Role of Pavement Management System Analysis in Preservation Program Development

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The traditional role of pavement management system (PMS) analysis is as an integral part of the preservation program and project development process. The Michigan Department of Transportation already has a well-developed process that does not include a PMS analysis method. To avoid the disruptive effects of injecting or mixing one into this complex but well-defined process, a new role for PMS analysis was created: an application software system that analyzes and processes data from the PMS data base for use by policy makers who are then able to do such things as control long-term network condition and funding requirements [via maintenance, rehabilitation, and reconstruction (MR&R) program development constraints] to reduce the total cost of pavement preservation, and to have decisions flow from the top down. The complete preservation program development process is divided into generic processes: data storage or data base, pre-MR&R program, MR&R program, and post-MR&R program. The pre-MR&R program is conducted at the policy-making level. Policy makers currently must make decisions on the basis of incomplete data of poor technical quality. In addition, no analysis tools are available to enable them to accomplish objectives such as reducing the total cost of pavement preservation, using technology to improve funding efficiency, reducing the cost of overhead, and managing pavements actively. It is proposed that PMS analysis correct these problems by providing policy-level management with complete, high-quality, processed data and analysis tools essential for making rational decisions.

The primary concern of highway officials is the cost-effective preservation of highway networks. Acting on this concern, the *Federal-Aid Highway Program Manual* (*1*) was revised in 1989 to set forth policy to select, design, and manage federal-aid highway pavements in a cost-effective manner and to identify pavement work eligible for federal-aid funding. The new policy requires that each state highway agency (SHA) have a PMS that is acceptable to FHWA and based on concepts described in AASHTO publications including *AASHTO Guidelines for Pavement Management Systems* (*2*). The AASHTO guidelines, in a schematic representation of the various modules of a PMS, indicate that the PMS consists of three major modules: the data base, the analysis method, and the feedback process (Figure 1). This implies that the PMS analysis method is an integral part of the agency's maintenance, rehabilitation, and reconstruction (MR&R) program development process.

It is proposed that the pavement preservation process consist of four independent processes: data storage or data base, pre-MR&R program development, MR&R program development, and post-MR&R program development, as shown in Figure 2. The PMS analysis is proposed to be an automated application software system that links the pre-MR&R process directly to the data base, so utility software is necessary to process PMS analysis data into the forms of information that users need. Such a utility software system can be thought of as an intraagency communication system that serves each of the four preservation processes. A schematic representation of a PMS designed as proposed is shown in Figure 3.

All agencies have always used the processes shown in Figure 2. However, studies of these processes indicated pre-MR&R program development (policy level) is the least well informed agency activity. More and better data for decision making exist at lower levels, but they are neither in proper form nor accessible to the policy-making level. As a result, the policy level has operated on incomplete information of poor technical quality. Policies developed on such information are too general to be practicable, except for funding allocation. Furthermore, the policy level has no means of controlling future funding requirements or network condition, no means of using the department's technical capability to improve the efficiency of available funds, and no means of judging the worth of proposed MR&R programs. In this environment, reactive management is necessary, whereas a management system that controls long-term network condition and funding requirements is more effective and desirable.

Another area of concern was the general ineffectiveness of technology—specifically pavement research—to bring on-line cost-saving methodology. For this reason, it appears that a direct communication link between applied pavement research and policy makers is essential if using technology is to be a way of improving funding efficiency. The primary problem appears to be the lack of a way for policy and technical activities to communicate. For such communication to be possible, all levels must describe projects, programs, and networks using the same terms—terms that are mutually understood and meaningful.

Policy makers are accustomed to using subjective terminology and making decisions about subjective issues. Technical activities deal primarily with objective terms that have specific definitions that apply to analytical problems. A mutually essential set of objective terms with specific definitions common to all agency activities was found to be a must for pavement management. Another essential is the ability to relate the performance of MR&R projects to MR&R programs, the performance of MR&R programs to networks, and vice versa. Because technical activities deal primarily with

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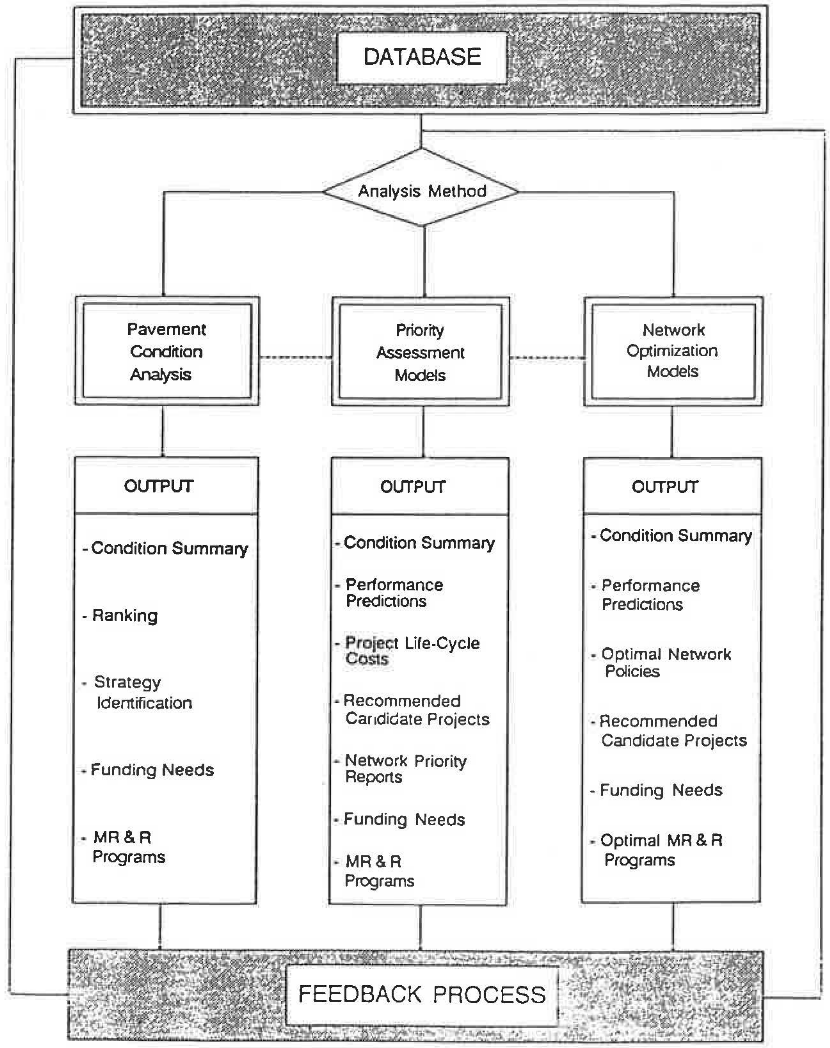

FIGURE 1 AASHTO's representation of a PMS.

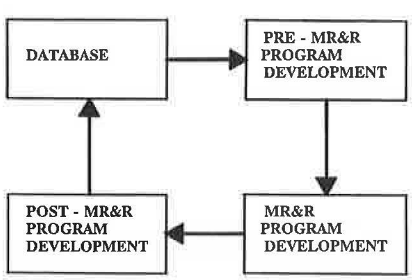

FIGURE 2 Components of complete pavement preservation process.

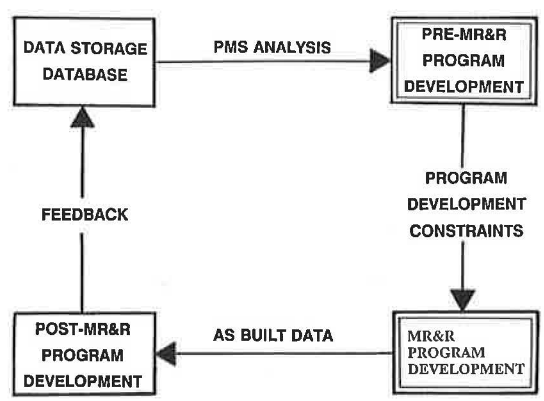

FIGURE 3 Pavement preservation components linked by PMS application and utility software.

projects, the policy level deals primarily with networks, and both deal with programs, all levels must use the same terms to describe them. These terms then become the interface between the project and network levels of analysis.

BACKGROUND

The Michigan Department of Transportation (DOT) formed a pavement management committee in 1980 and assigned it the following tasks:

1. Review the department's current procedures.
2. Determine means for better integrating functions.
3. Identify areas of needed improvement.
4. Make recommendations to upper management.

The committee's preliminary recommendation was that "the department should start development of a simplified PMS that eventually will address many of the needs identified." This recommendation was accepted, and the same committee was asked to develop proposals for improving the existing management system. During this time, a small research staff was directed to investigate technical aspects of pavement condition survey procedures and PMS analysis methodology. One problem for the committee was that department managers and committee membership changed often, producing a fluctuating environment of diverse opinions from which consensus could be reached on what should not be done but not on what should be done.

The research group, in the meantime, determined that a purely analytical PMS analysis method is feasible if it is based on a pool of data representing the lane-mile length, remaining service life (RSL), design service life (DSL), cost, and all benefits of each of all feasible MR&R treatments, of all uniform sections that make up all networks. The RSL comes from PMS pavement conditions surveys (*3*), the DSL from PMS project design analysis, and the cost from PMS cost analysis. Accurate project cost estimates are possible if the available data include a detailed research-level inventory of pavement condition for 100 percent of all networks and a complete physical inventory.

After several years of meetings, the PMS committee could not develop or find a suitable documented PMS to adopt. The analytical method developed as a research study was considered to be a baseline PMS method that the committee proposed to develop further. The research team that developed the method was converted to a full-time PMS development group. The PMS committee never made recommendations for further development and implementation, and its responsibility was changed to its current status of a PMS users group.

From 1980 to 1986, interviews with a wide cross section of key staff, opinions expressed by a majority of committee members, and results of studies of current practice all indicated that Michigan's current pavement management practices are well accepted and should not be modified by a formal PMS. Nevertheless, key staff repeatedly indicate the need for PMS to provide

1. Easier access to historical pavement information.
2. Better pavement performance data.
3. Analysis methods to provide information for decision making.
4. Simplified methods of developing and presenting pavement policy, funding allocations, and network priorities.

PAVEMENT PRESERVATION PROCESS

The basic activities in the pavement preservation processes have been conducted and institutionalized by all SHAs, and it is reported that the information needed to establish pavement preservation policy, allocate funds, and set network priorities should be the same for all SHAs (*4*). But it is understood that the activities and methodology used, although frequently similar, are specific to an agency. The reason that all SHAs do the same thing differently is attributed to operational and organizational differences from one SHA to the other, to the gap between revenues and needs, and to the subjective nature of pavement management associated with the quality and the completeness of information used to make policy decisions.

From the beginning all SHAs received revenues, planned where and how these funds would be allocated, designed projects, let contracts, supervised and monitored construction, and stored records of what was done. Improvements followed each year, and independent activities such as design, materials, testing, research, traffic and safety, and planning became separate activities with specific program and project development duties. All agencies are composed of the same basic activities, but each agency has different organizational and operational characteristics. Nevertheless, pavement preservation for all agencies consists of the four processes shown in Figure 2. An explanation of the activities basic to each process and its products is presented in the following sections.

Pre-MR&R Program Development

Developing the pre-MR&R program entails

1. Allocating funds to programs such as capacity improvement, network expansion, safety, bridge, and maintenance, as well as pavement preservation;
2. Establishing MR&R program development policies and constraints; and
3. Setting priorities for benefits to be provided by the MR&R program.

MR&R Program Development

Developing an MR&R program consists of project identification, programming, scheduling, design, cost estimating, traffic and safety, letting, and construction. When allocated funds are adequate to enable funding for all or most proposed MR&R projects, few program or project development problems occur. It is when the total cost of proposed projects exceeds available funds that problems mount. This process has been well established and is the most complex, organizationally and operationally.

Post-MR&R Program Development

All SHAs conduct some form of postprocessing of annually collected MR&R or as-built data. However, the process usually does not include improving methodology, identifying means to improve funding efficiency, or processing as-built data and information into forms most useful for developing new policies and making decisions. Hence, the post-MR&R process has not been useful to the policy level. The result has been that the policy level has little opportunity to learn from past programs and does not have the means to develop cost-saving policies. Post-MR&R also includes condition survey and pavement evaluation activities.

Data Base

The data base is the repository for all the agency's historical data and information about each annual preservation program. All agencies have had a data storage system that can be transformed to a data base: racks full of plan drawings, file folders full of test reports, boxes full of file folders, and warehouses full of boxes. Only recently have data and information storage been computerized.

PROPOSED ROLE OF PMS IN PAVEMENT PRESERVATION PROCESS

The new FHWA pavement policy (*1*) presents the type of information a PMS should deal with. The AASHTO PMS guide (*2*) describes the characteristics and parts of a PMS and its products. Both of these references are written as though every agency will have a different PMS analysis method. If all agencies have different systems for doing the same thing (maximize every available highway dollar), it follows that these systems are subjective. Then, should it be reasonable to declare that, based on our subjective system, we are maximizing the effectiveness of every available dollar? The point is that the PMS analysis method should not be a subjective system that attempts to take into account all the concerns and nitty gritty details that are necessary to MR&R program development. Instead, the PMS analysis method should be an accurate analysis method designed to provide reliable long-term outcomes of any feasible funding scheme. With complete and accurate data, the methodology is simple, direct, and essential for rational decision making. To meet these requirements, the PMS analysis method must provide

1. The answer to any feasible objective question about network preservation.
2. The ability to establish MR&R program development constraints that will
   - Control long-term network condition and funding requirements,
   - Guide the technical staff through MR&R program development, and
   - Minimize the total cost of network preservation.
3. The means to improve funding efficiency by way of improved technical practices.
4. A measure of the effectiveness of proposed MR&R programs and technical MR&R program development activities.
5. A quantitative measure of the benefits of alternative programs.

A PMS analysis method is analogous to an accounting method; that is, neither method makes decisions, and both methods' output data are only as reliable and accurate as the input data are complete and correct. The purpose of software systems that are the PMS, and that link the four preservation program processes as shown in Figure 3, follows.

PMS Analysis Application Software System

The purpose of PMS analysis is to provide the policy level with all the high-quality data and information needed to determine the pavement preservation MR&R strategy that will, at the lowest total long-term cost of preservation, result in the desired long-term network condition and funding requirements. This means that the traditional network-level analysis must be based on the following application software requirements:

1. The performance of projects, networks, and MR&R programs must all be characterized by the same parameters.
2. The data base contains cost-estimating data, an inventory of the highway infrastructure, basic data necessary to compute the benefits derived from any feasible MR&R treatment for any uniform section, and pavement condition data.
3. The pavement condition surveys provide the basic data needed to estimate cost of MR&R treatments and reactive maintenance, identify cause of deterioration, estimate rate of deterioration, and estimate the DSL of alternative MR&R treatments for 100 percent of each network.
4. The software system must have the ability to identify boundaries of contiguous segments of pavement having uniform condition and RSL.
5. Application software to automate project-level analysis of all uniform sections that make up any designated network.
6. Strategy analysis software for developing MR&R program development constraints and to conduct network life-cycle costing.

The basic methodology for these software requirements is explained by Kuo et al. (*4,5*). An interface among performance of projects, networks, and MR&R programs is created when their performance is characterized by RSL and lane-mile length. The DSL of a project is a constant that becomes its RSL at the time of construction. The means used to estimate RSL are illustrated in Figure 4. The performance of projects, MR&R programs, and networks is characterized in terms of RSL and lane-mile length. This automatically provides an interface between project- and network-level analysis and enables policy and technical levels to communicate with the same terms and the same definitions for the same things.

A detailed inventory of the pavement infrastructure and pavement distress is needed so that the PMS analysis software system can provide policy makers with

- Accurate cost estimates of MR&R, preventive maintenance, and repair treatments and reactive (routine) main-

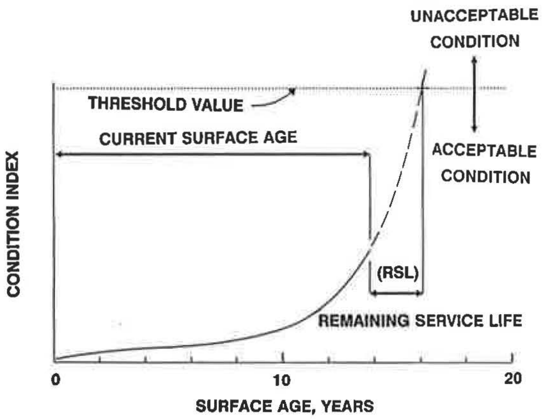

FIGURE 4 Pavement performance curve illustrating RSL concept.

tenance cost for all uniform sections that make up each network.

- Accurate assessments of the performance of each uniform section that, when combined, provide an accurate assessment of network performance.
- Accurate assessment of cost effectiveness and benefits derived from each of all feasible MR&R treatments.
- An accurate measure of funding efficiency and quantified benefits of proposed MR&R strategies and programs.
- Accurate estimates of cause and rate of deterioration.

For the PMS analysis software to provide this, it must consist of application software systems for analyzing pavement condition data, projects, networks, and strategies. The left half of Figure 5 illustrates the activities in and the flow of processed data through the PMS analysis software system starting from the data base and ending at the policy-planning level.

This PMS analysis method gives policy makers a way to conduct economic analysis to minimize the total cost of pavement preservation (network life-cycle cost). The methodology for network life-cycle cost analysis is simple (*5*). And a comparison of network and project life-cycle cost methods in another paper by Novak and Kuo in this Record illustrates the many advantages of network life-cycle cost analysis. A manual form of this PMS analysis method (*6*) illustrates how it provides the PMS products listed in the AASHTO guidelines for PMS (*2*,p.3). The proposed role for the PMS analysis enables policy makers to evaluate alternative funding schemes. Such a study was conducted for FHWA of three Michigan DOT highway districts (*7*). The results illustrate that when PMS analysis is designed to serve the pre-MR&R program process, there is much freedom for creatively allocating funds to other programs, for reducing the total cost of pavement preservation, and for reducing administrative overhead cost.

MR&R Program Development Constraints

The right half of Figure 5 indicates the MR&R program development process. The promulgated constraints (MR&R strategy, funding level, and benefit priorities) are the starting point for MR&R program development. Subordinate staff select projects and match their lengths and DSLs to those of the MR&R strategy. This approach may bother those who think in terms of doing what is best for the project. However, matching project length and DSL to an MR&R strategy pro-

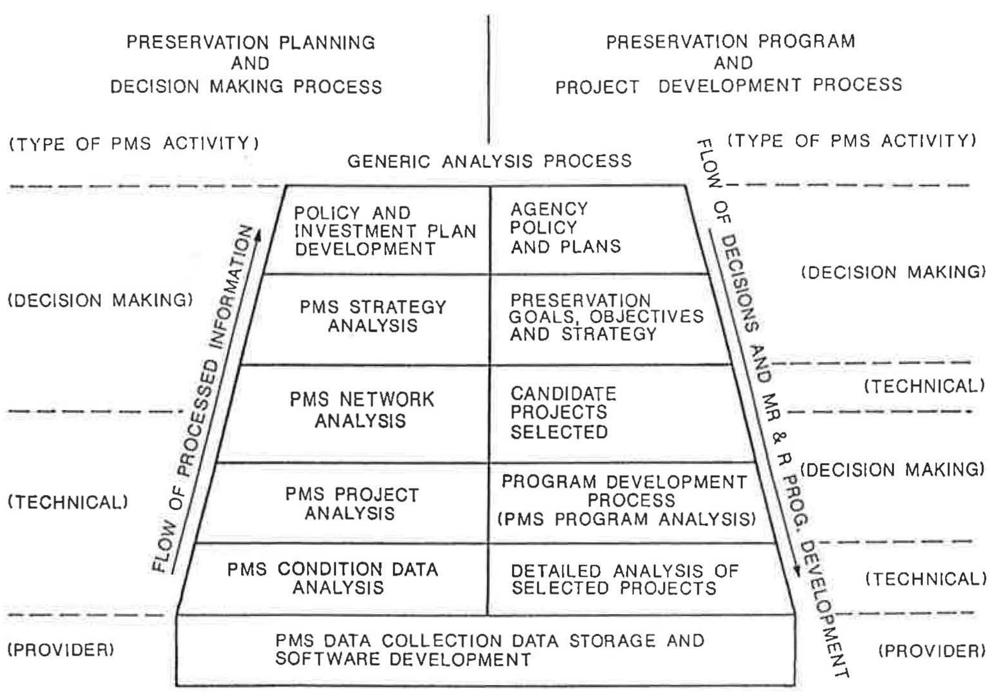

FIGURE 5 Relationship between PMS analysis method and pre-MR&R and actual MR&R program development processes. Also shown are flow of processed information and decisions and type of activities involved.

vides greater freedom to select projects, to select MR&R treatments, and to use engineering analysis to reduce project cost compared with systems that use project life-cycle cost methods to select treatments. As Figure 5 illustrates, a program analysis software system is available to assist with, and should be a necessary part of, finding alternative combinations of projects and treatments that maximize MR&R program benefits. Alternative programs are listed in order of benefit/cost ratio. The policy level knows, for its PMS analysis method, the minimum MR&R program cost and the maximum benefits that are theoretically possible for each network. A comparison of the theoretically best possible program and the proposed MR&R program provides a yardstick measure (efficiency) of its acceptability.

As-Built Data

The as-built data that flow from the MR&R program development activities are the final MR&R strategy, DSL, cost, location, lane-mile length, materials, layer thickness, and physical inventory types of data that are needed for analysis and processing before transfer to the data base. As-built data consist only of data and information that PMS users have asked to access via the PMS and data that are required as input data for the PMS analysis application software.

Feedback

Feedback consists of the data, information, and software improvements that are the products of post-MR&R program development.

DISADVANTAGES OF PROPOSED ROLE FOR PMS ANALYSIS

A PMS whose role is that of a data processing and communication link provides agencies with advantages, but it has its problems as well. The first problem is that of getting MR&R program development activities to give their data products to the PMS. Pavement design, cost estimation, and project programming and scheduling are examples of activities whose data products should be communicated to the post-MR&R program development process via PMS utility software. This means that whereas the PMS is not a part of the operational procedures for MR&R program development, all activities involved in program development must provide their key products to the post-MR&R process. Getting organizational units (such as research) to be a part of the feedback process and to supply key data to the data base are serious problems. However, it makes sense that the primary purpose for storing as-built data and for applied pavement research should be to reduce the future lane-mile cost of pavements per year of DSL. The PMS should be designed to have all the research-level condition and physical inventory data and the analysis software systems needed for applied research to serve the policy makers directly. Likewise, the accuracy of PMS cost estimates should be the responsibility of the activity that makes the agency's cost estimates. Other problems include formalizing pre- and post-MR&R program development and making adjustments needed to change to an active (as opposed to reactive) management style.

SUMMARY

In the absence of a PMS with a role and capabilities as outlined in this paper, the policy level does not have information that is complete enough or of sufficient quality to enable making good rational decisions, to implement cost-saving measures, to control the effectiveness of MR&R programs, to quantify the benefits of alternative MR&R programs, to minimize the cost of pavement preservation, to use technology to effect cost savings, to evaluate technical staff performance, to reduce the cost of overhead, or to move from a reactive to an active management style.

To correct such a situation, the proposed role for the PMS analysis method is to be a data processing and analysis link between the PMS data base and the policy makers. This role requires that the data base contain all the raw data and information of the highest possible quality so that the PMS analysis method can be programmed to answer any conceivable question about any conceivable funding scheme.

The proposed role requires use of RSL (to keep track of the rate of deterioration) and lane miles of pavement as measures of the quantity of pavement in each RSL category. These two terms enable all levels to communicate with each other and provide a simple interface between project and network analysis. For this to work, it is necessary that at least materials, pavement research, cost estimating, and pavement design activities be responsible for their respective areas of the post-MR&R program development (feedback) process. These activities are then in a position to serve the policy level directly by providing the most complete and accurate data the agency's technical staff can produce and to ensure that the policy level has complete, accurate, and reliable data and state-of-the-art tools necessary to maximize benefits from every available highway dollar.

CONCLUSIONS

1. The policy level currently must operate on incomplete information generally of poor quality. The proposed role of the PMS analysis method is to correct this problem by providing

- Complete and accurate pavement preservation and cost data;
- Economic analysis tools (network life-cycle cost analysis) to minimize the cost of pavement preservation for any given network condition;
- Network analysis tools (strategy analysis) that provide the ability to set MR&R program development constraints that will control long-term network condition and funding requirements;
- Analysis tools (based on the economic and network tools) to evaluate alternative funding schemes;
- Dedicated technical staff for the post-MR&R program development process whose ultimate responsibility is to reduce the cost of network preservation;

- Top-down decision making, which is made possible by having the policy level set the constraints for MR&R program development and by providing (via the PMS analysis method and utility software systems) monitoring capability that measures the efficiency of proposed MR&R programs and evaluates the cost effectiveness of technical staffs;
- Common terms (RSL, DSL, and lane-mile length) for describing the performance of projects, MR&R programs, and networks, which in turn provides an automatic interface between project- and network-level analysis and enables policy and technical levels to communicate using terms of mutual significance; and
- Means to quantify the benefits of alternative MR&R programs.

2. The agency's existing MR&R program development process is too complex and institutionalized, and it is unnecessary to insert or mix a PMS analysis method into it. However, PMS utility software is a necessary communication link between MR&R program development and the other three components of pavement preservation.

3. The proposed role for PMS analysis requires that the post-MR&R program consist of technical (applied research) staff. Typical technical skills include computer programming, pavement research, cost estimating, and pavement design. This provides for the policy level's need to have complete, accurate, and reliable data, information, answers, and state-of-the-art analysis capability at their immediate disposal.

GLOSSARY

Design service life (DSL): estimated number of years pavement is expected to be in acceptable condition.

Remaining service life (RSL): estimated number of years from the current year that pavement condition is expected to remain acceptable (RSL is a linear form of rate of deterioration, so PMS analyses based on RSL are simplified).

DSL and RSL categories: time is divided into 5-year categories so that the 0, 5, 10, 15, 20, 25, 30, 35, and 40 categories represent the periods 0–2, 3–7, 8–12, 13–17, 18–22, 23–27, 28–32, 33–37, and 38–42 years, respectively. For new projects, DSL and RSL are the same, and a project's RSL never exceeds it DSL.

Maintenance, rehabilitation, and reconstruction (MR&R): maintenance includes all preventive maintenance treatments that improve a pavement's condition and extend its RSL. All preventive maintenance treatments have a DSL; they are the bulk of projects that extend the RSL of currently acceptable pavements. Rehabilitation includes all project treatments that have a DSL and are not categorized as preventive maintenance or reconstruction. Reconstruction includes all project treatments that bury the original pavement or remove and replace one or more of its layers so that the reconstructed pavement has the same DSL and is in other respects equivalent to a newly constructed pavement.

MR&R treatment: any MR&R action that moves a section of pavement to a higher RSL category. All MR&R treatments are characterized by their DSLs.

MR&R projects: projects selected for, or proposed to be part of, future MR&R programs. They are identified by route title and other identifiers and by their begin and end location. They are characterized by lane-mile length and DSL.

MR&R program (also called *preservation program*): a list of MR&R projects selected for the annual improvement of performance of a designated network. MR&R programs are characterized by lane-mile length and the weighted average of the DSL (ADSL) of each of its projects. At time of construction, a project's ADSL equals its average RSL (ARSL).

MR&R strategy: a surrogate for an MR&R program, that is, MR&R strategies specify the lane-mile length of feasible MR&R projects and the percentage of network that is to be designed into each RSL category. A simple MR&R strategy would specify the lane-mile length (or percentage of network) and the ADSL of the MR&R program. MR&R strategies are used for planning and as development constraints.

Composite MR&R strategy: the planned use of a series of different MR&R strategies each to be applied for a specified time period, usually at least 5 years. Their purpose is to achieve incremental adjustment of network performance to reach ultimate network condition objectives at the least total network life-cycle cost.

MR&R strategy matrix: matrix that indicates the lane-mile length of pavement or percentage of network to be moved from each lower RSL category and to which higher RSL category it is moved.

Future MR&R requirements: MR&R strategy necessary to maintain or adjust the network's performance or condition.

Pavement condition: measured in terms of the pavement's longitudinal profile [roughness in international roughness index (IRI) inches per mile], transverse profile (rut depth to the nearest ⅛ in.), and an inventory of surface distress by type, severity, and extent expressed in terms of distress point accumulation. Each condition measure is summarized and reported for each contiguous 0.1-mi pavement segment. Two pavement condition categories are used, acceptable and unacceptable, on the basis of agency-established threshold values for each of the three measures of pavement condition. The condition of a pavement that is in acceptable condition is reported as the RSL of the condition measure having the shortest RSL.

Threshold value: value that defines each maximum acceptable measure of condition—IRI inches per mile, depth of rutting, and accumulation of distress. A pavement's condition is acceptable only if all three measures of condition are acceptable. Unacceptable condition occurs when one measure of condition reaches its threshold value.

Uniform sections: one or more contiguous 0.1-mi pavement segments whose condition or RSL may vary within specified limits. Uniform sections may be considered and treated the same as projects and are characterized by their lane-mile length and RSL or ARSL.

Network: state trunkline system or any designated portion thereof, consisting of contiguous uniform sections (projects)—the Interstate system, for example. Networks are characterized by lane-mile length, ARSL, percentage of network in unacceptable condition, and percentage of network in each RSL category.

Network condition: percentage of network in unacceptable condition.

Network performance: percentage of network in each RSL category. However, for planning and demonstration purposes, it is more convenient to indicate network performance in terms of the network's ARSL and the percentage of network in unacceptable condition.

Cost matrix: historical average cost per lane mile of construction for MR&R projects whose DSLs fall within each of the following DSL categories: 3–7, 8–12, 13–17, 18–22, 23–27, 28–32, 33–37 years, etc. More comprehensive cost matrices are developed on the basis of project analysis of 100 percent of the networks' uniform sections. Automated project analysis provides the cost, DSL, cost effectiveness, and benefits of all feasible MR&R treatments for all uniform sections in the network. From this project data and a designated range of cost effectiveness, the most cost-effective treatment for each uniform section provides the data for a cost matrix consisting of lane miles of pavement available in each RSL category and the lane-mile cost to move it to each higher RSL category.

Program development constraints: MR&R strategy and the funding level with which the MR&R program must comply to achieve the network performance and life-cycle cost required by policy makers.

Routine or reactive maintenance: maintenance conducted to provide reasonable pavement serviceability but not extend the pavement's RSL. The reactive maintenance workload is considered equal to the lane miles of pavement in unacceptable condition.

Life-cycle cost (LCC): total cost of ownership of a given section of pavement that occurs during the LCC analysis period. This ownership cost is considered to include the sum of the cost of annual MR&R programs plus the sum of the annual cost of reactive maintenance that is accumulated over the LCC analysis period. User costs are not included in the LCC analysis because it is assumed that current levels of network performance cannot be economically justified. That is, economic justification occurs when agency plus user cost is less than or equal to agency plus user savings that result from MR&R investments. It is believed that this is not the case, so minimum network LCC is based on the network performance specified by policy makers and the annual MR&R programs and reactive maintenance costs necessary to achieve and maintain that performance.

LCC analysis period: equal to the maximum DSL among all feasible MR&R treatments plus 5 years. In Michigan, where the maximum DSL is 35 years, a 40-year LCC analysis period is used.

Funding efficiency: ratio of cost of theoretically most cost-effective MR&R program to the cost of the proposed MR&R program.

PMS analysis method: application software system consisting of analysis methods for processing pavement condition and physical inventory data, automated project analysis, network analysis, and strategy analysis. It is thought that the PMS analysis method should not be agency-specific, but its products are not readily understood nor is it handy for novice personnel to use. Therefore, utility software is needed to make the PMS analysis method's products user-friendly and provide all the information users need in the form they desire. This utility software is agency-specific.

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