Dakota Department of Transportation	Planning	Program Engineer under Data Analysis under Division of Planning under Secretary of Transportation	- - - - -
Tennessee Department of Transportation	Several Divisions have Joint Responsibility	- - - - -	- - - - -
Texas Department of Highways and Public Transportation	Maintenance Division and Highway Design Division	- - - - -	- - - - -
Utah Department of Transportation	Pavement Management Unit in Planning and Programming	Pavement Management Unit under Office of Policy and System Planning under Director of Transportation	"Policy - Pavement Management Steering Committee" (40)
Vermont Agency of Transportation	Pvmt. Mgt. is overseen by a committee composed of 1 Engineering Executive "A" from the Planning Division and 4 Engineer "D"s: 1 each from the Const., Design, Maint., and Materials Divisions. In addition, the Directors of Engineering and Maintenance are Ex-office members, available for advise and arbitration.	- - - - -	- - - - -

TABLE A-2 (Continued)

AGENCY	WHAT POSITION(S) OR DIVISION(S) ARE RESPONSIBLE FOR PAVEMENTS OR MANAGING PAVEMENTS	ORGANIZATIONAL CHART OR STRUCTURE	APPLICABLE POLICY OR PROCEDURAL STATEMENTS
Virginia Department of Highways and Transportation	Maintenance and Materials Divisions Materials Division performs skid, roughness and deflection testing and designs pavements. Information sys. Division provides computer support. Each Dist. has pvmt. mgt. coordinator and conducts condition surveys	Pvmt. Mgmt. Engr. under Maint. Program Planning under Maint. Division	- - - - -
Washington State Department of Transportation	Pavement Management Section in the Materials Laboratory	Pvmt. Mgt. Section in materials lab under Construction under Assistant Secretary for Highway Divisions	- - - - -
Wisconsin Department of Transportation	Design, Maintenance, Materials and Program Development Sections in Both Central Office and Districts	Central Office Design under Bureau of Engr. Development. Central Office Maint. and Central Office Materials under Bureau of Engineering Operations. And Bureau of Program Management all under Division of Highways and Transportation Services	- - - - -
Wyoming State Highway Department	The Needs Analysis Section of the Planning Branch is responsible for the design & implementation of pvmt. mgt. system. This system is to be used by the District Engineer as a tool, to help determine which pavement sections require improvement.	Materials Branch, Construction & Maint. Branch, and Planning Branch Highway Analysis under Planning Branch	
District of Columbia Department of Public Works	Office of Materials Development and and Research	- - - - -	- - - - -
Alberta Transportation	Pavement Systems Unit, Surfacing Section Materials Eng. Branch	Pvmt. Systems Engineer under Assistant Director Surfacing under Director Materials Engr. Branch under Engineering under Deputy Minister	- - - - -
New Brunswick DOT	Planning, Design, Construction, Maintenance. Committee approach with Planning taking the key role	- - - - -	- - - - -
Nova Scotia DOT	Engineers and Superintendents	- - - - -	- - - - -
Ontario Ministry of Transportation and Communications	Planning, Programming, Design, Maintenance, Geotechnical, Research	Various units at Region and Head Office involved in Pavement Management Process for Network and Project Maintenance	- - - - -
Saskatchewan Highways and Transportation	Surfacing Branch, Maintenance Branch Operations Division, Research Branch	- - - - -	"Surfacing Manual - Seal Coat Policy" (98) "Surfacing Manual - Evaluating Structural Adequacy" (99)
San Diego, California	Field Operations Division, Principal Civil Engineer	Materials Lab under Construction does Road Rating and Visual Surveys. Pavement Management under Traffic Operations/Administration	- - - - -

TABLE A-3 HOW PAVEMENT MANAGEMENT DEVELOPED

AGENCY	HOW PAVEMENT MANAGEMENT DEVELOPED OR ESTABLISHED	UNDER WHOSE DIRECTION	REPORTS RELATED TO HOW PAVEMENT MANAGEMENT WAS DEVELOPED
State of Alabama Highway Department	Evolved from Needs Studies	Materials and Tests and Research Engineers	"Executive Summary for a Research Project Entitled a Pavement Rating Procedure" (100)
Arizona Department of Transportation	State Engineer Originally Authorized Development	- - - - -	"Arizona's Pavement Management System - Summary and Development - - -" (17) "Development of a Network Optimization Syst. Final Report. Vol. 1" (101)
Arkansas State Highway and Transportation Department	Under the Direction of the Pavement Management Engineer by Literature Review and personal visit to one state to analyze its program	Pavement Management Eng.	"Arkansas Pavement Management Program." (102)
California Department of Transportation (CALTRANS)	Developed within Caltrans	Caltrans Steering Committee	"Development of California's Pavement Management System" (34) "Pavement Management in California - Chapter H"(13)
Colorado Department of Highways	Utilized the Arizona System as a model	Pavement Management Steering Committee	"Summary Report of Colorado's Network Level - Pavement Management System" (103)
Connecticut Department of Transportation	Current Devlopment work is being performed by Division of Research	- - - - -	"Pavement Management in Connecticut Phase I - Feasibility" (104) "Pavement Management in Connecticut - Phase II - Development" (105)
Delaware Department of Transportation	Excerpts from other systems	Pavement Management Committee	- - - - -
Florida Department of Transportation	Pavement Management has evolved over the years. Many modules were developed by the Dept. prior to the current concept of an integrated pvmt. management syst. For instance the pvmt. condition survey process has been underway for many years. The formalized project priority process was developed by Planning over 15 years ago and has been constantly improved as the formal development of the Departments work program	- - - - -	- - - - -
Georgia Department of Transportation	Stanley Lord, Maintenance Jack Williams, Planning Data Services	- - - - -	"Task Force Report - Pavement Management System" (91)
Hawaii Department of Transportation	Use California's System with some modifications	- - - - -	- - - - -
Idaho Department of Transportation	Borrowed from Utah and modified for Idaho	Management Services Manager	(106) "Implementation of Idaho's Pavement Management System"
Illinois Department of Transportation	Being jointly developed by IDOT & University of Illinois	IDOT's Pavement Management Committee	"An Illinois Pavement Feedback System Feasibility and System Requirements - Interim Report." (26)

TABLE A-3 (Continued)

AGENCY	HOW PAVEMENT MANAGEMENT DEVELOPED OR ESTABLISHED	UNDER WHOSE DIRECTION	REPORTS RELATED TO HOW PAVEMENT MANAGEMENT WAS DEVELOPED
Iowa Department of Transportaion	The needs of Iowa's primary road system shifted away from construction and towards maintenance and rehabilitation, and as the availability of funds failed to keep pace with new and existing highway system needs, management came to recognize the need for a "pavement management system" based on objective data which would serve as an aid in formulating highway programming decisions. In 1979 a pavement management committee was formed at the request of the Highway Division Director to initiate the development of a pavement management system. Members of the committee include personnel as described in the answer to question A-2. A federally-funded, eight-state pilot study in Long Term Pavement Monitoring, which was in progress at this time, provided information and funding assistance for pavement management development. Information was developed on the type of data needed, the data collection frequency, and analysis required.	- - - - -	"Iowa's Pavement Management System." (68)
Kansas Department of Transportation	Being developed by Woodward-Clyde Consultants & PMS Task Force	Secretary of Transportation & Director of Planning and Development	"Kansas DOT Pavement Management System." (35) "Condition Surveys to support Pvmt Management in Kansas" (107)
Kentucky Department of Highways	The Pavement Management Unit was assembled within the Division of Maintenance in 1981. Shortly thereafter, the unit was moved to the State Highway Engineers Office under the Assistant State Highway Engineer for operations to provide for greater and more effective interacting of pavement management unit with other units of the Transportation Cabinet	By Engineer Responsible for it	"Pavement Management in Kentucky." (108)
Louisiana Department of Transportation and Development	- - - - -	- - - - -	- - - - -
Maine Department of Transportation	A study directed by C.A.D. in Nov. 1980 2 years initial development in Office of Policy Analysis	- - - - -	"Impacts of PMS on Policy and Multi-Level Decisions" (73)
Maryland Department of Transportation	Developed in house by the Office of Materials and Research	- - - - -	- - - - -
Massachusetts Department of Public Works	- - - - -	- - - - -	"Surface Characteristics of Pavements, Volume 2: - -" (109)
Michigan Department of Transportation	Presently being developed by the Materials and Technology Division	- - - - -	"Michigan Department of Transportation's Pavement Management System" (110)
Minnesota Department of Transportation	A Steerilng Committee was appointed and pavement section established. The planning was done in house and consultants used to develop portions of the system	- - - - -	"Pavement Management" Office Memo. (111) "Minutes of Pavement Management Steering Committee" (112)
Montana Department of Highways	Developed by a Technical Committee	L.S. Harris Project Coordinator	"Status of Pavement Management System" (113)
Nebraska Department of Roads	By Program Management	Lou Lamberty Director State Engineer	"Progress of Nebraska's Pavement Management System" (114)

TABLE A-3 (Continued)

AGENCY	HOW PAVEMENT MANAGEMENT DEVELOPED OR ESTABLISHED	UNDER WHOSE DIRECTION	REPORTS RELATED TO HOW PAVEMENT MANAGEMENT WAS DEVELOPED
Nevada Department of Transportation	In-House	Management Directive	"Nevada's Pavement Management System - 1982" (115) "Pavement Management System" (116)
New Hampshire Department of Transportation	Task Force of Planning, Maintenance, Research, Construction, & Computer Personnel	Department Administrator	"A Proposal for Improved Management of Highway Condition Preservation" (36) "The Highway System Monitoring Team Structure & Location within The Overall Highway Dept. Organization" (37)
New Jersey Department of Transportation	Through the Department's P.M. Task Force The Bureau of Maintenance and Research	- - - - -	- - - - -
New Mexico State Highway Department	Mostly In-House by the Present Pavement Management Engineer	- - - - -	"New Mexico State Highway Department Pavement Management Measurements and Systems" (9)
North Dakota State Highway Department	Pavement Management Coordinator in Planning Division	Chief Engineer	- - - - -
Ohio Department of Transportation	Developed by a Consultant	- - - - -	- - - - -
Oregon State Highway Division	Under the Direction of a Steering Committee and Task Force	- - - - -	"The Oregon Pavement Management System - A Progress Report" (117)
Pennsylvania Department of Transportation	Started with Task Force Development of STAMPP	- - - - -	"Systematic Technique to Analyze and Manage Pennsylvania Pavements" (38)
South Carolina Department of Highways and Public Transportation	Based on a 1980 study, a large number of roadway miles needed resurfacing at a tremendous cost. A modified P.M.S. was developed containing condition survey, rideability and structural adequacy	- - - - -	"Priority Programming" (118)
South Dakota Department of Transportation	Developed by Planning Division Personnel who utilized technology acquired from past FHWA Studies, ideas gathered from papers produced by other states and data readily available.	Glen Kietzmann	- - - - -
Tennessee Department of Transportation	Pavement Management Advisory Committee	Chief Engineer	"Proposed Program for Pavement Management in Tennessee" (39)
Texas State Highway Department and Public Transportation	Evolved from Research Studies Based on Department employee's experience	- - - - -	- - - - -

TABLE A-3 (Continued)

AGENCY	HOW PAVEMENT MANAGEMENT DEVELOPED OR ESTABLISHED	UNDER WHOSE DIRECTION	REPORTS RELATED TO HOW PAVEMENT MANAGEMENT WAS DEVELOPED
Utah Department of Transportation	Developed through a Pavement Management Task Force	Director Hurley	"Forming a Pavement Management Unit" (40)
Vermont Agency of Transportation	See "Pavement Management System" Reference No. (119)	- - - - -	"Pavement Management System" (119)
Virginia Department of Highways & Transportation	Established and Developed by Research and Maintenance	Directed by C.D. Leigh	"Status Report on P.M." (120) "Development of a P.M.S. for Virginia" (121) "An Approach to P.M. in Virginia" (122)
Washington Department of Transportation	Developed under Roger LeClerc (retired) Materials Engineer	- - - - -	"Development and Implementation of Washington State's P.M.S." (123)
Wyoming State Highway Department	The Superintendent of the Wyoming Highway Department created a steering committee in 1980 made up of personnel from Materials Laboratory, Construction and Maintenance and Planning. The committee was directed to research pavement management and recommend a plan of action to the Superintendent. In August, 1985 a plan of action was presented. At that time, the Superintendent directed that Planning Branch implement and be responsible for the proposed Pavement Management System. Since then, Planning Branch has refined and hopefully will soon implement a pavement management system.	Superintendent of Dept.	"Second Interim Report on Developemnt of Wyo. P.M.S." (124) "P.M.S. Staff Presentation" (125) "Project Definition for the P.M.S." (PVM) (126)
District of Columbia Department of Public Works	Task Force of D.C. Personnel and F.H.W.A.	Transportation Director	"Pvmt. Mgt. Task Force Executive Summary" (41) Pvmt. Mgt. task Force Final Report. (42)
Alberta Transportation	Developed by P.M.S. Ltd.	Materials Engineering Brand	(127, 128, 149)
New Brunswick Department of Transportation	In House by a Steering Committee of Planning, Design, Construction, Maintenance	- - - - -	- - - - -
Ontario Ministry of Transportation and Communications	Study Group	- - - - -	"Maintenance of the Highway Infrastructure - Pavement Management and Preservation" (129)
Saskatchewan Highways and Transportation	Developed by Surfacing Engineer, under Process of Incremental additions to evaluation, and design procedures	- - - - -	- - - - -
San Diego County California	Review of PMS of other county's and city's	- - - - -	"Pavement Management" (130)

TABLE A-4 HOW PAVEMENT MANAGEMENT IS STRUCTURED AND OPERATES

AGENCY	WHAT ELEMENTS OR ACTIVITIES CONTAINED IN THE PAVEMENT MANAGEMENT PROCESS	IS THE PROCESS FORMALIZED	IS THE PROCESS COMPUTERIZED? IF SO, TO WHAT EXTENT?	REPORTS RELATED TO HOW THE PAVEMENT MANAGEMENT PROCESS FUNCTIONS	INSTRUCTIONAL MANUALS AND GUIDELINES
Alabama Highway Department	Surface distress measurements, Highway Roughness, Traffic and Roadway Geometrics	Yes	Yes, extensively on IBM 3084 & IBM PC A7	(100)	- - - - -
Arizona Department of Transportation	Pavement Inventory, Network Optimization, Project Selection, Prediction models and more.	Yes	Yes; data input into a Data Base - Network Optimization and Predic- of distress computerized	(15, 17, 131)	- - - - -
Arkansas State Highway and Transportation Department	1) Pavement distress survey(visual w/actual measurements), 2) ride survey (Mays Ride Meter) 3) pavement condition rating (PCR) w/ADT adjustments, 4) Adjustments for predicted deterioration	Yes	contains a total of eleven separate programs	(102)	(132)
California Department of Transportation (CALTRANS)	Biennial Pavement Survey, annual transportation improvement program pavement performance research	Yes, Pavement management is a centralized process	Yes, the pvmt. survey data forms data base; computer analyzes data, selects candidate rehabilitation and maintenance locations and produces appropriate reports	(14, 65)	(14, 65)
Colorado Department of Highways	Allocate funds and suggest improvement actions (Routine maintenance seal coat, overlay) based on current pavement condition and available funds	Yes	Fully computerized currently on a mainframe, but efforts underway to transport it to a micro.	(103)	- - - - -
Connecticut Department of Transportation	Network-Level condition rating (distress and roughness); Network Level optimization; Project identification and selection; Project-Level optimization (future)	No. Under development	Computerization of system is ongoing Both mainframe & personal computers plus photolog laser video system will be utilized	- - - - -	- - - - -
Delaware Department of Transportation	Field observation of pavement surface roughness, maintenance requirements, plus traffic counts and skid testing. Geographical breakouts.	To some extent	Road segments are keyed to traffic count system. All computer and prioritized. Resurfacing cost data is computer generated.	- - - - -	- - - - -
Florida Department of Transportation	Pavement Management as a concept is global and encompasses all pavement management activities. Pavement Management is not an official or a computer program.	Many modules are formalized and well documented	System highly automated with a continuing ongoing effort to integrate more of files	- - - - -	- - - - -

TABLE A-4 (Continued)

AGENCY	WHAT ELEMENTS OR ACTIVITIES CONTAINED IN THE PAVEMENT MANAGEMENT PROCESS	IS THE PROCESS FORMALIZED	IS THE PROCESS COMPUTERIZED? IF SO, TO WHAT EXTENT?	REPORTS RELATED TO HOW THE PAVEMENT MANAGEMENT PROCESS FUNCTIONS	INSTRUCTIONAL MANUALS AND GUIDELINES
Georgia Department of Transportation	P.M.S. contains following files: Road Characteristic, Traffic Count, Railroad Highway Grade Crossing, Traffic Accident, Bridge Inventory, Project Plan, Pavement Roughness, Skid Resistance, Pavement Condition, and Road Life	Yes	On Line - Parts that have been fully developed	(91)	- - - - -
Hawaii Department of Transportation	Ride score, cracks, ruts, and raveling. Also, costs of various fixes	Yes. Follow California	Yes	- - - -	- - - - -
Idaho Department of Transportation	Idaho PMS is currently limited to pvmt. condition monitoring and ranking of pvmt. sections based on conditions	Yes	Fully computerized from field data collecting to data analyzing in office.	- - - -	- - - - -
Illinois Department of Transportation	As built design, materials properties construction info, condition survey, friction, roughness, maintenance, traffic, & climate info.	Certain aspects such as project programming	Yes, materials test data, some inventory items and programming data. Existing Bases are not really integrated	(26)	- - - - -
Iowa Department of Transportation	The objectives of the Iowa Pavement Management System, as established by the Pavement Management Committee, are as follows: 1. Provide a current data base for all offices concerned with pavements 2. Secure annual data updates identifying the current physical condition of all rural state highways. 3. Provide management with consolidated matrix information from which rational prioritization of projects and programming decisions can be made. 4. Provide a method of evaluating the performance of highways under different design, maintenance, and construction strategies. The basis for accomplishing the above objectives was the establishment of a pavement status data base which would be updated at appropriate intervals to provide all information needed to prioritize projects as specified in objective 3. The matrix prioritization process relies on the following pavement attributes: % remaining 18K ESAL, D-crack factor, structural rating from deflection testing, pavement width, rut depth, PSI deduction, longitudinal profile value, and average PSI decrease over the past six years. This information is gathered for all sections of Iowa's rural primary highway system and values are assigned based on the values of the eight attributes listed above. The result is an index listing which ranks each rural roadway section according to its performance characteristics. ▼	Iowa's Pavement Management System is a dynamic system still under development. The process is not formalized at this time, but as the system continues to evolve, responsibilities and activities are becoming more clearly defined.	Yes	(67, 68)	(69)

TABLE A-4 (Continued)

AGENCY	WHAT ELEMENTS OR ACTIVITIES CONTAINED IN THE PAVEMENT MANAGEMENT PROCESS	IS THE PROCESS FORMALIZED	IS THE PROCESS COMPUTERIZED? IF SO, TO WHAT EXTENT?	REPORTS RELATED TO HOW THE PAVEMENT MANAGEMENT PROCESS FUNCTIONS	INSTRUCTIONAL MANUALS AND GUIDELINES
Iowa (CONT)	Other outputs of the pavement management system include: - Section status which indicates present serviceability including such items as PSI, friction number, 18K ESAL, surface type, ADT, structural rating, etc. - Project history which includes cross-section information, aggregate and cement sources, date opened, mix type, subsequent rehabilitation projects, etc. - Pavement performance curves illustrating both system and project level experience over multi-year periods for selected measures of serviceability. Also under development are programs for project optimization and rehabilitation modeling based on historical data and the projection of future pavement performance.				
Kansas Department of Transportation	Network & Project Level Condition Surveys, Budgeting and Program, Development using "Time Optimization," Maint. Needs Analysis, Project Design, Performance Projection, Research	Yes	PMS uses large scale linear programming package several support programs including an LP Matrix Generator, and several integrated data bases.	(35)	(133)
Kentucky Department of Highways	Current Pvmt. Mgt. activities include evaluation, project selection and development of pvmt. rehab. strategies recommendations Pvmt. evaluation activities at statewide system level include ride quality & estimated pvmt. serviceability, skid resistance, visual condition ratings, and the accumulation of traffic volumes, and pavement fatique.	Yes	Yes. Almost all measurements are automatically recorded and stored in computer for retrieval, summaries, and analysis Also all information and data used are computer stored and retrieved and summarized automatically.	(108)	- - - - -
Maine Department of Transportation	Planning/Programming, Design, Construction, Maintenance evaluation and Research	Yes	Yes - all network data by Homogenous Section, including Traffic, Age, System, Distress & Serviceability and Miscellaneous Recommendations of D.E., prior approval of D.E. funds	(73)	(76, 79, 80)
Maryland Department of Transportation	Visual distress survey, traffic roughness, and surface frictional characteristics	Yes	Manual data input data analysis, and report generation using IBM PC	- - - -	(134)
Massachusetts Department of Public Works	- - - - -	- - - - -	- - - - -	(109)	- - - - -
Michigan Department of Transportation	A project management system, A network management system, and a Data management system.	Somewhat	Only Network Surveys are computerized	(110)	- - - - -

TABLE A-4 (Continued)

AGENCY	WHAT ELEMENTS OR ACTIVITIES CONTAINED IN THE PAVEMENT MANAGEMENT PROCESS	IS THE PROCESS FORMALIZED	IS THE PROCESS COMPUTERIZED? IF SO, TO WHAT EXTENT?	REPORTS RELATED TO HOW THE PAVEMENT MANAGEMENT PROCESS FUNCTIONS	INSTRUCTIONAL MANUALS AND GUIDELINES
Minnesota Department of Transportation	The data base contains condition ratings (roughness and distress) pavement strength construction history, maintenance costs, traffic (count and ESALS) & pvmt. friction. Will also, when complete, recommend potential rehab. candidates and the type of rehabilitation	Yes	All of the data is or soon will be computerized. Also the process to recommend potential rehabilitation candidates and the type of rehabilitation will be computerized	- - - -	(135, 136)
Missouri State Highway and Transportation Department	- - - - -	- - - - -	- - - - -	- - - - -	(137)
Montana Department of Highways	Condition inventory; PMS data to users; pavement life determination; management reports on pavements; "Candidate Projects Report Using Selected Repair Strategy."	Yes, but still expanding.	Yes. Adopted CA System. Store pvmt. condition inventory, produce candidate projects & costs using repair strategies and district priorities, all with computer.	- - - - -	(138)
Nebraska Department of Transportation	At network level- Program management, Planning, Budgeting, Design Monitoring Condition, Maintenance	Yes	Yes. It is about 90% complete	- - - - -	(139, 140)
Nevada Department of Transportation	Annual pavement condition survey; Computer analysis of required pavement repairs; Rehabilitation project prioritization.	Yes	Yes. Compilation of Condition Data; Identification of repair strategies; Calculation of project priority numbers.	(115, 116)	- - - - -
New Hampshire Department of Transportation	Initially used the following elements: 1. Roughness measured by Mays Meter 2. Cracking - subjective opinion of pvmt. experts. 3. Rutting - " " " " " 4. Excess patching - " " " " " 5. Foundation Quality - " " " " Recently aquired an ARAN Vehicle with IBM-PC A7 to speed the collection of data and process reports	It will become a formalized system. Primarily for resurfacing but has Dept. wide use in a total Highway Management System	Fully computerized	(37, 51)	(141)
New Jersey Department of Transportastion	Skid testing, Road Roughness Measurements, Pavement Condition (Distress), Ratings and Traffic Volumes	Yes	Skid and Mays Data collected on Magnetic Tape. Condition ratings done by hand on forms	- - - - -	(142, 143)
New Mexico State Highway Department	Pavement distress evaluations & pavement roughness surveys. This data is combined for a pavement rating which is used in project priority setting.	Yes	Only data handling is computerized	(9)	- - - - -

TABLE A-4 (Continued)

AGENCY	WHAT ELEMENTS OR ACTIVITIES CONTAINED IN THE PAVEMENT MANAGEMENT PROCESS	IS THE PROCESS FORMALIZED	IS THE PROCESS COMPUTERIZED? IF SO, TO WHAT EXTENT?	REPORTS RELATED TO HOW THE PAVEMENT MANAGEMENT PROCESS FUNCTIONS	INSTRUCTIONAL MANUALS AND GUIDELINES
North Dakota State Highway Department	Pavement evaluation, planning, programming, design, construction, maintenance, prioritization	Yes	Yes, Mainframe data storage, IBM PC A7 Data Analysis	- - - - -	(16)
Ohio Department of Transportation	Pavement Condition Rating (PCR), Present Serviceability Index (PSI) Skid Resistance, Truck Traffic, Engineering Judgement	Partially	Priority Ranking on a Project, Level for Multilane Highways Base of Data on Computer	- - - - -	(144)
Oregon State Highway Division	Pavement Condition Ratings, Pavement Management System Index (PMSI), Life Cycle Program (Network Level Prediction Model)	Yes	Statewide data bases on microcomputer and mainframe, can be tied to digital computerized mapping analysis system.	(117)	- - - - -
Pennsylvania Department of Transportation	Pavement design, Evaluation, Data base, Management	Yes	Full system under development for Oct. 1, 1986 Startup.	(38, 86-88)	(84)
South Carolina Department of Highways and Public Transportation	Condition Survey, Rideability, and Structural Adequacy	Yes	Condition Survey & other data key punched into computer and Pavement Condition Index (PCI) determined by computer process	- - - - -	
South Dakota Department of Transportation	Sufficiency ratings, profilometer, dynaflect, skid, accidents, traffic geometrics, age of grade and surface, PSR, maintenance costs, determination of type of improvement to be made, project ranking, estimates of costs using units and current prices, listings of projects by deficiencies, lists of prioritized projects, and anticipated improvements with cost for each project on the state highway system over the next 20 years.	Individual programs or documented but documentation of the overall process is not completely documented.	The process is made up of a bank of computer programs plus phases that require manual analysis. Overall process is not completely documented.		(145)

TABLE A-4 (Continued)

AGENCY	WHAT ELEMENTS OR ACTIVITIES CONTAINED IN THE PAVEMENT MANAGEMENT PROCESS	IS THE PROCESS FORMALIZED	IS THE PROCESS COMPUTERIZED? IF SO, TO WHAT EXTENT?	REPORTS RELATED TO HOW THE PAVEMENT MANAGEMENT PROCESS FUNCTIONS	INSTRUCTIONAL MANUALS AND GUIDELINES
Tennessee Department of Transportation	Note: TDOT is purchasing a van equipped for automated data collection. The following information is collected in the field and recorded on magnetic tape for computer analysis. 1. Pavement roughness 2. Rutting depth 3. Type and severity of distresses 4. Grade and Cross-fall 5. Curve radius and super elevation 6. Transverse pavement profile 7. Video log inventory Software is being developed for IBM Personal Computer that will generate the following reports: 1. Ride/Roughness 2. Surface Distress Rating 3. Rutting Condition 4. Grade and Cross-fall 5. Shim Quantities 6. Curve Radius 7. Resurfacing, Rehab. and Mtce. Needs 8. Project Priority Rankings 9. Safety Analysis	Not Yet	Being Computerized	(39)	(146)
Texas State Highway Department and Public Transportation	Annual Visual and ride evaluation of approximately one third of the State Highway System	No	Yes, standardized computer reports are the result of manually recorded data that is key entered to the mainframe		(49, 147)
Utah Department of Transportation	Preconstruction, Planning and Programming, Construction, Maintenance, Materials, Research, and Monitoring	Being Formalized	Is in the process of being developed. Pvmt. condition survey is computerized	(63)	- - - - -
Vermont Agency of Transportation	Pavement Inspection, Evaluation, Priority Determination, Treatment Type, Cost Estimation, and Pavement Section, and Project Monitoring	- - - - -	It is computerized	(119)	- - - - -
Virginia Department of Highways and Transportation	Condition Surveys, Skid Testing Deflection Testing, and Projections	Yes	Fully Computerized	(121, 122))	(148)
Washington Department of Transportation	Development of Pavement Priority Array, Review of the Rehabilitation Program, Analysis of General Program and needs, Monitoring of system conditions as well as projection of future condition	Somewhat	Yes, Fully	(123)	

TABLE A-4 (Continued)

AGENCY	WHAT ELEMENTS OR ACTIVITIES CONTAINED IN THE PAVEMENT MANAGEMENT PROCESS	IS THE PROCESS FORMALIZED	IS THE PROCESS COMPUTERIZED? IF SO, TO WHAT EXTENT?	REPORTS RELATED TO HOW THE PAVEMENT MANAGEMENT PROCESS FUNCTIONS	INSTRUCTIONAL MANUALS AND GUIDELINES
Wyoming State Highway Department	A computerized data base of over 7,000 roadway sections is the heart of our pavement management system. A computer program is being developed to prioritize those roadway sections based on pavement surface conditions.	The generation of recommendations will be formalized. The actual use of recommendations is at the District Engineers' discretion. PMS is seen as a tool to be used by the District Engineer.	Yes. The recommendation process is 100% computerized. The implementation process is 100% District Engineers' gut instinct. In the past, the District Engineers have usually accepted our recommendations.	(126)	-----
District of Columbia De-	Monitoring, Budgeting and Programming, and Research	Yes	All streets are stored in Mainframe computer block by block, Info. on pvmt. type, curb, gutter, sidewalk layer thickness, block length, pvmt. condition, classification, ADT etc.	-----	-----
Alberta Transportation	Pavement Information and Needs System (PINS) & Rehabilitation Information and Priority Programming System (RIPPS)	Yes	Yes, pvmt mgt. on Network Level including economic analysis and optimization	(127, 128, 149)	-----
New Brunswick Department of Transportation	Data Base includes strength, ride, surface age, traffic volume and composition. Deficiencies and priorities are established at Network Level only	To a degree in early stages	Data Base is computerized along with basic deficiency and Priority Identification Package	-----	-----
Ontario Ministry of Transportation	Major Maintenance (ie crack sealing, patching) and rehabilitation (overlays, recycling, etc.)	Not completely	Currently being computerized	(129)	
Saskatchewan Highways and Transportation	Condition surveys - based on sections of concern from Maint./Dis. Personnel. Annual ride measurements, and maint. activities and levels and (Deflection data) on rehab. candidates for design purposes only.	Have a formula procedure to establish future needs	Annual programs, ride, deflection systems are computerized and long range projections are computerized	-----	-----
San Diego County, CA	Visual Survey, Road Rating	Yes	Totally with listings of all factors and recommended treatments	(130)	(150)

TABLE A-5 OUTPUTS, EFFECTIVENESS, AND BENEFITS

AGENCY	OUTPUTS		REPORTS DOCUMENTING OUTPUTS	EFFECTIVENESS AND WEAKNESSES			BENEFITS FROM PAVEMENT MANAGEMENT	REFERENCES DOCUMENTING BENEFITS
	TYPES	WHERE AND HOW USED		HOW EFFECTIVE	COST EFFECTIVE?	WHAT WEAKNESSES?		
Alabama Highway Department	Prioritized Listings of Highway Systems for Resurfacing & Rehabilitation.	Final Stages of Development	- - - - -	Unknown at this time	Unknown at this time	Unknown	Unknown	
Arizona Department of Transportation	Pavement Condition now and future traffic, maint., etc.	Used in decision making process by mgt. with pvmt. mgt. & by Districts	(151, 152)	In use since 1980 with good support	Yes, See References	Difficult to distinguish need between reconstruction & preservation	Dollar savings formalized process, thus reducing internal disagreement. See References	(131, 153)
Arkansas State Highway and Transportation Dept.	Printouts by route and section priority etc. of pavement condition ratings.	Used to determine priorities for I4-R program, assist in determining overlay program priorities.	(154)	More effective as program develops	Yes	Needs to be tied to maint. program activities and effectiveness. Needs prediction capabilities.	Prioritize projects	
California Department of Transportation (CALTRANS)	See reports documenting outputs (14, 65)	Candidate locations are used to organize and prioritize projects. PMS identifies locations. Districts organize projects	(14, 65)	Very effective	PMS costs about 0.25% of total annual rehabilitation budget.	Data collection is time & labor intensive Anticipate industry will soon develop appropriate automated equipment.	Knowledge that rehabilitation & maint. funds are being expanded in a consistent manner statewide. Ability to analyze pavement performance since 1978, value will increase as history lengthens.	
Colorado Department of Highways	See References Documenting outputs (155)	- - - - -	(155)	Currently not used at full effectiveness	The feeling is "yes" although no analysis has been done.	A great deal needs to be done in impl. portions of NOS, especially in strategy recommendations.	It has enhanced Dept's credibility. An integral part of a funding request package to the Legislature. Strengthening the data collection process. Systemized and coordinated network level efforts.	- - - -

TABLE A-5 (Continued)

AGENCY	OUTPUTS		REPORTS DOCUMENTING OUTPUTS	EFFECTIVENESS AND WEAKNESSES			BENEFITS FROM PAVEMENT MANAGEMENT	REFERENCES DOCUMENTING BENEFITS
	TYPES	WHERE AND HOW USED		HOW EFFECTIVE	COST EFFECTIVE?	WHAT WEAKNESSES?		
Connecticut Department of Transportation	Network score for every PM section; Optimum expenditures per year for network	Will be used to determine amount of funds required for various treatments and to select pvmt. sections & specific rehab/maint. options	(105)	Not yet implemented	- - - -	- - - - -	The initial benefits include acquisition of personal computers & software, development of mainframe pvmt. mgt. programs to restructure and tie together existing pavement data, and development of a pavement condition rating method which utilizes photolog images.	- - - -
Delaware Department of Transportation	Prioritizes listings by different rating systems - resurfacing cost data.	To generate resurfacing programs for presentation to staff and Legislature.	- - -	Moderately	It probably isn't saving money yet.	Lack of data base so that pvmt. life can be projected - not used to provide life cycle costs and design data.	Better prioritized resurfacing programs	- - - -
Florida Department of Transportation.	Outputs from the pvmt. mgt. process include: Detail listings from the pvmt. condition survey. Detail Traffic data, budget information, the work program. The list is exhaustive. Many special outputs are generated by integrating pvmt. mgt. files and writing ad hoc programs against them. These are generated in addition to their routine periodic reports which are compiled.	- - - - -	- - -	Florida DOT has an integrated PMS that is constantly evolving.	- - - -	Need to modernize and update pvmt. condition survey techniques to increase the quality of the data and reduce the expense.	The benefits associated with the PMS are difficult to quantify However, the integration of the files, an enhanced awareness, and better data with which to respond to questions and needs appear to be immediate benefits.	- - -

TABLE A-5 (Continued)

AGENCY	OUTPUTS: TYPES	OUTPUTS: WHERE AND HOW USED	REPORTS DOCUMENTING OUTPUTS	EFFECTIVENESS AND WEAKNESSES: HOW EFFECTIVE	EFFECTIVENESS AND WEAKNESSES: COST EFFECTIVE?	EFFECTIVENESS AND WEAKNESSES: WHAT WEAKNESSES?	BENEFITS FROM PAVEMENT MANAGEMENT	REFERENCES DOCUMENTING BENEFITS
Georgia Department of Transportation	Pavement rating, Accident summary, Road Characteristics, Traffic Data, Last Roadway Improvements & Date	Determining Pavement Resurface Needs High accident locations, Road Characteristics & Traffic Volume.	- - -	Good	Yes	Not yet able to evaluate.	Consistent selection of resurface needs, selecting locations for improvements because of high accident experience. Provide Federal Data reporting require. Linking several info systems to common data base.	- - -
Hawaii Department of Transportation	Costs, Compatible Strategy and Rating	Used as a guide to prioritize resurfacing by the districts and to appropriate fundings by districts.	(156)	Moderately effective	Yes	The low volume roads will never get a high priority	1- Used to obtain more appropriation from Legislature. 2- Funding is distributed more equally among the districts. 3- Generally the lowest rating pavements are resurfaced.	- - -
Idaho Department of Transportation	Network Level: Pvmt conditions - List of pvmt sections ranked in priority for repair. Project Level: Overlay thickness recommendations.	Used by Districts as input in preparing maint. programs. Annual Interstate conditions reported to FHWA	(106)	Still needs minor revisions to be fully effective.	Not known yet.	Main weakness is in field testing - problems unit, testing equipment - especially the Cox Roadmeter.	Benefit obtained so far is a data base of pvmt. conditions that help evaluate pvmt. performances with time More benefits are expected when the economic analysis & optimization model completed (near future)	- - -
Illinois Department of Transportation.	Pavement condition rehab. info., project planning strategies.	Project planning & programming, Design Analysis.	(157)	Becoming increasingly effective	Yes, to the extent it can be used	Present systems lack a common reference scheme & a common data base. This is in the process of development.	Gives IDOT an overall perspective on the condition of the highway network & allows analysis of operating policies & procedures.	- - -
Iowa Department of Transportation	Computerization of the system is a necessity due to the large number of system miles (over 10,000) and the huge amount of historical data maintained for analysis purposes. System outputs include the following: 1. Pavement ▼	The data base reference system for the Iowa Pavement Management System was established in such a fashion that info. is available to any person in the organization with mainframe access and the proper logon codes. Items 1-6 are continuously available ▼	(67, 70-72)	As the system continues to develop and becomes more refined, increased benefits are being realized. Project prioritization data in the ▼	No specific benefit/cost data has been developed for the system at this time; however, an estimated development cost of approximately $250,000 is accumulated ▼	Pavement Management System problems and weaknesses are as follows: Development probably would have occurred more rapidly under the direction of a designated staff and resources rather than through the utilization of a committee approach. ▼	The primary and immediate benefit of the system, as it exists today, is that it provides the same accurate and up-to-date pavement performance information on all pavement sections, thus providing for the rational prioritization of projects and a sound basis on which ▼	- - -

TABLE A-5 (Continued)

AGENCY	OUTPUTS: TYPES	OUTPUTS: WHERE AND HOW USED	REPORTS DOCUMENTING OUTPUTS	EFFECTIVENESS AND WEAKNESSES: HOW EFFECTIVE	EFFECTIVENESS AND WEAKNESSES: COST EFFECTIVE?	EFFECTIVENESS AND WEAKNESSES: WHAT WEAKNESSES?	BENEFITS FROM PAVEMENT MANAGEMENT	REFERENCES DOCUMENTING BENEFITS
Iowa (CONT)	Status 2. Pavement Control Sections 3. Section Matrix Values 4. Matrix Limits 5. Project History Plot 6. Project History Screen 7. Four Matrix Reports, 8. PSI Trend Tables & Graphs 9. Network Level Rehabilitation Modeling Maps. 10. Optimization Listings.	for informational purposes and are used primarily on a project level basis. Matrix Reports (item 7) are updated annually and are used by upper level managers for budgeting and programming purposes. Items 8 and 9 are used for researching past & present pvmt. performance trends and to help develop appropriate rehabilitation strategies, both on a project and network level basis. It is anticipated that item 10 (Optimization Programs), when fully developed, will be used to aid in the selection of design alternates that will optimize life-cycle costs on a project level basis.		form of the pvmt. mgt. matrix listing is now in its 3rd year of use and each yr. it has provided managers with more refined, thorough & pertinent data for programming and other decision-making processes.	primarily from computer programming and manual searches through project history files. Operating costs, on an annual basis, include data collection, analysis & administration costs. This cost is estimated at $225,000 for in-house salary and support.	Data processing manpower requirements are greater than available supply; thereby necessitating schedule extensions and delays in development. Decision criteria used in the programming process are not well defined or documented with regard to the use of pavement management information.	programming decisions can be made. Less tangible, but possibly of greater benefit, will be the development of long term rehabilitation strategies which can be developed from analyzing performance data for various pavement designs and conditions. Proper decisions now can mean millions of dollars of savings in the future years.	
Kansas Department of Transportation	Selects sets of actions that produce best total performance for fixed budget. Evaluates and selects rehab. strategies.	See Reference (<u>96</u>)	(<u>35</u>, <u>96</u>)	In implementation stage no data available	No data available except for network survey. It is.	Time optimization model is complex and difficult to understand. Sophisticated computer resources needed.	Data is not yet available relative to the optimization models. However, objective annual network survey data available for the past 4 years has been useful in establishing system needs and has improved the effectiveness of rehab. programming.	- - -

TABLE A-5 (Continued)

AGENCY	OUTPUTS		REPORTS DOCUMENTING OUTPUTS	EFFECTIVENESS AND WEAKNESSES			BENEFITS FROM PAVEMENT MANAGEMENT	REFERENCES DOCUMENTING BENEFITS
	TYPES	WHERE AND HOW USED		HOW EFFECTIVE	COST EFFECTIVE?	WHAT WEAKNESSES?		
Kentucky Depart. of Transportation.	Condition ranking of pvmts, overlay needs, costs and treatment types.	Scheduling improvements. consequences of delays.	(45, 158)	Highly effective Because most outputs are used by the organization	Absolutely	Program is inadequate to deal with recognized needs (Understaffed and lacks certain equipment)	Main benefit is quantification of pavement conditions and improvement needs, ranking of pavements for improvements, and allocation of resurfacing monies to highway districts.	(108)
Maine Department of Transportation	1) Network level needs by Dist. by System - Includes miles of each type of improvement as well as secondary and tertiary options. 2) Project selection level-candidate lists developed for ea. District/System. 3) Project level-future.	For the F.A.P., outputs used by field evaluating teams from the control office to identify candidates and to finalize 2 year program selection. For state capital improvements and maint. & paving program they are similarly used by Dist. personnel to establish 2 year program.	(74, 75, 77, 78, 81, 82, 83)	Considering PMS only in effect 5 years; its success and acceptance has been beyond expectations.	Yes, and should increase with time.	1- Needs to be refined at the project level by recognizing alternatives generated by life cycle analysis. 2- Needs improved data for better assignment of strategies at the project selection level. 3- To integrate better with maint. mgt.	1- Justification for increase in state funds. 2- Ability to transfer Federal funds from Interstate 4R to primary as justified by needs. 3- Ability to distribute funds for State projects to district based on needs rather than allocating funds equally (ie. 1/7 each for 7 districts)	(73)
Maryland Department of Transportation.	Analysis of health of network 0.2 mile interval	By Chief Engineer; for resurfacing project approval. By Dist. Engr. to aid project selection.	(159)	Being used by top management.	Cannot measure as yet.	Has not been interfaced with maint. activities	Better project selection and ability to assess trend of network condition.	
Massachusetts	- - - - -	- - - - -	(160)	- - -	- - -	- - - - -	- - - - -	
Michigan Department of Transportation	1- Avg. ratings & deficiency percentages of uniform sections. 2- Uniform sections listed in order of avg. ratings. 3- Distribution of pvmt. rating and pvmt. type. 4- Distribution of pvmt. rating for each pvmt. type. 5- Cross-reference for cumulative ▼	Avg. rating of proposed projects used in a ranking process. Outputs also informally used to project future condition levels and and Budget needs.	(44)	It is an emerging system that has not to date been operationally used	N/A	It is an extremely capable and flexible system but its present weakest areas are automation, software development & staffing	Identifying condition trend of the network & relative condition of pavements in each dist. Can now forecast condition level that will result from current budgets. Can now determine mix of short, medium and long life fixes that will enable achieving condition goals at least cost. Can now provide answers to management questions ▼	

TABLE A-5 (Continued)

AGENCY	OUTPUTS		REPORTS DOCUMENTING OUTPUTS	EFFECTIVENESS AND WEAKNESSES			BENEFITS FROM PAVEMENT MANAGEMENT	REFERENCES DOCUMENTING BENEFITS
	TYPES	WHERE AND HOW USED		HOW EFFECTIVE	COST EFFECTIVE?	WHAT WEAKNESSES?		
Michigan CONT	roadway and control mile posts of uniform sections. 6- Listing of pvmt. rating of each 500 foot segment.						regarding condition, budgets, and cost-effectiveness of fix types.	
Minnesota Department of Transportation.	Present condition of the pvmt. network and soon a prediction of when a pvmt segment will need rehabilitation.	Used by Dists. and Programming to prioritize projects for the resurfacing program.	(161)	It is being used to make decisions.	- - -	Length of time necessary to computerize portions of it & to develop and implement the final stages has been frustrating.	A process to prioritize resurfacing projects & also getting people to think in terms of pvmt. life cycle costs when comparing rehabilitation alternatives.	- - -
Montana Department of Highways	Pvmt. condition inventory. Candidate projects; Dist. priorities. "Cracking," "Rutting", severity & extent (inventory) Thin "overlay & patch", "cost". (Candidate proj.) (Priorities)	Dist. rehab. proj. nominations, maint. costs & documentation; planning - programming; administration - decision making	(55)	Medium, still developing, first inventory completed in 1984	So far	PMS repair strategies not correlated with actual activity very well, not acquired respective cost confidence.	1- A better picture & increased interest in highway conditions. 2- Interest in monitoring PMS distress, better administrative perception of highway benefit/cost.	(162)
Nebraska Department of Roads	Pvmt. condition summary, maint. cost report, detail distress, pvmt. mgt. strategy/cost.	Used as guidelines for development of work program	(114, 163)	Too early to evaluate	Yes	Present system not yet capable of optimization (minimization life cycle costs)	Immediate review of current road condition. Evaluation of needs. Guide is setting 6 year program.	
Nevada Department of Transportation.	Pavement condition Report; repair strategies by ea. mile; Prioritized list of candidate 3R Projects.	Preparation of annual maint. programs. Development of 3R Project Program.	(48)	Very effective system to manage state roadways.	Yes	Pvmt. Performance with respect to time must be established to develop Network Optimization Program.	Network level analysis has proven to be an excellent tool to quantify the Dept.s needs for additional funding for pvmt. maint. and the 3R Program.	
New Hampshire Department of Transportation	Although in prelim. stages, expect a prioritization by PSR by Division for resurfacing and to assist in reconstruction program.	Surfacing program recommendation, Project & System Level Analysis Reports, to Legislature.	(141)	Too early to tell	To be determined	Too early to tell.	Increase in gas tax for 1981 for resurfacing.	(51, 164)

TABLE A-5 (Continued)

AGENCY	OUTPUTS: TYPES	OUTPUTS: WHERE AND HOW USED	REPORTS DOCUMENTING OUTPUTS	EFFECTIVENESS AND WEAKNESSES: HOW EFFECTIVE	EFFECTIVENESS AND WEAKNESSES: COST EFFECTIVE?	EFFECTIVENESS AND WEAKNESSES: WHAT WEAKNESSES?	BENEFITS FROM PAVEMENT MANAGEMENT	REFERENCES DOCUMENTING BENEFITS
New Jersey Department of Transportation.	Skid test inventory pvmt. mgt. priority list for resurfacing needs.	Establish resurfacing & pvmt. rehab. projects & priorities for the Bureau of Maint. & Division of Design.	(165, 166)	Good for establishing resurfacing needs and priorities.	Unknown	Lack of roadway functional classifications. Lack of economic model to determine different strategies.	1- Removing the subjectives from pvmt. rating. 2- accomplishing the higher priority work first. 3- Background data for budgets and increasing highway funding for resurfacing or pavement. rehab.	- - - -
New Mexico State Highway Dept.	System states reports and project priorities can be produced	System states data have been used in presentations to increase statelevel dept. funding.	- - -	Somewhat	Yes	It is not sufficiently advanced to optimize expenditures for pvmts.	Has forced a significant effect to purify the data base, has provided a more consistent pvmt. evaluation process and has caused some dept. employees to realize that their activities affect pvmt. mgt.	- - - -
North Dakota State Highway Dept.	Existing Condition Geometric Deficiencies.	Preliminary Design Reviews, Programming	(167, 168)	Increasing influence	- - -	Lack of structural inventory, Department wide acceptance	Quantitive Condition Assessment	- - -
Ohio Department of Transportation.	Statewide priority ranking and District priority ranking.	Districts use the output to prepare 2-year major rehab. programs.	(169)	Too early to evaluate	Too early to evaluate	Difficult to establish a workable data base.	Improved communications between Research, Planning, Design and Maint. Bureaus. Complete inventory of our multi-lane system.	- - -
Oregon State Highway Division	Cost and condition summaries (past, present, forecast)	As a programming tool for 6-year Highway Improvement Program to aid prioritization and allocation of funds.	(43)	Yes, it is germaine to planning	Yes	Need better information on pvmt. performance in order to refine prediction models.	Supplemented const. & maint. programs with a special state-funded pvmt. preservation program. Highway system conditions have shown overall improvement during last 3 years	(47, 170)
Pennsylvania Department of Transporta-	Maint. & project planning, budgeting, funding app.	Used to plan maint. activities, develop 4-R Program	(87, 88)	Presently vary	Yes	Full potential and development still evolving.	Savings in manpower, more rational planning & programming	(85)
South Carolina Department of Highways & Public Transportation.	Prioritized roads by pvmt. condition on the Primary & Secondary System.	Priority programming	- - -	Moderate	Unknown at this time.	Does not include Life Cycle Costs	1- Optimum use of available funds due to prioritization of road system. 2- Invaluable in keeping the Legislature informed concerning condition of roads in their jurisdiction.	- - -

TABLE A-5 (Continued)

AGENCY	OUTPUTS: TYPES	OUTPUTS: WHERE AND HOW USED	REPORTS DOCUMENTING OUTPUTS	EFFECTIVENESS AND WEAKNESSES: HOW EFFECTIVE	EFFECTIVENESS AND WEAKNESSES: COST EFFECTIVE?	EFFECTIVENESS AND WEAKNESSES: WHAT WEAKNESSES?	BENEFITS FROM PAVEMENT MANAGEMENT	REFERENCES DOCUMENTING BENEFITS
South Dakota Department of Transportation	Needs analysis & project analysis reports, individual improvement costs for each project. Year of needed improvement, & prioritized lists of projects.	- - - - -	- - -	Quite effective	- - -	By necessity, the process was developed in stages which resulted in a large number of programs each performing a specific function	We are now programming projects objectively on a statewide basis. Political input to programming is at a minimum. All state highways are evaluated using the same criteria. Future needs are based on realistic costs & types of improvement which will actually be constructed instead of wish lists based on ultimate designs that are fiscally not feasible. The Department has gained a sense of credibility with the public and the legislators.	- - -
Tennessee Department of Transportation	Project Listings with priorities. Mileage summaries by rating categories and deficiency type.	To select projects for rehab. or overlay. Identify major maint. needs, budget preparation and justification.	(39)	Not sure yet.	Think so.	Seem to be moving too slowly in getting it underway.	Have been able to better coordinate various pavement activities within each division. Have been able to get increase in fuel tax for improving maintenance.	- - -
Texas Department of Highways and Public Transportation	Standard reports or SAS generated reports are available.	Currently reports are provided for info. only.	(49, 146, 171)	Provides insight to changes in system.	Yes, but automated data collection, would reduce costs significantly.	Could be more useful if sample size is increased. No structural index, and historical index.	Feel can reasonably determine the current condition and the rehabilitation needs of the state network.	- - -
Utah Department of Transportation.	In the developmental process.	Used in preliminary project identification and general system condition & needs.	(63)	It is becoming very effective	Yes intuitively but hard data not available.	Still in developmental phase. Not totally implemented.	Opening up communications between divisions and/or districts plus an increased awareness on the part of upper management of the Pavement Management Process.	- - -
Vermont Agency of Transportation	Section Ident. No., Route No., Town(s), Begin and end Mile Markers, Length, Sys. and Federal Aid Eligibility, Annual Avg. Traffic, Percent trucks, estimated cost, Proposed treatment, number of accidents in last 5 years and project priority number.		(119)	It is all right. It is at least a start.	- - -	- - - - -	The computerization is an absolutely decided advantage over previous methods. Permitting retrieval of historic base materials.	

TABLE A-5 (Continued)

AGENCY	OUTPUTS		REPORTS DOCUMENTING OUTPUTS	EFFECTIVENESS AND WEAKNESSES			BENEFITS FROM PAVEMENT MANAGEMENT	REFERENCES DOCUMENTING BENEFITS
	TYPES	WHERE AND HOW USED		HOW EFFECTIVE	COST EFFECTIVE?	WHAT WEAKNESSES?		
Virginia Department of Highways and Transporta-	Pavement listing by section	Prioritizing pavement sections for overlays and the allocation of funds.	(172, 173)	Very effective	Yes	Secondary system is not fully developed, rigid pavements are yet to be included.	Better inventory of pavements and their condition, better means of allocating funds and establishing priorities, and documentation of pavement data.	- - -
Washington State Department of Transportation	Condition surveys, Project Specific Performance Curves, etc.	The outputs are used to develop the priority array as well as evaluate the condition of the highway system and the rehabilitation program.	(122, 123, 174)	Quite effective.	Yes	- - - - -	Development of Rehabilitation Program, analysis of funding needs, monitoring of pavement condition with time on project level as well as the network as a whole.	- - -
Wyoming State Highway Dept.	A computer listing of all roadway sections by system, route, and milepost with a condition state and a recommended rehab. strategy for each section.	- - - - -	- - -	Do not know at this time	Do not know at this time	The system presently being prepared for implementation is strictly a prioritization program. Hope to incorporate life-cycle curves and the ability to predict pavement failure into the program at some future date.	- - - - - -	- - -
District of Columbia Department of Public Works	Streets sorted by location, quadrant, ward, pavement condition, mileage report, etc.	P.M. acts as central information source and provides information and reports to the various departments, divisions and citizens.	(42)	It has been very effective in monitoring, budgeting, and programming		The program is in its early stage and have not yet started collected data to effectively to use for selection of rehabilitating, lacks cost data, lacks effective coordination of various departments, etc.	Provides list of streets by condition for budgeting and programming. Investigate citizens complaints and respond accordingly, keeps track of streets scheduled for rehabilitation, completion data and condition of LTPM.	- - - -
Alberta Transportation	1- Network Status Report & Histogram Summary. 2- Network Needs Report by Highway and Needs, 3- Rehab. Analysis, 4- Network Summary under two modes by optimization.	For planning and programming. Rehabilitation activities for short and long term.	- - - - -	Very Effective.	Yes	- - - - -	Long Term planning and programming rehabilitation actions, effect of deferred action.	- - - -

TABLE A-5 (Continued)

AGENCY	OUTPUTS		REPORTS DOCUMENTING OUTPUTS	EFFECTIVENESS AND WEAKNESSES			BENEFITS FROM PAVEMENT MANAGEMENT	REFERENCES DOCUMENTING BENEFITS
	TYPES	WHERE AND HOW USED		HOW EFFECTIVE	COST EFFECTIVE?	WHAT WEAKNESSES?		
New Brunswick Department of Transportation.	List of deficient sections. Priority List for rehabilitation work. Network Level Analysis.	Used to develop and recommend 5 year program for rehabilitation at Network Level	- - - - -	Too early to tell.	Don't know yet.	Surface distress & maintenance costs are weak points in data base. Pavement Life Cycle Cost Analysis not yet possible.	Too early to tell. If nothing else, it has served as a means of bringing seriousness of situation to senior management and has obtained support for further development.	- - - -
Ontario Ministry of Transportation and Communications.	Pavement performance History ie. extent and severity, preferred and alternative strategies.	Planning & Programming.	(175)	Time will tell.	Hopefully	None.	Coordinate and integrated plan and program looking at performance on all sections from beginning to end of their lives.	- - - -
Saskatchewan Highways and Transportation	Ride by Section, System, Pavement type, district and province. Deflection by reading with standard statistical analysis by section. Spread sheet of annual program.	Ride outputs are used by field and Head office staff to monitor and maintain average and minimum ride levels on system. Other outputs are used to develop budgets and strategies.	(176-181)	Department maintain a large system on a per capita basis for low cost per capita expenditures The department has been able to reach to changing age profile of system & systematically increase pavement rehabilitation programs.	- - - - -	Weakness in system is overall system status and road user cost optimization is not available on a routine basis.	Pavement Management enables department to evaluate alternative strategies, change direction and emphasis. Eg. minimal maintenance to extensive maintenance, stage pavement from full design. The use of pavement management enables an agency to measure effects of alternative strategy and plan for these effects when the strategy is implemented.	- - - -
San Diego County, Calif.	Recommendations for AC Recaps, armor seals, crack seals, etc.	By the field maintenance personnel, largely for developing budget projects.	(130)	Very effective.	Yes	Second stage would provide long range predictions and solutions.	Effective use of approximately $10,000,000, annual funds for special maintenance.	- - - - -

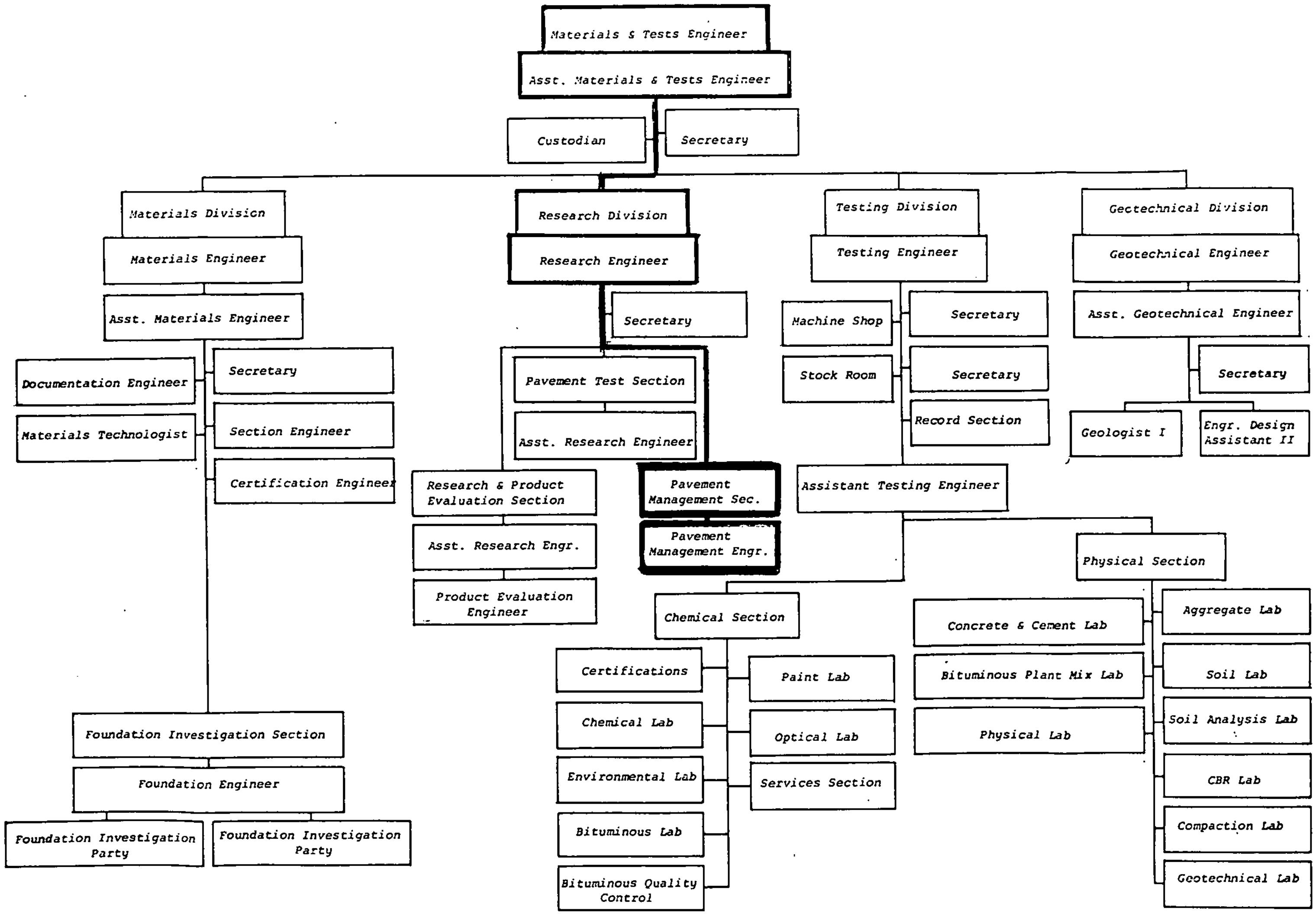
APPENDIX B

ORGANIZATION CHARTS

B-1

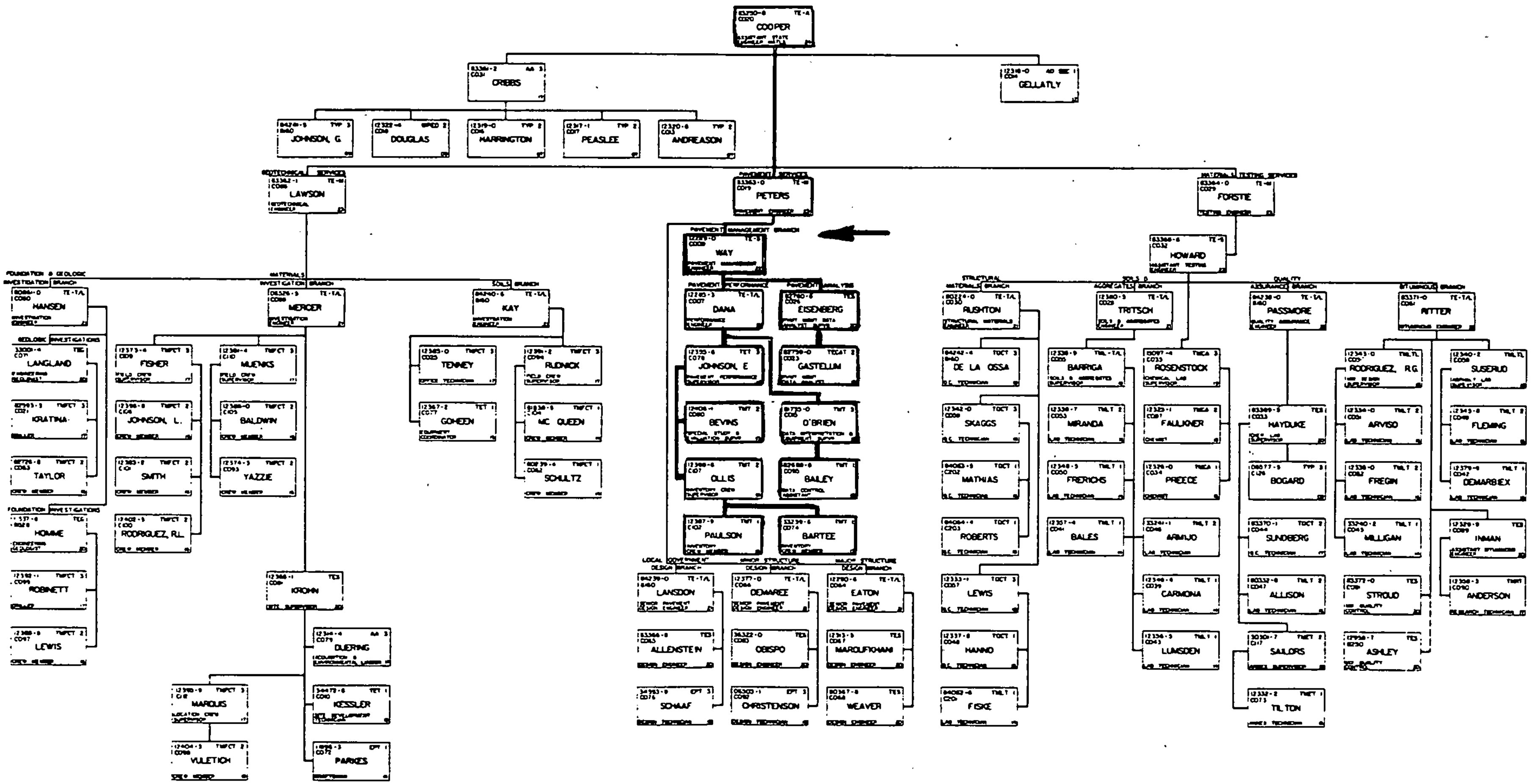
ALABAMA

BUREAU OF MATERIALS AND TESTS



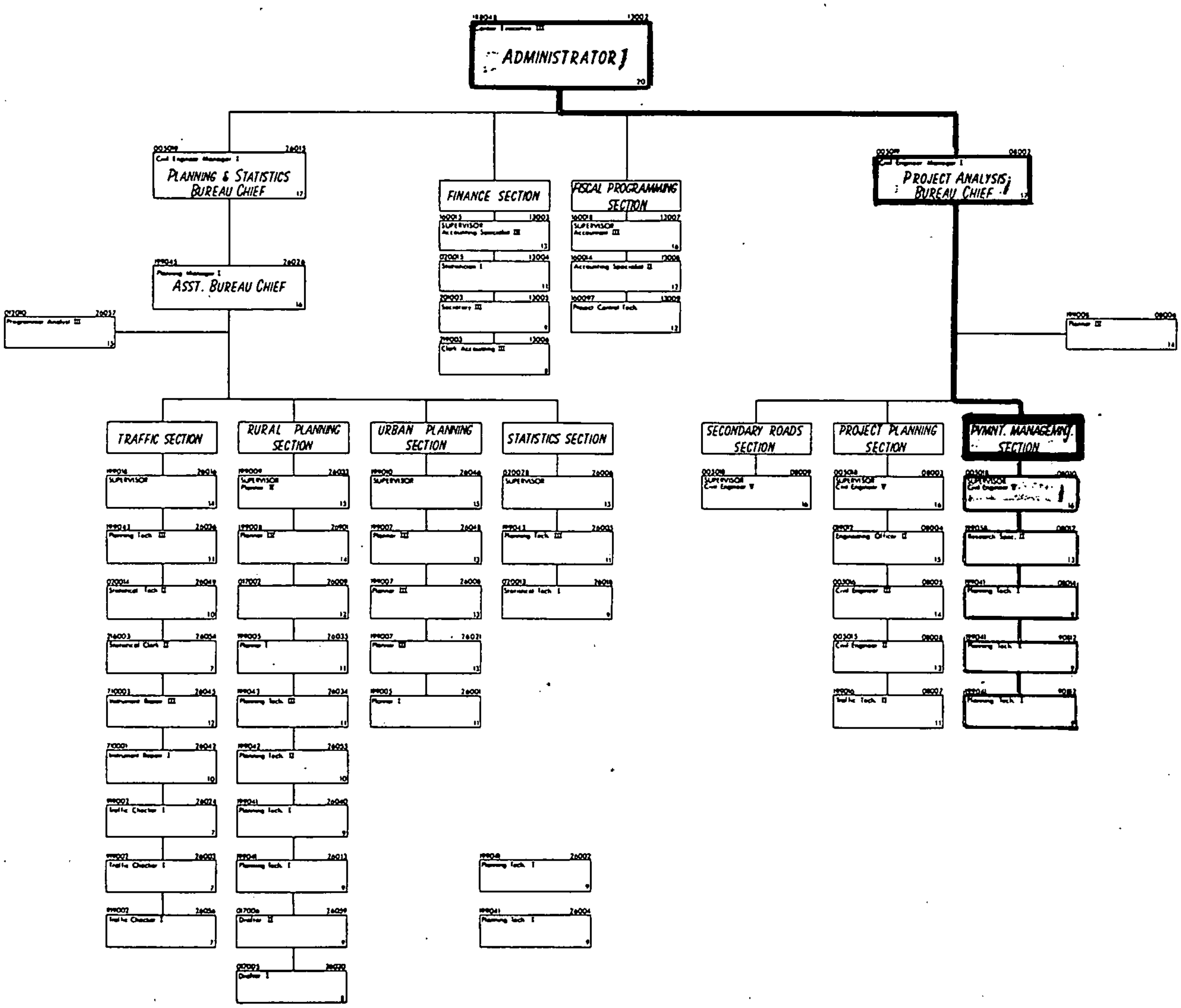
B-2 ARIZONA

MATERIALS SECTION



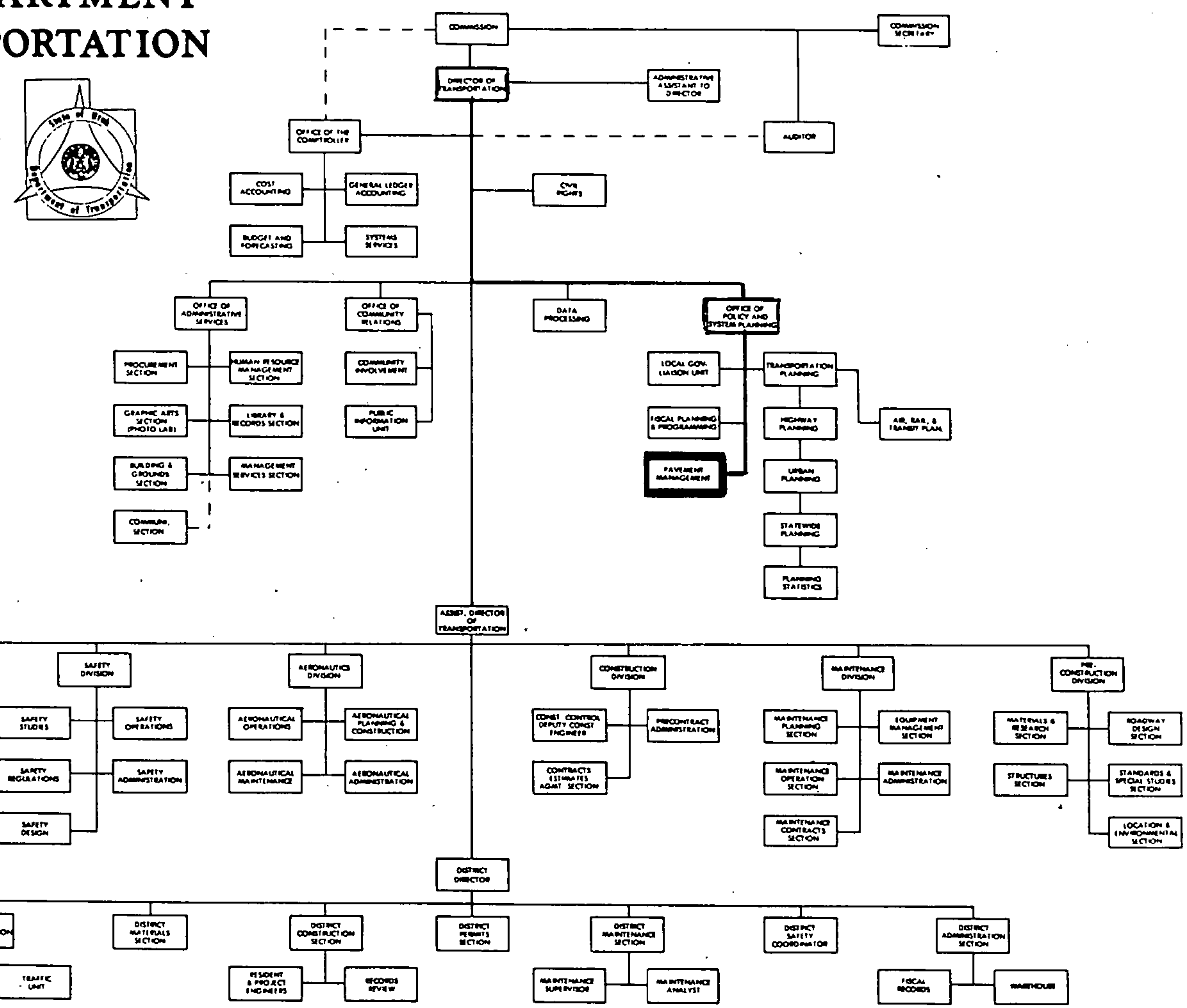
B-3

MONTANA
DEPARTMENT OF HIGHWAYS
PROGRAM DEVELOPMENT DIVISION
STAFFING CHART



UTAH DEPARTMENT OF TRANSPORTATION

FUNCTIONAL ORGANIZATION CHART



APPENDIX C

PAVEMENT MANAGEMENT POLICIES

Table C-1	Indiana
Table C-2	Kansas
Table C-3	Utah

C-1 INDIANA

Policy 6-6
REV: November 7, 1985

PAVEMENT MANAGEMENT COMMITTEE

1. POLICY:

The Indiana Department of Highways (DOH) shall develop a Pavement Management System to ensure good pavement management practices.

2. GUIDELINES:

A Pavement Management Committee shall be established. The committee consists of the following positions:

Deputy Director, Engineering & Management Services - Chairman
Chief Highway Engineer
Chief, Division of Maintenance
Chief, Division of Research & Training
Chief, Division of Planning
Chief, Division of Computer Services
Pavement Management Supervisor, Secretary

3. IMPLEMENTATION:

Pavement Management Committee:

(1) The Pavement Management Committee is responsible for developing a Pavement Management System.

(2) The committee shall encourage the implementation of good pavement management practices.

(3) The committee is responsible for the dissemination of pavement performance and cost experience information.

(4) The committee shall establish a Pavement Management Organization Chart.

(5) Essential information required to maintain a Pavement Management System consists of the following:

(a) Geometrics
(b) Traffic (new and future)
(c) Structural Capacity
(d) Ride Quality
(e) Surface Condition
(f) Skid Resistence
(g) Drainage Characteristics
(h) Unit Costs
(i) Resources
(j) Identification
(k) Network Partitioning
(l) Data Archiving
(m) Analysis Programming
(n) Program Design
(o) Data Base

C-2 KANSAS

KANSAS DEPARTMENT OF TRANSPORTATION STANDARD OPERATING MANUAL	SUBJECT NO. 0701.00/01	PAGE 1 OF 3
	REFERENCE CODE SOM0701	EFFECTIVE DATE 12-12-85
SUBJECT: PAVEMENT MANAGEMENT SYSTEM	APPROVED BY:	
SECTION: PLANNING AND DEVELOPMENT - Directive	Secretary of Transportation	

1. PURPOSE. To establish responsibilities, procedures, and guidelines for the agency wide administration of the Pavement Management System (PMS) for the Kansas Department of Transportation.

2. BACKGROUND. The Pavement Management System developed by the Kansas Department of Transportation consists of four main parts:

2.1 The **NETWORK OPTIMIZATION SYSTEM** (NOS) models the highway network to determine the action for each one mile segment of the entire state highway system to produce the optimal statewide benefit. The system can operate in either a "desired performance" mode or a "fixed budget" mode. In the fixed budget mode, the system selects the sets of actions on all road sections that produce the "best" total system performance for a fixed budget level. In the desired performance mode, the system selects actions to achieve the selected performance level at the lowest cost.

2.2 The **PROJECT OPTIMIZATION SYSTEM** (POS) serves two functions. First, it is a comprehensive design system for pavement structural sections on new grades. Second, it utilizes site specific cost and materials parameters to revise project scopes from the Network Optimization System. Alternative rehabilitation strategies for a single project or for groups of projects which meet cost and performance constraints from the NOS are further evaluated. The POS selects the strategy which minimizes the need for future maintenance.

2.3 The **DATA MANAGEMENT SYSTEM** (DMS) consists of: the annual pavement management survey results stored in the Pavement Management Database in the Division of Operations; Planning Database items concerning geometric features, traffic, and other data; Priority Optimization System outputs stored in the Office of Project Selection; and financial data such as inflation estimates prepared by the Office of Analysis and Evaluation in the Division of Planning and Development. Data are regularly transferred between these multiple data systems.

2.4 The **PRESERVATION PROJECT DEVELOPMENT COMMITTEE** (PPDC) develops projects and preliminary scope actions from the one mile segment output data from the Network Optimization System.

D.O.T. FORM 100

C-2 KANSAS (cont)

3. POLICY. It is the policy of the Secretary of Transportation that the Pavement Management System (PMS) will be used in conjunction with the Priority Optimization System to produce a set of statewide actions as part of a total highway improvement program that seeks to optimize system performance by obtaining the "best mix" of preservation projects.

4. RESPONSIBILITY.

4.1 The Director of Planning and Development is responsible for the operational control of the Network Optimization System. Responsibilities include:

4.1.1 Produce revenue forecasts.

4.1.2 Establish parameters for NOS runs.

4.1.3 Analyze effects of various resource allocation runs.

4.1.4 Establish parameters for NOS five period runs.

4.1.5 Establish desired performance level or fixed budget level.

4.1.6 Analyze system performance runs.

4.1.7 Establish and manage the Preservation Project Development Committee.

4.1.8 The Chief of the Office of Project Selection will provide leadership for the Preservation Project Development Committee. The Committee will consist of members from the Divisions of Operations and Planning and Development. Committee responsibilities include:

4.1.8.1 Develop projects from NOS one mile segments.

4.1.8.2 Establish list of projects.

4.1.8.2.1 Finalize, year 1.

4.1.8.2.2 Establish final 30%, year 2.

4.1.8.2.3 Establish final 70%, year 3.

4.1.8.3 Establish project scopes.

4.1.8.3.1 Final scopes, year 1.

4.1.8.3.2 Tentative scopes, years 2 and 3.

4.1.8.4 Request Operations Division reviews.

4.1.8.5 Incorporate results of Operations Division reviews.

4.1.8.6 Identify projects to be analyzed by POS.

4.1.8.7 Incorporate POS Run results.

4.1.8.8 Obtain program approval.

4.2 The Director of Operations is responsible for operational control of the Project Optimization System. Responsibilities include:

4.2.1 Collect additional site specific data.

4.2.2 Identify alternative sets of rehabilitation actions.

4.2.3 Identify new pavement design options.

4.2.4 Analyze data to determine optional actions or design.

4.2.5 Produce final scopes and costs for year 1.

4.2.6 Establish tentative project costs for years 2 and 3.

4.3 The Director of Operations is responsible for providing personnel and equipment for conducting the Annual NOS Pavement Surveys, and for storage and verification of the survey data.

4.4 The Director of Operations is also responsible for providing resources to produce the NOS and POS "Optimal" solutions to include:

4.4.1 Manpower with technical expertise.

4.4.2 Computer hardware and software.

5. SUNSET. January 1, 1989.

6. DISTRIBUTION.

Secretary of Transportation
State Transportation Engineer
Special Assistant to the Secretary
Division Directors
Chief Counsel
Inspector General
Bureau Chiefs

Utah Department of Transportation *Policy*

PAVEMENT MANAGEMENT STEERING COMMITTEE

POLICY: Preserving the State's investment in our highway surfaces and obtaining maximum cost effectiveness from our pavement rehabilitation and maintenance programs are major objectives of the UDOT. Therefore a Pavement Management Steering Committee is established to facilitate coordinating pavement management activities within the UDOT, improve efficiency in the decision-making process, provide feedback on the consequences of decisions, and ensure consistent pavement management decisions at all management levels.

SCOPE: Pavement management encompasses activities involved in planning, designing, constructing, maintaining, and rehabilitating pavement on the State Highway System. A Pavement Management System (PMS) provides a set of tools or methods to assist decision-makers in finding optimum strategies for providing and maintaining pavements in a serviceable condition over a planned period.

The Pavement Management Steering Committee has eight permanent members:

Assistant Director - Chairman
Pavement Management Engineer - Secretary
Engineer for Preconstruction
Engineer for Planning and Programming
Engineer for Construction
Engineer for Maintenance
One District Director
FHWA Representative - Ex Officio

Various divisions, sections, and districts shall provide needed staff support and input to the Steering Committee to assist it in accomplishing its responsibilities. Other UDOT employees may be invited to participate in Committee discussions at the discretion of the Chairman.

NUMBER 01-13
PAGE 1 of 2
EFFECTIVE DATE 10-25-85

Policy

RESPONSIBILITY: The Steering Committee shall provide overall direction to the UDOT Pavement Management Program. The Steering Committee is specifically charged with the following responsibilities:

1. Coordinate Pavement Management activities of the UDOT's various divisions, sections, and districts.
2. Establish and direct pavement management procedures and recommend policies for Transportation Commission action.
3. Establish and monitor the Pavement Management Unit work program.
4. Provide oversight of UDOT pavement activities and determine appropriate action.
5. Implement selected actions.
6. Monitor and evaluate the results of the Pavement Management Program.
7. Familiarize UDOT personnel with Pavement Management concepts and activities.

NUMBER 01-13
PAGE 2 of 2
EFFECTIVE DATE 10-25-85

APPENDIX D

SAMPLE PAVEMENT MANAGEMENT OUTPUT REPORTS

Part D-1 Oregon

Part D-2 Nevada

PART D-1 OREGON

STATE HIGHWAY SYSTEM

PRESERVATION REPORT

FEBRUARY, 1985

Pavement Management Unit
Planning Section
Oregon Department of Transportation

INTRODUCTION

The Preservation Study is a periodic assessment of existing highway system conditions and an estimate of the expenditures needed to preserve that system. Updates have been prepared every two years since 1976 using the same fundamental process. The study relies on field personnel for their assessment of current conditions. Comparisons with the conditions reported in previous years trace the deterioration of highway facilities, monitor the results of efforts to halt or retard deterioration, and provide insights for planning future programs.

The Preservation Study is divided into three general categories: pavements, bridges, and operations. Pavement preservation cost estimates are based on a variety of treatments ranging from structural overlays to minimum treatments such as chip seals and oil mats. Bridge preservation costs are based on the repair, replacement, and rehabilitation cost estimates made by bridge maintenance personnel. For the first time, the study discusses painting of steel bridges and steel bridge members as a separate preservation item. Operations cost estimates, provided by the Traffic Section, are for the 10-year study period 1984-1993. All costs are estimated in 1984 dollars and the effects of any future inflation or deterioration are not considered.

Early in 1984 a new work program was implemented as a supplement to existing pavement treatment programs. This 1984 Surface Preservation Program, which used low-cost rejuvenation treatments to address deterioration on lower volume roads, contributed significantly to the overall improvement of pavement condition.

SUMMARY

RESULTS

TABLE 1

PRESERVATION STUDY RESULTS
10-YEAR COSTS ESTIMATED IN 1984 DOLLARS

	QUANTITY	COST ($ Millions)
Pavement (Miles)	3,867	$539
Bridges (No.)	573	152
Operations [1]		212
TOTAL COST		$903

1 "Operations" includes a mix of needs ranging from traffic signals to passing lanes.

CONCLUSIONS

Pavements on the state highway system are currently in the best condition since the Preservation Study began in 1976. Fifty-seven percent of the State Highway System pavement miles are in fair or better condition. A major portion of the improvement occurred as a direct result of the 1984 Surface Preservation Program. This program rejuvenated over 500 miles to fair or better condition. The majority of the pavement miles involved were lower-volume routes that are low-priority for structural overlay funding.

A slight drop in overall bridge condition ocurred between 1982 and 1984. The most significant change in bridge condition was a shift of 70 bridges from good condition to fair condition. The number of bridges in poor condition remained essentially constant and is expected to remain stable during the next few years because of planned bridge replacements. The total estimated costs for bridge repair, replacement, and rehabilitation showed a drop from previous studies. This drop resulted primarily because a statewide reassessment of structures advised major rehabilitation instead of replacement for some of the longer structures.

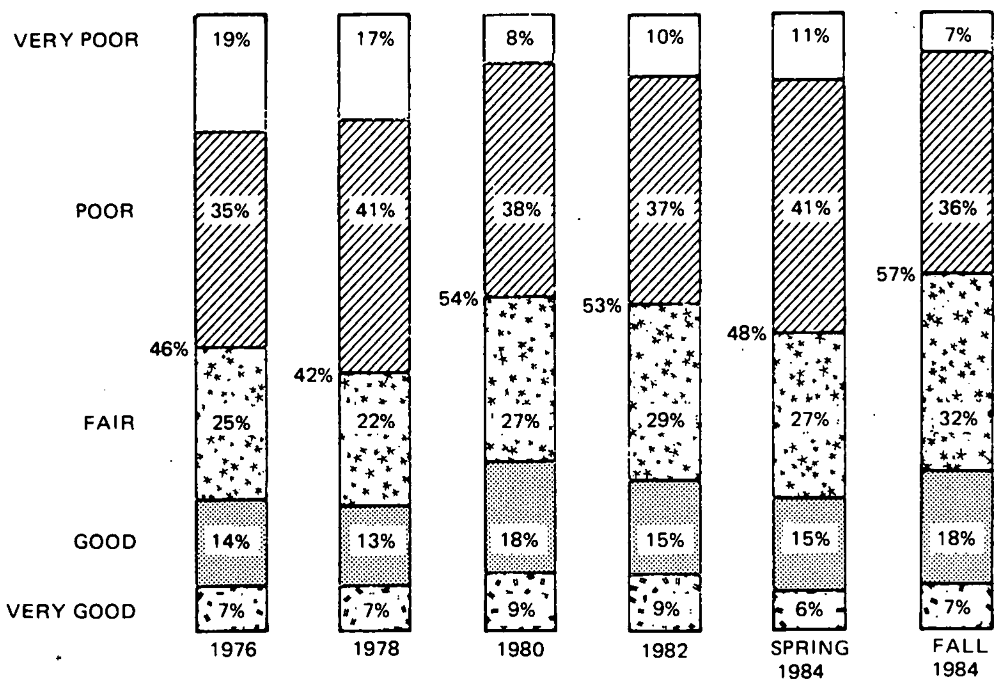
A substantial number of operational improvements are needed during the next ten years. There has been a slight increase in the projected projects and costs over those projected by the 1982 study.

PAVEMENTS

CONDITION

The pavement condition of the entire State Highway System was rated during the spring of 1984. Field staff used five categories ranging from Very Good to Very Poor to report pavement condition. Definitions and photographic examples of the pavement rating categories are shown in Appendix A, plates 1 through 5.

Pavement conditions were updated in the fall to reflect changes resulting from the highly successful 1984 work programs. All pavement conditions referred to in this report are fall 1984 conditions.



CHANGES IN ROADWAY CONDITION
PERCENT OF STATE SYSTEM IN EACH CONDITION BASED ON CENTERLINE MILES

FIGURE 1

SURVEY RESULTS

The overall pavement condition is the best that it has been since the Preservation Study began in 1976. (See Figure 1). Currently, 57% of the pavements in the State Highway System are rated fair or better. Table 2 details pavement condition mileage by Functional Classification. See Appendix B for definition of Functional Classes. Maps in Appendix D illustrate the 1984 pavement conditions.

TABLE 2

CONDITION OF STATE HIGHWAY SYSTEM PAVEMENTS
1984

Roadway Condition Rating	Principal Arterials: Interstate Miles	%	Principal Arterials: Non-Interstate Miles	%	Minor Arterials Miles	%	Collectors Miles	%	Highway System Miles	%
Very Good	62	9	303	12	149	6	22	1	536	7
Good	287	40	408	16	464	18	153	9	1,312	18
Fair	279	39	705	28	873	33	520	31	2,377	32
Poor	83	12	941	38	909	35	789	48	2,722	36
Very Poor	0	--	143	6	206	8	180	11	529	7
TOTALS	711	100	2,500	100	2,601	100	1,664	100	7,476	100

TABLE 3

PAVEMENT PRESERVATION COSTS - 1984
STATE HIGHWAY SYSTEM
($ Millions)

Condition	Structural Overlay Miles	Structural Overlay 10-Yr. Cost	Minimum Treatment Miles	Minimum Treatment 10-Yr. Cost	Total Miles	Total 10-Yr. Cost
Fair	617	$96	-	-	617	$ 96
Poor	1,181	330	1,541	47	2,722	377
Very Poor	227	57	302	9	529	66
TOTALS	2,025	$483	1,843	$56	3,868	$539

In past years, maintenance personnel had insufficient funds to carry out an effective pavement preservation program. High-volume routes have the highest priority for the limited surfacing dollar, leaving the lower-volume routes with insufficient funds to meet their needs. The Surface Preservation Program, implemented for the first time in 1984, made available $15 million in state funds to bridge this funding gap.

Many of the miles treated by this program were on lower-volume routes making it possible to use thin, low-cost treatments to rejuvenate deteriorated pavements. As little or no structural strength is added, these treatments will delay, but not eliminate, the eventual need for structural overlays. Some of the treatments utilized may be considered experimental and will be closely monitored to determine their suitability for future use.

The Surface Preservation Program contributed significantly to the overall highway system condition. This program improved more than 500 miles of poor or very poor pavements to fair or better condition. The continued existence of this program is expected to result in continued gains in the overall pavement condition, although not at the same rate.

COST ESTIMATE

Pavement preservation costs were estimated using a variety of treatments. The treatments ranged from structural overlays, on the major high-volume routes, to minimum treatments on low-volume routes. Determination of preservation need and the most appropriate treatment type was made in consultation with maintenance and design engineers. In making the determination, consideration was given to the character of traffic, location, climatic factors and current pavement condition.

Cost estimates for pavement preservation were significantly lower in this study than those of previous studies. This does not reflect an equally significant reduction in pavement preservation need. Instead, it reflects the use of minimum treatments on more miles in estimating the pavement preservation cost.

BRIDGES

CONDITION

Bridge inspectors periodically evaluate each bridge on the State Highway System as required by the Federal Bridge Inventory Program. As part of that evaluation, inspectors rate bridge deck, superstructure, and substructure conditions, and estimate the cost of correcting deficiencies. This study used these inspection reports because the reports guage physical condition as well as estimate costs for needed repair or replacement. As this study is concerned with preservation of the existing system, narrow width, slow-speed alignment, and other capacity problems are not considered.

To simplify condition and cost reporting, the numeric system used in the inspection reports for rating each bridge component was combined to obtain an overall Good-Fair-Poor Bridge Preservation Rating for each bridge. Appendix C shows the manner in which the lowest rated component determined the Bridge Preservation Rating, and the level of needed preservation work.

SURVEY RESULTS

In Table 4, 1984 bridge conditions are shown by Functional Classification. Table 5 shows the estimated costs for repairing bridges in the Fair category and the replacement or major rehabilitation of bridges in the Poor category. Map 3, Appendix D shows the distribution of bridges needing repair or replacement throughout the State.

TABLE 4

CONDITION OF STATE HIGHWAY SYSTEM BRIDGES
1984

Bridge Condition	Principal Arterials: Interstate Number	Interstate %	Principal Arterials: Non-Interstate Number	Non-Interstate %	Minor Arterials Number	Minor Arterials %	Collectors Number	Collectors %	Total Number	Total %
Good	619	82	669	76	468	74	153	70	1,909	77
Fair	137	18	180	21	138	22	49	23	504	20
Poor	2	*	29	3	23	4	15	7	69	3
TOTALS	758	100	878	100	629	100	217	100	2,482	100

* Less than 1%.

TABLE 5

ESTIMATED COSTS TO REPAIR, REHABILITATE OR REPLACE STATE BRIDGES
1984 DOLLARS
($ Millions)

Bridge Condition	Principal Arterials: Interstate Number	Interstate Cost	Principal Arterials: Non-Interstate Number	Non-Interstate Cost	Minor Arterials Number	Minor Arterials Cost	Collectors Number	Collectors Cost	Total Number	Total Cost
Fair	137	$4	180	$ 5	138	$ 2	49	$1	504	$ 12
Poor	2	1	29	122	23	14	15	3	69	140
TOTALS	139	$5	209	$127	161	$16	64	$4	573	$152

Overall bridge conditions as reported in 1982 and in 1984 are compared in Table 6 shown below:

TABLE 6

COMPARISON OF BRIDGE CONDITIONS AND COSTS
1982 to 1984
($ Millions)

Condition	1982 Totals		1984 Totals	
	%	Cost	%	Cost
Good	80		77	
Fair	17	$ 12	20	$12
Poor	3	161	3	$140
TOTAL COST		$173		$152

Bridges built during the last three decades of expansion are beginning to need minor repairs, accounting for the three percent shift from good to fair condition. The number of bridges in poor condition is now stabilized, and should remain so because of planned bridge replacements.

COST ESTIMATES

Bridge preservation cost estimates have decreased for the total number of structures involved. The estimated cost for repair of fair bridges remained constant even though there was a three percent increase in fair bridges. The slight decrease in per-bridge repair costs is due, in part, to the implementation of innovative, less costly repair methods. The total estimated costs for poor bridges has dropped since the 1982 study. This is the result of a statewide reassessment which advised major rehabilitation in lieu of replacement for some of the larger structures in the system.

BRIDGE PAINTING

In addition to the work needed to preserve structural integrity, bridges which have exposed steel members require protection against corrosion. The Bridge Section assesses painting needs by inspecting selected steel bridges, comparing conditions, and estimating painting costs. Their findings indicate that the general condition of bridge paint throughout the State is declining. During the next 10 years, most of the 407 steel bridges in the system will need painting. Seventy bridges are identified as needing immediate attention at a total estimated cost of $19 million. These costs are not included in preservation cost summaries.

OPERATIONS

CONDITION

While traffic operates at a satisfactory level on most State Highways, areas exist where low-cost localized changes can improve traffic control and safety. This study does not address those areas where major reconstruction or extensive improvements are needed. Safety projects include passing lanes, slow vehicle turnouts, turning storage lanes, guardrail, or rockfall protection. Traffic control projects include signals, railroad crossing control, signing and lighting.

The Highway Division Traffic Section maintains prioritized lists of needed operational improvements. These project lists, with adjustments for traffic growth, were used to determine the annual number and cost of projects during the 10-Year study period.

COST ESTIMATE

Table 7 summarizes operational improvements needed by project type and category. The table presents 10-year estimated costs along with the annual number of projects projected. The project mix for any one year may vary. The estimated number of projects needed has increased slightly since the last study, resulting in a corresponding increase in estimated total costs. The estimated total expenditure for the 10-year study period is $212 million.

TABLE 7

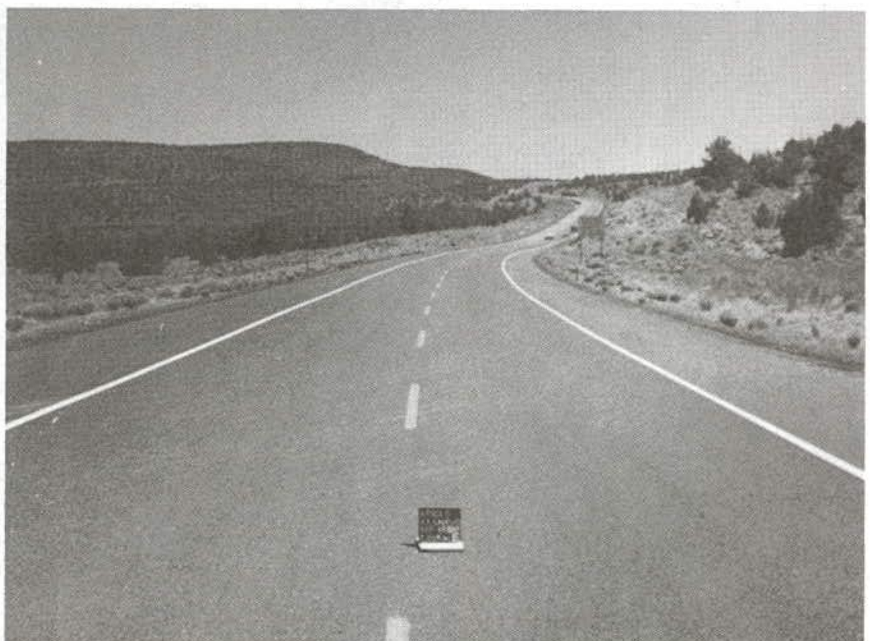
ESTIMATED COSTS TO PRESERVE TRAFFIC OPERATIONS
1984 Dollars
($ Millions)

Project Type	Project Categories	Annual No. Projects	10-Yr. Cost
Safety:			
	Rockfall	7	$ 18
	Passing Lanes	4	38
	Slow-Vehicle Turnouts	15	20
	Turning Lanes	39	43
	Guard Rail	5	6
Traffic Control:			
	Signals	84	59
	Other [1]	24	28
		TOTAL	$212

1 Railroad crossings, signing, illumination

PLATE 1
CONDITION - VERY GOOD

Pavement structure is stable, with no cracking, no patching, no deformation evident. Roadways in this category are usually fairly new. Riding qualities are excellent. Nothing would improve the roadway at this time.



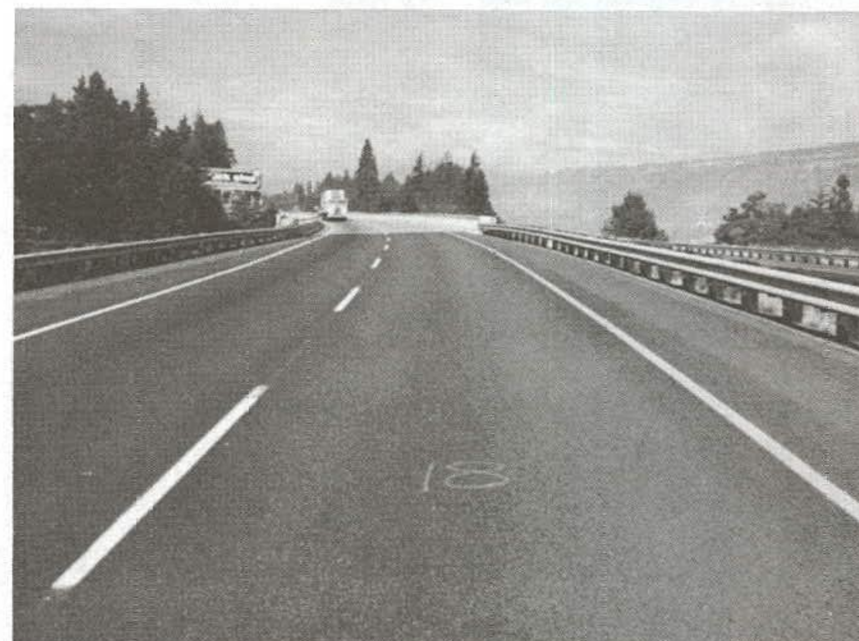
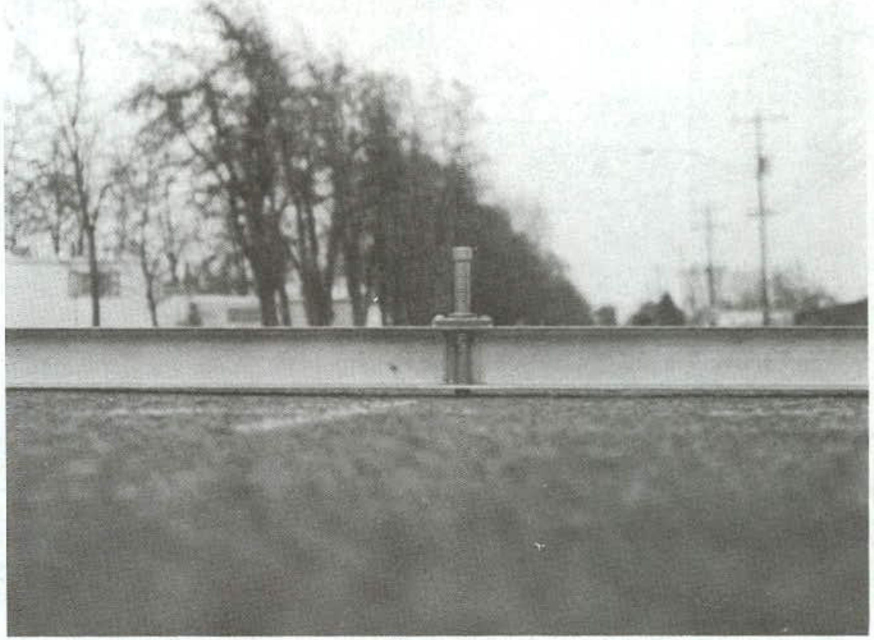
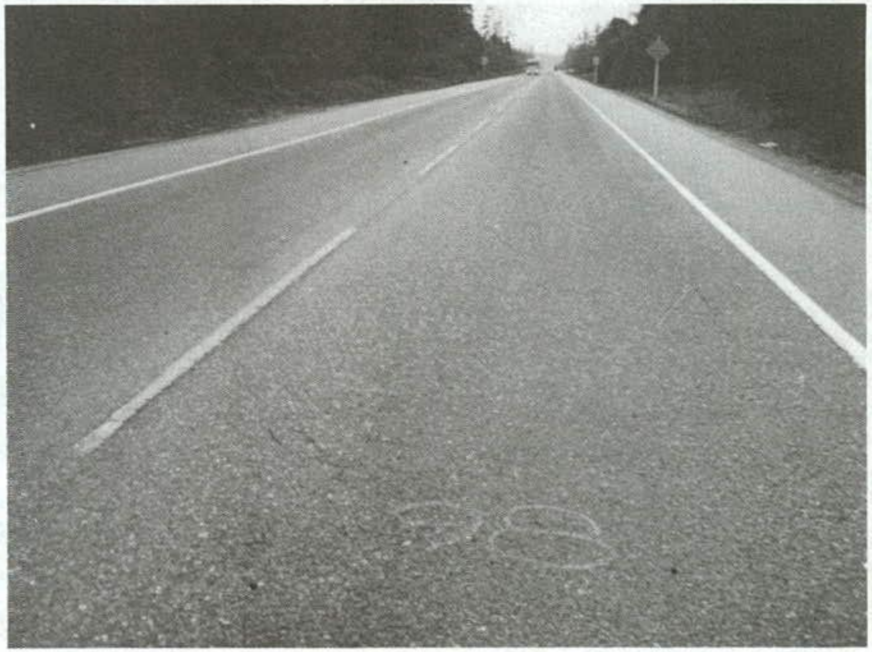


PLATE 2
CONDITION - GOOD

Pavement structure is stable, but may have surface erosion or minor cracking, which is generally hairline and hard to detect, minor patching, and possibly, some minor deformation. Riding qualities are very good. The pavement has a dry or light colored appearance. Some type of rejuvenation of the wearing surface is all that is required.





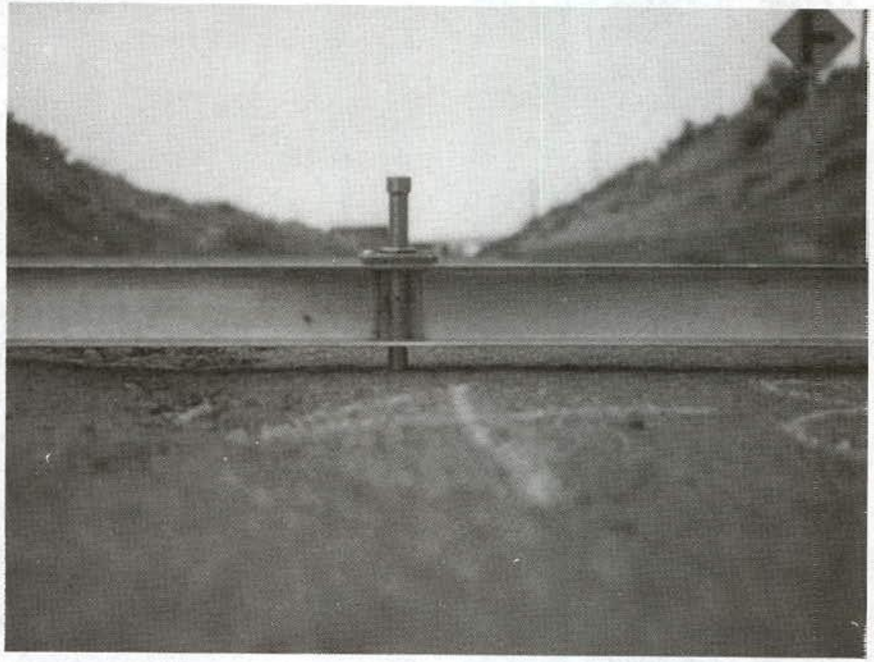
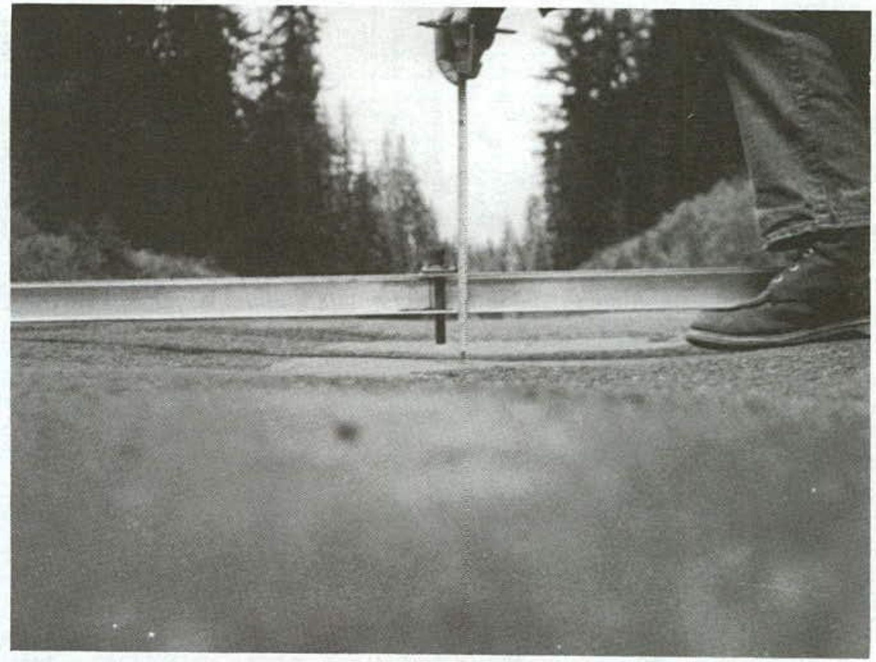


PLATE 3
CONDITION - FAIR

Pavement structure is generally stable with minor areas of structural weakness evident. Cracking is easier to detect. The pavement may be patched but not excessively. Although riding qualities are good, deformation is more pronounced and easily noticed.

PLATE 4
CONDITION - POOR

Roadway has areas of instability, marked evidence of structural deficiency, large crack patterns (alligatoring), heavy and numerous patches, and very noticeable deformation. Riding qualities range from acceptable to poor. Spot repair of the pavement base may be required.



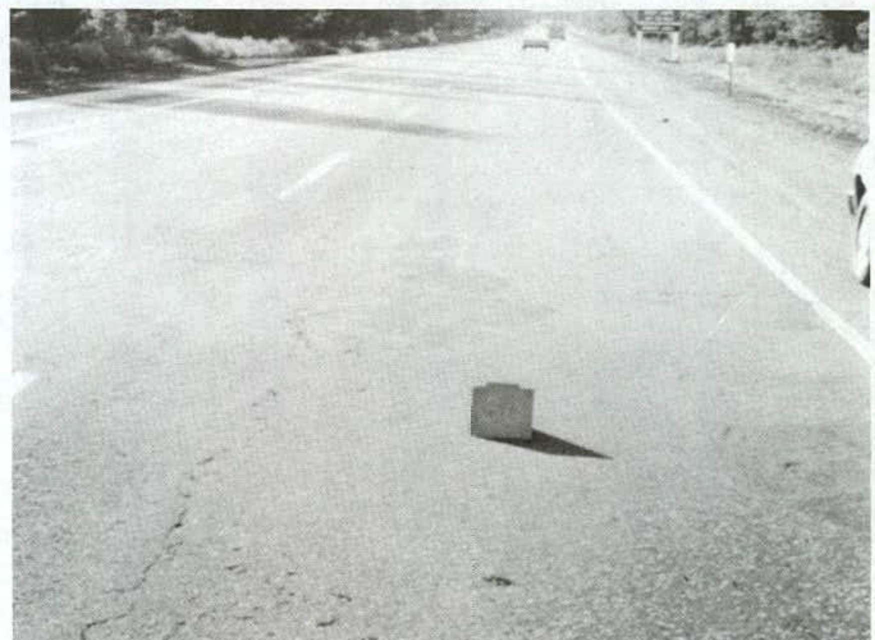


PLATE 5
CONDITION - VERY POOR

Costs of saving the pavement structural section would equal or exceed "complete reconstruction".

APPENDIX B

DEFINITION OF FUNCTIONAL CLASSES

Principal Arterial: Highways of national, interstate and statewide significance. This classification includes the Federal Interstate System as well as other important routes.

Minor Arterial: Highways of statewide and interregional significance. This classification includes the largest portion of the State Highway System.

Collectors: Highways of intraregional and intracounty significance that deliver traffic to arterials as well as provide access to adjacent properties.

APPENDIX C

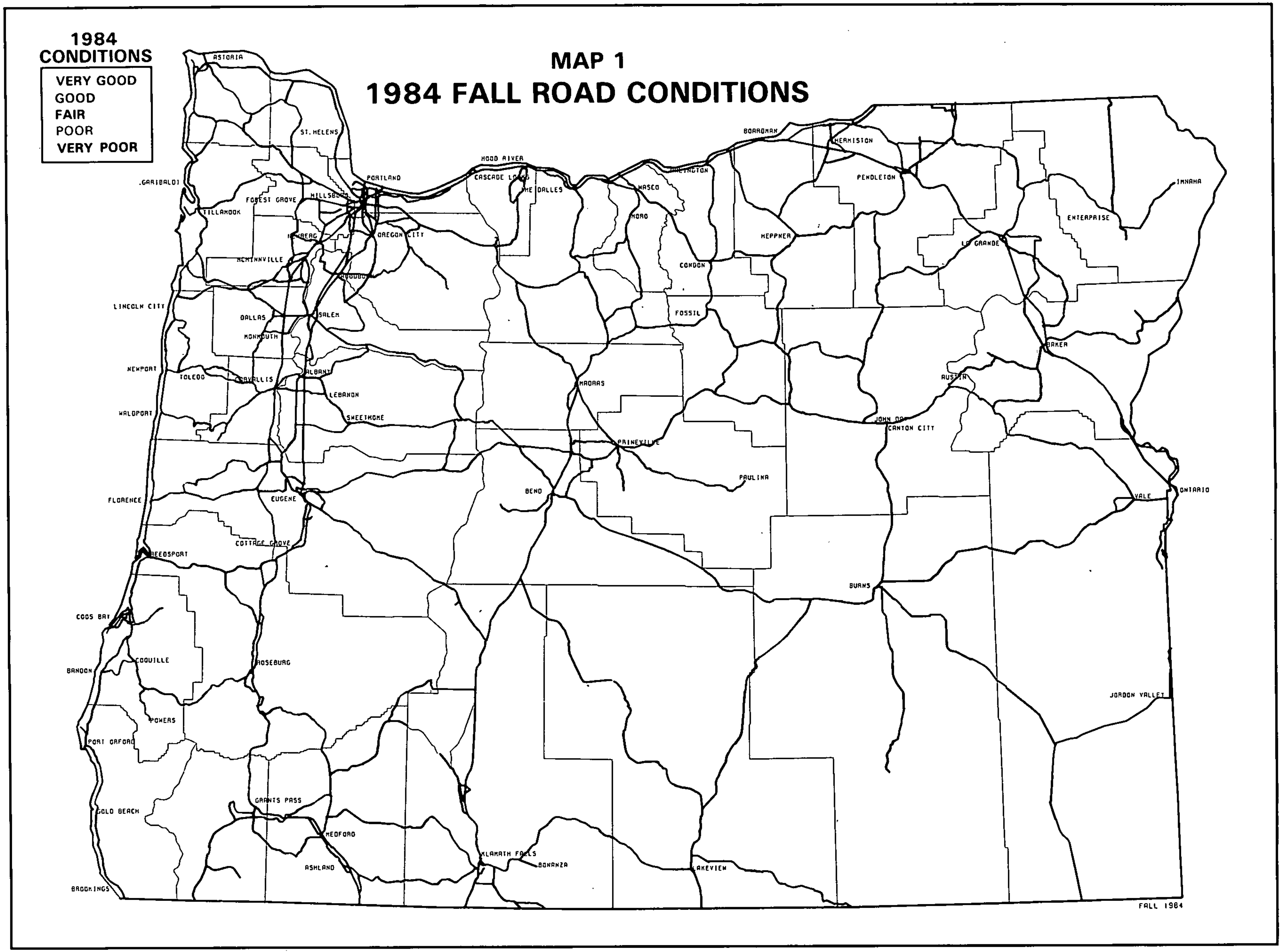
BRIDGE COMPONENTS AND CONDITION RATINGS

Primary components of a bridge are the superstructure, the substructure and the deck.

Although the deck is physically part of the superstructure it is considered and rated separately since it incorporates the wearing surface of the traffic lanes.

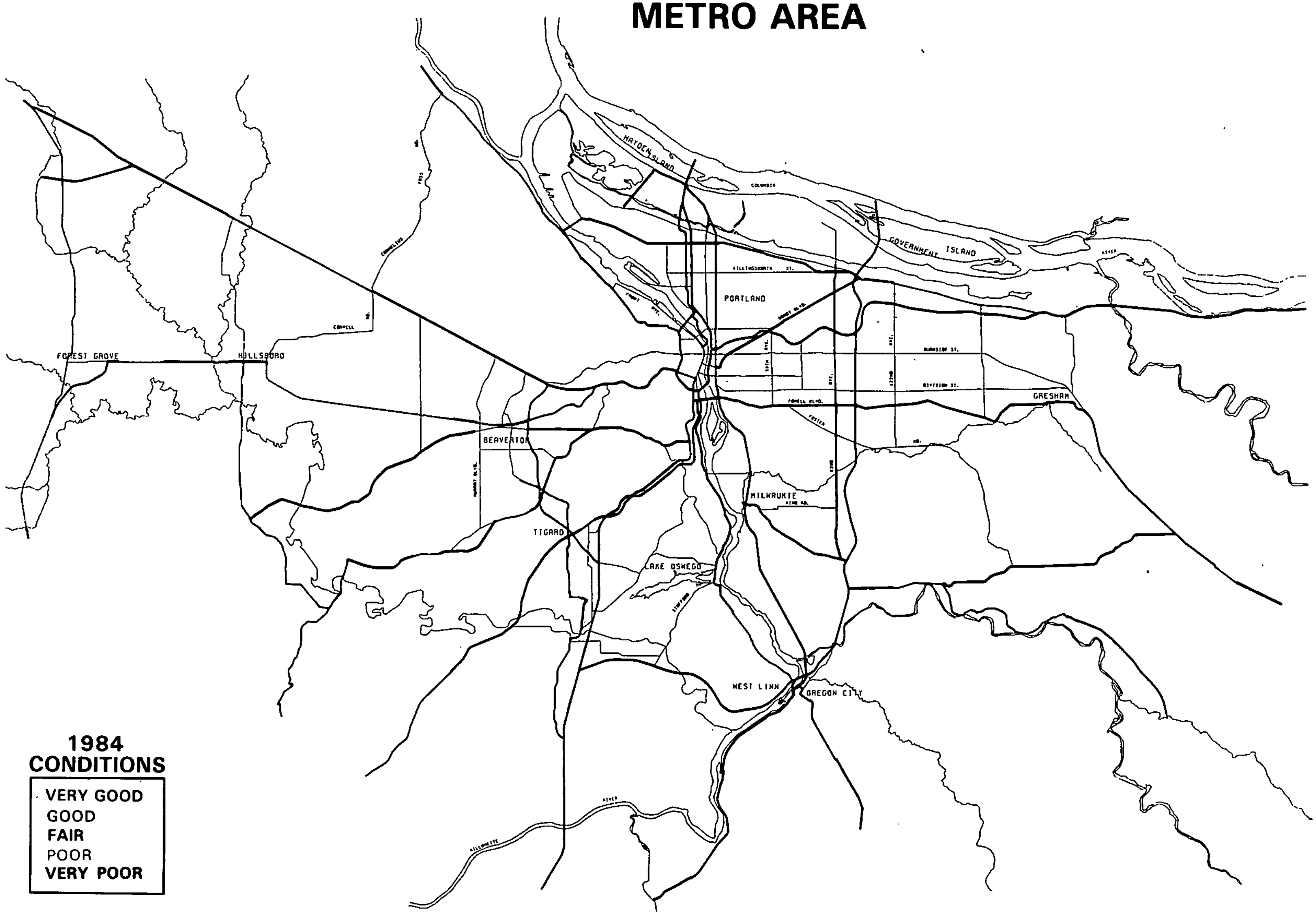
RELATIONSHIP OF BRIDGE COMPONENT RATING TO BRIDGE PRESERVATION CONDITION RATING

Lowest Rated Component	Component Condition	Bridge Preservation Condition	Preservation Need
Superstructure	Good		
OR Substructure	Good	GOOD	None
OR Deck	Good		
Superstructure	Fair		
OR Substructure	Fair		
OR Deck	Poor	FAIR	Repair
	OR Fair		
Superstructure	Poor	POOR	Replacement or Rehabilitation
OR Substructure	Poor		

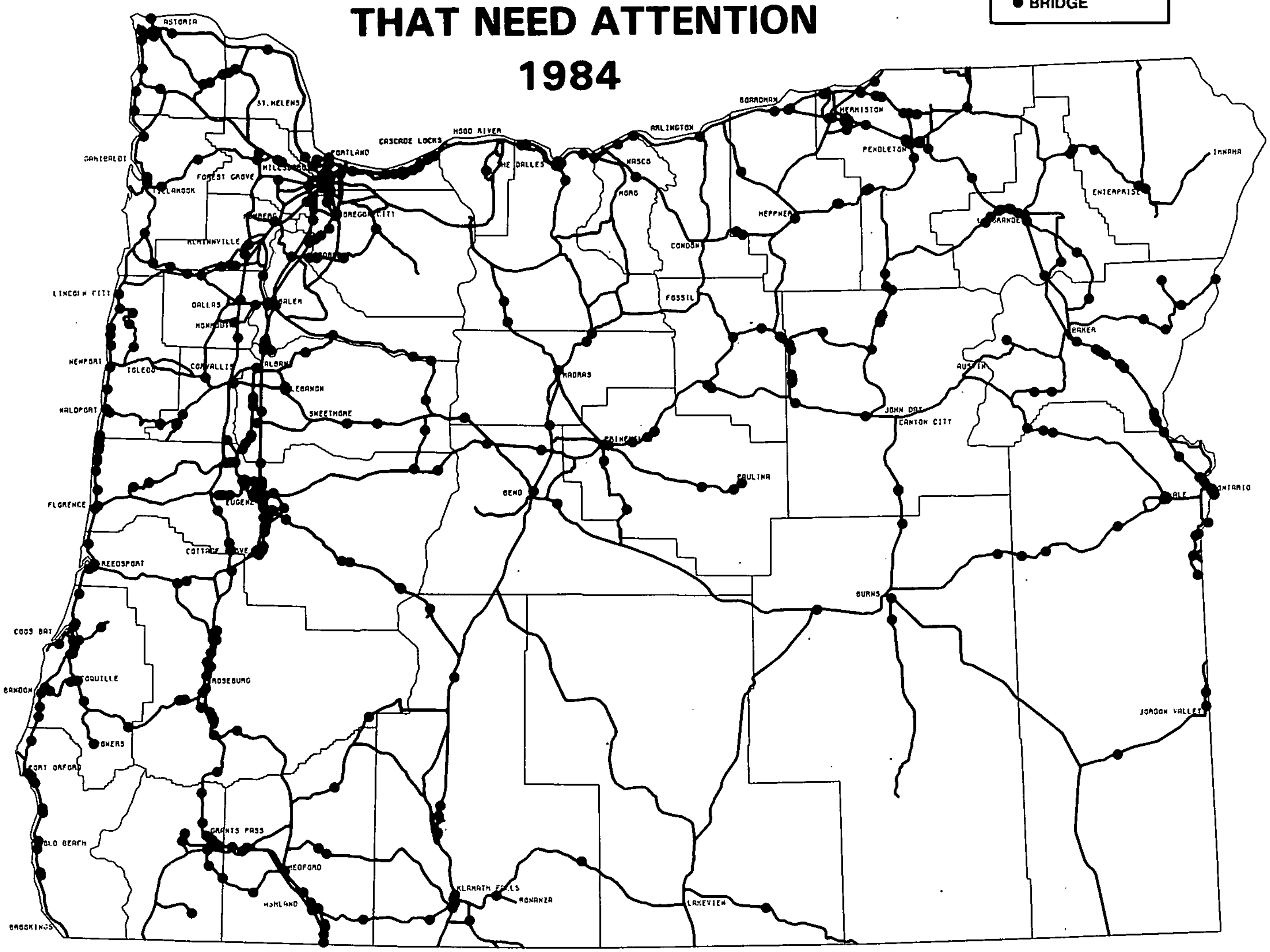


1984
CONDITIONS
VERY GOOD
GOOD
FAIR
POOR
VERY POOR
MAP 1
1984 FALL ROAD CONDITIONS
ASTORIA
ST. HELENS
PORTLAND
HILLSBORO
FOREST GROVE
TILLAMOOK
GARIBALDI
OREGON CITY
MCMINNVILLE
LINCOLN CITY
DALLAS
SALEM
MONMOUTH
NEWPORT
TOLEDO
CORVALLIS
ALBANY
LEBANON
SWEETHOME
WALDPORT
FLORENCE
EUGENE
COTTAGE GROVE
COOS BAY
BANDON
COQUILLE
ROSEBURG
POWERS
PORT ORFORD
GOLD BEACH
GRANTS PASS
MEDFORD
ASHLAND
BROOKINGS
HOOD RIVER
CASCADE LOCKS
MADRAS
PRINEVILLE
BEND
PAULINA
KLAMATH FALLS
BONANZA
LAKEVIEW
MORO
CONDON
FOSSIL
HEPPNER
BOARDMAN
HERMISTON
PENDLETON
LA GRANDE
ENTERPRISE
IMNAHA
BAKER
AUSTIN
CANTON CITY
BURNS
VALE
ONTARIO
JORDON VALLEY
FALL 1984

MAP 2
1984 FALL ROAD CONDITIONS METRO AREA



MAP 3
DISTRIBUTION OF BRIDGES THAT NEED ATTENTION
1984



State of Nevada
Department of Transportation

STATE HIGHWAY PRESERVATION REPORT

January 1985

NEVADA
DEPARTMENT OF TRANSPORTATION

Prepared by:
Operations Analysis Division

TABLE OF CONTENTS

TABLES

FIGURES

ACKNOWLEDGEMENT

The information contained in this report is based on data from the Nevada Department of Transportation's Pavement Management System. Sincere appreciation is extended to everyone in the Engineering Districts and at Headquarters who dedicate so much of their time and effort in collecting the data and processing the PMS condition reports.

INTRODUCTION

The State of Nevada has a substantial investment in its highway network. Federal-Aid first became available to Nevada for highway construction in 1917, and the Department has since built and now maintains approximately 5,300 miles of streets and highways. Today's costs to replace these roadways, not including Rights of Way, would exceed $3 billion. This investment must be protected, and the Department of Transportation has established as its number one priority the preservation of the existing highway system. However, even with proper maintenance these highways wear out and eventually require reconstruction and modernization.

An increasing portion of the department's annual construction budget has been focused on pavement resurfacing and rehabilitation projects, but we are still losing ground. Nevada is not unique in this respect; many states have experienced the same dilemma. Funding for proper pavement maintenance has not kept pace with inflation and deterioration.

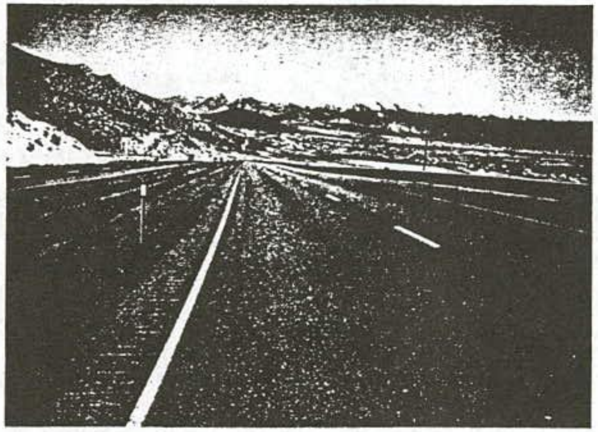
Many independent studies have been undertaken in an attempt to identify a means of significantly reducing pavement deterioration. Each study revealed one fact: that over the long run maintaining good roads costs substantially less on an annualized basis than allowing roads to deteriorate to the point where major reconstruction is required.

The Nevada Department of Transportation has developed a Pavement Management System to assist the agency to efficiently allocate its resources and make the best possible use of available funds. The status of the existing system reported here is a result of this pavement management system.

PAVEMENTS

Condition

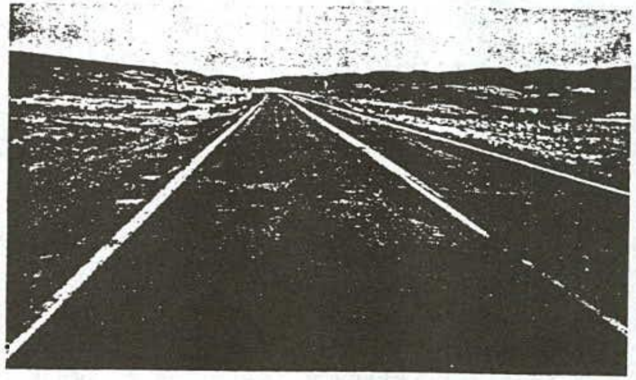
The condition of Nevada's highways is monitored through an annual pavement condition survey. Each directional mile of highway maintained by the State is evaluated during the survey, and the severity and extent of several pavement distresses are measured and recorded. Condition data for each mile are entered into the Pavement Management System pavement condition file and through computer analysis each mile is placed into one of four repair strategy categories: Preventive Maintenance; Corrective Maintenance; Overlay or Reconstruction.



Preventive Maintenance

Corrective Maintenance

Overlay



Reconstruct

Survey Results

Tables 1 and 2 illustrate the status of the existing condition of Nevada's highways, and the 1985 backlog of pavement resurfacing, restoration and rehabilitation (3R) work.

TABLE 1

1985

STATUS OF THE EXISTING SYSTEM

(Centerline Miles)

SYSTEM	PREVENTIVE MAINTENANCE	CORRECTIVE MAINTENANCE	OVERLAY	RECONSTRUCT	TOTAL
INTERSTATE	293	173	49	24	539
PRIMARY	702	483	298	364	1,847
SECONDARY	620	764	396	298	2,078
URBAN	85	98	45	14	242
STATE-AID	101	106	84	92	383
ACCESS & FRONTAGE	28	68	58	41	195
TOTAL	1,829	1,692	930	833	5,284

TABLE 2

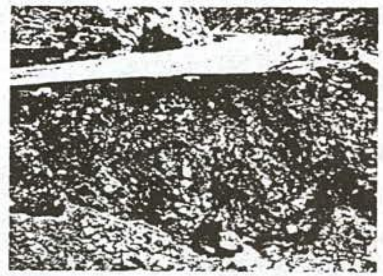
BACKLOG OF OVERLAY - RECONSTRUCTION NEEDS

1985

SYSTEM	REPAIR STRATEGY					
	OVERLAY		RECONSTRUCT		TOTAL	
	LANE MILES	COST	LANE MILES	COST	LANE MILES	COST
INTERSTATE	198	$16,854,000	98	$7,098,000	296	$23,952,000
PRIMARY	623	$53,099,536	763	$93,163,890	1386	$146,263,426
SECONDARY	799	$63,236,056	409	$39,601,016	1208	$102,837,072
URBAN	157	$8,976,318	54	$4,558,465	211	$13,534,783
STATE-AID	160	$8,444,160	184	$16,445,184	344	$24,889,344
ACCESS & FRONTAGE	102	$5,383,152	81	$7,239,456	183	$12,622,608
TOTALS	2039	$155,993,222	1589	$168,106,011	3628	$324,099,233

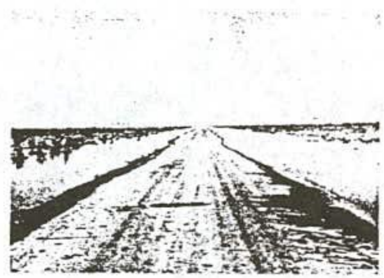
Pavement deterioration on Nevada's highways is growing at an alarming rate. The combination of the age of the system, the tremendous growth of the trucking industry and three consecutive winters with record snowfall and runoff have caused our estimated backlog of rehabilitation work to increase more rapidly than anticipated.

Shoulders were cut on S.R. 225 by the flooding Owyhee River



S.R. 360 was completely severed by recent flooding.

Flash flooding destroyed pavement and fill on this stretch of S.R. 360



High water covered S.R. 140 for weeks until a ditch was dug to carry away the water.

These photos illustrate some of the more apparent highway damage resulting from recent flooding. Many more miles received less apparent damage, but their load carrying ability has been severely reduced which will lead to premature pavement failures.

Since 1982, the Nevada Department of Transportation has awarded contracts totaling $115.5 million for pavement resurfacing, rehabilitation and reconstruction. These contracts resurfaced 1148 lane miles of highway. Even with this substantial effort, more miles deteriorated than were resurfaced, and the backlog continued to grow.

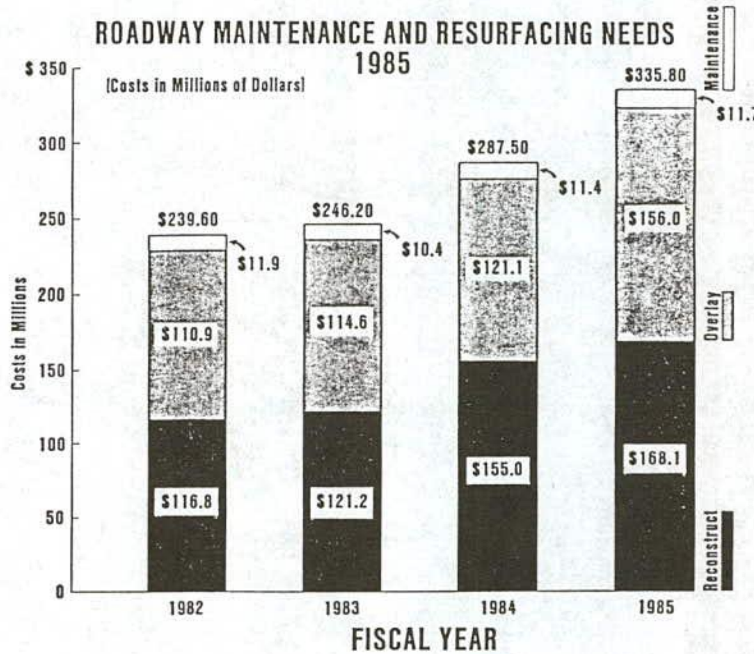


FIGURE 1. Estimate of the Costs to Eliminate the Backlog of Pavement Repair Work

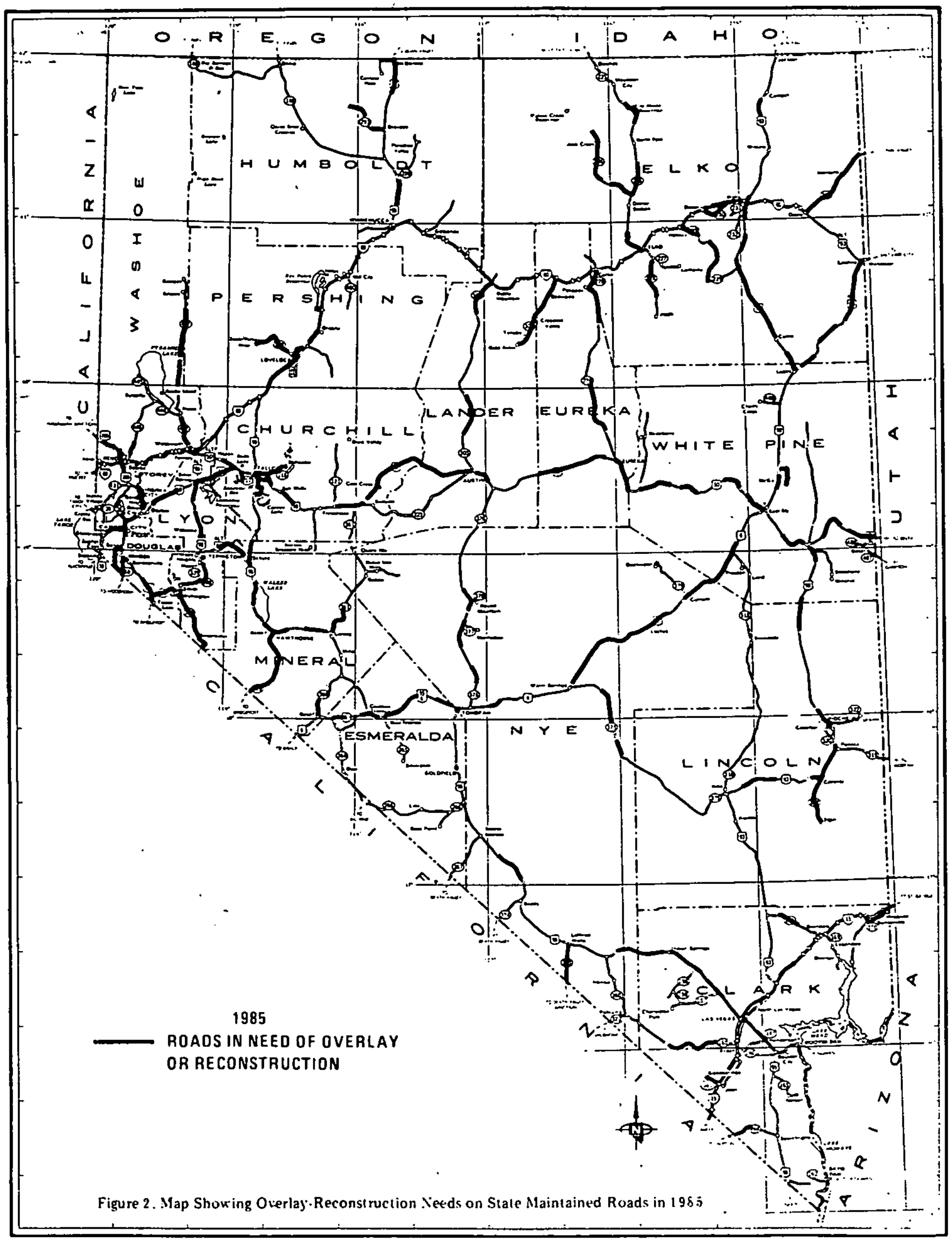


Figure 2. Map Showing Overlay-Reconstruction Needs on State Maintained Roads in 1985

<u>Cost Estimates</u>

The estimate of the costs necessary to eliminate the increasing backlog of 3R work and return the highway system to a service level where it will be most economical to maintain is shown in TABLE 3. The State Funds required to finance the plan are summarized in TABLE 4. Without an increase in expenditures, the deficit will grow to $657 million by the year 2000 and over 50 percent of the system will be in need of overlay or reconstruction.

COMPARISON OF BACKLOG 3R NEEDS – PRESENT vs. PROPOSED EXPENDITURE PLANS

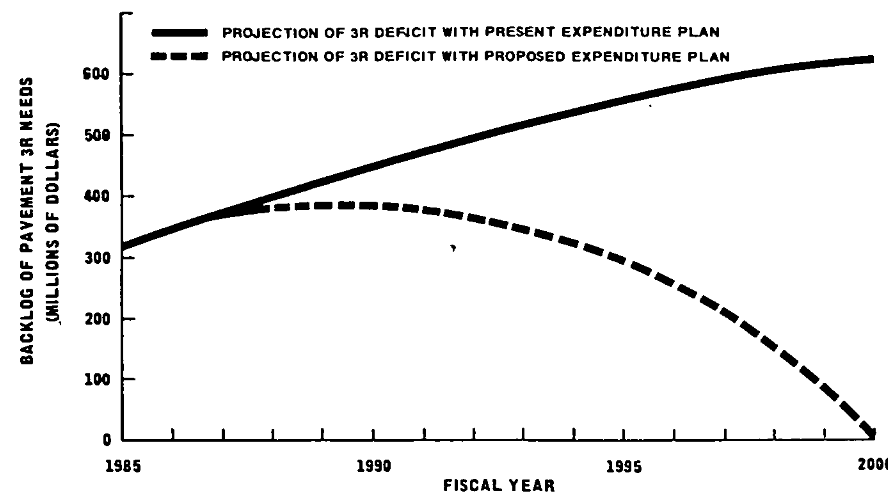


Figure 3. Comparison of Backlog 3R Needs - Present vs Proposed Expenditure Plans.

TABLE 3

COSTS NECESSARY TO PRESERVE THE EXISTING SYSTEM

Based on the 1985 Pavement Management Report
Costs Shown in Millions of Dollars

Inflation Rate = 2.5%
Revenue Growth = 5.0%

	Resurfacing, Restoration and Rehabilitation Work (3R)							Normal - Heavy Maintenance Work				
	"A"	"B"	"C"	"D"	"E"	"F"	"G"	"H"	"I"	"J"	"K"	
F.Y.	Def + Infl.	System Deter Costs	Total 3R Needs	State Funds	Fed Funds	Prop 3R Expend	Accum Deficit	Norm Maint Costs	Backlog 3R Maint Costs	Total Maint Needs	Prop Maint Expend	F.Y.
							324.10					
1986	332.20	58.99	391.19	18.30	24.43	42.73	348.46	11.67	6.13	17.80	17.80	1986
1987	357.17	60.46	417.63	21.98	25.00	46.98	370.65	11.96	6.59	18.55	18.55	1987
1988	379.92	61.98	441.89	33.32	26.44	59.76	382.13	12.26	7.01	19.27	19.27	1988
1989	391.68	63.53	455.21	35.43	27.97	63.40	391.81	12.57	7.22	19.79	19.79	1989
1990	401.60	65.11	466.72	48.75	29.58	78.33	388.39	12.88	7.41	20.29	20.29	1990
1991	398.09	66.74	464.84	51.95	31.29	83.24	381.60	13.20	7.34	20.54	20.54	1991
1992	391.14	68.41	459.55	63.94	33.09	97.03	362.52	13.53	7.21	20.75	20.75	1992
1993	371.58	70.12	441.70	68.20	35.00	103.20	338.50	13.87	6.85	20.72	20.72	1993
1994	346.97	71.87	418.84	72.75	36.96	109.71	309.13	14.22	6.40	20.62	20.62	1994
1995	316.85	73.67	390.52	77.62	39.03	116.65	273.87	14.57	5.84	20.42	20.42	1995
1996	280.72	75.51	356.23	82.83	41.22	124.05	232.19	14.94	5.18	20.11	20.11	1996
1997	237.99	77.40	315.39	88.39	43.52	131.91	183.48	15.31	4.39	19.70	19.70	1997
1998	188.07	79.33	267.40	94.33	45.96	140.29	127.11	15.69	3.47	19.16	19.16	1998
1999	130.29	81.32	211.61	100.51	48.54	149.05	62.56	16.09	2.40	18.49	18.49	1999
2000	64.12	83.35	147.48	96.22	51.26	147.48	.00	16.49	1.18	17.67	17.67	2000

Explanation of TABLE 3

Column

A= The accumulated deficit created by the backlog of resurfacing projects plus 2 1/2% annual inflation.

B= Estimated cost to cover annual deterioration of the existing system.

C= A + B (Total Resurfacing Needs)

D= State Funds for 3R program

E= Federal Fund available for 3R work

F= D + E (Proposed 3R expenditure)

G= The accumulated deficit created by the backlog of resurfacing projects

H= Normal pavement maintenance costs

I= Additional maintenance costs required to hold the system 3R backlog mileage together until it can be contracted

J= H + I (Total maintenance Needs)

K= Proposed maintenance expenditure

TABLE 4

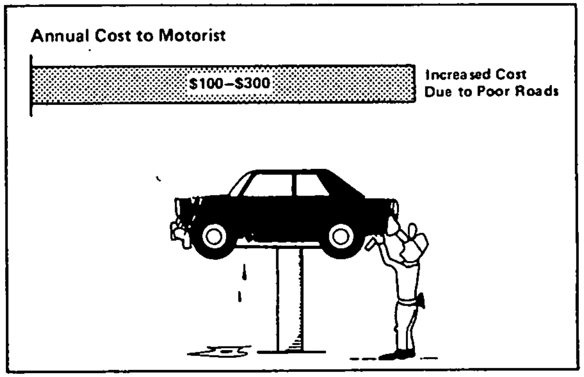
SUMMARY OF STATE FUNDS NECESSARY TO PRESERVE THE EXISTING SYSTEM

(Costs Show in Millions of Dollars)

FISCAL YEAR	REQUIRED EXPENDITURE (NEEDS)	STATE FUNDS FROM PRESENT TAX STRUCTURE (EXISTING)	ADDITIONAL STATE FUNDS REQUIRED (NEW)
1986	36.10	33.60	2.50
1987	40.53	35.28	5.25
1988	52.59	37.04	15.55
1989	55.22	38.90	16.32
1990	69.04	40.84	28.20
1991	72.49	42.88	29.61
1992	84.69	45.03	39.66
1993	88.92	47.28	41.64
1994	93.37	49.64	43.73
1995	98.04	52.12	45.92
1996	102.94	54.73	48.21
1997	108.09	57.47	50.62
1998	113.49	60.34	53.15
1999	119.17	63.36	55.81
2000	113.89	66.53	47.36

CONCLUSION

The cost of operating a motor vehicle increases as the condition of the roadway surface on which it is driven worsens. The poor roadway condition created by the backlog of 3R projects on Nevada's highways is presently costing the traveling public about $40 million per year in increased vehicle maintenance and repair costs. This amounts to about $100-$300 per vehicle.



WHICH COSTS MORE . . . . . HIGHWAY OR CAR MAINTENANCE?

Preservation of the state's highway system is fundamental to the continued economic growth of our State. The Nevada Department of Transportaion is doing all it can to make the best use of its available resources for maintaining the existing highway system. However, unless additional revenue for roadway maintenance and resurfacing becomes available, the condition of the system will continue to deteriorate. The result will be more expensive maintenance costs and poorer quality roads.

APPENDIX E

SIXTEEN KEY QUESTIONS FROM THE PAVEMENT SEMINAR FOR CHIEF ADMINISTRATIVE OFFICERS (*1*)

1- Do I place sufficient emphasis on pavements?

2- Do I have an effective organization to manage the pavement/rehabilitation program?

3- Am I encouraging the development and training of staff personnel?

4- Am I using state-of-the-art methods for the design and rehabilitation of pavements?

5- Can I determine the life-cycle costs of different types of pavements/rehabilitation?

6- When is the right time to rehabilitate or reconstruct an existing pavement?

7- What are the payoffs of the various maintenance/rehabilitation strategies?

8- Do special interest groups unduly influence pavement type selections, designs, and specifications?

9- Can I evaluate the effects of materials and construction quality on pavement/rehabilitation performance?

10- Do I know the past and present condition of the pavement network?

11- Do I have a sound basis for establishing pavement needs?

12- Can I predict the future performance of the pavement network?

13- Do I have a sound basis for allocating resources (funds and manpower) for maintenance/rehabilitation/new pavements?

14- Can I evaluate the effects of changing vehicle characteristics (ie., increasing axle loads, changing axle and wheel spacing, increasing truck traffic volume, changing suspension systems, "increasing" tire pressure, etc.) on pavement performance?

15- Do I know the truck loading being applied to pavements?

16- How can I work more effectively with legislators and support requests for additional resources (funds and manpower)?

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