Abridgment

Pavement Management: The Network-Level Decision Process

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The pavement management process is described in terms of two generalized management levels: the network level, involving global administrative decisions, and the project level, involving technical decisions for specific projects. A general framework for a comprehensive pavement management system (PMS) is described, based on the flow of information at either management level. Some essential features of pavement management systems are identified, and the network-level subsystems of the general PMS framework are discussed in detail. Specific network-level techniques that seem promising for use within a comprehensive PMS are identified. It is concluded that, although the development of network-level techniques has generally lagged behind project-level development, implementation of a comprehensive PMS can begin immediately by using existing technology.

Pavement management involves the coordination, scheduling, and accomplishment of all activities performed by a highway agency in the process of providing adequate pavements to serve the public. The systems approach to pavement management provides a rational, highly structured decision process with the objective of providing the highest possible value for public funds expended on pavements. This is accomplished by comparing investment alternatives (coordination of design, construction, maintenance, and evaluation activities) and making efficient use of existing methods and knowledge (1,2). The idea behind a pavement management system (PMS) is to improve the efficiency of the normal decision-making process, to expand its scope, to provide feedback as to the consequences of decisions, and to ensure the consistency of decisions made at different levels within the agency (3).

A PMS is a system that provides decision makers at all management levels with optimal strategies derived through clearly established rational procedures. Such a system provides an evaluation of alternative strategies over a specified analysis period based on predicted values of quantifiable pavement attributes and subject to predetermined criteria and constraints. A PMS involves an integrated, coordinated treatment of all areas of pavement management and is a dynamic process that incorporates feedback on the various attributes, criteria, and constraints included in the optimization procedure. Fuller discussion of the essential characteristics of a PMS and their secondary requirements is available elsewhere (3,4).

FRAMEWORK FOR PMS

The three major activity types of a comprehensive PMS are shown in Figure 1. Decision-making activities are characterized by their scope: wide-ranging or global decisions that affect the whole highway network and specific decisions on individual projects. The network-management level primarily involves programming and budgeting decisions for groups of projects or an entire network. The project-management level is characterized by predominantly technical management concerns on individual projects. Of course, technical activities occur at the network level, and administrative activities occur at the project level. It is necessary to make a distinction, however, because detailed technical decisions for individual projects involve considerations fundamentally different from the more global decisions that must be made for a network.

These two types of decision-making processes constitute virtually the entire system from the typical user's point of view. That is to say, the PMS is primarily a tool for use by decision makers. Other activities that provide feedback for updating components are vital to the proper functioning of the system but generally remain behind the scenes.

A total PMS functions at all management levels, but each level requires different types and amounts of data, uses different decision criteria, and operates under different constraints. Consequently, the detailed structure of the total system may vary considerably from level to level; however, the basic sequence of actions within levels is the same.

The flow of information within a comprehensive PMS framework is illustrated in Figure 2. First, pertinent information is gathered, and the consequences of the available choices are analyzed in the light of this information. Based on this analysis and on other nonquantifiable considerations (which may involve political and social issues), a decision is made. The decision is then implemented, and the results are recorded in the data base and passed on to other management levels.

This three-subsystem concept as applied to a two-level PMS is shown in Figure 3, as well as the relationships among the subsystems and with the data base. The result of a decision at the network level forms part of the input for the project-level decision process and vice versa. Thus, the information flow within such a management system is cyclical in nature. Not illustrated is the fact that a single decision at the network level often triggers multiple decisions for a large number of individual projects.

NETWORK-LEVEL SUBSYSTEMS AND MANAGEMENT ACTIVITIES

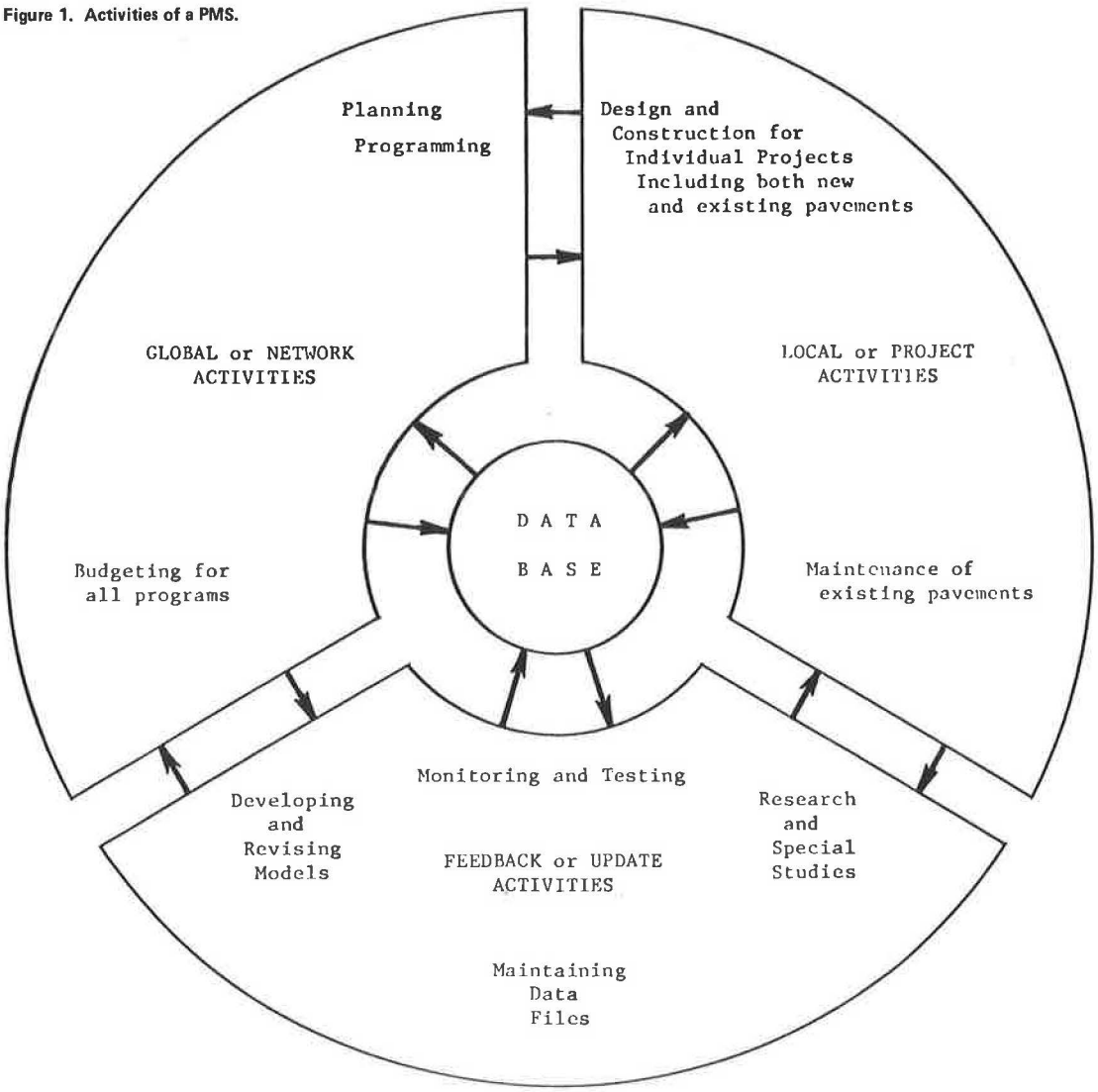
The network-level subsystems of Figure 3 are discussed briefly below. More-comprehensive discussion, including project-level activities, is available elsewhere (3,4).

Information Subsystem

The information subsystem contains information necessary to determine the condition of the network as a whole. The essential activities required to support this subsystem include

1. Determination of the pavement attributes to be measured, such as structural capacity, ride quality, surface condition, and skid resistance, to a degree of accuracy, intensity, and frequency appropriate to the class of roadway, agency resources, etc.;
2. Identification of homogeneous sections or links in the network;
3. Collection of nonpavement information such as geometry, traffic, and accidents;
4. Conducting of field measurement programs;
5. Generation of historical maintenance data and construction records;
6. Estimation of unit costs for materials and work;

Figure 1. Activities of a PMS.



7. Identification of available resources; and
8. Identification of already committed improvements.

Analysis Subsystem

The essential function of the analysis subsystem is to consider pavement improvement and maintenance needs and to arrive at a program of rehabilitation, new construction, and/or maintenance. This is accomplished through the following activities:

1. Identify needs and "candidates" for improvement;
2. Generate alternatives for each candidate project (i.e., several types, thicknesses, and timings for new construction, rehabilitation, or maintenance);
3. Select program-analysis period, discount rate, minimum ride-quality levels, etc., for technical and economic analysis;
4. Identify the basis for deciding on the final program, i.e., solely economic (maximization of benefits or minimization of costs) or partly economic and partly nonquantitative;
5. Estimate performance for each alternative;
6. Perform economic analysis for each alternative; and
7. Develop initial programs for construction, rehabilitation, and maintenance, optimized according to a selected measure of benefit or ranked by priority.

Implementation Subsystem

The implementation subsystem of the network-management level of Figure 3 includes accomplishment of the selected program of work. Major activities are

1. Identifying the recommended work program,
2. Submitting the program for legislative or administrative approval,
3. Budgeting and reporting of program to project-management levels,
4. Scheduling and accomplishing work,
5. Updating data records and prediction models periodically, and
6. Revising program as necessary.

EXISTING TECHNOLOGY AND THE GENERAL PMS FRAMEWORK

This framework provides a basis to compare and assess the current pavement management procedures

Figure 2. Flow of information at a typical management level within a total PMS.

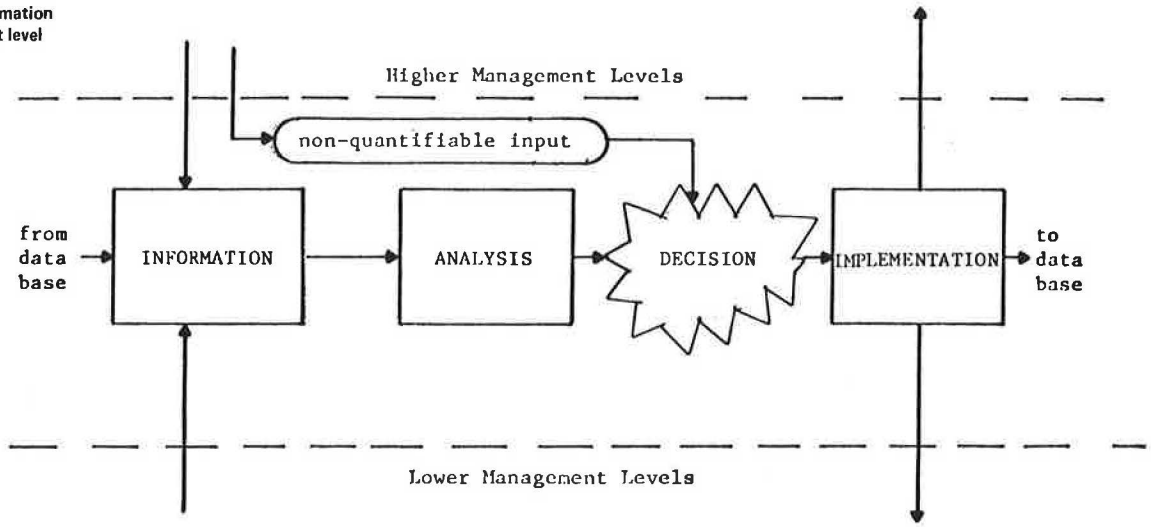
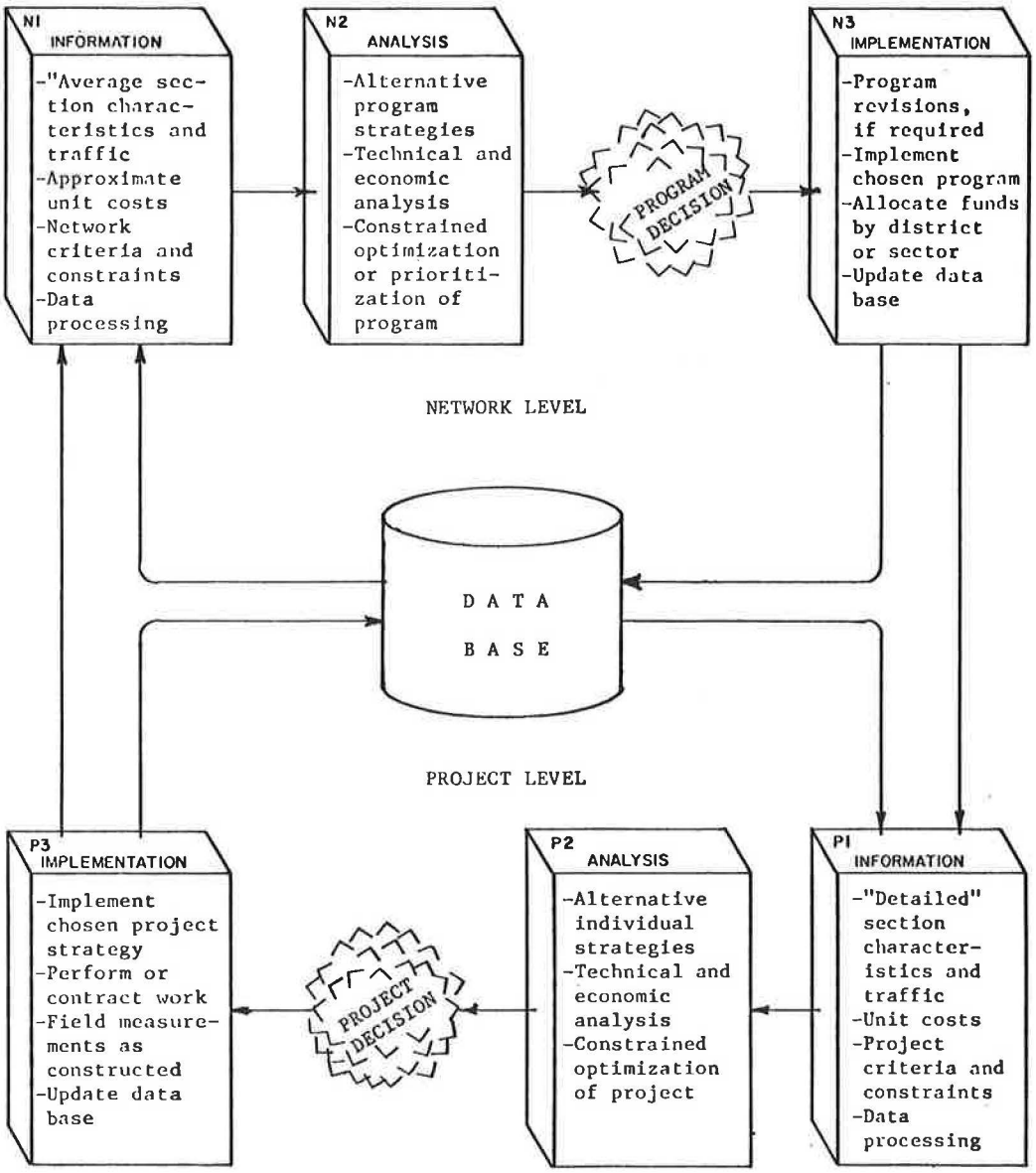


Figure 3. Framework and major subsystems of a two-level, comprehensive PMS.



used by various highway agencies. The Workshop on Pavement Management sponsored by the Federal Highway Administration and conducted in Tumwater (Olympia), Washington, in November 1977 provides a succinct statement of current practice for several states (5).

The techniques described at Tumwater are principally directed toward detailed technical decisions for individual projects. The network-level decisions that are made usually aggregate the project-level results to develop priorities in a program for rehabilitation. Such a process is not optimization of network alternatives. Most participating agencies recognized the need for systematic network-level decisions, and some are moving in that direction. Arizona, for example, is currently developing a network-level constrained optimization scheme to complement its existing project-level system (according to Fred N. Finn). Another example is the Rehabilitation and Maintenance Strategies (RAMS) program under development for the Texas State Department of Highways and Public Transportation by Lytton and others (6-8). In addition, some relative newcomers (such as Idaho) have made impressive starts, and considerable development and implementation has occurred in Canada (9-12). Finally, potentially useful network-level techniques have been reported by several other researchers (13-15).

Even though much of the work discussed at the Tumwater Workshop is project-oriented, several states use procedures that are appropriate for network-level use. A few of the more promising techniques are discussed below and placed within the framework of Figure 3.

Because of the broad scope of network-level decision making, it is nearly essential that a single variable or objective function be chosen for optimization. A strategy can then be selected to maximize (or minimize) the value of this single variable, subject to any applicable constraints. The most straightforward approach involves the choice of a directly measurable variable as an objective function.

This concept has been developed to a considerable extent by New York State. There the user is considered to be the final judge of the pavement. New York has developed a specialized measure of riding quality (related to the Present Serviceability Rating concept) that is applied to all pavement sections in the highway network. This measurement variable is used to set priorities for projects. The procedure involves physical-roughness measurements that are correlated to user ratings. The New York rating procedure also uses psychophysical scaling techniques in the determination of the rating score, large rating panels (from 60 to 80 people), and separate evaluations for flexible, rigid, and composite pavements.

A second approach to the use of a single objective function involves the combination of multiple variables to produce a single index. Arizona uses a combination of cracking, riding quality, deflection, age, traffic, environment, and functional class of roadway to produce a weighted average of total lane miles in acceptable condition over the specified analysis period. This combined-attribute approach guarantees the consideration of all important pavement variables in the optimization procedure. The single attribute, if carefully chosen, will reflect to some degree all of the multiple values cited above yet will be more efficiently and less expensively measured. The choice between single- or multiple-attribute objective functions depends on whether the agency can find a single variable that it considers a satisfactory measure of pavement adequacy.

Another important part of network-level analysis involves consideration of the relative costs of alternative strategies. The Arizona system considers a road's life-cycle costs to be constrained by some preset budget level. At the other extreme, the Washington State Department of Transportation uses the present value of total expected costs over a long-term analysis period as a parameter for optimization. Many states favor consideration of costs that include a budget constraint. For network-level analysis, evaluation of cost could be in a benefit/cost ratio form, just as for project-level analyses. The use of either a budget constraint or an optimization with respect to a benefit/cost ratio is compatible with the framework and concepts described in this paper. The choice is largely a matter of attitude and perspective of the implementing agency.

The network analysis could provide the ability to estimate the average network service level to be expected for a given budget and, conversely, given the desired network service level, to estimate the required budget. Once the procedure to calculate costs and service levels or benefits under various strategies has been established, both analyses can be provided on a routine basis and could be helpful in responding to various legislative inquiries.

SUMMARY

Clearly, no existing method represents a complete, working PMS as envisioned in Figure 3. Many agencies have, however, taken a good first step in achieving such a system, and a few systems currently in use or under development are well advanced. The development of a total management system must, in fact, proceed through many small steps so that each component may be tried and modified, new components may be properly interfaced, and a smooth transition may be effected in the operating procedures of the agency. Only after such a process will the management system be accepted and used by an agency.

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Simplified Structural Analyses of Flexible Pavements for Secondary Roads Based on ILLI-PAVE

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A procedure based on the results of a stress-dependent finite-element computer model and used to calculate the resilient response parameters of conventional flexible pavements subjected to traffic loads is presented. Flexible pavements composed either of a granular base protected by a surface treatment or of an asphalt-concrete surface layer and a granular base are considered. Asphalt-concrete surface-layer thickness, base thickness, modulus of elasticity of the asphalt concrete, and subgrade resilient modulus at the break point (the input data required to calculate the resilient response parameters) are discussed. The basis of a flexible pavement design process for secondary roads is proposed.

This paper describes the development of a simplified procedure for the structural analysis of pavements for secondary roads. Preliminary research conducted by the Transportation Materials Engineering Group of the University of Illinois has indicated the feasibility of predicting critical pavement-response characteristics (stresses, strains, and deflections) by means of simple algorithms. Those algorithms have been reviewed and extended to include other parameters considered to play an important role in pavement response to loading.

A finite-element computer program for flexible pavement analysis originally developed by Wilson (1) and later modified by Duncan and others (2) and by Raad and Figueroa (3) served as the main research tool. The recent modifications introduced by Raad and Figueroa (3) provide a more rational assessment of the state of stress of pavement materials approaching failure (and consequently their moduli values) according to the Mohr-Coulomb theory of failure. The finite-element computer program for flexible pavement analysis (ILLI-PAVE) offers an alternate iterative method of solution in addition to the already known incremental procedure. Stress-dependent material models can be considered in this model. Traylor (4) showed that the ILLI-PAVE program adequately predicted the flexible pavement response to loading when the results of the computer modeling and field test data were compared.

The objective of this research was to develop a procedure that would eliminate the need to use a computer model for flexible pavement analysis every time the pavement response to loading was to be determined. The methodology consisted of the ILLI-PAVE analyses of pavements having all possible combinations of input parameters identified to be the best determinants of pavement response to loading. The parameters were chosen within the range of material properties and layer thicknesses expected for secondary roads. Multivariable regression analyses were performed on the ILLI-PAVE results to develop algorithms expressing each pavement response (dependent variable) in terms of material properties and geometric characteristics (independent variables) of the flexible pavement. A description of the assumed loading conditions, composition of pavement cross section, and range of material properties is given below.

DESCRIPTION

Loading Conditions

A constant load of 40 kN (9 kips) was maintained throughout the study to account for half of the 80-kN (18-kip) single-axle load commonly used for