Development and Implementation of a Pavement Management System for Minnesota

LOREN HILL, ALAN CHEETHAM, AND RALPH HAAS

The Minnesota Department of Transportation (Mn/DOT) began the planning for its network level pavement management system (PMS) in the early 1980s, with actual development and implementation in the mid to late 1980s. Staging, preimplementation planning, and strong organizational support were major factors in the success of the PMS. A background summary of the PMS development is provided and the requirements for preimplementation planning are identified. A system overview is presented of the overall logic and the major products. The PMS is comprehensive and incorporates a number of programs for data management functions, user interface, analysis, and reporting. It operates on a personal computer workstation and is linked to the Transportation Information System on the Mn/DOT's mainframe computer. The PMS is flexible in the options provided to the user and in the range of detail for summarized graphical and tabular reporting functions. Two major subsystems are incorporated in the PMS: (a) Status and Needs Subsystem, and (b) Rehabilitation Optimization Subsystem. The former is capable of displaying the present status of each segment of the network, or the network as a whole, in terms of present serviceability rating, structural adequacy rating, surface rating, and a composite pavement quality index. The latter is able to consider a large number of alternatives. It calculates capital, maintenance (optionally), and user delay (optionally) costs for each combination of alternative segment and possible implementation year (i.e., projects are considered in advance, and deferred, from the needs year). The outputs range from detailed calculations of optimized effectiveness for individual segments to summary reports of changes in an average performance index parameter for the network for different budget levels. Minnesota has a comprehensive, flexible PMS in place and operational, tailored to its requirements. Among the key reasons for the successful development and implementation were careful preimplementation planning; strong support throughout the department including senior management; a sound technical basis for the system in terms of the data base, models, programs, and reporting functions; and a commitment by those responsible for its operation and use.

Minnesota's trunk highway system represents a large public investment. Like any investment, it deserves good management through timely and effective maintenance and rehabilitation.

Several years ago, a number of engineers and administrators in the Minnesota Department of Transportation (Mn/DOT) felt it was desirable to develop and implement a pavement management system (PMS) specifically geared to the state's requirements, resources, and conditions. One resulting action was the establishment of a pavement management section, within the Office of Research and Development. An initial part of this section's responsibilities was to review the available information on pavement management and the implementation experience of several other states and provinces (*1*). It was also recognized that for a PMS to be accepted and serve the needs of different users, the support, cooperation, and guidance of various offices and people would be required. Consequently, a steering committee was formed with broad representation ranging from the district level to several headquarters divisions and offices. Mn/DOT already had a number of key elements of a PMS, including a basis for linking all data files through the Transportation Information System (TIS). It was desired to take full advantage of these working methods and procedures.

In September 1984, the steering committee wrote a pavement management work plan, and followed this up in December 1984 by identifying a number of key analysis capabilities and requirements for the PMS. The steering committee was well aware that the full-scale development and implementation of a PMS required careful planning, including proper staging and taking full advantage of both Mn/DOT's own procedures plus outside expertise and assistance. Consequently, it was decided in early 1985 to retain an outside advisor, with the following responsibilities:

1. Review the current Mn/DOT process of programming pavement projects, the existing data bases, methods, resources, plans for future development, etc.;
2. Establish whether the commonly defined network versus project levels of pavement management were also appropriate to Minnesota's conditions and requirements;
3. Define the different levels of PMS users within Mn/DOT, and their general requirements from the PMS;
4. Define a set of building-block requirements for an Mn/DOT PMS, compare current methods and procedures plus future development plans with these requirements, and identify strengths and potential areas of concern; and
5. Recommend a staged implementation plan, including a suggested schedule and the role of outside consulting help.

The study, primarily directed to the network level of pavement management, was completed in June 1985 (*2*).

The following sections first briefly define the PMS users and the building blocks that were identified for subsequent

L. Hill, Minnesota Department of Transportation, 1400 Gervais Ave., Maplewood, Minn. 55109. A. Cheetham, Pavement Management Systems Inc., P.O. Box 191, Columbia, S.C. 29202. R. Haas, Department of Civil Engineering, University of Waterloo, 200 University Avenue West, Waterloo, Ontario, Canada N2L 3G1.

development and implementation of the PMS. Then the actual PMS is described in terms of its staging, components, operation, and products. The requirements of different types of levels of PMS users in Mn/DOT were defined by Haas (*2*) as a basis for identifying the building blocks and key elements of the actual PMS.

Figure 1 shows three major levels of Mn/DOT users and some of the requirements they expected from a PMS. The basic building blocks for Mn/DOT's network level PMS are shown in Figure 2. They represent the logical progression of activities required to go from the data base to the final programs and budget. All these building blocks, and their component data files, are linked through a common reference base (i.e., the TIS). An expansion of the basic blocks into detailed sets of components and specific outputs for each component were also developed as a basis for the design of the PMS.

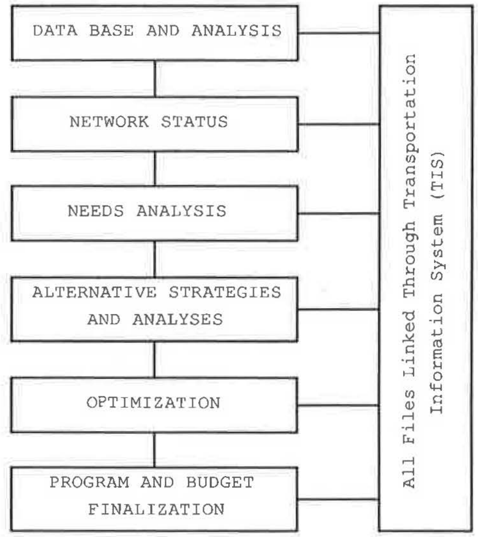

FIGURE 2 Basic building blocks for Mn/DOT's network level PMS.

STAGING OF THE PMS

A staged implementation plan was developed for Mn/DOT's PMS, as shown in Figure 3 (*2*). It was important that each

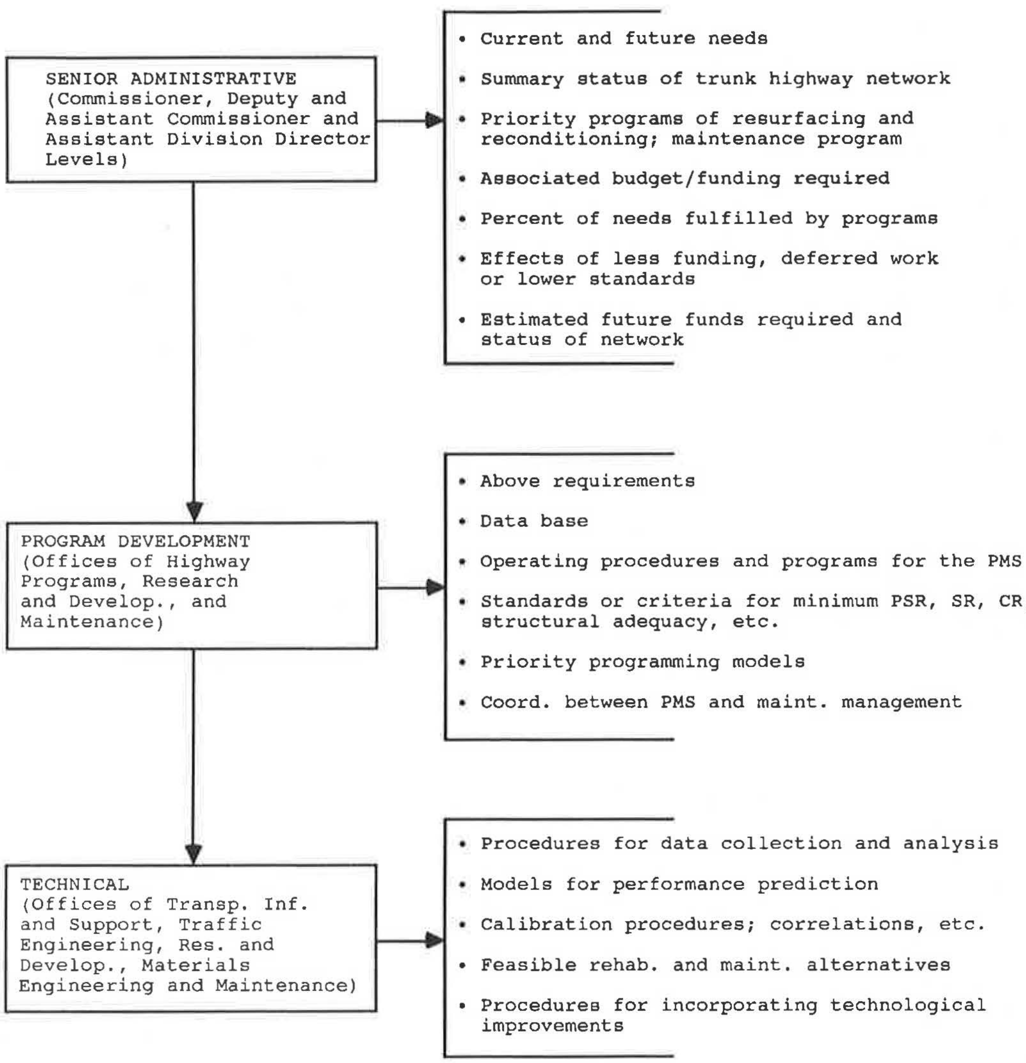

FIGURE 1 Some requirements of different levels of Mn/DOT's PMS users.

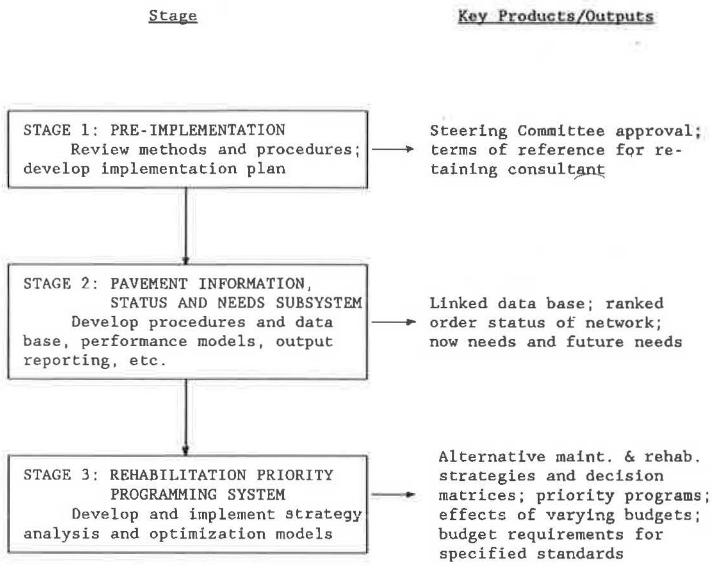

FIGURE 3 Major stages in the development and implementation of Mn/DOT's PMS.

stage in the implementation had distinct, usable products, which are noted in Figure 3 and subsequently illustrated in more detail.

The first stage, preimplementation, included the prior work of the early 1980s, previously noted. The second stage, a pavement information and needs system, also had many of the components in place, such as the TIS and related data files, before actual design and implementation of the stage began. The third stage of the network PMS involved a multiyear priority programming model.

Overall, the development and implementation of the three stages required about 4 years.

SYSTEM OVERVIEW

The overall logic of Mn/DOT's PMS is shown in Figure 4. It operates on two primary data files: SEGSUM (segment data), and SURFDIS (surface defect data by Reference Post), which are transferred from the TIS on the mainframe to a PMS workstation. The system documentation report (*3*) provides detailed documentation of the PMS.

The major outputs of the PMS, as shown in Figure 4, are status and needs reports and plots, and optimization reports and plots.

The Mn/DOT PMS operates on a personal computer workstation (IBM PC or compatible) running under DOS and utilizing PC/FOCUS for data base management functions. The system requires 640 kB of memory (RAM) and hard disk storage of approximately 20 MB (not including space required for PC/FOCUS). PC/FOCUS is also used to provide the user interface (which is menu based), segment list reporting, and segment data subset screening. The analysis programs and all reporting programs (other than segment lists) are FORTRAN programs. SPF/PC is used to edit user input parameter files for program execution.

USE OF THE PMS

The PMS, which is intended normally to be used for annual updates, involves the following steps:

1. Field work to update ride, deflection, and surface defect data on a segment basis, and entry of data to mainframe computer;
2. Extraction and transfer of the data stored in the TIS on the mainframe to the PC (files SEGSUM and SURFDIS);
3. Execution of the pavement performance program (PNSCAL) from the system utilities menu to produce the main data file (SEGSNEW);
4. Creation of data subsets using PC/FOCUS as required for the status and needs reporting programs, through the status and needs reports (standard report segment subset) menu;
5. Generation of status and needs reports through the status and needs reports (standard reports) menu;
6. Updating the rehabilitation alternatives analysis parameter files as required through the system utilities menu;
7. Analysis of rehabilitation alternatives through the rehabilitation optimization menu;
8. Optimization analysis through the rehabilitation optimization menu;
9. Creation of data subsets using PC/FOCUS as required for the optimization reporting programs through the optimization reporting (optimization report segment subset) menu; and
10. Generation of optimization reports through the optimization reports menu.

As part of the analysis procedures, it is likely that the rehabilitation alternatives analysis and the optimization analysis will be run several times with variations in the user inputs to test various scenarios and to answer what-if questions.

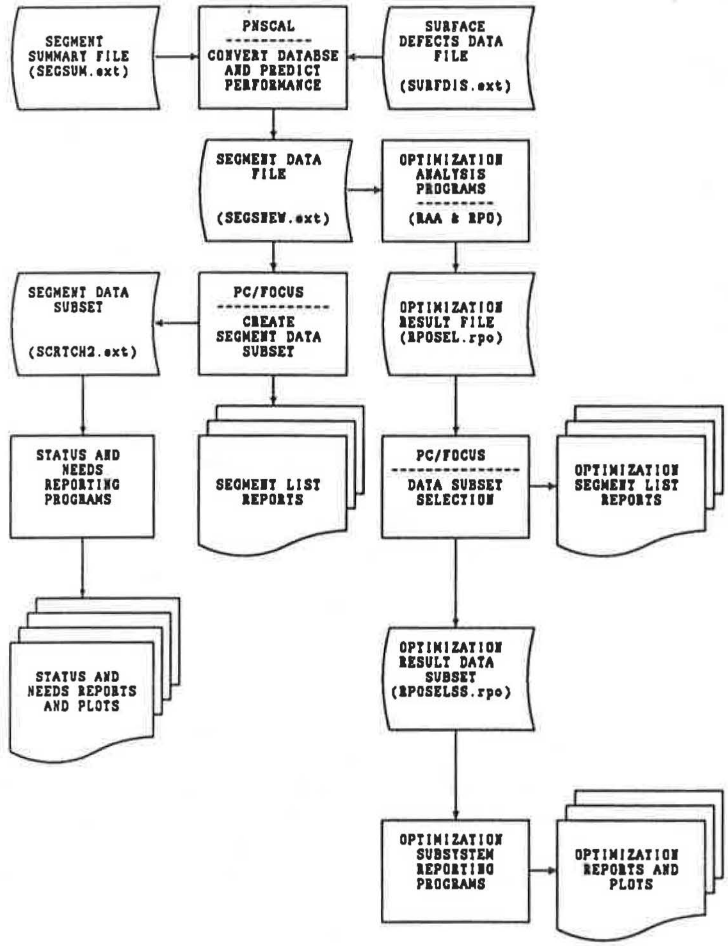

FIGURE 4 Overview of Mn/DOT's PMS.

MAJOR PROGRAMS IN THE PMS AND THEIR OUTPUTS

The PMS incorporates 14 FORTRAN programs, as presented in Table 1, together with their key purpose or outputs.

Illustrations of these outputs, with summary descriptions of the analysis procedures (e.g., equations and models) are provided in the following sections. These illustrations are subdivided into status and needs (see Figure 4), represented by the first seven programs of Table 1, and optimization (see Figure 4), represented by the last seven programs of Table 1.

The example outputs of the following paragraphs should be viewed as illustrative only, because they are based on preliminary runs of a newly installed system, and in some cases on incomplete data. Consequently, any actual numbers should not be considered as absolute at this time.

STATUS AND NEEDS

The Status and Needs Subsystem is shown in Figure 5. Of the seven total FORTRAN programs in this subsystem, one is used for performance prediction, two produce printed reports, and four produce graphical outputs.

Performance Predictions

Performance predictions in the Mn/DOT PMS involve the following for each segment:

1. Input the data (SEGSUM) record,
2. Predict surface distresses (for 20 years), calculate surface rating (SR), and calculate average SR values; and
3. Predict present serviceability rating (PSR), structural adequacy rating (SAR), and composite pavement quality index (PQI).

Details of the models used and the input factors are contained in the system documentation report (*3*), along with typical curves.

Status Reports

A segment summary report (present status) is presented in Table 2, for a particular Interstate route in the Metro district of Oakdale. Also presented at the bottom of the table are the totals for the network. The distributions for these totals can also easily be displayed in graphical form, as shown in Figure 6.

TABLE 1 MAJOR FORTRAN PROGRAMS IN THE PMS

PROGRAM NAME	MENU	PURPOSE
PNSCAL	SU	Performance Predictions
SEGSUMR	SNR	Segment Summary Report
NEEDS	SNR	Segment Needs Report
PERF	SNR	Segment Performance Graphs
INDHIST	SNR	Index Distributions
HIST3D	SNR	Index Distributions (3-D)
BARCHRT	SNR	Needs Year Distributions
RAA	ROS	Rehab. Alternatives Analysis
RPO	ROS	Rehab. Priority Optimization
RORRPS	ROR	Performance Summary Report
RORAPH	ROR	Annual Performance Distributions
RORH3D	ROR	Performance Distributions (3-D)
RORPRF	ROR	Segment/Alternative Performance
RORRLR	ROR	Network Remaining Life Report

Menu: SU = SYSTEM UTILITIES
SNR = STATUS AND NEEDS REPORTS (PDR in PMS.FMU)
ROS = REHABILITATION OPTIMIZATION
ROR = OPTIMIZATION SUBSYSTEM REPORTS

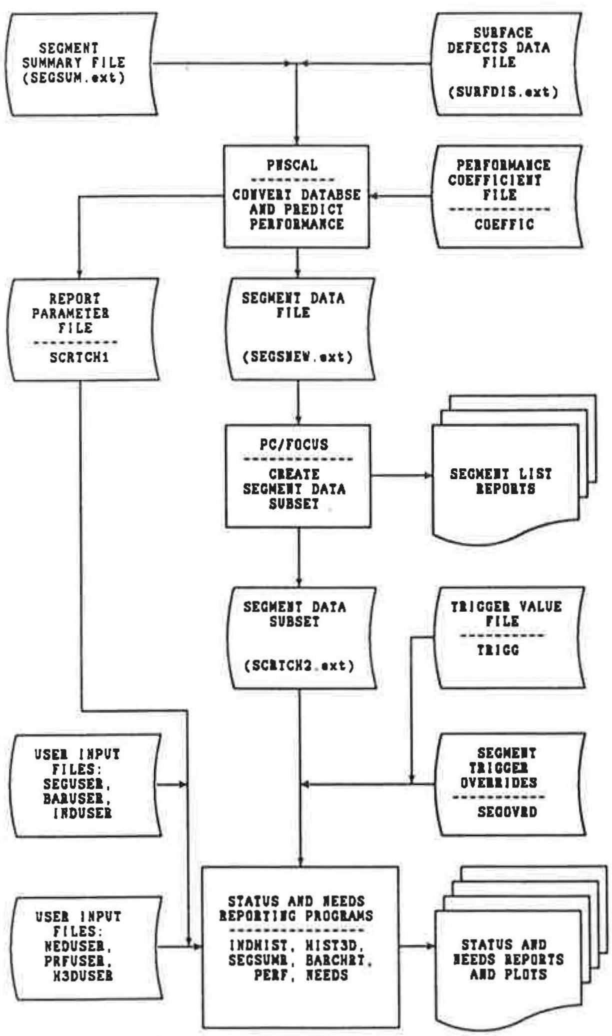

FIGURE 5 Status and Needs Subsystem.

Needs Reports

A segment needs report is presented in Table 3. It indicates the needs or trigger years, on the basis of application of the performance models. The trigger year occurs when the predicted performance, for any particular index or parameter noted earlier, reaches a minimum acceptable level, as specified by the user. An example application of the performance prediction models for a particular segment is shown in Figure 7.

The needs year distribution summary presented at the bottom of Table 3 can also be shown graphically (Figure 8), on the basis of surface rating (SR).

REHABILITATION OPTIMIZATION

The Rehabilitation Optimization Subsystem is shown in Figure 9. It incorporates seven FORTRAN programs (see Table 1), the first two of which carry out the analysis and optimization; the five remaining are used to produce reports.

Rehabilitation Alternatives Analysis

The set of rehabilitation alternatives used in Minnesota as of 1991 is presented in Table 4. A selection of alternatives from this set to be analyzed for any particular segment can be determined by using decision trees or by using an override. There are three basic decision trees: one for concrete (CON and CRC); one for bituminous (BIT and BOB); and one for bituminous over concrete (BOC). The decision tree is applied to each possible implementation year (i.e., projects are advanced and delayed from their needs or trigger year) because the conditions used in the decision tree can change from year to year.

TABLE 2 EXAMPLE PRESENT STATUS SEGMENT SUMMARY REPORT

Mn/DOT PAVEMENT MANAGEMENT SYSTEM — SEGMENT SUMMARY REPORT — MAR 9, 1989

ISTH ROUTE SYSTEM — INTERSTATE — PAGE 31

SEGMENT DESCRIPTION	DIST	CTRL SECT	LENGTH MILES	LANES	DIR	SURF TYPE	SUBGRD MODULUS	AADT	HCADT	NCADT % GRTH RATE	-1989- PSR	-1989- SR	SRVY YEAR	CR	1989 SAR	SRVY YEAR	PQI
ISTH 0694 038+00.723 040+00.492 ANOKA-RAMSEY CO LN .3 MI W OF TH-35W END CONC/BEG BOC	9	6285	1.751	4	I	CONC	N/A	74473	6599	11.1	3.0	2.5	(85)	3.4			2.4
ISTH 0694 040+00.492 041+00.111 .3 MI W OF TH-35W END CONC/BEG BOC .3 MI E OF TH-35W END BOC/BEG CONC	9	6285	.620	4	I	BOB	N/A	59592	5215	9.4	2.9	3.7	(86)	3.6			3.0
ISTH 0694 041+00.111 045+00.200 .3 MI E OF TH-35W END BOC/BEG CONC .1 MI E OF TH-49,RICE ST CHG IN SURF YR	9	6285	4.081	4	I	CONC	N/A	56288	4943	18.7	3.1	2.4	(85)	3.2			2.3
ISTH 0694 045+00.200 045+00.400 .1 MI E OF TH-49,RICE ST CHG IN SURF YR .3 MI E OF TH-49,RICE ST CHG IN SURF YR	9	6285	.200	4	I	CONC	N/A	59480	5196	8.6	3.0	2.9	(85)	3.5			2.8
ISTH 0694 045+00.400 046+00.043 .3 MI E OF TH-49,RICE ST CHG IN SURF YR BN RR, BR 9196 & 9197 CHG IN SURF YR	9	6285	.638	4	I	CONC	N/A	60124	5269	15.4	3.0	2.7	(85)	3.5			2.6
ISTH 0694 046+00.043 046+00.240 BN RR, BR 9196 & 9197 CHG IN SURF YR .2 MI E OF BN RR CHG IN SURF YR	9	6285	.197	4	I	CONC	N/A	33493	3665	15.1	3.1	2.6	(85)	3.7			2.5
ISTH 0694 046+00.240 046+00.449 .2 MI E OF BN RR CHG IN SURF YR W JCT ISTH-35E	9	6285	.209	4	I	CONC	N/A	29263	3410	15.6	3.1	2.6	(85)	3.7			2.5
ISTH 0694 047+00.104 058+00.187 JCT ISTH-94, JCT ISTH-494	9	6286	11.066	4	I	CRCP	N/A	35352	2523	.0	3.5	3.4	(87)	3.8			3.5

TOTAL FOR ROUTE-SYS : ISTH

ROADWAY PAVEMENT QUALITY (PQI) MILEAGES

BELOW 2.0	2.1 TO 2.5	2.6 TO 2.8	2.9 TO 3.0	3.1 TO 3.5	3.6 TO 4.0	ABOVE** 4.0	** **	TOTAL MILES	AVG PQI
178.8	501.7	477.4	155.7	278.1	95.6	111.4		1798.6	2.8

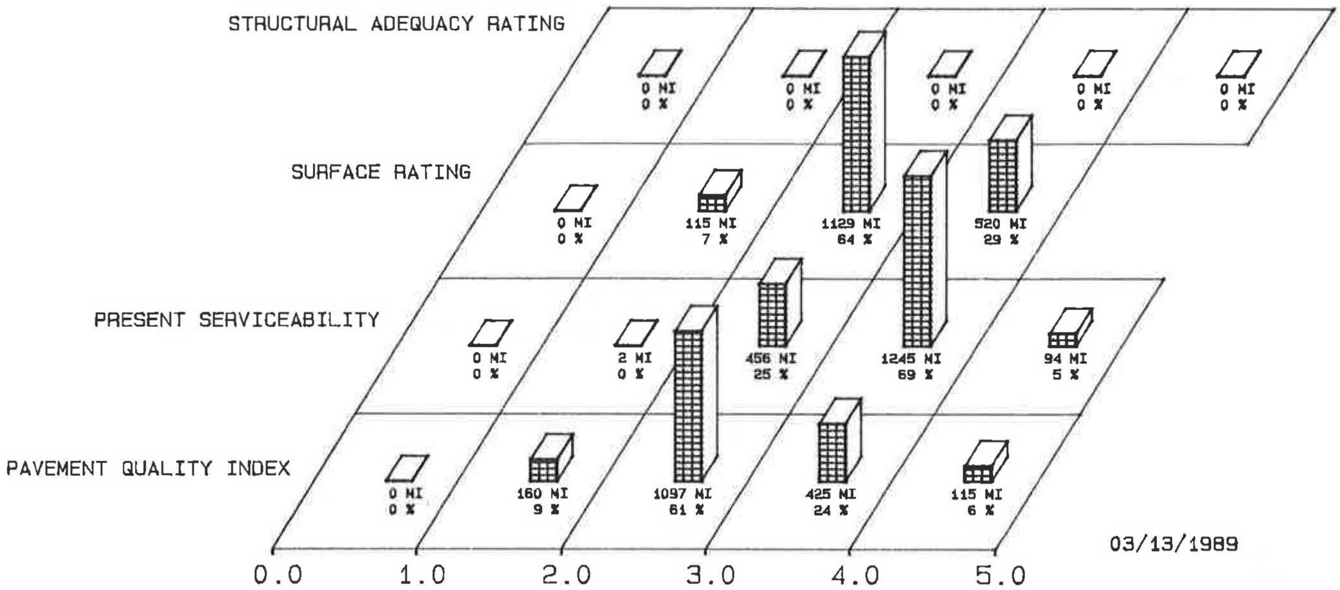

FIGURE 6 Summary distribution of present status for the Interstate network.

Analysis of the alternatives (i.e., performance predictions and calculation of capital, maintenance, and user delay costs) is similarly then carried out for each possible implementation year. As well, alternatives can be defined for implementation at a fixed repeat cycle (RC). Performance models for the rehabilitation alternatives, as well as the improvement (or jump) in the performance parameter when the rehabilitation is applied, are described in the system documentation report (*3*). For some alternatives, such as minor joint reseal, the jump is 0 for some of the parameters (e.g., ride).

Economic analysis of each alternative includes calculation of the present worth of costs of the rehabilitation for each implementation year, ongoing maintenance, and user costs. As well, cost-effectiveness for each combination of alternative and implementation year is calculated. Details of the models used are contained in the system documentation report (*3*); a summary of the cost-effective calculation is provided by Hill and Haas (*4*). Of particular interest is the comprehensive user-delay cost model, which may or may not be included in the analysis as an option. It considers such factors as traffic handling method, traffic volumes, length of the rehabilitation or maintenance zone, number of days, speeds, capacity, type of facility (multilane, two-lane, shoulders, etc.), and direction of travel.

Detailed reports of the alternatives analyzed for each segment for each year of the program period can be generated in the Mn/DOT PMS. However, only network summary report examples will be provided in this document.

Optimization Analysis

The optimization used in Mn/DOT's PMS is based on marginal cost-effectiveness calculations, as described by Hill and Haas (*4*). Although it is a near optimization rather than a true optimization method, the results are not significantly different for practical purposes.

The analysis can be performed in either of the following modes:

1. Effectiveness maximization, where the primary constraints are specified budget limits for each year of the program period;
2. Cost minimization, where the constraints are either

- Minimum average network performance (PSR, SR, SAR, or PQI), or
- Maximum percent of mileage below the minimum acceptable level.

Consequently, eliminating budget constraints is only appropriate for cost minimization whereas eliminating performance constraints is only appropriate for effectiveness maximization.

An example summary report for the effectiveness maximization mode is shown in Figure 10 for an annual budget limit of $15,000,000. (Actual predicted costs, which are slightly lower, are listed in the third row of the diagram.) This example is based on effectiveness maximization for PSR.

Figure 10 shows, on the left part of the diagram, how average PSR will change for the expected budget (solid line) from about 3.4 in 1989 to about 3.2 in 1998, and for 0 budget (dotted line) to a low of about 2.7 in 1998. The right part of the diagram shows the associated accumulation of deficient mileage, in terms of percent below the minimum or trigger PSR level. For the expected budget, this would increase from about 10 to 32 percent over the program period, whereas for 0 budget it would increase to about 65 percent.

TABLE 3 EXAMPLE SEGMENT NEEDS REPORT

M/n PAVEMENT MANAGEMENT SYSTEM | SEGMENT NEEDS REPORT | MAR 9, 1989

INTERSTATE | PAGE 31

	DIST	CTRL SECT	LNTH (MI)	LANES	DIR	SURF TYPE	1st NEED YR-NDX	PQI TRIG YR	SAR TRIG YR	SR TRIG YR	PSR TRIG YR
ISTH 0694 038+00.723 040+00.492 ANOKA-RAMSEY CO LN .3 MI W OF TH-35W END CONC/BEG BOC	9	6285	1.8	4	I	CONC	89-SR	2.4-(2.5)-89		2.5-(2.5)-89	3.0-(2.9)-90
ISTH 0694 040+00.492 041+00.111 .3 MI W OF TH-35W END CONC/BEG BOC .3 MI E OF TH-35W END BOC/BEG CONC	9	6285	.6	4	I	BOB	90-PSR	3.0-(2.5)-93		3.7-(2.5)-99	2.9-(2.8)-90
ISTH 0694 041+00.111 045+00.200 .3 MI E OF TH-35W END BOC/BEG CONC .1 MI E OF TH-49,RICE ST CHG IN SURF YR	9	6285	4.1	4	I	CONC	89-SR	2.3-(2.5)-89		2.4-(2.5)-89	3.1-(2.9)-92
ISTH 0694 045+00.200 045+00.400 .1 MI E OF TH-49,RICE ST CHG IN SURF YR .3 MI E OF TH-49,RICE ST CHG IN SURF YR	9	6285	.2	4	I	CONC	90-PSR	2.8-(2.5)-92		2.9-(2.5)-94	3.0-(2.9)-90
ISTH 0694 045+00.400 046+00.043 .3 MI E OF TH-49,RICE ST CHG IN SURF YR BN RR, BR 9196 & 9197 CHG IN SURF YR	9	6285	.6	4	I	CONC	90-PSR	2.6-(2.5)-90		2.7-(2.5)-91	3.0-(2.9)-90
ISTH 0694 046+00.043 046+00.240 BN RR, BR 9196 & 9197 CHG IN SURF YR .2 MI E OF BN RR CHG IN SURF YR	9	6285	.2	4	I	CONC	89-PQI	2.5-(2.5)-89		2.6-(2.5)-90	3.1-(2.9)-92
ISTH 0694 046+00.240 046+00.449 .2 MI E OF BN RR CHG IN SURF YR W JCT ISTH-35E	9	6285	.2	4	I	CONC	89-PQI	2.5-(2.5)-89		2.6-(2.5)-90	3.1-(2.9)-92
ISTH 0694 047+00.104 058+00.187 JCT ISTH-94, JCT ISTH-494	9	6286	11.1	4	I	CRCP	93-SR	3.5-(2.5)-93		3.4-(2.5)-93	3.5-(2.9)-99

SEGMENT NEEDS MILEAGE SUMMARY

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
PSR	448	61	130	93	73	132	176	117	67	111	68	33	66	49	50	3	25	0	13	23	21
SR	486	229	125	167	194	86	126	109	57	14	46	53	22	0	2	2	43	18	0	9	0
SAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PQI	680	177	148	234	178	54	36	122	36	26	6	12	26	0	0	0	11	21	21	0	0

TOTAL MILEAGE: 1798.6

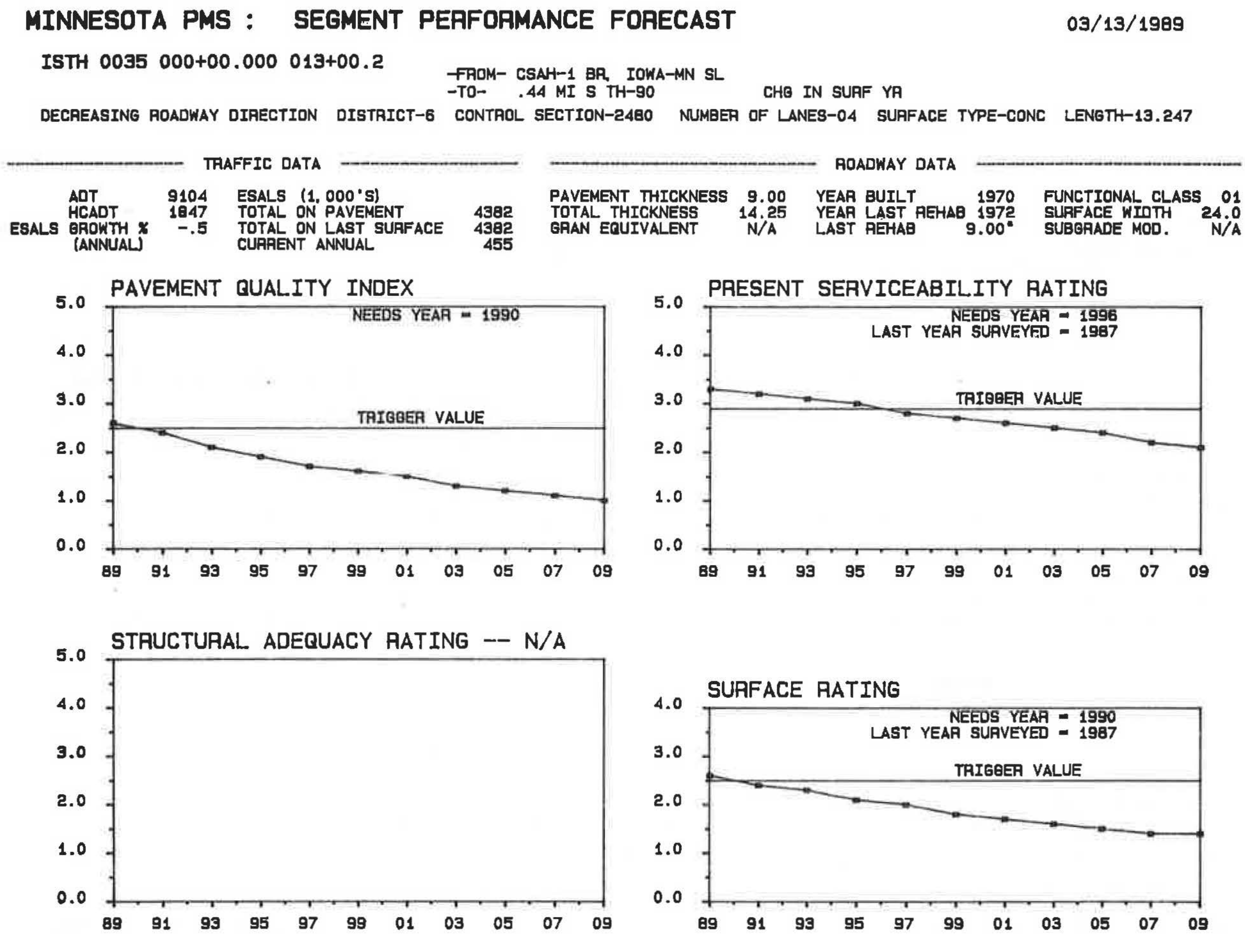

FIGURE 7 **Example application of the performance prediction models to a segment.**

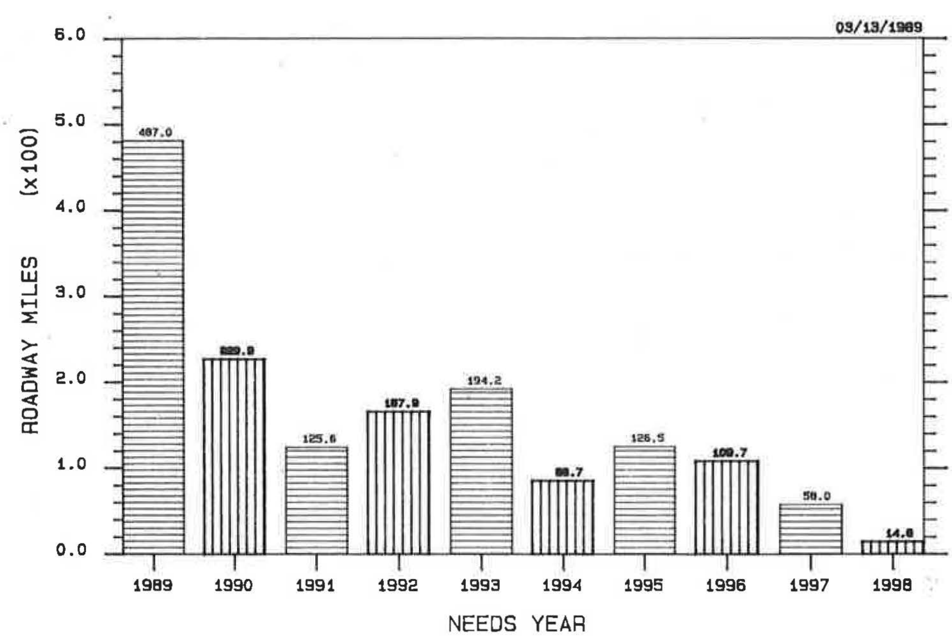

FIGURE 8 **Graphical summary of the needs year distribution for the Interstate network.**

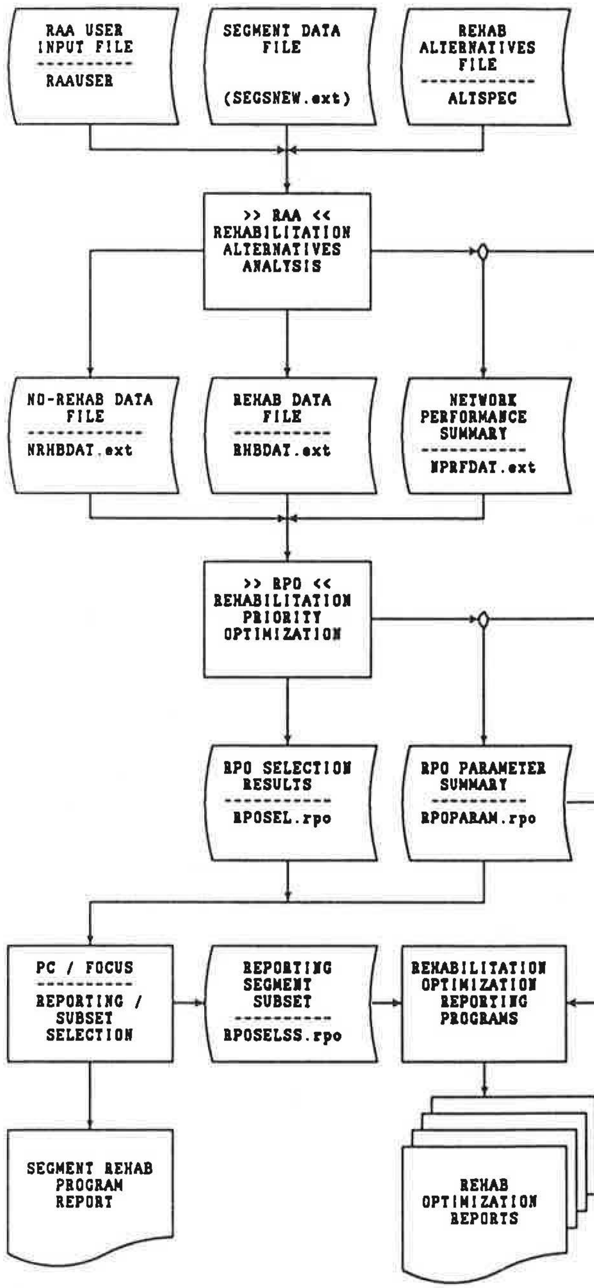

FIGURE 9 Rehabilitation Optimization Subsystem.

TABLE 4 CURRENT SET OF REHABILITATION ALTERNATIVES IN Mn/DOT's PMS

No.	Alternative Description	Cost $/mi	R C	Dec. Tre.	Res.
1	Overlay 1" - 2341	25000	5	BIT	BOB
2	Overlay 1.5" - 2341	36000	0	BIT	BOB
3	Overlay 1" - 2361	33000	5	BIT	BOB
4	Overlay 3" - 2331	75000	0	BIT	BOB
5	Overlay 5" - 2361	150000	0	BIT	BOB
6	Overlay 6" - 2361	180000	0	BIT	BOB
7	Mill 2" Overlay 3"	82000	0	BIT	BOB
8	Mill 3" Overlay 4"	97000	0	BIT	BOB
9	Seal Coat	6000	3	BIT	
10	Partial Reconst.	350000	0	BIT	BIT
11	Reconstruct	500000	0	BIT	BIT
12	Reconstruct	750000	0	BIT	BIT
13	Minor Joint Reseal	30000	0	CON	
14	Major Joint Rep/Res	125000	0	CON	
15	Overlay 3"	100000	0	CON	BOC
16	Overlay 1.5"	60000	0	CON	BOC
17	Overlay 5"	180000	0	CON	BOC
18	Unbonded	332000	0	CON	BOC
19	Plane & Reseal	50000	0	CON	
20	Reconstruct	500000	0	CON	CON
21	Plane, Joint Rep/Res	195000	0	CON	
22	Seal Coat	6000	3	BOC	
23	Overlay 1" - 2361	45000	0	BOC	
24	Overlay 1" - 2341	35000	0	BOC	
25	Overlay 3" - 2331	90000	0	BOC	
26	Mill 4" Overlay 5"	179245	0	BOC	
27	Mill 2" Overlay 3"	100000	0	BOC	
28	Rehab Crack/O.L 1.5"	81000	0	BOC	
29	Reconstruct	500000	0	BOC	BIT
30	Partial Recon/Reseal	300000	0	BOC	
31	Mill 3" Overlay 4"	165000	0	BOC	
32	Mill 5" Overlay 6"	207165	0	BOC	
33	Mill 6" Overlay 7"	221455	0	BOC	
34	Mill 7" Overlay 8"	235045	0	BOC	

Mn/DOT : REHABILITATION PERFORMANCE SUMMARY REPORT 03/12/1989

YEAR		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
COST	($1000)	14897	14929	14880	14998	14933	14987	14952	14864	14969	14986
NON-REHAB	AVERAGE PQI	3.3	3.2	3.2	3.1	3.0	3.0	2.9	2.8	2.8	2.7
REHAB	AVERAGE PQI	3.3	3.3	3.2	3.2	3.2	3.1	3.1	3.2	3.1	3.1
NON-REHAB	% PQI < MIN	9	12	15	19	26	33	43	52	60	64
REHAB	% PQI < MIN	8	10	11	14	16	20	22	27	31	31

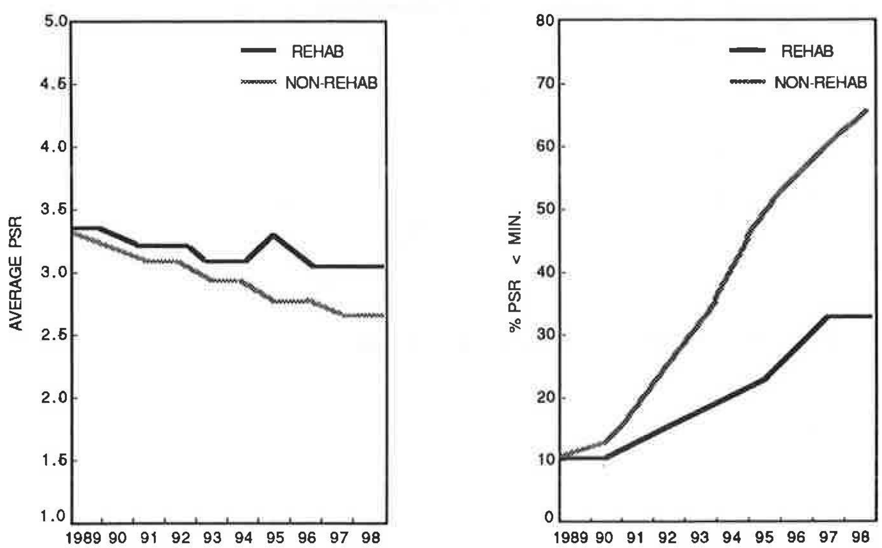

FIGURE 10 Example performance summary report for network optimization.

TABLE 5 CHANGES IN ALL THE PERFORMANCE INDICES FOR THE OPTIMIZATION OF FIGURE 10

Mn/DOT REHABILITATION OPTIMIZATION SYSTEM 03/13/1989

PERFORMANCE SUMMARY REPORT: DISTRICT 2

ANALYSIS MODE :Effectiveness-Maximization - 1989 to 1998 RPO RUN I.D.: IN1

TOTAL NO. OF SEGMENTS: 338 TOTAL MILEAGE: 1798.6 NO. OF SEGMENTS WITH REHAB: 188 MILEAGE: 505.4

	YEAR	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL BUDGET		15000000	15000000	15000000	15000000	15000000	15000000	15000000	15000000	15000000	15000000
PREDICTED EXPENDITURE		14896812	14928770	14880217	14998219	14933333	14987280	14951803	14864090	14969476	14986425
PSR	REHAB	75%	74%	67%	63%	58%	51%	46%	41%	38%	35%
% > 3.0	NON-REHAB	74%	71%	63%	57%	53%	44%	37%	30%	26%	20%
PSR	REHAB	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% < 1.5	NON-REHAB	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
SR	REHAB	75%	64%	59%	54%	46%	40%	34%	27%	26%	25%
% > 2.5	NON-REHAB	73%	61%	52%	44%	34%	26%	17%	11%	10%	9%
SR	REHAB	1%	2%	5%	5%	7%	7%	10%	13%	16%	23%
% < 1.5	NON-REHAB	1%	2%	5%	5%	8%	8%	13%	17%	22%	30%
SAR	REHAB	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% > 3.0	NON-REHAB	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
SAR	REHAB	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% < 1.5	NON-REHAB	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
PQI	REHAB	32%	30%	30%	26%	23%	22%	17%	17%	18%	18%
% > 3.0	NON-REHAB	28%	23%	18%	13%	8%	5%	3%	3%	2%	2%
PQI	REHAB	4%	5%	7%	9%	12%	15%	23%	30%	35%	40%
% < 1.5	NON-REHAB	4%	6%	7%	10%	13%	18%	28%	37%	44%	53%

Because Figure 10 is based on effectiveness maximization for PSR, changes in the other performance indices may also be wanted, as given in Table 5.

CONCLUSION

The Mn/DOT has a comprehensive network-level PMS in place and operational. Developed in stages, it was based on careful preimplementation planning, both as to scope and to service to the various users in the department. The PMS components are linked through the TIS plus a number of programs for data management functions, user interface, analysis, and reporting. Two major subsystems are contained in the PMS: (a) Status and Needs Subsystem, and (b) Rehabilitation Optimization Subsystem. Each incorporates considerable flexibility and is capable of providing the user with a number of detailed and summary reports.

REFERENCES

1. F. V. Maurer and E. E. Ofstead. Minnesota's Pavement Management System: How It Came About and the Steps Taken. *Proc., Second North American Conference on Managing Pavements*, Vol. 3, Toronto, Canada, Nov. 1987, pp. 3.83–3.93.
2. R. Haas. *Minnesota's Pavement Management System: Implementation Recommendations.* Minnesota Department of Transportation, St. Paul, June 1985.
3. Pavement Management Systems Limited. *Minnesota Department of Transportation Pavement Management System: System Documentation.* Minnesota Department of Transportation, St. Paul, June 1989.
4. L. Hill and R. Haas. *Module E: Multi-Year Prioritization.* Advanced Course on Pavement Management Systems, FHWA, U.S. Department of Transportation, June 1990.

Publication of this paper sponsored by Committee on Pavement Management Systems.