Impact of a Comprehensive Pavement Management System Developed in Pennsylvania

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ABSTRACT

A comprehensive pavement management system has been developed by a task force of the Pennsylvania Department of Transportation, which uniformly evaluates the various aspects of rigid and bituminous surface pavement distress conditions across Pennsylvania's highway network. The system, STAMPP, is intended to evaluate pavement condition annually in one-half-lane mile segments, and to group segments of similar conditions in a county, a district, or a state according to distress extent and severity. In addition, the system will, in a systematic manner, recommend appropriate treatment of each segment based on the combinations of distress elements and their severity, and will develop dollar needs for each of Pennsylvania's 67 counties, thereby providing a basis for an equitable distribution of maintenance funds to the counties based on pavement needs. To illustrate the relative impact of STAMPP on the distribution of maintenance and rehabilitation funds to Pennsylvania's counties, a partial comparison of the dollar distribution is shown. Built into the system are the capacities to adjust for improvements and to expand to include other conceptually possible future parameters.

In 1983, pavement management personnel of the Pennsylvania Department of Transportation (PennDOT) felt the need to develop a systematic technique to analyze and manage Pennsylvania's pavements (STAMPP). To achieve this objective, the Secretary of Transportation named an eight-member task force from various organizations within the department. Members of the task force were relieved of their normal duties for the duration of the project, so as to give it their undivided attention (1-3). The task force identified the following five objectives:

1. To provide a uniform statewide pavement condition evaluation that would improve decision making.
2. To provide management with the information and tools with which to monitor the condition of the Pennsylvania highway network, assess future needs, establish county pavement condition rankings, and optimize investments.
3. To provide condition information to fulfill the requirement that maintenance funds be allocated to individual counties based on needs.
4. To provide information for monitoring the performance of various pavement designs, rehabilitation, and maintenance techniques.
5. To provide information for identifying candidate projects for maintenance and improvement programs.

BASIC DATA UTILIZED IN SYSTEM DEVELOPMENT

The following data base elements were utilized in developing STAMPP (1):

1. Pennsylvania Automated Roadway Information System (PARIS). This data base contains the history of the latest state highway construction, including functional class, type of highway configuration, base and surface material types and depths, widths, years resurfaced, and various other highway characteristics.
2. Traffic data, including truck counts.
3. Ride quality. This data base includes present serviceability index ratings from 0-5 as well as roughness measured by the Mays Meter.
4. Pavement condition, including ratings of several surface distress items from field condition surveys for both rigid and flexible pavements, and their shoulders.

PAVEMENT CONDITION SURVEY

STAMPP is based on highway distress characteristics that include limited shoulder distress data. In this data base, pavements were divided into three categories: (a) rigid, (b) flexible, and (c) rigid base with flexible overlays. Paved and unpaved shoulders were considered an integral part of pavement management.

A Condition Survey Input Form was developed for rigid pavements and another was developed for bituminous surface pavements including overlays on rigid bases (see Figures 1 and 2) (1-3). The conditions to be surveyed in each type are shown in the figures, together with parameters defined reasonably well enough to give sufficient accuracy and reproducibility for a given section of pavement.

Each pavement section to be evaluated was arbitrarily chosen to be approximately one-half of a lane mile in length, and the percentage of the sections having a defect of a given severity was reported, except when discrete counts were more meaningful than percentages. For example, the percentage of the sections containing more than 0.5 in. of faulting and the number of pot holes deeper than 3 in. were

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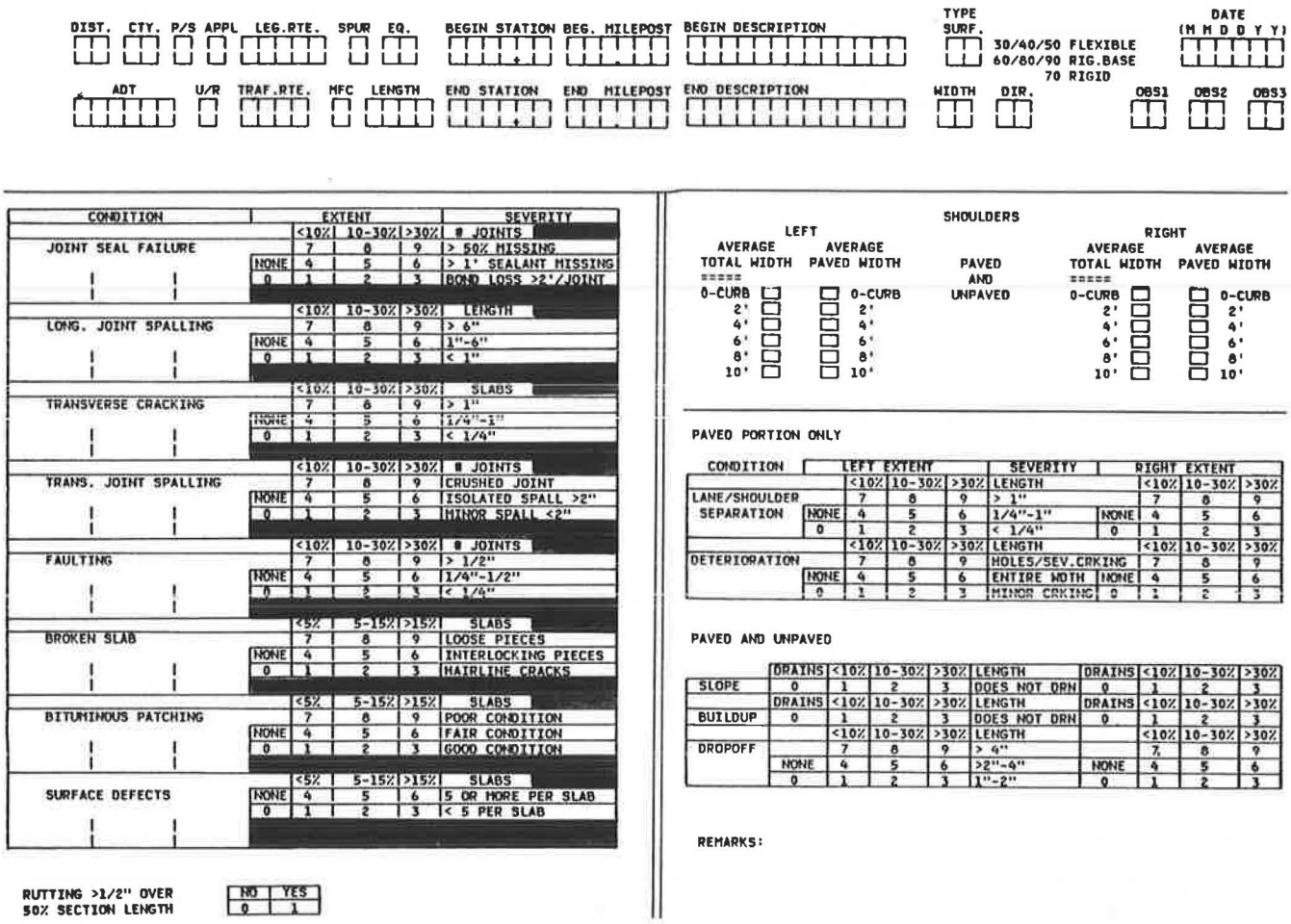


FIGURE 1 Condition survey input form—rigid pavement.

reported. Unique situations such as the presence of rutting on concrete pavements required only "yes" or "no" notation.

A detailed manual on pavement condition surveys (including illustrations) was developed by the task force to assist field personnel in the data collection phase (4). The manual was field tested and field personnel were trained in its use so that the data would be as uniform as possible for similar conditions. The test sections were tied to permanent physical features on the roadway where possible, thus lending themselves to ease of locating and permanence.

PAVEMENT TREATMENT STRATEGIES

Pavement maintenance and rehabilitation strategies were developed, relating pavement condition to the strategy conceived through experience to be the best for providing extended pavement life and acceptable level of service under prevailing environmental conditions and expected traffic loadings.

For rigid pavements, ten preventative and corrective strategies were developed and each was identified by a number (1 through 10) as follows (2,3):

1. Spot joint seal,
2. Joint seal,
3. Joint rehabilitation,
4. Joint spall repair,
5. Joint replacement,
6. Subsealing,
7. Subsealing, slabjacking,
8. Subsealing, slabjacking, and grinding,
9. Slab replacement, and
10. Overlays (bituminous or concrete).

By using the pavement condition survey distress items shown in Figure 1, as well as a numerical definition for extents and severities ranging from 1 through 9, a matrix was developed for rigid pavement treatment strategies (Figure 3). The numerical definitions for extents and severities of transverse cracking are illustrated as follows:

Severity (in slabs)	None	<10%	10-30%	>30%
>1 in.		7	8	9
1/4-1 in.		4	5	6
<1/4 in.		1	2	3

The matrix combines the condition survey numerical definitions shown horizontally on top of the matrix with the conditions listed vertically and numbered A through K, and indicates the type of treatment recommended by a number (1 through 10) in the body of the matrix. Routine maintenance is marked by (X). Figure 3 shows the matrix for rigid pavement treatment strategies with an example of how they are used. Individual treatments are specified for each cell in the matrix in the simplest case. The arrows in the matrix show that when 30 percent transverse cracking occurs, a slab replacement is

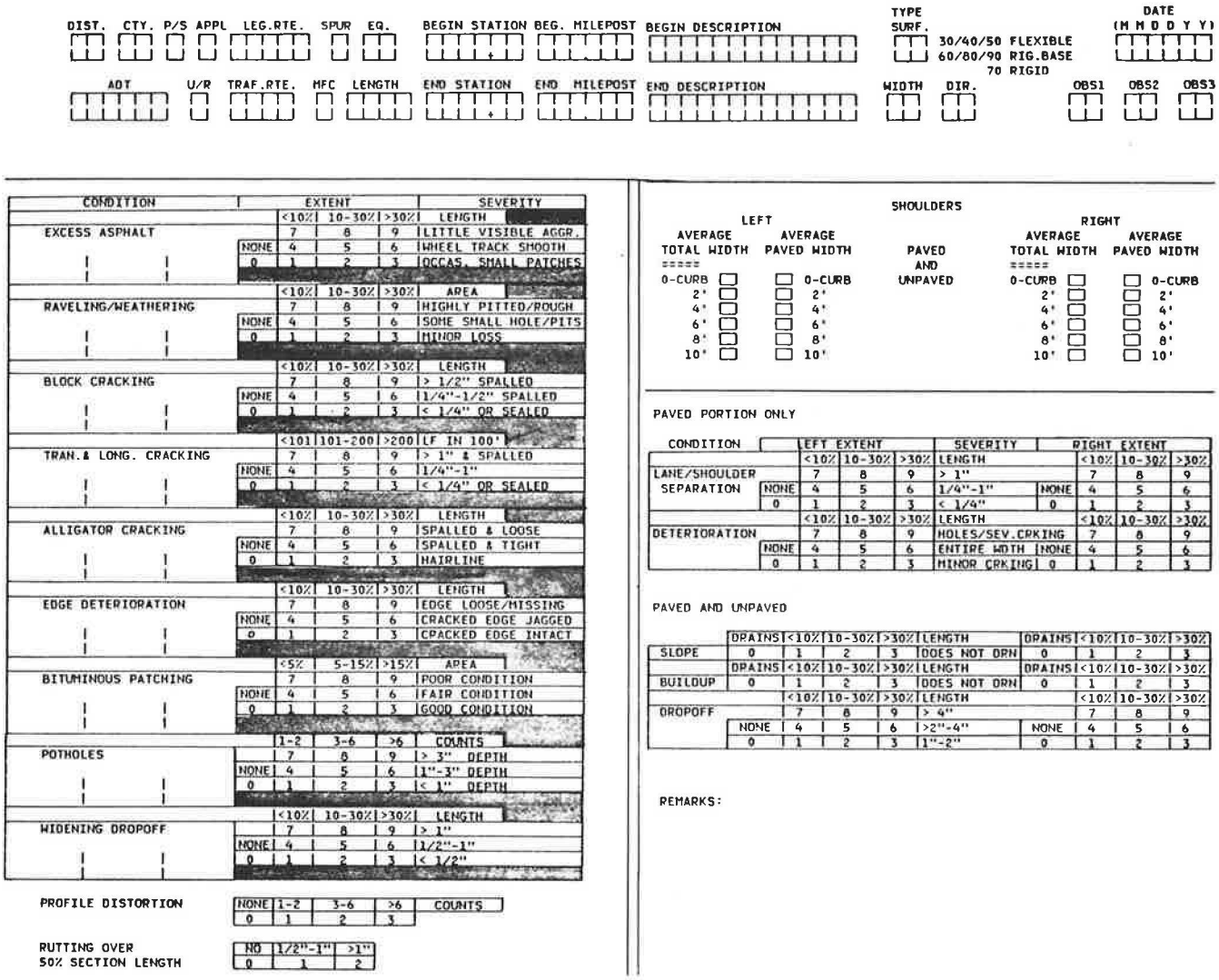


FIGURE 2 Condition survey input form—bituminous surface pavement.

recommended. Conditions that require more than 30 percent patching trigger an overlay. For example, the overlay category would be triggered when two or more conditions occur on the same section and warrant a more intensive corrective action. As an example, when more than 30 percent of the slabs of a section are broken, accompanied by more than 10 percent of the section exhibiting crushed joints, the recommended treatment is number 10, an overlay.

The type of overlay recommended will undergo cost analysis and will depend on average daily truck traffic (ADTT) loadings, as follows:

ADTT	Overlay Strategy
0-1,000	3-1/2 in. bituminous
1,001-2,000	6-in. bituminous
2,001-3,000	Bit or concrete overlay
Over 3,000	Reconstruct

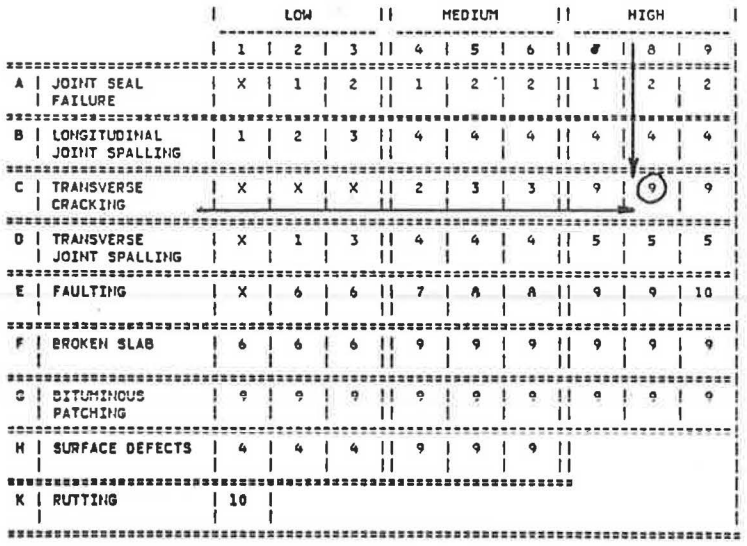
Less severe conditions may be alleviated by preventive maintenance or corrective rehabilitation repairs before overlaying. In all cases, it is assumed that drainage and mandatory base repairs are performed and that surface friction requirements are satisfied. No overlay will be expected to have a long functional life without satisfying these requirements.

For bituminous surface pavements, 15 maintenance-rehabilitation strategies were identified and are shown below the matrix for bituminous surface pavement treatment strategies in Figure 4. Shoulder treatment strategies are similarly shown in Figure 5 for paved and unpaved shoulders (1).

PILOT STUDY AND IMPLEMENTATION

The developed STAMPP concept was field tested by the task force on the roads of one of Pennsylvania's 67 counties, which offered a full range of conditions that may be met (1,2). A sample condition survey from the pilot study is shown in Figure 6. Results of the survey and recommended corrective actions using STAMPP were compared with those that had been planned for recommended action by the responsible personnel in the county using normal procedures. In general, there was good agreement between the two sets, but a few adjustments had to be made to improve the STAMPP procedure (2).

To familiarize those responsible for implementation of the STAMPP concept with its details, and to gain their acceptance, a report and a slide presentation were prepared and presented to all concerned administrative personnel over a period of several



		LOW			MEDIUM			HIGH		
		1	2	3	4	5	6	7	8	9
A	JOINT SEAL FAILURE	X	1	2	1	2	2	1	2	2
B	LONGITUDINAL JOINT SPALLING	1	2	3	4	4	4	4	4	4
C	TRANSVERSE CRACKING	X	X	X	2	3	3	9	9	9
D	TRANSVERSE JOINT SPALLING	X	1	3	4	4	4	5	5	5
E	FAULTING	X	6	6	7	8	8	9	9	10
F	BROKEN SLAB	6	6	6	9	9	9	9	9	9
G	BITUMINOUS PATCHING	9	9	9	9	9	9	9	9	9
H	SURFACE DEFECTS	4	4	4	9	9	9			
K	RUTTING	10								

(X) ROUTINE MAINTENANCE
(1) SPOT JOINT SEAL
(2) JOINT SEAL
(3) JOINT REHABILITATION
(4) JOINT SPALL REPAIR
(5) JOINT REPLACE
(6) SUBSEAL
(7) SUBSEAL & SLABJACK
(8) SUBSEAL & SLABJACK & GRIND
(9) SLAB REPLACE
(10) OVERLAY

COMBINATIONS FOR OVERLAY:

>30% PATCHING

OVERLAY REPAIR RECOMMENDATIONS:

ADTT	REPAIR
0 - 1000	3-1/2" BITUMINOUS
1001 - 2000	6" BITUMINOUS
2001 - 3000	CONCRETE OVERLAY
ABOVE 3000	RECONSTRUCT

EXPLANATION OF TREATMENT STRATEGIES

NUMBERS ACROSS THE TOP OF THE STRATEGY GRID (1 THRU 9) REFER TO MARKS ON THE CONDITION SURVEY INPUT FORM. LETTERS DOWN THE SIDE (A THRU K) REFER TO CORRESPONDING CONDITIONS. FOR EXAMPLE, A SECTION HAVING SEVERE TRANSVERSE CRACKING OVER 20% OF ITS SLABS IS CODED C8. C8 CONDITION ALONE INDICATES TREATMENT #9 - SLAB REPLACE.

	NONE	EXTENT			
	0	1	2	3	LOW
		4	5	6	MEDIUM
		7	8	9	HIGH

ANY COMBINATION OF CONDITIONS THAT REQUIRE >30% PATCHING WILL INDICATE TREATMENT #10 - OVERLAY.

FIGURE 3 Rigid pavement treatment strategies.

weeks (2). Later, training sessions were conducted on implementing each phase in all Pennsylvania's 11 districts and in the central office. The training sessions were intended for explanation of detailed procedures and obtaining uniformity of application across the state.

The next step was to undertake a condition survey on the Pennsylvania highway system. Because of its extent (about 45,000 mi), the initial survey was conducted on about 12,000 mi designated as the Priority Commercial Network (PCN). The PCN is defined as those roadways carrying 500 or more trucks per day, or those of significant importance to regional industries such as the coal industry (2,3).

The first pavement condition survey was collected by January 1984, and was entered into the personal computers and became available for maintenance planning and programming. A subsequent quality control random survey of 5 percent of the PCN mileage showed that the initial survey and the recommended treatments were sufficiently accurate to lend credibility to the system (2). However, an expansion of STAMPP was needed to include guide rail and drainage information, which must be taken into account when allocating maintenance funds to the counties (3). Field Manuals for guide rail condition surveys and drainage condition surveys have recently been developed (5,6).

THE EFFECT OF STAMPP ON MAINTENANCE FUND DISTRIBUTION

Maintenance funds (about $600 million) have been distributed annually to Pennsylvania's 67 counties using a legislated formula that is intended to reflect county needs (3). The present form of the formula is:

$$ASHMA = 0.15\ (BD + LM + VM + SI) + 0.40\ RPQI$$

where

ASHMA = additional state highway maintenance appropriations,
BD = the percent of the total state bridge deck area in a given county,
LM = the percent of the total state lane miles in a given county,
VM = the percent of the total state vehicle miles traveled in a given county,
SI = the snow index for a given county based on the number of snow days with accumulation of 1 in. or more, and
RPQI = the relative pavement quality index, which is the only regulated portion of the formula, and has been defined as

		LOW			MEDIUM			HIGH		
		1	2	3	4	5	6	7	8	9
A	EXCESS ASPHALT	X	X	X	X	X	X	X	X	X
B	RAVELING/ WEATHERING	2	2	4 (7)	2	4 (5)	4 (7)	5	8 (5)	8 (12)
C	BLOCK CRACKING	2	2	4 (7)	1	1+8 (5)	1+8 (7)	1+5	1+8 (1+5)	10 (13)
D	TRANSVERSE AND LONGITUD.CRACKING	X	X	X	1	1	1	1+2	1+2	10 (13)
E	ALLIGATOR CRACKING	2	2	2	2+3	2+3 (5)	3+8 (3+12)	6	6	6+8 (6+12)
F	EDGE DETERIORATION	X	2	2	3	2+3	2+3	3	5	11
G	BITUMINOUS PATCHING	X	X	X	3	5	5	3	3+5	10 (13)
H	POTHOLES	3	3	3	3	3	3	3	3	6
I	WIDENING DROPOFF	X	2	2	X	5*	5*	3	10* (13)*	10* (13)*
J	PROFILE DISTORTION	6 OR 9*	6 OR 9*	6 OR 9*	* ASSUME 6' WIDTH FOR COST					
K	RUTTING	X	8 (13)		( ) URBAN AREA					

(X) ROUTINE MAINTENANCE
(1) CRACK SEAL
(2) SKIN PATCH
(3) MANUAL PATCH
(4) SEAL COAT
(5) MECHANIZED PATCH
(6) BASE REPAIR
(7) SURFACE TREATMENT - 1" PLANT MIX
(8) LEVEL & SEAL COAT
(9) JOINT REPAIR
(10) MILL & LEVEL & SEAL COAT
(11) WIDEN
(12) LEVEL & RESURFACE
(13) MILL (RECYCLE) & LEVEL & RESURFACE
(14) RECONSTRUCTION

* TYPE SURFACE:
30/40/50 FLEXIBLE - (6) BASE REPAIR
60/80/90 RIGID BASE - (9) JOINT REPAIR

COMBINATIONS FOR SEAL COAT (4):
C8 + E3 + >ADT 2000 + RURAL
C8 + E5 + >ADT 2000 + RURAL

COMBINATIONS FOR WIDEN (11):
>2' NARROWER THAN DESIGN MANUAL PART2 CRITERIA

COMBINATIONS FOR (8):
SEAL COAT (4) + K1
B5 + B7 + RURAL
C2 + C8 + RURAL

COMBINATIONS FOR RESURFACING (12):
E8 + B8 + >ADT 2000

COMBINATIONS FOR ----- (9 + 13) -----
>D7 +>I7 + J3 + (URBAN)
D9 + I9 + (URBAN)
I9 + J3 + (URBAN)
OR ----- (8 + 9) -----
OR (RURAL)
OR (RURAL)
OR (RURAL)

COMBINATIONS FOR ----- (13) -----
K1 + B9 + (>ADT 2000 OR URBAN)
K1 + C6 + "
K1 + C9 + "
K1 + E6 + "
K1 + E8 + "
K1 + E9 + "
K2 + E6 + B8 + (>ADT 2000 OR URBAN)
K2 + C5 + C8 + "
>E7 + C5 + "
>E7 + C6 + "
>E7 + C8 + "
>C9 + E6 + "
C9 + E8 + "
C9 + E9 + "
G6 + G9 + "

----- (10) -----
K2 + (<ADT 2000 + RURAL)
K2 + "
K2 + "
K2 + "
K2 + "
K2 + "
OR (<ADT 2000 + RURAL)

COMBINATIONS FOR ----- (12) -----
>E9 + B9 + (>ADT 2000 OR URBAN)
>E8 + B9 + "
E9 + B8 + "

OR ----- (8) -----
OR (<ADT 2000 + RURAL)

FIGURE 4 Bituminous surface pavement treatment strategies.

RPQI = LM x VM x FDD x TOS

where FDD is a prorated freezing degree-days index and TOS is the average of two consecutive 6-month cycles of the Trained Observer Survey indices (7), which has been replaced by STAMPP.

As may be seen from the RPQI equation, the effect of the TOS is only about 25 percent of the RPQI or about 10 percent of the ASHMA formula.

The proposed new RPQI portion of the formula is expressed as

RPQI = 0.85 STAMPP Index + 0.05 Truck Index
+ 0.10 Drainage and Guide Rail Index

where STAMPP Index is the county's STAMPP dollar need expressed as a percentage of the total STAMPP dollar need for the entire State (3).

EXAMPLE

As an example, the old RPQI for a given county was calculated as follows:

1983 average 2-cycle TOS Index = 0.02033,

Vehicle - Mile Index, County's VM/$\sum$VM (all counties) = 0.011476,

Lane - Mile Index, County's LM/$\sum$LM (all counties) = 0.021131,

Freezing Degree-Days (Snow Index) = (Snow Days > 1 in./$\sum$Snow Days) = 0.19534,

County's Index = 0.02033 x 0.011476 x 0.021131 x 0.19534,

County's Index = 9.6326×10^{-8},

$\sum$Indices for all 67 counties = 4.37314×10^{-6},

County's RPQI = $9.6326 \times 10^{-8} / 4.37314 \times 10^{-6}$ = 0.02203, and

ASHMA = 0.15 (BD + LM + VM + SI) + 0.40 (0.02203).

Thus, the TOS contribution to the formula is 0.25 RPQI or (0.25)[(0.40)(0.02203)] = 0.0022 or 0.22 percent of the RPQI.

The new proposed RPQI considers 100 percent of the county's pavement maintenance and rehabilitation needs relative to all 67 counties without remultiplying this percentage by VMI x LMI x SI. In the proposed ASHMA formula, 0.40 of 85 percent of RPQI is considered--that is, 0.40 (.85) = 0.34 as compared to 0.40 (0.22) = 0.088 in the old formula. Thus, the new RPQI will contribute 3.86 times the old RPQI to the ASHMA formula.

Although the proposed shape of the formula is expected to undergo further modifications to improve it (3), it nevertheless reflects the impact that the STAMPP procedure is expected to have on the allocation of funds--0.85 RPQI or 0.34 ASHMA.

Using 0.85 STAMPP rather than 0.25 TOS should make the formula more sensitive to actual pavement needs, thus conceptually more equitable. This is so because whereas TOS looks specifically at maintenance needs, STAMPP looks at the pavement condition that includes not only maintenance needs, but also

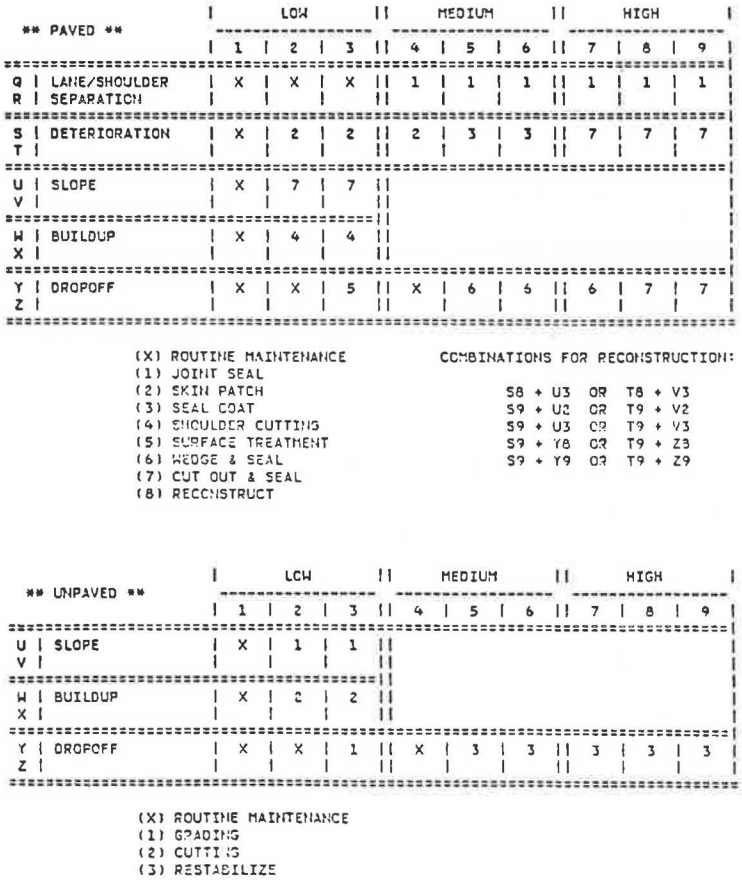


FIGURE 5 Shoulder treatment strategies.

SYSTEMATIC TECHNIQUE to ANALYZE and MANAGE PENNSYLVANIA PAVEMENTS (STAMPP)

CONDITION SUMMARY

CENTRE COUNTY
L.R. 27
FROM STATION 1399+11 TO STATION 1689+87
LENGTH - 5.51 MILES
1983 DATA (FILE NAME 'CENDAT83')

FLEXIBLE PAVEMENT

		SEVERITY AND EXTENT								
	NONE	LOW			MEDIUM			HIGH		
CONDITION	0	1	2	3	4	5	6	7	8	9
EXCESS ASPHALT	5.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RAVELING/WEATHERING	0.00	0.00	0.00	3.04	0.00	0.00	2.47	0.00	0.00	0.00
BLOCK CRACKING	5.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TRANS. & LONG. CRACKING	0.57	1.43	1.61	0.00	2.48	0.00	0.00	0.00	0.00	0.00
ALLIGATOR CRACKING	0.00	0.33	1.86	0.00	1.49	2.30	1.02	0.45	0.57	0.00
EDGE DETERIORATION	0.33	1.08	1.86	2.24	0.00	0.00	0.00	1.90	0.00	0.00
BITUMINOUS PATCHING	0.70	3.89	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00
POTHOLES	4.94	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00
WIDENING DROPOFF	5.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PROFILE DISTORTION	5.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RUTTING	4.48	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(LENGTHS IN MILES)

RIGID PAVEMENT

(NONE)

SHOULDERS

		SEVERITY AND EXTENT								
	NONE	LOW			MEDIUM			HIGH		
CONDITION	0	1	2	3	4	5	6	7	8	9
LANE/SHLDR SEPARATION	1.75	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00
DETERIORATION	0.33	0.00	0.00	0.00	0.00	0.00	1.06	0.70	0.00	0.45
SLOPE	5.51	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BUILDUP	5.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DROPOFF	4.83	1.26	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00

(LENGTHS IN MILES)

FIGURE 6 Systematic technique to analyze and manage Pennsylvania pavements (STAMPP): condition summary.

other possible corrective and rehabilitative measures.

In addition, an internal study at the PennDOT has concluded that STAMPP is superior to TOS because STAMPP is a comprehensive, 100 percent annual survey of the total highway system, whereas TOS is a sampling procedure (3). Furthermore, STAMPP not only gives a count of actual pavement deficiencies, but also recommends treatments and develops dollar needs in a standardized way (3). The impact of STAMPP on fund allocation will hopefully fulfill the third project objective that fund allocation be based on needs, which was defined by the task force at the outset of developing STAMPP.

To illustrate the impact of STAMPP on modifying the $600-million allocation to the 67 counties, a partial comparison is shown in Table 1 between the STAMPP ASHMA allocation index and the ASHMA index utilizing TOS. The table includes only a sample of the impact and the changes in allocation for a few of the 67 counties in Pennsylvania, without using county names and without applying other adjustments used in modifying the ASHMA formula.

It can be seen, whereas, for example, from Table 1 that county A would get 0.074 ($600 million) = $44.5 million using the STAMPP index, rather than 0.115 ($600 million) = $68.97 million using the TOS index--that is, only 64.6 percent of the allocation using TOS, which is a decrease of 35.4 percent. On the other hand, county B would get 0.036 ($600 million) = $21.32 million using the STAMPP index, rather than 0.026 ($600 million) = $15.36 million using the TOS index, which would be an increase of 38.8 percent.

Using the STAMPP system, allocations are subject to change annually according to changes in a county's pavement condition rather than remaining fixed over long periods of time, regardless of changes in pavement condition.

TABLE 1 Comparison of ASHMA Allocation of Funds Using STAMPP and TOS

County	ASHMA Index Using STAMPP (S)	ASHMA Index Using TOS (T)	Ratio of STAMPP to TOS (S/T)
A	0.074234	0.114954	0.646
B	0.035535	0.025607	1.388
C	0.034217	0.047257	0.724
D	0.032582	0.045046	0.723
E	0.032786	0.035697	0.918
F	0.030257	0.030397	0.995
G	0.028725	0.017018	1.688
H	0.026762	0.033292	0.804
I	0.026517	0.031488	0.842
J	0.025479	0.038959	0.654

Note: S = STAMPP and T = TOS.

SUMMARY

A comprehensive pavement management system has been developed in Pennsylvania that will

1. Take into account the various aspects of pavement distress conditions and rank them uniformly across the extensive Pennsylvania roadway system, according to severity and the need for correcting.
2. Systematically recommend the type of needed treatments based on combinations of distress elements and their severity.
3. Provide a scientific basis for an equitable distribution of maintenance and rehabilitation funds according to pavement needs.
4. Have the flexibility to allow the addition and modification of parameters relevant to the objectives of the system, including system improvement and extension to other desirable parameters and capabilities that may arise.

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