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REVIEW OF CURRENT STATE PRACTICES RELATING PAVEMENT DISTRESS AND PERFORMANCE

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INTRODUCTION

Since 1970, leading researchers and practitioners in the pavements area have felt that the major deterrent to implementing improved pavement design and evaluation methodology was the lack of a meaningful relationship between distress and performance.

It is generally agreed that distress resulting from traffic and environmental factors (cracking, rutting) can be predicting using available analytical techniques. Further, it is possible to measure pavement performance. However, there is no available means of relating distress to performance.

In January 1977, a small workshop was held to define better the procedures through which such a relationship could be developed. The objective of the workshop is shown in Fig. 1 as relating predicted distress to measured performance. The purpose of this circular is to summarize current state practices relating distress to performance.

The data presented in this circular were collected using the included questionnaire which was sent to all state highway departments, Canadian provinces, and military agencies. Space limitations do not permit summarizing the full responses in this circular. It should be noted that these questions were the first of their kind to be used in a study to relate distress to performance. There were understandable differences in interpretation by the responding agencies. Others were difficult to classify and likewise the responses had to be interpreted. It is hoped that material contained in this circular will at least get the study of distress-performance relationships off in the right direction.

DISCUSSION OF EACH SECTION OF QUESTIONNAIRE

Thirty-four of the fifty states, and two Canadian provinces (Ontario and British Columbia) responded to the questionnaire (Table 1). Eighteen of the thirty-four responding agencies have indicated the opinion that distress can be related to performance. However, for most of the agencies, the concept is quite new and not much work has been done in the area.

The agencies that have performed research in the area feel, in general, tnat relating such things as deflections and surface conditions (cracking, rutting, etc.) of the pavement section to performance indicators such as Present Serviceability Index (PSI) and Present Serviceability Rating (PSR) provide the best opportunity to establish the distress-performance relationship.

The agencies that appear to have made the greatest progress in relating distress to performance are California, Colorado, Florida, Minnesota, Michigan, Utah and Washington (2,3,4,5,6,7,8). In Canada, Ontario has done much work in this area. All of these agencies have also kept good records of the general statistics related to the current condition of their highways.

Types of Distress

Table 2 summarizes the percentages of total mileage exhibiting indicated types of distress reported by each responding agency. While the questionnaire asked the respondent to give the estimate mileage in their jurisdictions having given types of distress, percentages have been calculated by the author, based on reported mileage given in the 1974 Highway Statistics Manual (9). Most of the states responding had a good idea of what pavement distress problems were at hand, even if some did not know the total mileage at hand. Some of the states (Hawaii, Louisiana, Mississippi, Nevada, North Carolina, North Dakota, Wyoming, and British Columbia) did not distinguish between rigid and flexible pavement; they answered the question for only flexible or rigid pavement.

The methods used to measure the basic types of distress (cracking, distortion, and disintegration) are of a good mix between visual and objective measurements (Table 3). The instruments and procedures used to accomplish these measurements were so varied as to be difficult to classify.

Performance Measurement

For determination of performance, most of the re-

Figure 1. Schematic sketch of scope of workshop on relating pavement distress to performance.

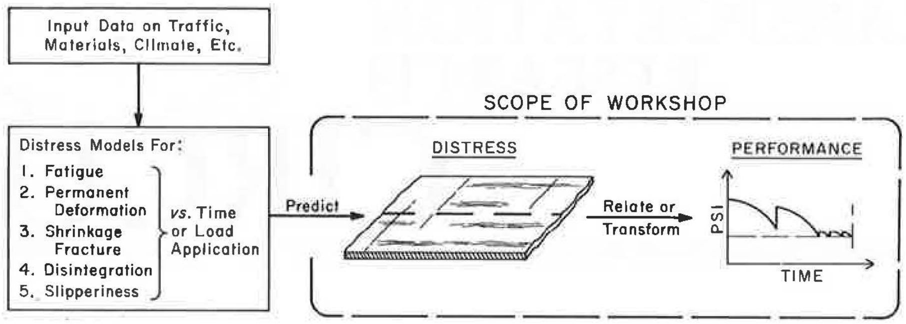

Table 1. Summary of responses.

States	
Arizona	Nevada
California	New Jersey
Colorado	New Mexico
Connecticut	New York
Washington D.C.	North Carolina
Florida	North Dakota
Georgia	Oregon
Hawaii	Pennsylvania
Illinois	South Carolina
Louisiana	Tennessee
Maryland	Texas
Massachusetts	Utah
Michigan	Vermont
Minnesota	Virginia
Mississippi	Washington
Montana	Wisconsin
Nebraska	Wyoming
Canadian Provinces	
British Columbia	Ontario

Table 2. Percent of total mileage exhibiting indicated types of distress.

State	Flexible Pavement		Rigid Pavement		
	Rutting	Transverse Cracking	Faulting	Longitudinal Cracking	Transverse Cracking
Arizona	0 - 5	5	0.5	0	-
California	1	3	12	2	2
Colorado	11	11	0.5	1	-
Georgia	16	23	1	0.5	-
Louisiana	0	-	-	0	0
Massachusetts	58	15	-	-	-
Minnesota	4	67	1	0	0
Mississippi	5	9	4	5	9
Montana	62	93	-	-	-
North Dakota	1	77	1	-	-
Texas	83	65	0	0	1
Utah	17	65	-	11	2
Virginia	3	3	0	0	0
Washington	35	11	2	-	-
Wyoming	-	-	0.5	1	0

sponding agencies gave some kind of measured surface condition, be it visual or objective (Table 4). There was no clear-cut majority for any particular definition or method of determination.

The PSI measurement was performed in a variety of ways, the most popular instrument being the Mays meter, but it is by no means a large majority (Table 5). The difficulties that arise when PSI measurements are used vary considerably. The groups of problems are outlined in Table 6. The reproducibility of the performance measurement data between raters is usually handled by having numerous trials of measurements on the same highways, although most of the states had no information to indicate reproducibility of results between individual raters (Table 7). Calibration checks of equipment are the most popular check of reproducibility of results between equipment (Table 7).

Most states seem reluctant to use PSR instead of PSI ratings, the most common reason being that PSR ratings are too subjective (Table 8).

The definition of service life of a pavement was most commonly stated as either the time to the first major maintenance repair or the time that a pavement serves the public with safety and comfort (Table 9). Excessive maintenance before the end of the pavement's design life was easily the most popular definition of an unsatisfactory design life (Table 9).

When relating pavement performance measurements with the need for reconstruction or major rehabilitation, PSI is the most popular indicator (Table 10).

Factors Affecting Pavement Performance

The three major distress modes were outlined in this section of the questionnaire. The questions were intended to provide information as to the degree each type affects performance of both flexible and rigid pavement.

The replies indicate that the three types of pavement distress which can be predicted in flexible pavement (alligator cracking, rutting, and transverse cracking) all effect pavement performance. Alligator cracking is considered to have the largest effect on flexible pavement performance (Table 11). Rutting, then transverse cracking, both are considered to have some lesser influence on flexible pavement performance.

Of the distress modes summarized for rigid pavement (longitudinal cracking, transverse cracking, and faulting), faulting is considered to have the largest effect on performance (Table 11).

Other types of distress considered to affect performance are summarized in Table 12. The results from this section are of special interest, since not many of the states responded to this section of the questionnaire.

Distress Criteria

Few states have established fixed levels of distress when rehabilitation is required. For those states responding, it appears that area cracking of 20 to 25 percent, rut depths of about one-half inch, and/or about a 20 percent disintegration in area is required to initiate action for pavement rehabilitation. These values apply to both rigid and flexible pavement. Again, only a few states responded to this section of the questionnaire.

Some of the other factors which contribute to the establishment of distress limits associated with rehabilitation include: traffic loading and volume, available funds, and engineering experience and judgement.

Relation Between Distress and Performance

Results of the questionnaire showed that few states have made an effort to relate distress to performance. The few that have are in the infant stage of their research. They include the states of Washington, Utah, California, Michigan, Colorado, Florida and Minnesota and the province of Ontario.

The methods used by the responding agencies to handle the time delay effects of distress are many and varied, thus making them quite difficult to classify.

The various agencies responding do indicate that information relating distress to performance would be useful in the design of new and rehabilitation of old highways and to estimate performance for establishing future rehabilitation and maintenance strategies.

Miscellaneous

The methods used for the collection and storage of performance data and pavement condition surveys were varied. The bulk of the information was collected by some type of machine or by visual surveys and stored by some sort of location identification in a computer bank (Table 13).

The use of performance data is most ofen used in setting up some kind of system of priorities in choosing when and where some pavement section needs rehabilitation. The data was quite difficult to summarize.

The Mays meter, the Chloe profilometer, and the PCA Roadmeter are common instruments used in taking PSI measurements (Table 14). Many different types of equipment are employed in the distress measurement process (Table 14), the use of a rut gage being most widespread.

Most of the states do not relate deflection measurements to performance; the states that do all have different methods of doing so, and thus are hard to lump together in groups (Table 15).

CONCLUSIONS

Very few of the states responding to the questionnaire have a clear idea of the relationship of distress to performance. The states that did indicate that they use a distress or performance type study in pavement evaluation have a multitude of different definitions of what the distress-performance relationship should be.

Of all the methods to determine distress-performance relationships, the methods employed by Florida, Ontario, Utah and Washington appear to be the furthest along. Adapting a common procedure now, however, is needed to ensure optimal results.

This questionnaire points out that state agencies must adopt more uniform techniques of data collection if the distress-performance relationship is to become an integral part of pavement design.

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Table 3. Number of states using visual and/or objective means of evaluating distress.

Types of Distress	Visual	Objective	Other	Total
Cracking	29	7	2	38
Distortion	25	16	2	43
Disintegration	29	7	2	38

Table 4. Number of states with the same definition and determination of performance.

PERFORMANCE DEFINITION	NUMBER	PERFORMANCE DETERMINATION	NUMBER
Smooth Ride	9	Low Maintenance Cost	3
Safe Ride	5	Comfort Ride Index	1
Low Maintenance Cost	5	Pavement Condition Rating (Visually)	2
Accumulated Service	7	Smooth Ride	4
Aesthetic Condition	1	Safe Ride	3
Minimum Disruption of Service	1	Visually Surveyed (Bi-annually)	3
Structural Integrity	2	Present Serviceability Index vs. Years of Construction	7
Surface Condition	4	Number of Accidents	1
AASHO Road Test: Change in PSI vs. Equivalent 18 kip Axle Loads	2	Distress Measures	5
Riding Quality Index	1	Complaints (Amount)	1
Present Serviceability Index	4	Present Serviceability Rating	1
Average of a Structural Rating and PSR, using a PCA Roadmeter	1	Surveys of Pavement	1
		Condition Sum of Stress	1
Distress Factors plus Surface Conditions	2	Determinants Objective Measures	3
Sum of Different Distress Determinations	1	Surface Conditions	2
Service to Traveling Public	1	No Answer	4
No Answer	5	Ambiguous Answer	2
TOTAL	52	TOTAL	46

Table 5. Number of states with similar methods to measure the present serviceability index.

PSI Measuring Method	Number
PSI Measurements Not Used	10
Chloe Profilometer	3
Mays Meter	6
Wisconsin Road Meter	1
Bureau of Public Roads Meter	2
General Motors Rapid	2
Condition Surveys	3
AASHO Data	1
PCA Roadmeter	3
Distress Measurements	1
British Columbia Road Meter	1
No Answer	3
Ambiguous Answer	2
TOTAL	38

Table 6. Number of states that have similar problems in the use of PSI.

Difficulty with PSI Use	Number
No Answer	12
It is too Dependent on Roughness	7
It is not Sensitive Enough	4
Equipment Problems (Calibrating)	3
Time Consuming	5
Poor Correlations with Original Determinations	2
Lack of a National Standard	2
Unable to Fully Measure Distortion Caused by Active Days	1
Poor Evaluation of Overlaid Sections	1
Poor Reproducibility	3
It Does Not Adequately Identify with Users' Emotions	1
Difficult to Directly Measure	1
It Does Not Fully Define Present Serviceability	1
It is Not Correlated with the Design and Performance Criteria Used	1
It is Useful Only on a Long-Term Basis	1
It is Difficult to Correct Raw Data to PSI	1
Too Much Human Error	1
It Considers Roughness Only	1
TOTAL	48

Table 7. Number of states that have similar methods to indicate reproducibility of results between raters and equipment.

Reproducibility Method	Between Raters	Between Equipment
Considerable Trials on the Same Highway	3	-
Considerable Trials on the Same Vehicle	3	-
Different Panel of Raters	2	-
Regional and National Correlation Tests	-	1
Raters' Data is Standardized	1	-
Calibration Checks	-	13
Rechecks	1	-
Central Panel that Samples District Ratings and Determines if Statistical Adjustment is Needed	1	-
A Regional AASHO Road Test Work	-	1
Surveys by the Same Team	3	-
Same Equipment Used	-	5
Use of a User Attitude Index	1	1
Equipment Correlation Tests	-	1
Pavement Management Committee	-	1
Ambiguous Answer	2	0
No Answer	22	10
Other	3	2
TOTAL	42	35

Table 8. Number of states that have similar objections to the use of PSR over PSI data.

Reason Not to Use PSR over PSI	Number
Too Much Manpower and Money	3
Too Subjective	7
Pavement Rideability Does not Indicate the Actual Structural Condition	1
PSI is a More Accurate Measurement than PSR	2
PSI Data can be Individually Evaluated in Pavement Management Analysis	1
PSR is too Difficult to Determine	1
No Objection to Use of PSR	8
No Answer	8
Ambiguous Answer	1
Other	1
Neither PSI nor PSR are Used	2
TOTAL	35

Table 9. Number of states with similar definitions of service life and unsatisfactory performance.

Service Life Definition	Number	Unsatisfactory Performance Definition	Number
Time to First Major Contract Maintenance	2	Smooth Ride Toss in Too Short a Time	2
Time to Serve Traffic With Comfort and Safety	8	Poor Surface Condition in too Short a Time	1
Number of Years of Service Prior to Overlayment	13	Excessive Maintenance Before End of Design Life	25
Condition Rating -- Between 2.5 and 2.9, Service Life is Over	1	Pavement Designed for a Terminal Present Serviceability Index of 2.5 for Multi-Lane Highway and 2.0 for Other Roads at the End of the Design Period	1
Pavement Life Reaches Desired Service Life	1		
Available Funds	1		
No Answer	6	No Answer	9
Other	1	Other	1
TOTAL	33	TOTAL	39

Table 10. Number of states that have similar methods of using performance to determine the need for reconstruction.

Use of Performance to Determine the Need for Pavement Rehabilitation of Reconstruction	Number
Present Serviceability Index	14
Visual Surveys - Rating Systems	4
Number of Complaints and Accidents that are Reported	1
Arrangement of a Priority Array of Distress (Roughness Skill Resistance, Deflections, Etc.	2
Present Serviceability Rating	3
A Condition Rating	4
An Attitude Index	1
When Performance is Reported to be Below A Satisfactory Level	2
Studies that are Made on Individual Projects Rather Than on the Whole	1
Other	3
No Answer	4
TOTAL	39

Table 11. Factors affecting performance: number of states indicating level which distress type affects performance.

Level	Flexible Pavements			Rigid Pavements		
	Alligator Cracking	Rutting	Transverse Cracking	Longitudinal Cracking	Transverse Cracking	Faulting
No Effect	0	0	0	0	0	0
Minor Effect	2	6	6	10	7	4
Significant Effect	6	6	6	1	4	6
Very Significant Effect	11	6	3	2	3	8
No Answer	-	-	-	-	-	-

Table 12. Number of states with similar factors that affect performance besides the three basic distress modes.

Type of Factor	Number
Bleeding	1
Polishing of Aggregate	2
Stripping	1
Skid Measurements	9
Drainage Effects	4
Traffic Volume	1
Speed of Vehicles	2
Improved Construction Methods	1
Roughness of Pavement	1
Deflection of Pavement	3
Seal of Joints	1
Slab Movement	3
Aggregate Quality	2
Rutting from Studded Tires	1
Degree of Maintenance	2
Vehicle Weight	1
Width of Pavement	1
Shoulder Maintenance	1
Patching	2
No Answer	14

Table 13. Number of states that have similar methods of collecting and storing performance data and condition survey data.

Collection Method	Number	Storage Method	Number
Machine Collection	12	Store by Location and Date of Test, in Computer	13
Visually Collected	3		
Bi-Annual Surveys	1	Manually Stored	3
Serviceability Surveys	2	On a Project Site	1
Condition Surveys	2		
Other	1	Other	0
No Answer	10	No Answer	11

(a) Performance Data

Collection Method	Number	Storage Method	Number
Machine Collection	5	Store by Location and Date of Test, in Computer	13
Visually Collected	6		
Bi-Annual Surveys	0	Manually Stored	5
Serviceability Surveys	0	On a Project Site	0
Condition Surveys	1		
Other	3	Other	3
No Answer	7	No Answer	7

(b) Condition Survey Data

Table 14. Number of states with similar methods to take PSI measurements and distress measurements.

Method of PSI Measurement	Number	Method of Distress Measurement	Number
Mays Meter	10	Rut Gage	10
Chloe Profilometer	3	Mu Meter	1
Rapid Travel Profilometer (from General Motors)	3	California Travelling Deflectometer	1
PCA Roadmeter	7	Straight Edge	4
BPR Type Roadmeter	3	Transit	2
Visual Surveys	2	String Line	3
Sufficiency Dating	1	Road Rater	1
Cox Roadmeter	2	Visual Surveys	5
Pavement Condition Survey	1	Benklemen Beam	3
California Profilograph	1	Profilometer	1
Lane - Wells Dynafleet	1	Skid Trailer	4
British Columbia Car Roadmeter	1	Degree of Cracking and Patching	2
		PÇA Roadmeter	1
		Fault Gage	1
No Answer	9	No Answer	11

Table 15. Number of states that have similar definitions of the relation of deflection measurements to performance measurements.

Definition of Relation of Deflection Measurements to Performance Measurements	Number
By presence of absence of frost and variations in moisture content	1
Years of past studies on deflection and pavement failure history	1
AASHO road test performance curve	2
Dynafleet deflection data - with evaluation by a simplified elastic layer analysis	1
A relation between surface curvature index and performance	1
Relation of years to failure as a function of maximum observed deflection	1
Correlation of Benkleman Beam and Impulse Index to a Performance Rating	1
Other	5
No Relation	20

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QUESTIONNAIRE

Current Practices on Relating Pavement Distress to Performance

Please Return To:

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Identification:

Agency: ____________________

Department: ____________________

Prepared By: ____________________

Title: ____________________

Date: ____________________

If you desire that your replies to this questionnaire be held in confidence, please check

INTRODUCTION

A workshop in Austin, Texas, December 1970 attended by a representative cross section of North American pavement experts, considered the major research needs that face the highway industry. The top research priority was agreed to involve solving the problem of relating pavement distress to performance.

A considerable amount of technology has been developed for analyzing pavement response to traffic and environmental factors, and for using this information to predict distress. Distress is generally considered to consist of a loss of physical integrity of the pavement (such as cracking, distortion, or disintegration). It can, in addition, consist of pavement slipperiness.

It is also widely accepted that distress is directly responsible for losses in serviceability, although there are varying degrees of time delay between the cause and effect. We have models to analyze or predict distress in physical terms, and we have engineering technology to measure or estimate performance in user terms. Yet we do not have technology to relate distress to performance, except by essentially subjective means. The need exists to develop quantitatively and objectively based relationships for this purpose.

In 1973, Task Force A2T59 entitled "Relating Pavement Distress to Performance" was formed to organize a workshop directly addressing this problem. A mini-workshop is scheduled for January 1977. Included as a part of the workshop will be a discussion of current practices of measuring distress and/or performance and efforts made to relate the two. To properly summarize this information it was considered necessary to develop the attached questionnaire for circulation to all state highway departments, Department of Defense Agencies, and Canadian Provinces concerned with the task of managing pavements.

Although the intent of the form is to obtain information relative to current practices, speculation as to the possibility for future efforts should also be discussed. Be specific in all answers given. Where publications are available documenting specific parts of the questionnaire, a copy of the report would be most welcome.

Please return the completed form by August 15, 1976.

I. Types of Distress

1) What types of distress (including an estimate of mileage) are most prevalent in your state, province, jurisdiction? Refer to HRB Special Report 113 for definition of terms and types of pavement definitions.

Flexible		Miles	Rigid		Miles
Cracking			**Cracking**		
alligator	☐	____	D-cracking	☐	____
transverse	☐	____	longitudinal	☐	____
longitudinal	☐	____	random	☐	____
block	☐	____	transverse	☐	____
other ________	☐	____	other ________	☐	____
________	☐	____	________	☐	____
Distortion			**Distortion**		
rutting	☐	____	faulting	☐	____
corrugations	☐	____	blowups	☐	____
others ________	☐	____	others ________	☐	____
________	☐	____	________	☐	____
Disintegration			**Disintegration**		
ravelling	☐	____	Slab spalling	☐	____
pot holes	☐	____	Joint spalling	☐	____
polishing	☐	____	scaling	☐	____
others ________	☐	____	others ________	☐	____
________	☐	____	________	☐	____

2) What procedures do you use to measure distress? Include reports describing your measurement procedures, if available.

Distress	Objective Measurements	Visual Surveys	Other
Cracking	☐	☐	☐
Distortion	☐	☐	☐
Disintegration	☐	☐	☐

Comments: ____________________

3) What is your estimate of mileage of roadway in your jurisdiction with no distress? ________

II. Performance Measurements

1. How is performance defined? ____________________

2. How is performance determined? ____________________

3. How is PSI[(1)] measured? ____________________

4. What difficulties arise with the use of PSI? ____________________

5. Do you distinguish between rigid and flexible pavements? Yes ☐ ☐
If yes, indicate differences in measurement techniques. ____________________

(1) For definition, refer to paper by W. N. Carey, Jr. and P. E. Irick, "The Pavement Serviceability-Performance Concept," HRB Bulletin 250.

6. What information do you have available to indicate reproducibility of results?

   (i) Between raters ____________

   (ii) Between equipment ____________

7. Why not use PSR ratings and eliminate the need for PSI? ____________

8. How is service life defined? ____________

9. How do you define unsatisfactory performance in terms of design expectations (e.g. service life)? ____________

10. How is performance used in determining the need for rehabilitation or reconstruction? (e.g. PSR or PSI of 2.5 indicates need for rehabilitation) ____________

III. Factors Affecting Performance

1. To what degree do the following distress manifestations affect performance? Use F for flexible and R for rigid. For each type of distress, indicate a numerical value, e.g., % cracking, rut depth, etc., for your evaluation of very significant, significant, minor, and none.

Distress Mechanism	very significant	significant	minor	none
Cracking				
longitudinal				
transverse				
alligator				
____				
____				
Distortion				
rutting				
settlement				
faulting				
____				
____				
Disintegration				
Spalling				
Ravelling				
____				
____				

2. What other factors affect performance? ____________

   How? ____________

V. Relation Between Distress and Performance

1. Have you made any attempt to relate distress to performance? Yes ☐ No ☐ If yes, how? ____________

2. How should (or are) time delay effects on distress to be handled? (i.e. the effects of today's distress on tomorrow's serviceability)? ____________

3. What utility would it be to you to relate distress to performance (e.g. how would you use the information)? ____________

VI. Miscellaneous

1. How do you collect and store performance information? ____________

   Results of condition survey? (e.g. cracking, etc.) ____________

2. How is the information in (1) above used? ____________

3. What type of equipment and data acquistion systems are used to measure (a) PSI (e.g. Mays, PCA, GMR) ____________

   (b) distress (e.g. rut depth gage, etc.) ____________

4. Have deflection measurements been related to performance? Yes ☐ No ☐ If yes, how? ____________

IV. Distress Criteria

1. At what level of distress as measured in (I) above is rehabilitation required?

Distress Manifestation	Flexible	Rigid
Cracking (e.g. % area)		
Distortion (e.g. rut depth)		
Disintegration (e.g. % area ravelled)		

2. For each of the distress limits cited above, is there also a corresponding terminal performance level?

Distress Limit	Corresponding Performance Level	
	Flexible	Rigid
Cracking		
Distortion		
Disintegration		

3. What other factors contribute to the establishment of distress limits? ____________

   How? ____________

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