Strategic Planning for Pavement Rehabilitation and Maintenance Management System

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A strategic planning scheme has been developed for a pavement rehabilitation and maintenance management system. Four usual phases compose the analysis framework: (a) problem analysis and data collection, (b) formulation of the mathematical model, (c) optimization, and (d) analysis of the solution. Matrices of roadway inventory, current pavement condition rating, gain of rating, pavement survival rate, minimum rating requirement, resource requirement, and resource availability are assembled in phase 1. In phase 2, the resource allocation problem is formulated in a zero-one integer linear programming model that maximizes the overall effectiveness of all proposed maintenance and rehabilitation activities subject to the following constraints: decision variable constraints; available supplies, equipment, work force, overhead, and state betterment budget constraints; and minimum distress rating and pavement rating constraints. The formulation of several other constraints, such as social, political, and geometric constraints, is also discussed. In phase 3, the mathematical model is used to determine the optimal maintenance strategy for each highway segment included in the analysis. Solutions are analyzed in phase 4. The formulation of this resource allocation method for strategic planning of maintenance and rehabilitation provides a basic framework within which management decisions can be made and altered while the effect that those decisions will have on the quality of pavements within a highway network can be fully recognized.

Funding for highway maintenance operations can be expected to become more stringently controlled in the future. In addition, highway management decisions will be greatly affected by new social attitudes toward the use of scarce natural resources; environmental impact; and human responses, values, and preferences. Strategic planning for the optimal allocation of limited resources will result in a significant amount of economic saving. Thus a systematic methodology is urgently needed to establish priorities for the optimal investment of available resources while satisfying the demands of the public for quality highway pavements. Moreover, the use of analytical techniques for the determination of optimal resource allocation policies for a given highway system can identify maintenance practices that can potentially save money by using money more effectively.

Management scientists have developed many mathematical models for resource allocation optimization. In operations research, resource allocation problems can usually be formulated in two alternative optimization schemes: (a) maximize the overall effectiveness subject to limited resources or (b) minimize the use of resources subject to minimum requirements of effectiveness. The former scheme is adapted herein for the system development because the current maintenance budget systems seem more consistent with maximizing effectiveness than with minimizing the use of resources. However, conversion from one formulation to the other can easily be accomplished. In addition, the methodology based on zero-one integer linear programming techniques may be readily applicable for the resource allocation of a highway maintenance system.

The purpose of this paper is to present basic concepts required for the development of a comprehensive pavement rehabilitation resource allocation system. A conceptual model based on the zero-one integer linear programming algorithm is presented. Special emphasis has been placed on (a) evaluation and rating of the condition of current pavement distress; (b) demands for pavement performance and service life; (c) effectiveness of different maintenance strategies and pavement maintenance survival rates; (d) requirements and availability of materials, supplies, equipment, work force, and overhead costs for pavement maintenance and rehabilitation; and (e) various budgetary constraints.

The terms used in the paper are defined below.

GLOSSARY

1. Analysis period is a period selected to be longer than any maintenance or rehabilitation method, including reconstruction, and expected to last without requiring additional maintenance work.
2. Types of distress are manifestations of pavement distress categorized by visual rating and other forms of evaluating pavements and include cracking, patching, rutting, roughness, raveling, flushing, and corrugations.
3. Environmental factors are soil or climatic variables that affect maintenance effectiveness. Soil variables include expansive clays and shales and frost heave Climatic variables include temperature and moisture

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cycling and poor drainage.

4. Highway network is the overall highway system included in the analysis.

5. Highway section is the conventional division of a highway system.

6. Highway segment is a portion of a highway section or a combination of several sections such that a segment can be treated as a unity in the analysis.

7. Maintenance activity is a general term for all work done to restore quality to a given pavement condition. In a more restricted sense, maintenance activity refers to the less extensive work done to upgrade the condition of a pavement.

8. Maintenance effectiveness is the sum of probabilities of retaining the overall gains of pavement rating due to maintenance activity on all highway segments over the analysis period.

9. Maintenance strategies are different activities to be selected for each highway segment in the analysis to increase the pavement rating above specified minimum requirement.

10. Pavement condition rating is the score of pavement quality for each type of distress of each highway segment.

11. Pavement rating score is a sum of all of the pavement condition ratings for each form of distress.

12. Pavement survival is the retention of a pavement condition rating higher than the pavement had when maintenance was applied.

13. Potential gain of rating is the expected increase of pavement rating score when a given type of maintenance or rehabilitation is applied.

14. Rehabilitation activity is a term reserved for the more extensive repair or reconstruction work done to a pavement to return it very nearly to its original structural capacity or safety condition.

15. Survival probability is the likelihood that a given maintenance strategy will retain its gain in pavement rating score over the analysis period when it is applied to a pavement with a given type of distress.

16. Traffic condition is the volume and weight of the traffic loading applied to a pavement.

MANAGEMENT PLANNING AND CONTROL SYSTEMS

In pavement maintenance management, strategic planning for resource allocation at the district highway department level is based on the policies and guidelines prescribed by federal and state transportation administrations. The objective at the district level is to maximize the total effectiveness of all maintenance and rehabilitation activities scheduled for the next year. Strategic planning is essentially built around a financial structure to provide the most cost-effective decisions on maintenance strategies so that all highway segments within the district can be maintained above a specified level of serviceability for normal driving. Guidelines set by strategic planning will eventually be carried out by district engineers for management control and construction supervisors for operational control.

A strategic planning scheme for pavement maintenance and management has been developed in four phases: (a) problem analysis and data collection, (b) formulation of the mathematical model, (c) optimization, and (d) analysis of the solution.

PHASE 1: PROBLEM ANALYSIS AND DATA COLLECTION

Phase 1 of the strategic planning for a pavement maintenance management system is the task of problem analysis and data collection that is categorized into four subtasks: (a) management decision, (b) roadway description, (c) pavement condition, and (d) resource information.

Management Decision

Management decisions determine the number of highway segments that will be considered in a highway network, the number of maintenance strategies that will be employed, the number of types of distress to be included in determining the current condition of all highway segments, and the analysis period for planning and control.

Highway Segment

One highway segment can be a portion of a highway section or a combination of several sections such that a segment can be treated as a unity in the study. The traffic condition and environmental factors that affect the effectiveness of maintenance and rehabilitation activities within the unity must be very similar if not identical. Then the strategic planning system will select an optimal maintenance strategy for each unity, that is, each highway segment specified by the decision maker. Highway sections that are expected to provide acceptable serviceability and require no maintenance during the next year need not be included in the scope of the study.

Maintenance Strategies

Undoubtedly, numerous practical applications of maintenance strategies can be listed. However, the more strategies included in a given analysis, the more effort is required in assembling maintenance effectiveness data and in the mathematical programming of the problem. As a consequence, the current list has been restricted to 11 rehabilitation and maintenance strategies, from strip seal to reconstruction: strip seal, fog seal, chip seal, light patching and chip seal, extensive patching and chip seal, chip seal and planned thin overlay, plant mix seal or open-graded friction course, thin overlay [less than 5.08 cm (2 in) of asphalt concrete], moderately heavy overlay [5.08 to 7.62 cm (2 to 3 in) of asphalt concrete], heavy overlay [7.62 to 15.24 cm (3 to 6 in) of asphalt concrete], and reconstruction. These strategies are listed in order of increasing unit cost. Usually, the first 4 strategies are funded from the state maintenance budget. Funding for the next 4 strategies is either from state maintenance budget or from the betterment budget. The last 3 strategies are funded from the betterment budget as contract work.

Pavement Distress

Usually, pavement distress manifestations can be categorized into the following 9 types: rutting, raveling, flushing, corrugations, roughness, alligator cracking, longitudinal cracking, transverse cracking, and patching. This classification has been used in several visual rating systems for evaluating pavements (1, 2, 3, 4).

Analysis Period

A heavy overlay will, undoubtedly, last longer than seal coats when applied to the same highway pavement. To calculate the overall effectiveness of all maintenance activities, one must analyze the pavement survival rates over a specified time period. An analysis period should be selected to be longer than any maintenance or rehabilitation method, including reconstruction, is expected to last without requiring additional maintenance work. A period of 10 years is recommended for analysis. This does not mean that maintenance decisions and budgeting for the next 10 years will be studied. Instead, only the next year's maintenance strategies and budgeting will be determined, but their choice will be based on the effectiveness of each maintenance strategy within the given analysis period.

Roadway Description

After the number of highway segments to be considered in a resource allocation scheme is determined by management decisions, the type of pavement, length, width, traffic, and environmental conditions of each segment can be established. The roadway data collected on each highway segment can be organized into a roadway inventory matrix. Traffic and environmental multiplying factors can be used to increase with traffic and climatic conditions that accelerate the appearance of various forms of distress. The formulation of these two factors will be discussed subsequently.

Pavement Condition

The pavement condition can be analyzed in the following aspects:

1. Current pavement condition rating of each segment for each type of distress,
2. Potential gains of rating of each segment for each maintenance strategy and type of distress,
3. Pavement survival rate of each maintenance strategy for each type of distress and time period on each type of pavement,
4. Minimum rating requirement of each segment for each type of distress and time period, and
5. Rating requirement of each segment and time period.

Current Pavement Condition Rating

Several pavement condition rating systems currently in use (1, 2, 3, 4) are readily applicable to the resource allocation model developed herein. By using such a rating system, one can fill out a current pavement condition rating matrix (Figure 1) based on the rating of each highway segment and each type of distress.

Potential Gain of Rating

Potential gain of rating is defined as the net expected increase of pavement rating of each segment for each type of distress and maintenance strategy. The potential gain of rating for a given kind of distress cannot exceed the amount of rating that it lost by that form of distress. A gain-of-rating matrix (Figure 2) is devised for each highway segment. When the number of segments gets large, the task of composing this collection of matrices can be done most efficiently by computer. Some maintenance strategies might not improve but rather might reduce the pavement ratings of certain types of distress. As an example, seal coating does not improve rutting, and a fog seal may accentuate flushing. In these cases, a zero or negative gain of rating will be required.

Pavement Survival Rate

Figure 3 shows a pavement survival matrix that contains the survival probability of each highway segment for each type of distress and maintenance strategy over the analysis period. Where maintenance and rehabilitation are concerned, the term "survival" indicates that the pavement condition is still expected to be rated high enough not to require additional maintenance or rehabilitation work. For instance, for a specific highway segment i, maintenance strategy j, and type of distress k at t years after maintenance work has been performed, a typical survival rate P_{ijkt} may be as follows:

$$P_{ijkt} = \begin{cases} 1.00 & \text{if } t = 0 \text{ year} \\ 0.90 & \text{if } t = 1 \text{ year} \\ 0.70 & \text{if } t = 2 \text{ years} \\ 0.40 & \text{if } t = 3 \text{ years} \\ 0 & \text{if } t \geq 4 \text{ years} \end{cases} \quad (1)$$

This example indicates that the pavement survival rate is 100 percent immediately after the maintenance work is accomplished; 90 percent, 70 percent, and 40 percent respectively at the end of the first, second, and third years; and 0 percent at the end of the fourth year. Suppose the current rating of a specific type of distress k is 5 and the gain of rating of type of distress k is 15 if maintenance strategy j is applied; the rating after the maintenance is done is 20. The rating drops to 18.5, 15.5, and 11 respectively, at the end of the first, second, and third years. The rating will return to 5 after the end of the fourth year.

The maintenance effectiveness when strategy j is applied per unit surface area of highway segment i when type of distress k is present is defined as

$$\sum_{t=1}^{N_T} d_{ijk} P_{ijkt} \quad (2)$$

where

d_{ijk} = potential gains of pavement rating of highway segment i for maintenance strategy j and type of distress k;
P_{ijkt} = pavement survival probability of highway segment i for maintenance strategy j and type of distress k at time t; and
N_T = number of years in analysis period.

Estimating the potential gains of rating of each highway segment can be a painstaking process for highway engineers. For instance, if 100 highway segments are considered in the analysis framework, the data for 100 gain-of-rating matrices as shown in Figure 2 must be assembled. This problem may be simplified by categorizing the existing pavements into several major types, such as (a) surface treatment pavement, (b) hot-mixed asphalt concrete (HMAC) pavement without overlay, and (c) HMAC overlaid pavement. The gain of rating of the three types of pavement at typical traffic and environmental conditions can thus be used to compose three basic matrices. The gain of rating of each individual highway segment can now be derived by multiplying a traffic adjustment index and an environmental adjustment index to the basic matrix. The maintenance effectiveness can be rewritten as

$$\sum_{t=1}^{N_T} D_{njk} \times \max[1 - a_i b_i (1 - P_{ijkt}), 0] \quad (3)$$

where

D_{njk} = potential gains of pavement rating of maintenance strategy j and type of distress k if highway segment i is type of pavement n,
a_i = traffic adjustment index of highway segment i, and
b_i = environmental adjustment index of highway segment i.

The master matrix of probability of pavement survival P_{ijkt} represents characteristic survival curves that may be modified by different traffic volumes and environmental effects. The characteristic curves should be the highest expected probabilities within a given district so that the adjustment factors, a_i and b_i, will always be one or greater. Thus an increase in a_i or b_i will represent increasingly heavier traffic loading or more severe environmental conditions and will reduce the probability of survival. This is shown in Figure 4.

Figure 1. Current pavement condition rating matrix.

		HIGHWAY SEGMENT NUMBER						
		1	2	3	...	...	...	N_H
DISTRESS TYPE	1							
	2							
	3							
	...							
	...							
	N_D							

N_H - the total number of highway segments in analysis.

N_D - the total number of distress types.

Figure 2. Gain-of-rating matrix of each highway segment.

		DISTRESS TYPE						
		1	2	3	...	...	...	N_D
MAINTENANCE STRATEGY	1	12	10	8				10
	2	10	10	7				8
	3	8	10	6				6
	...							
	...							
	N_S	0	5	-4				-6

N_S - the total number of maintenance strategies

N_D - the total number of distress types.

Figure 3. Pavement survival matrix of each highway segment and type of distress.

		TIME AFTER MAINTENANCE							
		0	1	2	3	4	...	...	...	N_T
MAINTENANCE STRATEGIES	1	1.00	.90	.70	.40	0.0				
	2	1.00	.80	.50	.20	0.0				
	3	1.00	.60	.20	0.0					
	...									
	...									
	N_S	1.00	0.50	0.0						

N_S - the total number of maintenance strategies

N_T - the analysis period in years.

Minimum Rating Requirement

Figure 5 shows a rating requirement matrix of each highway segment. Some instructions for preparing the matrix need to be given.

1. For highway segment i and type of distress k, the rating requirement $R_{ikt} = 0$ if $t \geq T_{ik}$. T_{ik} is the expected service life of the maintenance activity of the next year for that highway segment and type of distress; that is, another maintenance activity will be scheduled for highway segment i at or before time T_{ik}.
2. For highway segment i, the total rating requirement of all types of distress $W_{it} = 0$ if $t \geq T_i$. T_i is the expected service life of the maintenance activity of the next year for highway segment i. Another maintenance activity will be scheduled for this segment at or before time T_i.
3. The total rating requirement is not necessarily the sum of the rating requirements of all types of distress. Usually, for highway segment i and at time t,

$$W_{it} > \sum_{R=1}^{N_D} R_{ikt} \tag{4}$$

where N_D = total number of types of distress in the analysis. The constraint of total rating requirement is unnecessary if

$$W_{it} < \sum_{k=1}^{N_D} R_{ikt} \tag{5}$$

Resource Information

The resource allocation scheme to be described is especially devised for annual budgeting and management. However, a substantial degree of flexibility for decision making has been retained. For instance, seasonal (or even monthly) reviews of the selected maintenance strategies are strongly encouraged so that inflated costs and the scarcity of resources as well as the need for changing pavement rating score requirements can be included in the management analysis framework to alter or justify previous maintenance decisions.

Resources for pavement maintenance and rehabilitation can be categorized in the following groups: (a) material and supply, (b) equipment, (c) personnel, (d) district overhead cost, and (e) betterment budget for contract work. First of all, the number of types of material, equipment, and work forces must be identified. In light of the availability of the resources and the design engineer's preference, the types of materials, equipment, and work forces adopted and used for maintenance and rehabilitation in one district are not necessarily the same as those adopted and used in another district.

PHASE 2: MATHEMATICAL MODEL

Phase 2 of strategic planning for the pavement maintenance and management system is to formulate the mathematical model. The objective of the resource allocation model for highway maintenance is to maximize the

Figure 4. Effects of traffic and environmental adjustment indexes.

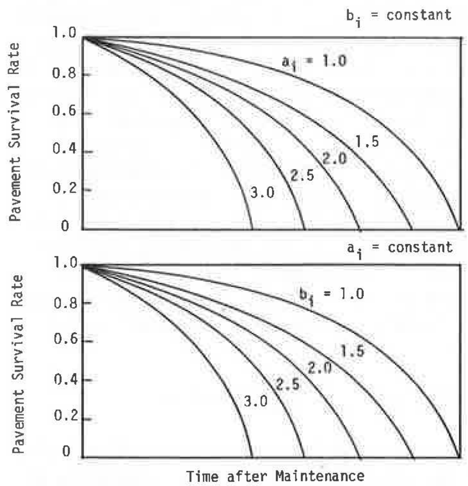

Figure 5. Minimum rating-requirement matrix of each highway segment.

		TIME AFTER MAINTENANCE						
		0	1	2	...	...	...	N_T
DISTRESS TYPES	1							
	2							
	3							
	...							
	...							
	N_D							
TOTAL								

N_D - the total number of distress types.

N_T - the analysis period in years.

overall effectiveness of maintenance activities subject to constraints such as limited resources and minimum requirements of pavement quality and service life. Mathematically, the most basic and simplified form of this problem is written as follows.

$$\sum_{i=1}^{N_H}\sum_{j=1}^{N_S}\sum_{k=1}^{N_D}\sum_{t=1}^{N_T} L_{1i}L_{2i}d_{ijk}P_{ijkt}x_{ij} \qquad (6)$$

subject to seven constraints. The decision variable constraint is

$$\sum_{j=1}^{N_S} x_{ij} \leq 1 \qquad i = 1, 2, \ldots, N_H \qquad (7)$$

The available supplies constraint is

$$\sum_{i=1}^{N_H}\sum_{j=1}^{N_S} s_{ijg}L_{1i}L_{2i}x_{ij} \leq S_g \qquad g = 1, 2, \ldots, N_G \qquad (8)$$

The available equipment constraint is

$$\sum_{i=1}^{N_H}\sum_{j=1}^{N_S} e_{ijf}L_{1i}L_{2i}x_{ij} \leq E_f \qquad f = 1, 2, \ldots, N_F \qquad (9)$$

The available work force constraint is

$$\sum_{i=1}^{N_H}\sum_{j=1}^{N_S} h_{ijq}L_{1i}L_{2i}x_{ij} \leq H_q \qquad q = 1, 2, \ldots, N_Q \qquad (10)$$

The available overhead is

$$\sum_{i=1}^{N_H}\sum_{j=1}^{N_S} C_{ij}L_{1i}L_{2i}x_{ij} \leq C \qquad (11)$$

The minimum rating for each type of distress is

$$r_{ik} + \sum_{j=1}^{N_S} d_{ijk}P_{ijkt}x_{ij} \geq R_{ikt} \qquad i = 1, 2, \ldots, N_H;\ k = 1, 2, \ldots, N_D;\ t = 0, 1, \ldots, N_T \qquad (12)$$

The minimum overall pavement rating score is

$$\sum_{k=1}^{N_D}\left\{r_{ik} + \sum_{j=1}^{N_S} d_{ijk}P_{ijkt}x_{ij}\right\} \geq W_{it} \qquad i = 1, 2, \ldots, N_H;\ t = 0, 1, \ldots, N_T \qquad (13)$$

where

N_H = number of highway segments in analysis,
N_S = number of maintenance strategies,
L_{1i} = pavement length of highway segment i in kilometers,
L_{2i} = pavement width of highway segment i in meters,
x_{ij} = a decision variable that will be 1 if maintenance strategy j is selected for highway segment i and 0 otherwise,
s_{ijg} = amount of type g material (or supply) per unit surface area [1.6 km (1 mile) long and 0.3 m (1 ft) wide] required in highway segment i if maintenance strategy j is selected,
S_g = total amount of type g material (or supply) available,
N_G = number of different types of material (or supply),
e_{ijf} = amount of type f equipment required in highway segment i if maintenance strategy j is selected, in equipment days per unit 1.6 km long (1 mile long) and 0.3-m-wide (1-ft-wide) surface area,
E_f = total amount of type f equipment available in equipment days,
N_F = number of different types of equipment,
h_{ijq} = amount of type q work force required in highway segment i if maintenance strategy j is selected, in person-days per unit 1.6 km long (1 mile long) and 0.3-m-wide (1-ft-wide) surface area,
H_q = total amount of type q work force available in person-days,
N_Q = number of different types of work forces,
C_{ij} = overhead cost in dollars per unit surface area 1.6 km (1 mile) long and 0.3 m (1 ft) wide required in highway segment i if maintenance strategy j is selected,
C = total overhead budget available in dollars,
r_{ik} = current pavement rating of highway segment i and type of distress k,
R_{ikt} = minimum required pavement rating of highway segment i and type of distress k at time t,
W_{it} = minimum required pavement rating of highway segment i of all types of distress at time t.

Equation 6 is the objective function that maximizes the overall effectiveness of all maintenance activities. Equation 7 is the feasibility constraint that ensures that at most one maintenance strategy will be selected for the highway segment i because each x_{ij} can have a value of only 0 or 1. Equations 8, 9, 10, and 11 represent respectively the resource availability constraints of material, equipment, work force, and overhead budget. The pavement rating requirement constraints of each individual type of distress and all types of distress are represented by equations 12 and 13.

As has been mentioned, this is a basic and simplified model. To elaborate the model for more versatile and realistic applications, many other variables and constraints can be incorporated. For instance, for political or social reasons, keeping the labor forces busy may be necessary. This constraint can be written as follows:

$$\sum_{i=1}^{N_H}\sum_{j=1}^{N_S} h_{ijq} L_{1i} L_{2i} x_{ij} \geq H'_q \qquad q = 1, 2, \ldots, N_Q \tag{14}$$

in which H'_q is the minimum required amount of q type of work force in person-days to be used during the year. Also the minimum amount of each specific material type g, which is S'_g, that must be used during the year can be constrained as follows:

$$\sum_{i=1}^{N_H}\sum_{j=1}^{N_S} S_{ijg} L_{1i} L_{2i} x_{ij} \geq S'_g \qquad g = 1, 2, \ldots, N_G \tag{15}$$

The need to keep the pavement rating score of certain highway segments higher than other segments, for political or geometric reasons, can be recognized in the constraints by raising the R_{ikt} and W_{it} values.

PHASE 3: OPTIMIZATION

Many important problems find their mathematical models in linear programming forms with binary variables taking only the values of zero or one. Use of these binary values for the decision variable allows one to make the important decision to do nothing to a given pavement segment. The third phase of the strategic planning for the pavement maintenance and management system is to apply the zero-one integer linear programming algorithm to the mathematical model. The algorithm of zero-one integer linear programming can be found in many operations research textbooks (5, pp. 337-342). The computer code documented in reference (6, pp. 91-104) is readily applicable to the management of pavement maintenance. A maintenance-engineer-oriented input-output system can be added to the computer program to facilitate the implementation of this resource allocation system. A computer program to solve the set of equations in this paper has been written and has been used to establish maintenance priorities on small highway networks.

PHASE 4: ANALYSIS OF SOLUTION

Phase 4 of the strategic planning is the analysis of the solution. The mathematical model assembled in phase 2 is solved in phase 3. However, constraints on resource availability and pavement rating requirements may be too binding to obtain a feasible solution. When this is the case, a management decision is required to increase the availability of specific types of resources such as material, equipment-days, person-days, district budget, and betterment budget or to decrease the rating requirement of specific highway segments or both. After the reformulation of the resource availability or pavement rating requirement constraints, the zero-one integer linear programming algorithm is applied to the revised mathematical model. The problem feasibility is checked again. When infeasible, the procedure mentioned is iterated until a feasible solution is obtained. Then, the solution must be examined carefully by the maintenance engineer and top management. If unacceptable, it is necessary to go back to phase 1 of the strategic planning to reevaluate and readjust the problem analysis and data collection. For instance, certain highway segments may have to be deleted from the analysis because of the scarce resources and high rating requirements of other segments. No maintenance activities will be done to those deleted segments in the next year. In other words, maintenance activities are postponed.

CONCLUSIONS AND RECOMMENDATIONS

A consistent method of establishing priorities for maintenance and rehabilitation work on various segments of a highway network and remaining within management, material, and budgetary constraints is best accomplished by linear programming that uses a zero-one binary decision variable. This paper has presented a formulation of the maintenance resource allocation problem that can be adapted by any highway agency to its own needs. The formulation required the introduction of new concepts to describe the objective of better management of maintenance and rehabilitation resources.

The primary concept is that of "maintenance effectiveness," which is defined mathematically in equation 6. It is assumed that the maintenance management wishes to use all of the available monetary resources in maintaining a minimum acceptable pavement rating score on all segments of a highway network and in making the work that is done last as long as possible. Thus, the money and work force will be best used if there is a low probability of having to redo a given segment in the near future. In accordance with this idea, maintenance effectiveness is defined as the sum of probable increases of pavement rating score due to maintenance work on all highway segments in the network. This sum is a measure of the durability of the maintenance work. Of course, the more durable the maintenance is, the more effective is the maintenance strategy adopted.

To evaluate this overall effectiveness, one must first establish the effectiveness of different types of maintenance work in preventing the reappearance of different kinds of distress. This requires the composition of several maintenance strategy survival matrices that give the probability that a given maintenance strategy will retain its increased pavement rating score when it is applied to a pavement with a given type of distress. In particular, it answers questions such as, How likely is it that this overlay on this transversely cracked pavement will be cracked as severely 3 years from now? Obviously, answers to questions such as these are the subject of much ongoing research. But, at the present, values for such probabilities can be drawn from the opinions of experienced engineers and revised later by combining them with theoretical predictions by using Bayesian inference methods (7).

An essential part of this maintenance effectiveness scheme is the pavement rating method used. The consistency and practical effectiveness of this resource allocation scheme will depend heavily on the consistency of the rating method and of those who rate the pavements. Limited experience with pavement rating schools in Texas has indicated that careful training can substantially improve the rating consistency between teams as well as reduce personal bias.

The formulation of this resource allocation method for strategic planning of maintenance and rehabilitation provides a basic framework within which management decisions can be made and altered while fully recognizing the effect those decisions will have on the quality of pavements within a highway network.

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