Maintenance Planning Methodology for Statewide Pavement Management

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After the successful implementation of a pavement management information system (PMIS) for a district road network the Mississippi Department of Transportation undertook a project to extend the system to the state network of more than 12,000 mi. An overview of systems development and the major products is presented. The system incorporates a number of microcomputer programs for data management functions, user interface, analysis, and reporting. The system was developed by using the FOXPRO data base software. Four major subsystems are identified: (*a*) a pavement management system inventory and monitoring data base, (*b*) condition data analysis accomplished through interface program, (*c*) a maintenance, planning, and budgeting (MPB) program, and (*d*) a priority ranking of rehabilitation projects. The condition data are collected with automated equipment. The raw condition data are used to calculate (*a*) distress quantities by severity in each section and (*b*) two composite measures, visual pavement condition evaluation rating and pavement condition rating. The MPB program selects two alternative strategies if the road condition warrants major maintenance activity. It also calculates the agency cost and vehicle operating cost. The fourth subsystem ranks the pavement network, relying on traffic volume, condition, and functional classification, to produce a list of projects for the annual work program. Pavement management reports can be summarized for the network as a whole, each district, each county, or individual sections.

Mississippi has a state-maintained highway network of more than 12,000 mi. It is essential to maintain the network in a serviceable and safe condition at a minimum cost to both the agency and the road users. To adequately meet this responsibility management requires well-documented information to make defensible decisions on the basis of sound principles of management and engineering. A pavement management system (PMS) helps engineers in making informed decisions. PMS is defined (*1*) as "a set of tools or methods that (can) assist decision makers in finding cost-effective strategies for providing, evaluating and maintaining pavements in a serviceable condition." Pavement management should be viewed as a part of an overall highway management system comprising a highway information system and several application modules or decision support models. The development and implementation of a comprehensive pavement management system suitable for the Mississippi Department of Transportation (MDOT) are described in this paper.

The development and simultaneous implementation of PMS were planned with the following objectives:

- Establish and maintain a computerized data base of inventory, traffic, and other field data for analysis;
- Maintain a data base of the conditions and histories of pavements;
- Integrate inventory, traffic, and condition data to form a PMS data base for easy and efficient use, with a provision to update them with new data as and when they are available;
- Develop an interface program to access and convert the raw data from the field and store them in a suitable format for easy access in all maintenance and budget analyses;
- Develop, with a provision to update, guidelines for triggering maintenance action and policies to remedy the distresses in each type of pavement;
- Evaluate vehicle operating cost;
- Establish a ranked list of sections requiring maintenance treatment annually;
- Estimate budget requirements for implementing the annual maintenance work program; and
- Set up a feedback mechanism from field personnel to modify/improve the overall PMS activities.

The MDOT PMS is a customized system that assists the department in preparing network-level highway maintenance programs and budget analysis reports. The modules of MDOT PMS and their logical structure are shown in Figure 1. Not all modules shown in Figure 1 are integrated in this phase of the study; those marked by broken lines will be pursued in a subsequent project. For discussion purposes the basic activities may be categorized under four "building blocks" on which the entire system rests. These basic blocks include

- Data base, inventory, and monitoring data;
- A condition data analysis/interface program;
- A PMS analysis and maintenance planning and budgeting (MPB) program; and
- A priority ranking and an annual work program.

In the following sections each of these topics is described giving the specifics, for example, the data required, the analysis routines, and anticipated output reports.

PMS DATA BASE

The data base, an organized collection of information or data, is an important element of a PMS and the core of the system in which all the inputs are loaded in a suitable and ready-to-use format. Quick access to the data base is crucial to the efficiency of pavement management. Easy updating, fast retrieval, the capability of expanding the data base for new data categories, and the capability of combin-

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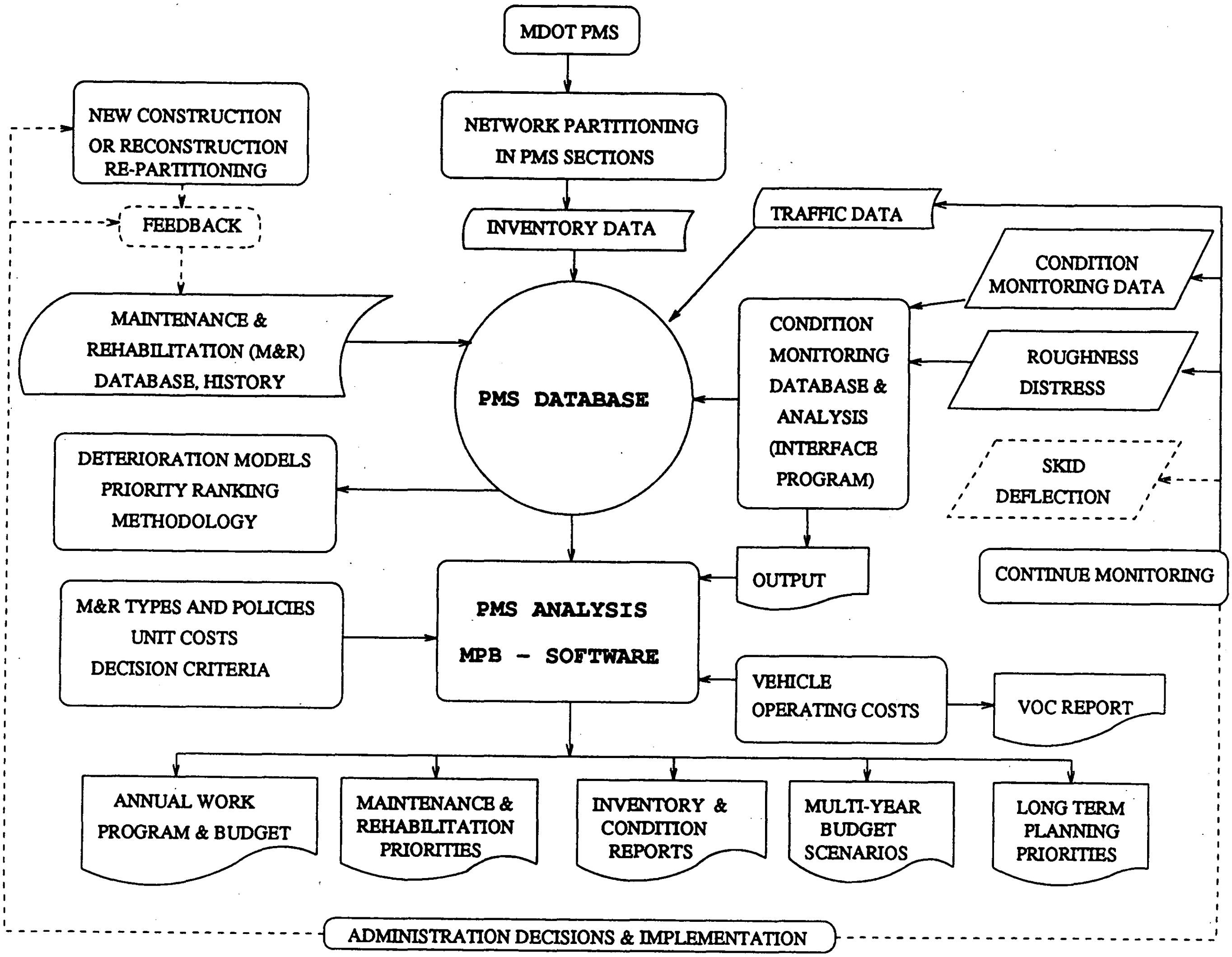


FIGURE 1 MDOT PMS development and implementation program.

ing the files to create various and informative output listings for the management level of any organization are some of the requirements of a data base. After a careful study of several data management software packages, the FOXPRO data base was selected for the MDOT PMS. FOXPRO has pull-down menus, pop-up dialogues, list boxes, and scroll bars. It is menu driven, and the table to be viewed appears in a moveable and sizeable window.

Although the entire PMS data base consists of only one file, it can include as many records as the number of homogeneous sections in the network. For purposes of bookkeeping seven subfiles—testdata.dbf, testorgm.dbf, overlay.dbf, traffic.dbf, rating.dbf, memo.ndx, and password.ndx—were developed to store the appropriate data elements. Essential historical information constitutes the first three subfiles. Items contained in the fourth subfile (traffic subfile) are average daily traffic (ADT), annual growth rate, percentage of trucks, and 18-kip equivalent single axle load (ESAL) factor for both flexible and rigid surfaces. A condition rating subfile for each section includes a distress rating (DR) calculated from the raw coded ratings for each of several distress categories, together with a roughness rating (RR) derived from the road roughness. Rut depth collected by direct measurements is another field in the condition rating file. More about the condition rating procedure and how raw data are reduced will be discussed in a later section.

Each piece of information or field in the data base is identified with what is known as a *homogeneous section* or simply a *section*. A homogeneous section is a segment of highway having basically the same roadway characteristics, for example, geometrical and structural compositions, pavement type, age of surfacing, and traffic.

All seven subfiles are linked together by a unique section identification field with the acronym SECIDNUM. The SECIDNUM consists of route number, county number, direction of travel, and beginning log mile of the section. Through the SECIDNUM only the different subfiles can be accessed or merged to generate numerous other blocks of information.

Inventory Data Base

The inventory data base contains data on the physical features of pavements and has 103 attributes for each section. These include geometric data, such as the total number of lanes, the width of the pavement, and the widths of shoulders; material data, such as the type of material used in different layers and type of subgrade; structural data, such as the thicknesses of various layers; and overlay data and the rehabilitation histories of the sections.

Making use of the capabilities of FOXPRO, a variety of summary reports of the network can be presented. A typical plot showing the distribution of pavement types is shown in Figure 2.

The traffic data base includes ADT, percentage of trucks, growth rate, cumulative ESAL, and so on, and has 36 data elements for each section. There is a memo pad data base in which remarks about a section can be stored against the section identification number. For the sake of security of the entire data base, a password data base has been established. That data base requires details about the user, such as name, district, address, password, and so on.

Monitoring Data Base (Condition Data Base)

The condition data collected from the field include distresses in pavements, including rutting and roughness of the road. The data are obtained from the outside lane in both directions for multilane divided roadways and in an easterly or northerly direction for two-lane or multilane undivided roadways. The traffic in the two directions on two-lane roads is considered to be the same, as is the load distribution. All the pertinent distresses are surveyed for 100 percent of the design lane by using high-speed automated equipment. The distress manifestations are photographed by using five high-resolution electronic color video cameras capturing different views. Office evaluation and reductions in field distress (extent and severity) are attempted only for two 500-ft sample segments per mile of the section unless section length is less than 0.5 mi. The video images are analyzed in the office by experienced personnel who document the distress type, severity, and extent. The distress type and severity are coded in accordance with the Mississippi Distress Manual, much like the Strategic Highway Research Program Long-Term Pavement Project manual, with revisions to include the distress extent as well. The distresses are then extrapolated for the whole section. Rutting is calculated from elevation measurements obtained by using five ultrasonic sensors mounted on the vehicle. Faulting is also measured by elevation measurements obtained with ultrasonic sensors. Illustrated in Figure 3 is the distribution of alligator cracking for the District 2 data base.

MDOT PMS uses a South Dakota-type profiler for roughness measurements. The roughness data are collected longitudinally in both wheelpaths for 100 percent of the road lane surveyed. The ride quality is expressed in terms of the international roughness index (IRI). The measurements from the South Dakota-type profiler are used in a computational procedure called quarter-car simulation, which represents the response of a single wheel yielding IRI (in m/km).

The condition data base contains 30 attributes indicating the ratings of the sections. It includes roughness rating, distress rating, pavement condition rating (PCR), and survey year. Ride quality, designated as RR, is measured on a scale of from 0 to 100, and is computed by Equation 1:

$$RR = \left(\frac{12-IRI}{12}\right)^{a} 100 \tag{1}$$

DR is calculated by a deduct point approach. A detailed procedure for DR calculation can be seen in a later section. PCR is an aggregate index scaling the overall index of a section, the development of which is described in the next section.

PCR and Its Development

PCR is an aggregate index employed to assess the overall condition of pavements. PCR is a rater's assessment, on a scale of from 0 to 100, of the serviceability of a pavement with respect to quality of ride and pavement distresses. As used by MDOT, PCR is an objective statistic determined by combining ride quality and distress manifestations.

The Delphi technique was used to gather expert opinions and form the rating scale. The pavement condition was indicated on a PCR scale of from 0 to 100, with 100 representing the best pavement condition and 0 representing the worst pavement condition. Three service levels on a pavement deterioration curve, which are important from practical considerations, were requested from a panel of engineers. The three levels are (*a*) the trigger-level PCR requiring routine maintenance, (*b*) the trigger-level PCR warranting an overlay, and (*c*) the PCR level when major rehabilitation/reconstruction would be required. A panel of 11 department engineers was provided with a hypothetical performance curve on which each member was to write the number that best describes the three levels. Arrived at by consensus opinion are PCR numbers 76, 57, and

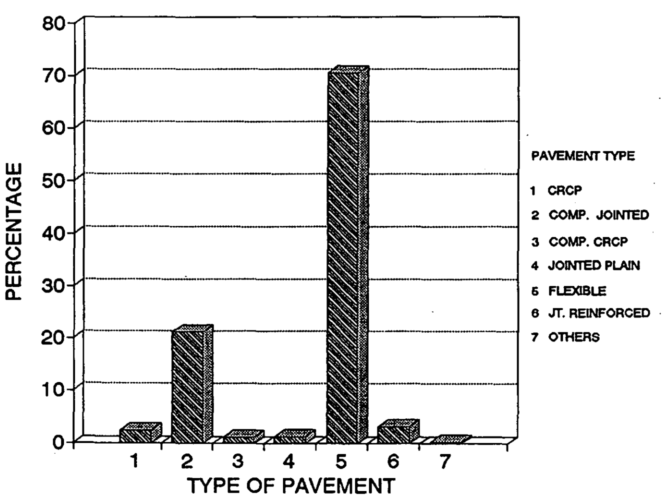


FIGURE 2 Percentage of different types of pavements.

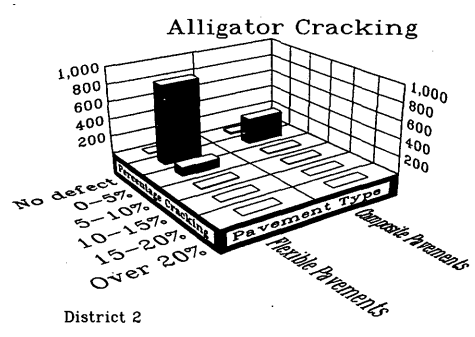


FIGURE 3 Percentage distribution of typical cracking.

38 corresponding to the three trigger levels. With the guidelines of PCR scale developed as already described, a panel was formed to rate the PCRs of 26 selected pavement sections by visual observation and by riding over these sections. Four types of pavements are recognized in the study. After the elimination of outliers by Chevnaut's criterion, the mean of the panel rating for each section was considered to be its PCR (subjective).

The sample section units previously referred to were surveyed manually for distress in accordance with the Mississippi Distress Manual. Deduct points, much like weighting factors, are introduced to signify the magnitude of the effect that each particular distress type, severity, and extent combination has on pavement condition. The underlying principle in the development of deduct point curves is much like that adopted in the PAVER PMS (*2*). A complete set of curves has been provided previously (*3*).

For the calculation of PCR the equation form selected is:

$$PCR = 100\left[\frac{(12 - IRI)}{12}\right]^a \cdot \left[\frac{(DP_{max} - DP)}{DP_{max}}\right]^b \tag{2}$$

where

IRI = international roughness index (m/Km),
DP_{max} = probable maximum deduct points for the type of pavement: 205, 230, 185, and 145 for flexible, composite, jointed, and continuously reinforced concrete pavements, respectively; and
DP = total deduct points calculated for the distresses present.

For each pavement type the panel-rated PCR is substituted on the left side of Equation 2 and regression analysis is conducted to determine the coefficients a and b in Equation 2. Only a and b of flexible pavement group are given here for brevity: $a = 0.96$ and $b = 1.49$. The PCR calculated (employing Equation 2) is a composite index that will be used to assess the overall condition of the network, present and future, once PCR prediction models are developed. A graphical representation of the miles of pavements in different PCR categories is presented in Figure 4. Other graphical representations available are RR, bar chart; DR, bar chart; and rut depth, bar chart.

CONDITION INTERFACE PROGRAM

The interface program developed converts the condition data obtained from video interpretation into a suitable format for ready use in maintenance selection and estimation of contract quantities. The interface program analyzes the raw data and gives the following three reports:

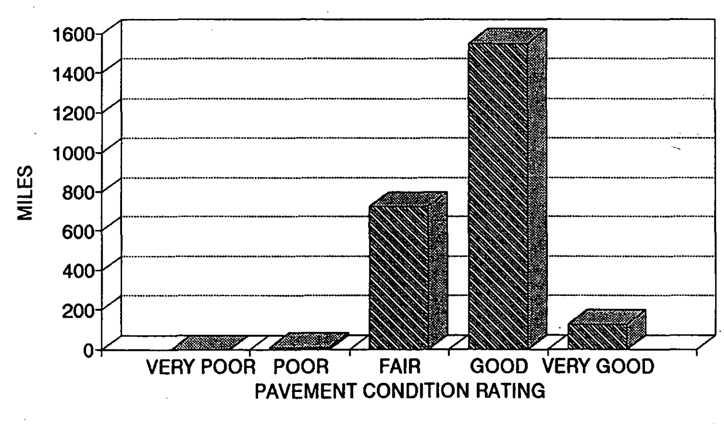
1. Video distress data report by sample unit, which gives the distress in each 500-ft sample unit of a section. This includes the distress type, severity, and quantity on each sample unit.
2. A section video distress summary report yields a distress summary report of the entire section. As shown in Table 1 it includes distress type, severity, and distress density of the whole section.
3. On the basis of the distress quantities an aggregate distress index, designated visual pavement condition evaluation rating (VPCER), is assigned to each section. VPCER is a composite rating derived from the extent and severity of three major distress groups: surface cracking, deformation, and surface defects. On the basis of the extent and severity of these distress groups the values of visual ratings are assigned none, low, medium, and high (or N, L, M, and H, respectively).

A summary of all of the distresses collected in the field and the condition measures calculated for each section are displayed in another table. The various distress elements, which are tabulated and subsequently used in the analysis program, include rut depth, IRI, PCR, and VPCER.

MPB PROGRAM

The MPB program analyzes the roads/highways in each district by each PMS section across all carriageway lanes and shoulders and selects rational maintenance treatments, accumulates maintenance costs, performs economic analysis, and produces a rank listing of all roads.

The required input data for the MPB analysis are collected from the data base. This information includes type of pavement, VPCER,



PCR: VERY POOR 0-29 ; POOR 30-54 ; FAIR 55-74; GOOD 75-89
VERY GOOD 90-100 .

FIGURE 4 District 2 pavement network categorized according to condition.

TABLE 1 Section Video Distress Summary Report

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Beginning Log Mile: 0.000
SECIDNUM:        55 08N000.000          Survey Date: 08/15/91
County:          8, Road: I55N          Pavement Type: ASP
Road:            I55N                   Section Length: 11516m Surveyed width: 3.66m
Surveyed Lane:   1
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DISTRESS	CODE	SEVERITY	DISTRESS QUANTITY	UNIT	DISTRESS DENSITY
Alligator	CA	0	528.9 Total: 528.9	sq.m	1.26% 1.26%
Transverse Transverse	CT CT	0 1	Total:142.16 26.33	sq.m sq.m	0.34% 0.06% 0.40%
Patch	PA	0	4.91 Total: 4.91	sq.m	0.01%

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Distress Groups:  Cracking (CA,CB,CT,CL,CR,CE)    Distress Density: 1.66% Distress Index: 0
                  Deformation (PH, SD)            Distress Density: 0.00% Distress Index: 0
                  Surface Defects (PA,RW,BL)      Distress Density: 0.01% Distress Index: 0
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IRI, rutting, whether lane widening or shoulder construction is required, analysis period, and so on. With the input information, which in essence portrays the condition of the pavement and the criteria for intervention, a suitable maintenance treatment is chosen. Typical methods for maintenance treatment selection currently in use include (*a*) assignment of maintenance treatments on the basis of past experience, (*b*) a life-cycle cost analysis that selects the most economical one, and (*c*) an optimization of benefit or a reduction in pavement distress over a period of time (*4*).

The MDOT PMS uses the first method, based on a unique approach that considers both distress severity and extent. Depending on the conditions a pavement may require major maintenance (for example, resurfacing) or minor maintenance, such as pothole filling or crack filling and so on. Detailed data on each maintenance treatment are needed, including the unit cost, the expected performance immediately after its application, and long-term performance. A catalog table for a major maintenance treatment is included in Table 2. The expected life, years of maintenance-free service, and unit

TABLE 2 Typical Attributes of M,R&R Strategy

M,R&R CATALOGUE TABLE

Code Number: AC01
Description: AC Structural Overlay (0.10m Default Thickness)

Pavement Type	Expected Life (Years)	Min. Year to Major Maintenance	Cost ($)	Cost Unit	Cost Multi-plier	Production Rate/Day*	Factor for Condition		
							IRI**	PCR**	VPCER***
ASP	20	15	0.89	c.y.	1.0	100	1.0	1.0	N
COMP	20	15	0.89	c.y.	1.1	100	1.0	1.0	N
JCP	20	15	0.89	c.y.	1.2	100	1.0	1.0	N
CRC	20	15	0.89	c.y.	1.1	100	1.0	1.0	N
JRCP	20	15	0.89	c.y.	1.1	100	1.0	1.0	N

* Units for cost and production rate are same

** Factor indicating the condition of road after M & R; 1 means no distress condition, and zero implies maximum possible distresses.

*** VPCER: Visual pavement condition evaluation rating based on distress extent and severity.

cost from the table serve as inputs to the MPB program. Information on the production rate per day is useful for determining the time required to apply this treatment to a section. The last three columns in the table indicate factors for assessing the posttreatment conditions of pavements in terms of IRI, PCR, and VPCER, respectively.

The distress manifestations, for example, rut depth and IRI, need to be grouped into four categories, which then become useful in maintenance strategy selection. On the basis of these groupings MPB condition and maintenance intervention (CMI) criteria are arrived at. The CMI table, explaining the significance of CMI attributes, can be seen in Table 3.

Maintenance policies have been developed for maintenance strategy selection. A typical policy table for asphalt pavement is shown in Table 4. Not only can they be updated or modified but new policy tables can also be created by the user. Similar policies are established for each type of pavement. Two major maintenance treatments can be assigned for a given condition scenario.

Also, policy guidelines are established for local minor maintenance, which are based on visual distress type and severity level. Having decided the type of maintenance treatment to be provided, the next step is to calculate the cost of the treatment. Because the dimensions of the section are known from the inventory data base and the amount of distress is assembled by the interface program, the maintenance quantity can be easily estimated. This is multiplied by the unit cost to obtain the cost of the treatment.

The long-term maintenance costs for each section are calculated in conjunction with the vehicle operating cost model described in a later section. Pavement deterioration models, as described previ-

TABLE 3 CMI Criteria Based on Pavement Condition

CMI Attribute	0	1	2	3
IRI,m/km	< 2.00	2.00 to 4.00	4.00 to 6.00	> 6.00
Rut,mm	< 6.00	6.00 to 12.00	12.00 to 25.00	> 25.00
VPCER (Distress)	N (None)	L (Low)	M (Moderate)	H (High)

CMI Criteria Explanation

0: Pavement in excellent condition, no major maintenance required
1: Warning level, no major maintenance required
2: Major maintenance intervention level
3: Maximum applicable pavement deterioration, major maintenance required

TABLE 4 M,R&R Policy Table for Asphalt Pavement

ICMI IRI	RCMI Rut	DISTR VPCER	PAVEMENT TYPE: ASP NO: Codes		Maintenance Treatment Strategy	Change in Surface Level*
0-1	0-1	N	1.	None	No Major Maintenance	N
		L	1.	MM Codes	Local Minor Maintenance	
			2.	AC15	Surface Seal	N
		M - H	1.	AC08+AC10	1" Milling and inlay	N
			2.	AC05	Modified AC Overlay - 1.5"	Y
	2-3	N - L	1.	AC08+AC10	1" Milling and Inlay	N
			2.	AC13+AC10	Heater Scarification & 1" AC Repaving	N
		M - H	1.	AC09+AC11	1.5" AC Milling & Inlay	N
			2.	AC06	1.5" AC Modified AC Overlay with SAMI	Y
2-3	0-1	N - L	1.	AC10	1" AC Resurfacing	Y
		M - H	1.	AC08+AC10	1" Ac Milling and Inlay	N
			2.	AC13+AC10	AC Repaving	N
	2-3	N - L	1.	AC09+AC11	2" Milling and Inlay	N
			2.	AC05	2" Modified AC Overlay	Y
		M - H	1.	AC16	AC Surface Reconstruction	N
			2.	AC04	2" AC Overlay with SAMI	Y

* Whether existing surface level changes or not owing to M & R activity.

ously (*5*), are used for various types of pavements to determine the present serviceability index (PSI) in future years during the analysis period. If the PSI of any section falls below 2.5, then major maintenance is warranted according to a tentatively selected fixed policy. The present worth of major maintenance, if applicable, is calculated; this constitutes the long-term cost.

Agency Cost

Agency cost comprises major, minor, and routine maintenance and lane widening and shoulder costs. The major maintenance policy table stipulates two alternative strategies for each candidate section. The agency cost can be based on Strategy 1 or Strategy 2. Strategy 1, the base strategy, refers to the maintenance treatment that is most economical. Strategy 2, the alternate strategy, is the most appropriate for the distresses present; it is higher in cost, however. In addition, \$500/mi is earmarked for annual routine/emergency costs.

Vehicle Operating Cost

The vehicle operating cost (VOC) model and life cycle analysis (*5*) are developed to quantify the cost-effectiveness of alternate strategies for investment planning and maintenance management of roads and highways. The methodology evaluates user costs on the basis of vehicle operating cost data from FHWA in conjunction with the deterioration models developed by World Bank (*6*) and NCHRP studies (*7*). Detailed documentation of the VOC model has been provided previously (*5*).

The input data for user cost calculations are generally available from the inventory and condition data base files of the PMS data base. The required data can be grouped into three categories:

1. Section-specific data including ADT, traffic growth rate, and 18-kip ESAL;
2. Decision criteria including maintenance intervention criteria for each pavement classification, adjusted present serviceability rating (PSR) (or IRI) after M,R&R treatment, and the analysis period; and
3. Vehicle operating unit costs (for each vehicle type) for fuel, depreciation, oil, repair, and tires.

The calculation of VOC comprises the following steps:

- Pavement deterioration prediction over the analysis period for each pavement type on the basis of current condition. Cumulative ESAL plays a major role in the deterioration prediction.
- Cumulative traffic prediction by vehicle type over the analysis period.
- Calculation of the VOC stream for each year of the analysis period as a function of pavement condition, vehicle type, associated VOC parameters, and geometric characteristics.

The VOC calculations for a typical pavement section include the year and the total ADT in that year, the cumulative ESAL, the predicted IRI/PSI, and components of VOC owing to fuel, depreciation, oil, repair, and tires. The total VOC for a 30-year analysis period for a pavement with an initial IRI of 1.11 m/km is illustrated in Figure 5.

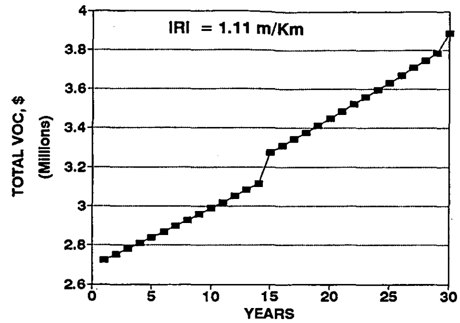

FIGURE 5 Typical VOC for 30-year analysis period.

Total Cost

The sum of major and minor maintenance, lane widening/shoulder, and annual routine/emergency costs yields the total agency cost. Long-term maintenance can be made a part of the total agency cost as well. A typical output from the MPB program with agency cost and user cost applicable to the two suggested treatment strategies is shown in Table 5. There is provision at almost every step to update the inputs on the basis of feedback from the field.

PRIORITY RANKING AND ANNUAL WORK PROGRAM

A formal procedure that ranks the sections in the order in which the maintenance actions are to be undertaken is developed, thereby assembling a work program on a networkwide basis. Two approaches are used for priority ranking: (*a*) on the basis of agency cost excluding long-term cost and (*b*) on the basis of functional classification of the road, traffic, and condition.

The first method ranks the sections on the basis of decreasing agency cost. The agency cost (first cost) can be with respect to either Strategy 1 or Strategy 2, as explained in a previous section.

The second method of priority ranking is based on functional classification, traffic in terms of ADT, condition of the pavement, and committed priority, if applicable. Committed priority is assigned under unusual circumstances such as consideration of safety and an increase in the importance of a road. The functional classification recognizes three categories: Interstate, US, and state routes. The traffic is classified into three groups on the basis of ADT, as follows: low, <2,000; medium, 2,000 to 5,000; and high, >5,000.

Each of the group of pavements has been assigned an adjustment factor, analogous to a weighting factor, depending on the traffic (three levels) and functional classification (three levels). To recognize pavement condition in the priority ranking the network is partitioned into three categories: Priority Category 1 requires major maintenance, Priority Category 2 warrants local minor maintenance, and others are placed in Priority Category 3. The priority indexes of 100, 58, and 24 are assigned to Categories 1, 2, and 3, respectively. For every section in each of these categories an adjusted priority index is calculated by multiplying the adjustment factor by the priority index. The sections are then ranked in descending order of the adjusted priority index (API). Should there be more than one

TABLE 5 MPB Report for a Section

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County Number : 36                                    Pavement Type : Flexible
   Road Name  : SR7N                                 Section Length: 1643 m
Beg. Log Mile : 0.000                           Surveyed Lane width: 3.66 m
                                                Total Section Width: 6.71 m

Lane Widening/Addition: ?   : N          New Shoulder Construction Type: 0
Widening Area: 0.00 s.m;
          IRI: 2.93 m/km
                                         New Shoulder Area:       0 s.m
      Rutting:  1.52mm
        VCPER:  H

First Year of Analysis: 1993             Analysis Period: 30 year
Planned Year of Maintenance: 1993        Years Before Maintenance (YBM)=0
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Section Maintenance Data	Strategy 1	Strategy 2
Major Maintenance Treatment Code	AC08 AC10	AC05
Change in Original Pavmt. Surf. level?	No	Yes
(a) Major Maintenance Cost,	$44804	$52711
(b) Lane Widening/Shoulder cost	$0	$11980
(c) Local Minor Maintenance Cost	$1389	$1389
(d) Annual Routine/Emergency Cost	$0	$0
(e) Long Term Maintenance Cost (PW)	$34405	$34405
Total Agency Cost, (a+b+c+d)	$46193	$66079
Total Agency Cost/s.y.	$3.51	$5.01
Total User Cost for 30 Years (PW)	$2266690	$2266690
Average User Cost (30 years)/1000 vehicle mile(PW)	$212.00	$212.00

section with the same API, the ordering is based on the section with the highest VOC, which receives first priority for maintenance treatment.

The priority ranking list also contains the cost of maintenance for each section and the cumulative cost of maintenance for those sections requiring maintenance. This list becomes useful either for estimating the budget required for the so-called need projects or assembling a list of projects constrained by the available budget.

SUMMARY

A PMS is established for the optimal use of funds for maintaining the Mississippi State road network of more than 12,000 mi. The MDOT PMS has four main modules: a data base, an interface program, a PMS, and analysis and priority ranking. A comprehensive data base, the heart of the PMS, is developed with FOXPRO software. It includes inventory, traffic, overlay, and other data bases. A unique section identification number, identified by the acronym SECIDNUM, is introduced. It will be an index for a given section by which all the data for a section can be accessed.

Truck-mounted high-speed automatic video cameras are used to capture surface distress manifestations. The IRI and rutting/faulting are surveyed by a South Dakota-type profiler and by height measurements obtained by using ultrasonic sensors, respectively. An interface program that will transform the condition data into a suitable format for analysis was developed. With the total quantity of each distress calculated in the program, contract packaging is simplified. The need for a composite measure to indicate the overall condition of a section is addressed by introducing what is known as PCR, which combines distresses and IRI to give a single index. The analysis of the condition data yields the required maintenance strategy and the corresponding agency cost. The agency cost includes major maintenance, minor maintenance, lane widening/shoulder, routine maintenance, and long-term costs. An index based on the condition of the pavement, functional classification, and traffic is used for priority ranking of projects.

Although the MDOT PMS provides needed information for maintenance and rehabilitation of the state's road system, it encompasses some unique features, including

- Rapid network quality condition data collection;
- An interface program that accesses the raw condition data and presents the individual distress quantities in a suitable format for rational maintenance treatment selection;
- A unique maintenance policy table for each pavement type that relies on all of the major distress groups, rutting, and road roughness;
- A VOC model that can be used for life-cycle analysis and long-term maintenance cost prediction; and
- A rational ranking/prioritization system for assembling an annual work program.

Other key items that will be researched in the future are as follows:

- Video interpretation of distress manifestations will need continued improvement;
- Structural evaluations of pavements, both at the network level and at the project level, need to be incorporated into the system, as do the surface texture/skid resistances of pavements;
- Prediction models for both distresses and PCR measures are needed; and
- A rational optimization/prioritization scheme for single-year as well as multiyear work planning is needed.

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