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16. ABSTRACT
A Pavement Management System (PMS) has been developed to monitor deteriorating pavement, to disseminate repair strategy information, to substantiate cost-effective rehabilitation strategies, and to be used as a basis for managing existing pavements in the State highway system. PMS begins with a statewide pavement condition field survey taken every two years. This survey identifies the location, nature, severity, and extent of pavement problems so data from the survey together with costs, rehabilitation strategies, traffic data, highway classification data, and other information has been computerized. The computer follows an engineering logic process to identify an appropriate level of repair
for pavement. Because of the characteristic differences in flexible and rigid pavement problems and remedies, each pavement type is treated separately in the PMS. The end product is a series of reports describing pavement condition, rehabilitation strategy, and cost; candidate projects for various highway
programs; and alternative repair strategies. This information will be used as a basis for establishing the magnitude and character of the various highway programs, the priority of repair work, and the funding to provide a designated level of service for California.

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Development of the California Pavement Management System

Volume 1

System Description

Caltrans

FINAL REPORT

October 1978

Division of Maintenance   FHWA-CA-HM-7139-78-03

NOTICE

ADDENDUM
(February, 1980)

The system described in this report has been fully implemented by the California Department of Transportation to effectively manage statewide pavement resurfacing and rehabilitation.

The system identifies problem locations. District managers use the system to formulate candidate projects. Headquarters program advisors and managers use system information to prioritize, program and budget projects, and to determine statewide program funding levels and geographic fund allocation. The system is used to perform special analyses and studies for top management concerning highway system condition, pavement performance and program performance at a point in time or over time intervals. The system also supplies useful information to Project Designers, Materials Engineers and Maintenance Managers.

The rehabilitation cost formulas on Pages 97 through 99 have been modified for divided roadway facilities to improve the accuracy of the estimates to support programming stability. Costs are now calculated for each roadway separately (for its unique problems), and both roadway costs are then combined for the location cost.

The unit cost factors on Pages 100 and 101 represent 1978-79 base year values. Currently, these factors have been updated to 1979-80 values based on the California Construction Cost Index. Cost factor updates are anticipated annually, but can be accommodated with ease at any time.

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PREFACE

PMS as used in this report is a Pavement Management System developed by the California Department of Transportation (Caltrans) in cooperation with the Federal Highway Administration (FHWA). Following are several key points which the reader should keep in mind as he progresses through the report.

- The majority of the work and decisions identified will fall in the rehabilitation area. PMS in California is not a management system for maintenance.

- PMS is a management system aimed at assisting in using available resources more effectively through an informed and improved decision process. PMS is not a design system; design is the function of the engineering staff.

- Caltrans rejects a wide variety of pavement rating systems including: sufficiency ratings, sums of defects, serviceability ratings, PSI's and PSR's etc. on the finding that they are "relatively" useless. They all have the "apple and orange" problem and at best are limited to crudely indicating that a pavement needs attention. All wind up being dominated by one factor or another. What is stressed in the California PMS is a determination, on a sound engineering basis, of the appropriate repair which can only be determined by assessing the pavement conditions, their extent and severity.

- At the present time, and on the basis of available information, Caltrans believes it unrealistic and impractical to try to predict on a long-range basis, future dates of failure, modes of failure and the appropriate type of repair for these projected failures. Some pavement management systems which have been investigated indicate appropriate rehabilitation strategies 15-20-30 years in the future. This is too academic and theoretical. It is much more realistic to inventory pavement conditions at reasonable frequencies to identify real problems and reasonable solutions with sufficient lead time to program repairs.

- In California there are 12,000 or more individual interchange ramps, collector roads, etc. There are indications that these facilities are exhibiting even more problems than the highway traveled way. A review of the special problems associated with these kind of facilities leads Caltrans to the conclusion that it would be unduly complicated and impractical to incorporate ramps, etc., in the PMS described in this report. In California a ramp and collector road pavement management system will be addressed separately.

Extensive computerized systems have been developed for all major PMS components in order to operate the PMS effectively. An essential key to the PMS is a limited series of user reports specfifically tailored for each user's needs in the Transportation Districts and in Caltrans Headquarters.

METRIC CONVERSIONS

1 Inch	=	2.54 Centimeters
1 Foot	=	0.3048 Meters
1 Yard	=	0.9144 Meters
1 Mile	=	1.60935 Kilometers
1 Ton (short)	=	907.185 Kilograms
1 Gallon/Square Yard	=	4.5272 Liters per Sq. Meter
1 Station	=	100 Lineal Feet = 30.48 Meters

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF ILLUSTRATIONS

TABLE OF ILLUSTRATIONS (Continued)

TABLE OF ILLUSTRATIONS (Continued)

INTRODUCTION

California's network of state highways is a very large system composed of both rigid and flexible pavement including 15,000 centerline and 47,000 lane miles. The majority of the existing state highway pavements have been constructed within the last twenty years. It is evident from Pavement Management System (PMS) studies that the California Department of Transportation (Caltrans) engineers the design of pavements well, since they have and continue to provide the service life for which they were designed. A substantial portion of these well-designed pavements have already or will soon be reaching the end of their service lives. Pavement conditions are deteriorating and rehabilitation is required if the public is going to continue to receive the level of service which it deserves and expects and if the State is to avoid extraordinary maintenance costs, the problems associated with maintenance forces constantly working on "band-aid" solutions and the associated problems of user delays to the traveling public.

Caltrans has developed a PMS which emphasizes an engineered approach to pavement rehabilitation, and a structured systems approach for the management of existing pavements. Caltrans PMS advances the state-of-the-art whereby management is provided new tools which will assist them in making more cost-effective decisions.

The PMS is a straightforward approach which brings together the following processes:

- o Inventorying pavement conditions.
- o Analyzing the extent and severity of pavement conditions.
- o Identifying appropriate repair strategies.
- o Identifying cost effective strategies and reasonable alternatives for candidate projects.
- o Relating the repair strategies to the appropriate Caltrans highway program structure.
- o Organizing candidate projects for each Caltrans highway program component within each Transportation District, on a statewide basis, and other required groupings.

By incorporating these elements in a structured systems approach, program levels and trends for rehabilitation can be quantified and justified. The PMS will assist in programming and scheduling improvements according to departmental rehabilitation policies and promote a more consistent level of pavement performance statewide. It has the flexibility to respond to program level constraints and level of service decisions without altering the basic engineering logic.

I. Pavement Condition Rating Systems

A. Flexible Pavement

1. Prior Condition Rating System

California conducted biennial flexible pavement condition surveys in 1969-70, 1971-72, 1973-74 and 1975-76. The flexible pavement rating system used was conceived by a steering committee influenced to some degree by state of the art papers by various researchers who were apparently further advanced than Caltrans at the time. Conceptually, the rating system identified severity and extent for each of 6 pavement problems:

- Alligator/Block cracking
- Transverse cracking
- Longitudinal cracking
- Ravel
- Rutting
- Patching

Prior thinking was to apply weighted factors to both severity and extent ratings to portray relative significance. The weighted ratings for severity and extent were then multiplied together to produce a single value, which was intended to represent the magnitude of the problem. It was intended that the range of the values vary to somewhat reflect the importance each condition in relation to the others.

Several major problems were evident with the prior conditon reporting system:

- o Different extent and severity values produced identical numeric values. It is essential when assessing structural adequacy to clearly distinguish between extent and severity of pavement conditions in order to identify appropriate repair strategies.

- o Duplication of numeric values made it impractical if not impossible to perform statistical analysis in the development of performance models. Caltrans' research work "Establish Criteria for Rehabilitation of California Pavements" pointed out this problem.

- o The prior condition rating system was too sensitive in the extent category. This resulted in substantially different numeric values for a minor difference in the extent of a pavement problem.

2. Present Condition Rating System

The present condition rating system shown in Figure I-1 was developed to eliminate the problems encountered in the prior rating system. The system reduces the sensitivity in the extent category; it is more descriptive since the resulting pavement condition rating is unique

FLEXIBLE PAVEMENT CONDITION RATING SYSTEM

PROBLEM	SEVERITY		EXTENT
ALLIGATOR AND BLOCK CRACKING	TYPE		% LENGTH
	A	LONGITUDINAL CRACKING IN WHEEL PATHS ①	1
			3
	B	ALLIGATOR CRACKING IN WHEEL PATHS ①	33
	BLK	BLOCK CRACKING IN MAJORITY OF LANE WIDTH	99
	C	SPECIAL OR UNUSUAL ALLIGATOR CRACKING	DESCRIBE & EXPLAIN SEVERITY & EXTENT IN NOTES

PROBLEM	SEVERITY	EXTENT
LONGITUDINAL CRACKING	CRACK WIDTH	LENGTH/STA.
	< 1/8" (HAIRLINE)	≤ 100'
		200'
	1/8"-1/4"	300'
	> 1/4"	900'

PROBLEM	SEVERITY	EXTENT
TRANSVERSE CRACKING	CRACK WIDTH (MEAN)	NO. CRACKS/STA.
	< 1/8"	1
		2
	1/8"-1/4"	3
	> 1/4"	9

PROBLEM	SEVERITY		EXTENT
RAVEL AND WEATHERING	CONDITION	RATING	% OF LENGTH
	LOSS OF FINE AGGREGATE	FINE	1
			3
	LOSS OF COARSE AGGREGATE	COARSE	33
			99

PROBLEM	SEVERITY	EXTENT
RUTTING	DEPTH	% OF LENGTH ①
	≥ 3/4"	1
		3
		33
		99

PROBLEM	SEVERITY		EXTENT
PATCHING	QUALITY	RATING	% AREA
	SOUND	GOOD OR FAIR	1
			3
	UNSOUND	POOR	33
			99

PROBLEM	SEVERITY	EXTENT
DRIP TRACK (RAVEL)	CONDITION	OCCURRENCE/SEC.
	EXISTS	1
		2
		3
		9

① ONE WHEEL PATH CRACKED OR RUTTED THE ENTIRE LENGTH OF SEGMENT = 50% OF LENGTH

Figure I-1

and the interpretation is specific. By distinguishing the nature of the problem in separate terms for severity and extent, more accurate performance evaluation is possible.

A particular advantage of the present system is evident in the alligator/block cracking rating system. It is possible to differentiate between load associated (alligator cracking) and nonload associated cracking (block cracking). It has become abundantly clear in recent field investi- gations that the presence of alligator cracking in the wheel paths is much more significant than the width of a crack when assessing structural section repair strategies.

The present pavement condition rating system permits correlation of the California pavement rating system with the AASHO Road Test Pavement Serviceability Index (PSI). The present system cannot be manipulated to produce an overall single numerical expression of all seven pavement conditions. It is highly questionable if such an overall expression is meaningful. Certainly it is of no value in assessing extent or severity of pavement problems, or in determining appropriate repair strategies, or the meaningful assessment of pavement performance.

B. Rigid Pavement

1. Prior Condition Rating System

The first rigid pavement survey was conducted in 1976 on all of California's approximately 15,000 lane miles of rigid pavement. Pavement problems identified and rated were as follows:

- o Slab breakup
- o Patching
- o Faulting
- o Lane/shoulder joint separation
- o Lane/shoulder displacement
- o Right shoulder condition
- o Bridge approach ride comfort
- o Bridge approach slab condition

It is of significance that the rigid pavement rating system developed for the 1976 survey did not present the single value problem encountered in the flexible pavement rating system. From the beginning those involved in the development of the rigid pavement condition rating system felt it important to maintain a separate identity of severity and extent.

2. Present Condition Rating System

The present system which has been developed is shown in Figure I-2.

RIGID PAVEMENT CONDITION RATING SYSTEM

PROBLEM	SEVERITY		EXTENT	
SLAB BREAKUP	STAGE CRACKING ①		% SLABS/SEGMENT	
	1ST. STAGE		1	
	2ND. STAGE		3	
	3RD. STAGE ②		33	
			99	
CRACK SPALLING (3RD STAGE ONLY)	AVERAGE WIDTH	RATING		
	< 1/4''	NOM		
	≥ 1/4''-1 1/2''	MOD		
	≥ 1 1/2''	SEV		
PATCHING (FULL LANE WIDTH)	CONDITION	RATING	% AREA/SEGMENT	
	GOOD	GOOD	1	
	FAIR	FAIR	3	
	POOR	POOR	33	
			99	
FAULTING (STEP OFF)	CONDITION		% SLABS/SEGMENT	RATING
	VISABLE		≥ 25	YES
LANE/SHOULDER JOINT SEPERATION (RT. EDGE)	JOINT WIDTH		% LENGTH/SEGMENT	RATING
	≥ 1/4''		≥ 10	YES
LANE/SHOULDER DISPLACEMENT (RT. EDGE)	JOINT WIDTH		% LENGTH/SEGMENT	RATING
	≥ 3/4'' UP		≥ 10	UP
	≥ 3/4'' DOWN		≥ 10	DOWN
RIGHT SHOULDER CONDITION	OVERALL CONDITION	RATING		
	GOOD	GOOD		
	FAIR	FAIR		
	POOR	POOR		
BRIDGE APPROACH RIDE COMFORT	PCA RIDE RATING	RATING		
	ACCEPTABLE < 17	NUMBER		
	UNACCEPTABLE ≥ 17	NUMBER		

① SEE FIGURE I-3.

② ALSO CORNER CRACKING AND FRAGMENTED SLABS. EACH SEGMENT RATED FOR ALL THREE SEVERITIES AND ACCOMPANYING EXTENT.

Figure I-2

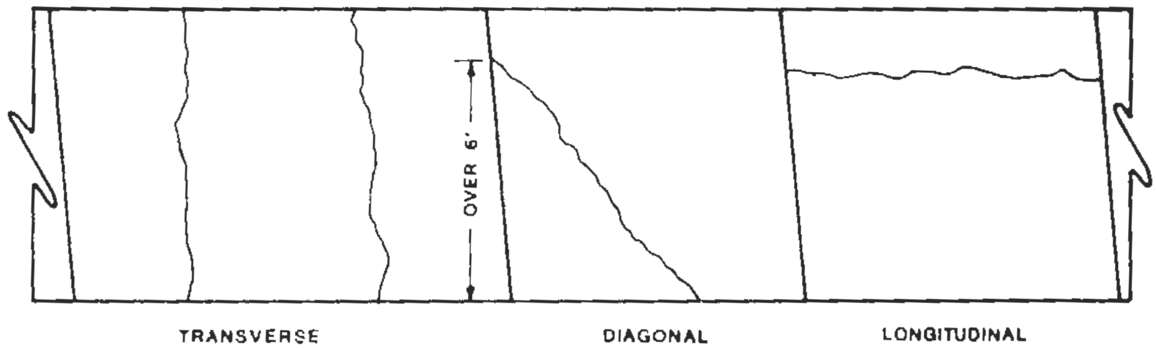
The present rating system has been changed to include the more conventional description of first, second and third stage cracking. This is in agreement with the nationally accepted AASHTO definitions which are published in the Highway Research Board publication "Standard Nomenclature and Definitions for Pavement Components and Deficiencies, Special Report 113". Figure I-3 graphically portrays first, second and third stage cracking.

The present rating system is substantially superior to the prior rating system in that portions of pavement within a given segment of rigid pavement experiencing two or three stages of cracking can each be rated along with the extent for each stage. This is a real advantage in evaluating pavement performance and in determining appropriate corrective pavement strategies. The prior system was confined to identifying one average severity of cracking for a segment with limited information regarding extent.

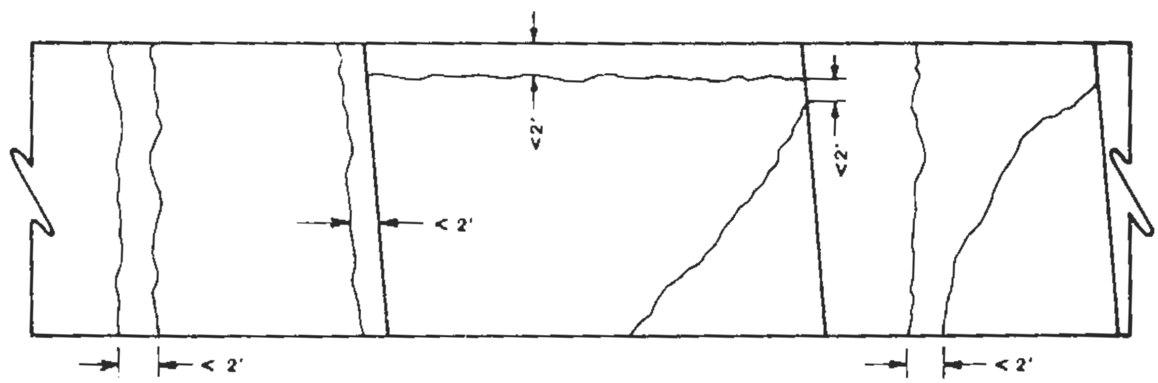
The severity of crack spalling for third stage cracking has been added to the rating system. This is an important characteristic of slab breakup for determining an appropriate pavement repair strategy.

Also, the change in identifying slab breakup condition substantially assists in tracking the progression of rigid pavement failure for use in the development of pavement performance models.

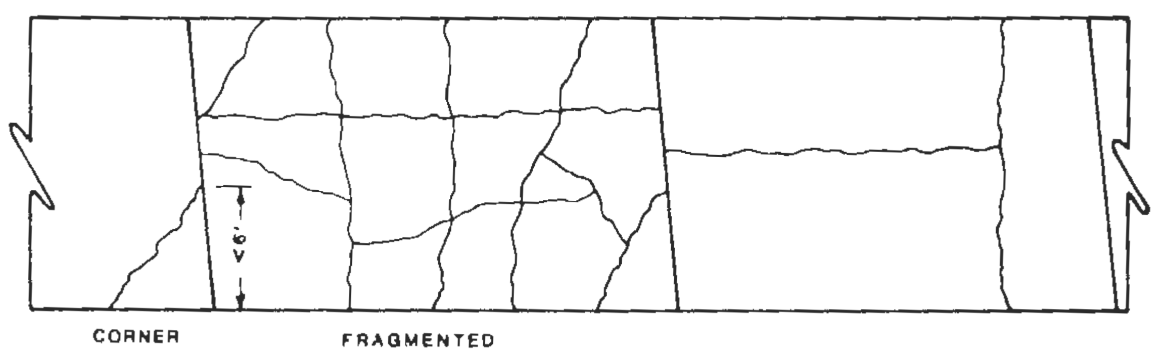
SLAB BREAKUP



FIRST STAGE CRACKING



SECOND STAGE CRACKING



THIRD STAGE CRACKING

Figure I-3

Although the conditions rated for rigid pavement understandably differ from those rated for flexible pavement, the rating system is similar in concept, essentially a system which describes pavement problems in terms of their severity and extent.

C. Ride Quality

1. Data Collection and Interpretation

The purpose of obtaining ride score is to identify when pavement corrective work should be undertaken to improve ride quality. The ride score value at which the ride quality is judged unsatisfactory is called the trigger value.

Mechanical devices for objectively measuring ride quality have been under development for several years. A PCA ride meter with a strip chart recorder, measuring movement between the body of a car and its rear-axle housing was developed by the Caltrans Materials and Research Department in cooperation with the U.S. Department of Transportation FHWA. (Ref. Highway Research Report "Evaluation of Bridge Approach Roughness" June 1973.) This recording technique was rejected because of the laborious data reduction required for strip charts and because of a lack of consistent measurement.

Ride quality measurements in California are currently made with equipment developed by Soiltest Corporation (Model ML 500B) based on the PCA concept but with improved sensing devices and register flexibility.

Ride score is a single numeric value used to represent relative ride quality. It is computed from the sum of 1/8 inch vertical movements accumulated over a measured distance as counted by the road meter.

Ride score, as used in California's PMS, is calculated by the following formula:

$$\text{Ride Score} = \frac{\text{Summation of 1/8" road meter counts}}{\text{Length in miles} \times 50 \text{ (constant)}}$$

Ride Score Calculation Example:

Length being rated equals 1.57 miles.

Road Meter Data				
Register Number	Measured Vertical Movement	Recorded Counts	Multiplier (i.e. Reg. #)	Count Values
1	1/8"	505	1	505
2	1/4"	210	2	420
3	3/8"	92	3	276
4	1/2"	35	4	140
5	5/8"	10	5	50
6	3/4"	3	6	18
12	1 1/2"	0	12	0
		Count Summation equals		1409

$$\text{Ride Score} = \frac{1409}{1.57 \times 50} = 18$$

A wide range of pavement roughness conditions on both flexible and rigid pavements were field evaluated to determine a ride score trigger value. Raters were asked to judge whether the pavement provided a satisfactory ride or was so rough it should be improved.

To ensure typical user reaction to pavement roughness and to avoid technical bias, the evaluation was conducted by both technical and non-technical Caltrans staff. The technical staff was composed of several high level engineering managers.

A series of 7 rigid pavement test sites on the Interstate 80 freeway in Contra Costa County with ride scores ranging from 34 to 63 were evaluated. A 1972 Plymouth Satellite sedan and 1971 Plymouth station wagon, both standard size vehicles, were used. All raters evaluated test sites in both vehicles. The consensus was that rigid pavement should be fixed when ride score is 50 or greater.

A second field evaluation was made by non-technical Caltrans employees. The vehicles used were 1973 Plymouth Satellite sedans. The consensus of that group was that rigid pavement should be improved when the ride score is 45 or greater.

A series of 18 flexible pavement test sites on a conventional primary highway with ride score ranges from 35-75 were evaluated in El Dorado County on Route 50. A full size 1972

Plymouth Satellite sedan, and a compact size 1973 Plymouth Valiant sedan were used. Both vehicles had comparable riding qualities as evidenced from evaluation of test sites and comparison of raters evaluations. The consensus of the technical raters was that flexible pavement should be improved when ride score is 50 or greater.

The flexible pavement ride was also evaluated by non-technical staff using 12 of the test sites evaluated by the technical staff. Two runs were made on each of the 12 test sites. The non-technical group's consensus was that flexible pavement should be improved when the ride score is 35 to 40 or higher.

2. Ride Score Application

In recognition of the above a ride score of 45 was selected to identify those locations that should be seriously considered for ride quality improvement for both rigid and flexible pavements when no other pavement condition merits improvement.

The recommended ride score "trigger value" of 45 correlates very closely with FHWA criteria using the Pavement Serviceability Index (PSI). The FHWA criteria would indicate improvement of pavements with a PSI of 2.5 or less. For rigid pavement a 2.5 PSI corresponds to a ride score of about 47 in the absence of other pavement problems.

Ride score trigger levels are not adjusted for traffic volumes or speed. The evaluation of triggered projects includes a separate consideration of traffic volume and speed in selection of corrective strategies.

Ride score should not be used as a sole criterion to trigger corrective work on city street portions of state highways because conventional ride improvement strategies may not necessarily correct the cause of poor ride quality (e.g., intersecting roadway crown, manhole covers, trench backfill subsidence, rail tracks, etc.).

Pavement deterioration can progress quite rapidly. Limited investigation to date on PMS projects indicates substantive changes can occur in as little as two years. In addition, it is important to recognize the lead time required from problem identification to implementation of a repair strategy.

D. Bridge Approach Ride Quality

1. Data Collection

Bridge approach slabs pose significant problems because they are large expensive reinforced concrete structures which are difficult to replace. In the 1975-76 survey it was decided to utilize a simple subjective evaluation to describe the existing condition. Bridge approach slabs were rated on the basis of differential settlement (ride quality) and slab condition.

In reviewing the results of the 1975-76 survey, it was concluded that a subjective rating was unsatisfactory. The ratings were inconsistent and required a disproportionate amount of time. Slab condition was eliminated as a factor in determining the appropriate type of repair because an engineering evaluation would still be necessary. Ride quality was important, and a method was developed to use ride meter equipment to objectively measure ride quality.

The ride meter takes measurements for approximately 100 feet approaching and leaving bridge ends. For bridge approach ride quality measurement, counts at register 5 or above are required for significant data. Counts below register 5 are not included. This filters out all surface irregularities which do not produce both a +5/8" and -5/8" displacement as a minimum.

2. Data Interpretation

Road meter equipment is used to measure bridge approach ride quality as in the case of pavement ride score, but the values are calculated in a different manner. If the highest count recorded on registers 5 through 12 is less than three, the ride quality is simply the value of the highest register recording count. If three or more counts are recorded on registers 5 through 12 the ride quality is either the sum of the two highest register numbers recording count or twice the register number recording three or more counts, whichever is higher. A range of values from <5 to 24 result. This method accounts for the impact and rebound of a vehicle passing over a bump or dip.

Twenty three separate approach and leave slabs with a broad range of ride quality were evaluated to establish an acceptable level of service. Two vehicles, a 1974 Ford Pinto and a 1972 American Motors Matador were used in the field evaluation process. There were no significant rating variations between the two test cars. The slabs were prerated with the ride meter and selected for evaluation.

Field tests were made by a team of engineering managers. They concluded ride meter equipment could identify unsatisfactory bridge approach ride quality. The available range of scores was from 10 (relatively smooth ride) to 23 (lurching ride) as measured by the ride meter. The majority of raters subjectively decided that ride quality was unsatisfactory when the bridge approach slab rating was 17 or greater.

3. Data Application

There are separate and distinct circumstances which materially affect Caltrans' District's perspective in evaluating the need for bridge approach surveys. Districts having numerous bridge approaches with poor ride quality or those who perceive this condition occurring soon, favor collecting bridge approach data. Conversely, Districts having an abundance of AC pavement, few bridges, or new facilities generally do not see a need for bridge approach ride quality information.

The survey of bridge approaches will be done by the Districts wanting the information, in conjunction with their pavement condition survey.

After the slabs with poor ride quality have been identified, the decision for, and method of rehabilitation, will be left to the individual Districts as a normal maintenance correction.

E. Skid Resistance Rating

1. Skid Resistance Inventory

Federal Instructional Memorandum 21-2-73 dated July 19, 1973 required all states to have a skid accident reduction program as part of their Highway Safety Programs. A part of this program required a statewide inventory of skid resistance measurements to be operational by December 31, 1975.

California completed a statewide skid test inventory in January 1973. The inventory was accomplished with towed trailer skid testers that comply with applicable ASTM Standards. Values from the skid tests are measured in terms of skid numbers which are measured at 40 mph or converted to equivalent 40 mph values and designated SN (40).

In November 1975 Caltrans established procedures for a continuing skid testing program that complies with Federal Instructional Memorandum 21-2-73. The frequency of skid tests are:

Each year - all interstate highways
Each 2 years - other freeways and expressways
Each 4 years - other state highways

2. Current Practice in California

Currently, an SN (40) $\leq$37 is used by the Transportation Districts to trigger investigation. This is a common reference skid number used in various research papers, federal directives, and Caltrans' program guidelines. The investigations do not automatically result in a skid correction project but rather an engineering analysis of a specific pavement location considering the many variables involved (traffic, accidents, speed, environmental conditions, geometrics, etc.). The primary concern for low skid resistance is skidding accidents. The analysis must include the actual accident history as well as the contribution of low skid resistance to wet weather accidents.

Caltrans' investigations have led to the development of performance curves or wear rate curves (Figure I-4) and established a relationship between truck passes and a declining skid resistance for the following pavement surfaces:

- o Open Graded AC
- o Dense Graded AC
- o Chip Seals
- o Slurry, Sand Seals
- o PCC

Performance curves for grooved pavements or AC pavements treated with liquid seals have not yet been established. Attempts to correlate skid numbers to pavement age, annual traffic volume, or the traffic index for the life of the pavement section were inconclusive. As a part of future

WEAR RATE CURVES

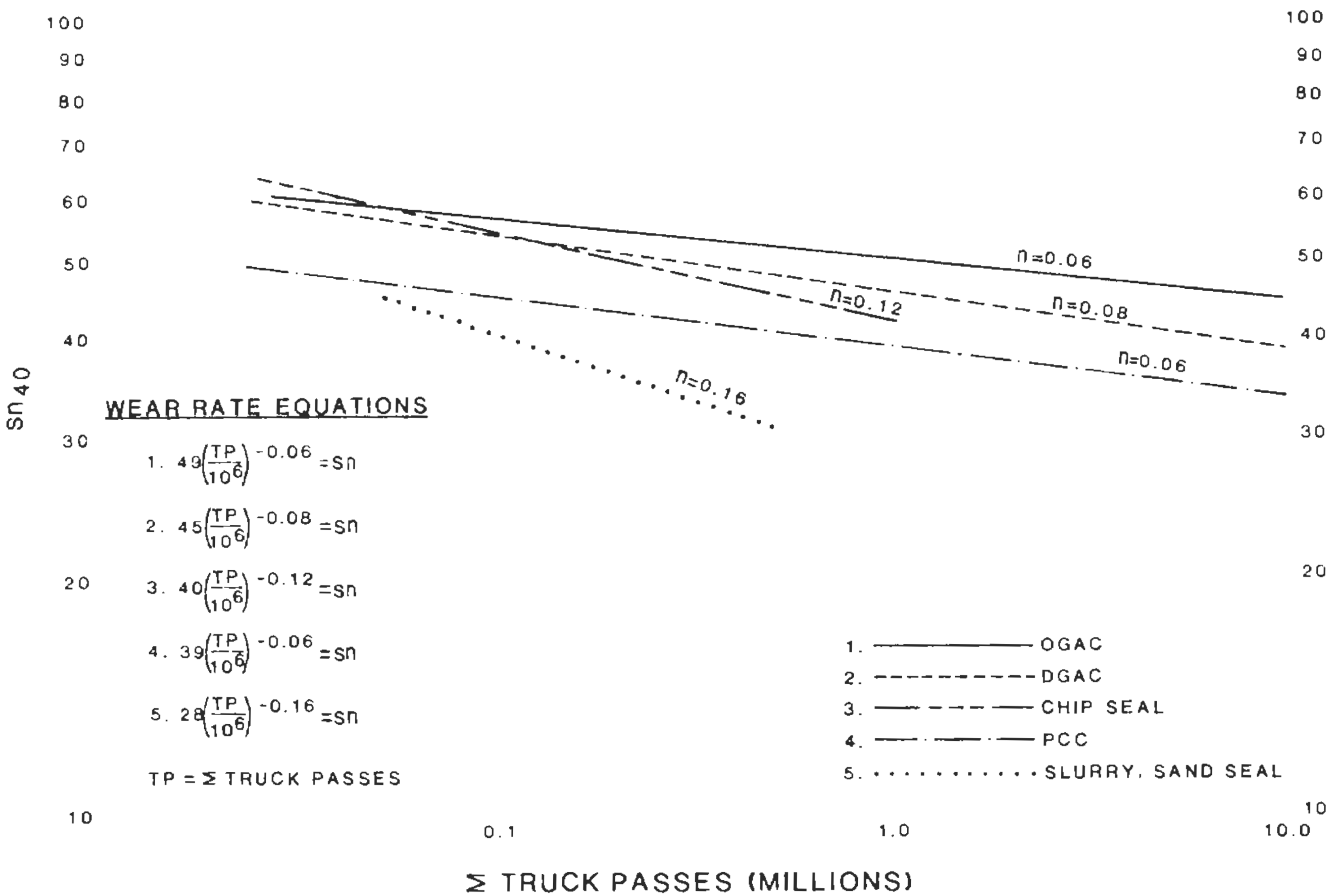


Figure I-4

PMS studies, it is intended to establish sufficient test sections to further refine performance curves (wear rate curves) relating skid resistance to the common pavement surface types and treatments.

3. Use of Skid Resistance Information in the Pavement Management System

Skid numbers from the continuous skid inventory program are included as an information item in the Pavement Condition Inventories. This will assist in avoiding recommendations of corrective pavement strategies which might have detrimental impacts on pavement skid resistance. (For example, it is inappropriate to consider an asphalt seal on a pavement with a low skid resistance.)

Low skid numbers are investigated by Caltrans' Office of Traffic, and procedures and corrective projects are in cluded in Caltrans' Traffic Safety Program. Skid evaluation has not been included in the pavement condition evaluation system described in Section III because it would create a duplication of effort.

The performance curves (wear rate curves), which have been developed to predict declining skid resistance of pavement, can be used as a planning tool to estimate the anticipated skid resistance life of existing pavements and proposed pavement strategies.

II. Pavement Condition Survey

A. Survey Frequency

This PMS is oriented toward decision making at both the program and the project level. In order to address project level decisions and make comparative judgements between specific projects total system survey coverage is required. Consequently, statistical sampling for the survey was dismissed.

Caltrans conducts a pavement condition survey each two years. Every lane of every mile (47,000 lane miles) of the entire state highway system is surveyed. Volume II of this report contains detailed instructions for the conduct of the survey.

The 1975-76 pavement condition survey data collection and machine processing cost approximately $362,000. Consideration was given to the possibility of reducing the cost by eliminating certain select portions of the State Highway System from alternate surveys, in effect, surveying portions of the system on a four year frequency instead of the present biennial basis.

Candidates considered for less frequent surveys were:

1. Sections with very minor problems in the last survey.

   Results of the four biennial pavement condition surveys made since 1969 have been reviewed. Many sections of pavement with minor problems deteriorated within a two year period to a condition which could trigger remedial maintenance or rehabilitation.

If these sections with good ratings were evaluated on a four year cycle, it is probable that many would deteriorate before detection. Identification of progressive pavement deterioration at an early point in time can allow remedial maintenance to extend the life of pavement serviceability resulting in a more cost effective approach.

2. Sections that have been resurfaced or rehabilitated subsequent to the last pavement condition survey.

The monitoring and evaluation of recently completed projects is important in determining the progressive deterioration rate of pavement and the development of performance information.

3. Sections which are in geographic or environmental areas where pavement deterioration is very gradual.

Investigations to date have not established a correlation between pavement deterioration rates and environmental conditions. Until such a correlation is established, there is no basis on which to reduce survey frequency.

4. Sections which experience low traffic volumes.

Investigations to date have not established a direct correlation or trend relating ADT and pavement deterioration rate. This applies to both structural condition and ride quality ratings.

5. Sections which are not of statewide significance.

Routes of statewide significance include Interstate, Rural Principal Arterials, and Urban Connecting Links. Many high volume urban freeways are not included in the above category and need to be evaluated concurrently with the rest of the State Highway System. There are several thousand miles of non-statewide significant routes in which it is essential to protect the existing investment and insure the application of cost effective repair strategies in order to maximize pavement serviceability.

6. Conclusions.

Considering the cost and time required to collect and process survey data for California's State Highway System, it is deemed infeasible to survey annually. It is also generally inappropriate to survey at three or four year intervals considering the deterioration rates of some pavement types as discussed in Section IV of this report. A two year frequency seems most appropriate for uniform data collection, supplemented by other surveys for special studies or unique problems.

Following full implementation of a PMS in California and the development of an adequate historical data base for performance and trend analyses, consideration will be given to the adviseability of reducing the extent and frequency of condition surveys. There is currently insufficient historical information to take the risk.

B. Decentralized versus Centralized Pavement Condition Surveys

1. Decentralized Survey - Current Practice

The pavement condition survey is conducted every two years using Transportation District personnel, trained in headquarters, who survey all lane miles of flexible and rigid pavements. The survey is completed in all districts within a six months time frame. Recent statewide pavement condition survey costs are estimated at:

75-76 18 man years; $362,000 (including EDP costs)
77-78 12 man years; $335,000 (including EDP costs)

Survey operations have been in a state of refinement as the PMS program developed. Future surveys will be more routine in nature. For example, the major task of bridge and roadway section identification has been accomplished, and need not be repeated. Routine operation should reduce 1979-80 survey costs by an estimated 20% from the 1977-78 survey cost.

2. Centralized Survey

Consideration has been given to revising the manner in which the present pavement condition surveys are conducted. A continuous survey conducted over a two year period with a limited staff of pavement raters from headquarters has some attractive features.

The limited staff would require much less training effort and more consistant survey results could be expected. The continuous survey approach would partially eliminate some District manpower and budgeting difficulties, particularly where District priorities interfere with assigning experienced raters to the periodic surveys. Surveillance frequency could be more easily adjusted for specific segments of highway, resulting in more efficient use of raters. On the other hand, it may prove difficult to retain a headquarter rating staff who would be amenable to travel throughout the State on a continuous basis.

It is estimated that a 1979-80 centralized survey approach would require about 9 man years and cost on the order of $315,000, including EDP costs.

3. Conclusion

The present decentralized pavement condition survey presents a complete picture of the state of deterioration of highways based on information gathered within a six month time span. A centralized survey could be conducted on a continuous basis to provide new information on a two year frequency. Various areas of the State would be examined at substantially different times. There may be no valid comparison between a December 1978 pavement in Los Angeles and an April 1980 pavement in Eureka, yet both pavements may be in competition for the same funding for rehabilitation.

Pavement condition surveys should be conducted following the most damaging season of the year, before problems are hidden by maintenance operations. In California, this would be in late Spring. The centralized survey would preclude this since it would have to be conducted on a year around basis due to the limited staffing approach.

Work load reductions due to reduced length of roadway being sampled, improved measuring equipment, and standardization of data collection operations will result in lower costs for either type survey. These factors, therefore, should not be determinants on the issue of a centralized or decentralized survey.

The primary purpose of PMS is to improve the decision making process as it relates to the establishment of pavement repair program levels, project priorities and cost effective repair measures. Although the total cost of the biennial pavement condition surveys are appreciable, it must be considered in light of the current annual funding level of over $90 million for California's pavement reconstruction, resurfacing and maintenance programs.

The decision to centralize or decentralize pavement condition surveys should not be made solely on an economic basis. The cost differential is not as significant as some of the other factors discussed above. Following the full implementation of PMS in California and the development of a strong data base consideration will again be given to the best course of action to follow in future surveys.

III. Pavement Condition Evaluation System

A. General Approach to a Pavement Condition Evaluation System

The function of this evaluation system is to correlate pavement problems to feasible repair strategies. Levels of service (trigger values) have been set for each type of problem that merits improvement. For each lane of homogeneous road segment in the highway system, each problem type is evaluated independently, and a repair strategy or acceptable alternatives are identified. After all problem types are evaluated, the solutions for all triggered problems are compared. The strategy that will correct all problems and provide an acceptable level of service is defined as the dominant strategy.

In some cases the need for additional information and an engineering analysis is required. For example where load associated alligator cracking exists in flexible pavement, deflection measurements and structural overlay design are required to accurately determine the appropriate structural rehabilitation.

A limited knowledge of in-place pavement structural section information is required in order to properly design pavement rehabilitation by either the gravel equivalent method or the deflection analysis method of design. Rehabilitation design has not been included as a function within this PMS.

Record research to obtain data on existing base type and thickness would be difficult to obtain and would be incomplete but would represent the best available information short of obtaining field samples. Field samples are taken in limited cases for project design purposes where the specific situation warrants and the records could be retained for updating or initiating portions of an inventory. Field sampling for the purpose of completing an inventory is clearly unwarranted.

Construction compliance test information such as compaction test results, grading analysis, sand equivalent values and R-value test data are of no real value in assisting the designer in engineering the appropriate rehabilitation strategy.

In California an expensive statewide data base for storage and retrival of pavement structural section data would have negligible value in the operation of the PMS. The development and maintenance of a structural section inventory for specific project design purposes is left to the discretion of the Districts.

B. Pavement Condition Evaluation System for Flexible Pavement

The following pages briefly illustrate the flexible pavement condition evaluation process. The evaluation procedure can be shown conceptually:

FLEXIBLE PAVEMENT CONDITION EVALUATION PROCEDURE

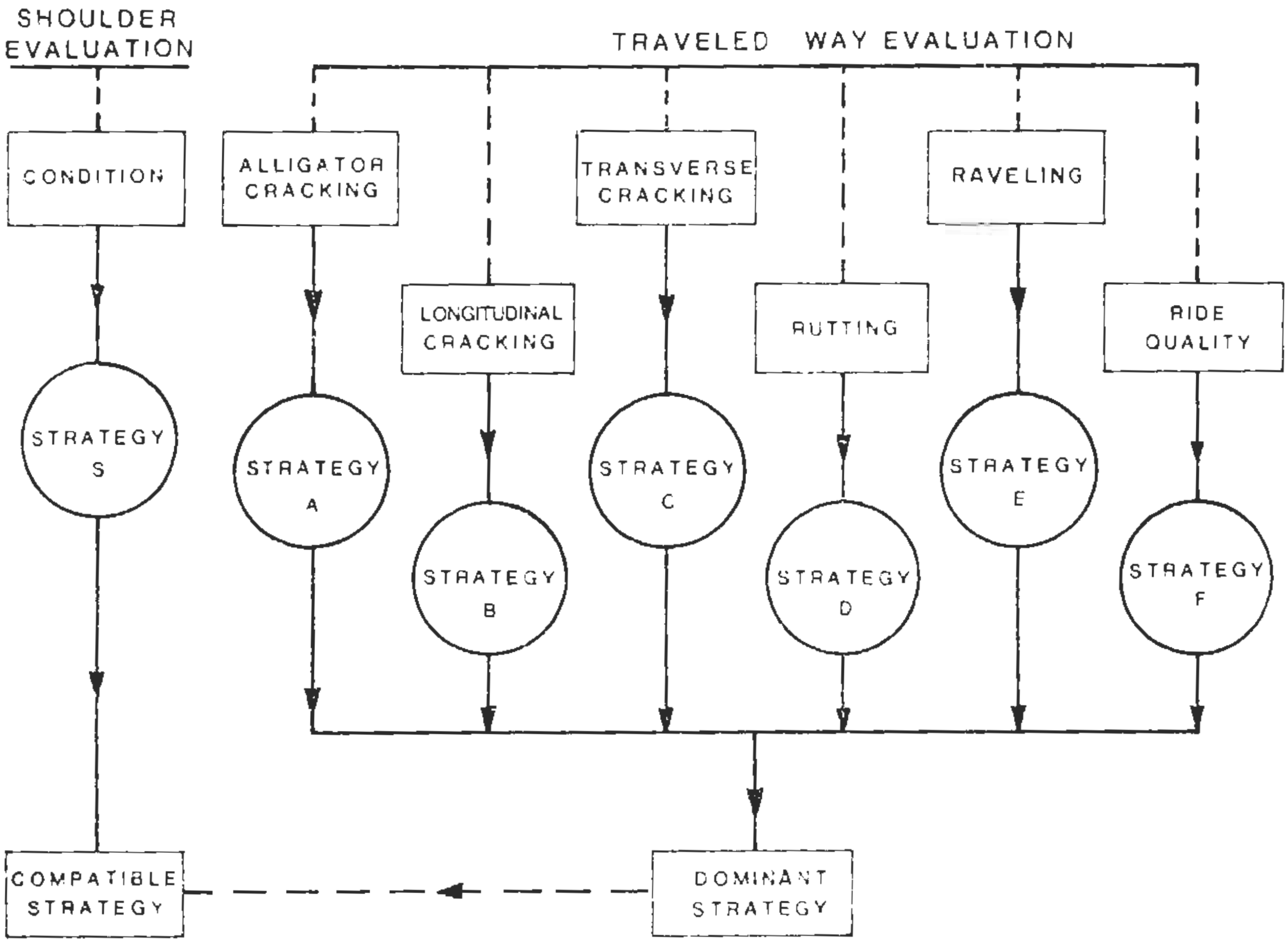


Figure III-1

Decision trees such as Figure III-2 are used to evaluate pavement conditions and identify problems and appropriate rehabilitation strategies. The limiting values (trigger values) directing the decision path used are adjustable. This provides flexibility for adjusting levels of service.

The flexible pavement conditions are evaluated as follows:

FLEXIBLE PAVEMENT
ALLIGATOR / BLOCK CRACKING

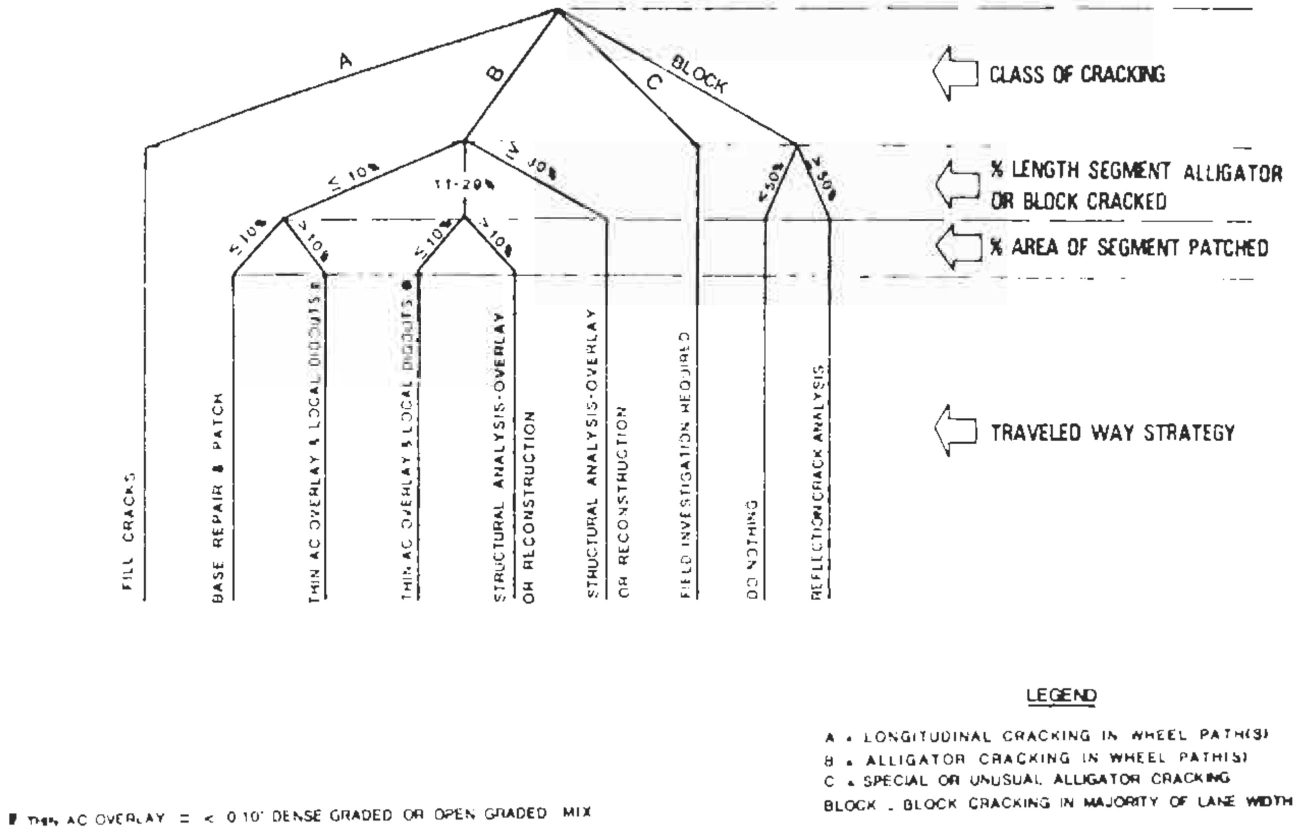


Figure III-2

Flexible pavement conditions are evaluated as shown in the following examples.

Example 1: Given - 20% length with Type A alligator cracking, no patching.
Repair Strategy - Fill cracks.

Example 2: Given - 20% length with Type B alligator cracking, no patching.
Repair Strategy - Base repair and patch plus thin AC overlay and local digouts.

Example 3: Given - 40% length with Type B alligator cracking, 10% area patched.
Repair Strategy - Structural analysis (structural overlay based on measured deflections, or reconstruction.)

FLEXIBLE PAVEMENT

LONGITUDINAL AND TRANSVERSE CRACKING

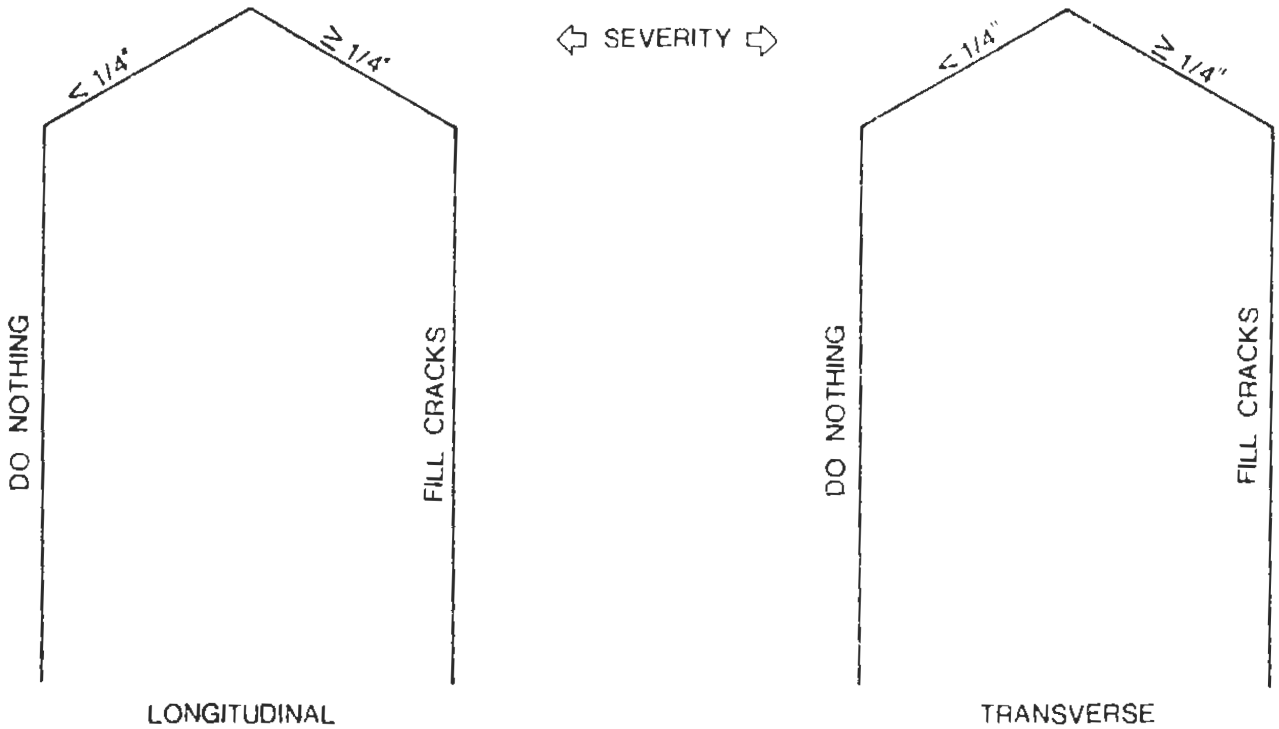


Figure III-3

Example 4: Given - Longitudinal cracks 200 feet per station, less than 1/8" wide cracks.
Repair Strategy - Do nothing.

Example 5: Given - Longitudinal cracks 100 feet per station, greater than 1/4" wide cracks.
Repair Strategy - Fill cracks.

Example 6: Given - Transverse cracks, 8 cracks per station, less than 1/8" wide cracks.
Repair Strategy - Do nothing.

Example 7: Given - Transverse cracks, 7 cracks per station, Individual cracks 1/8" - 1/4" wide.
Repair Strategy - Do nothing.

FLEXIBLE PAVEMENT RUTTING

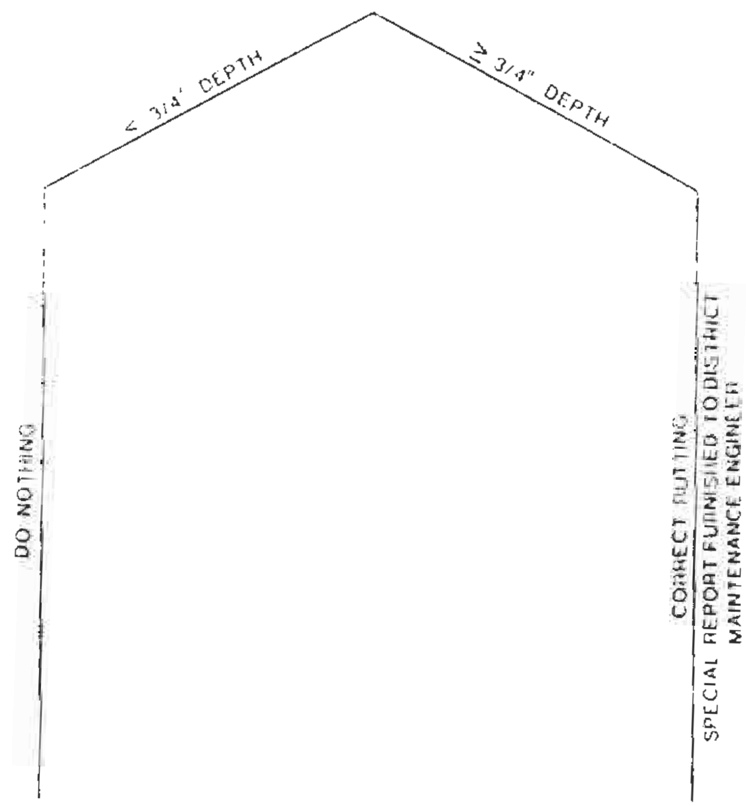
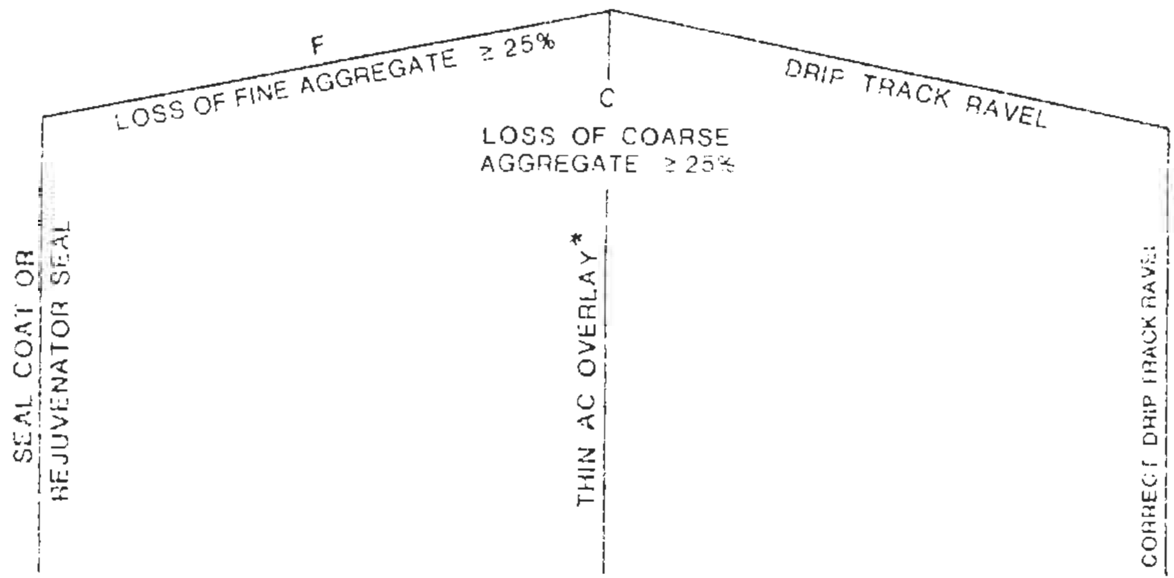


Figure III-4

Example 8: Given - 40% length, rut depth 1".
Repair strategy - Special report furnished to district maintenance engineer.

Note: This is not a very common problem in California. Maintenance forces will routinely patch ruts if pavement condition survey identifies location.

FLEXIBLE PAVEMENT RAVELING AND WEATHERING



*THIN AC OVERLAY =< 0.10' DENSE GRADED OR OPEN GRADED MIX

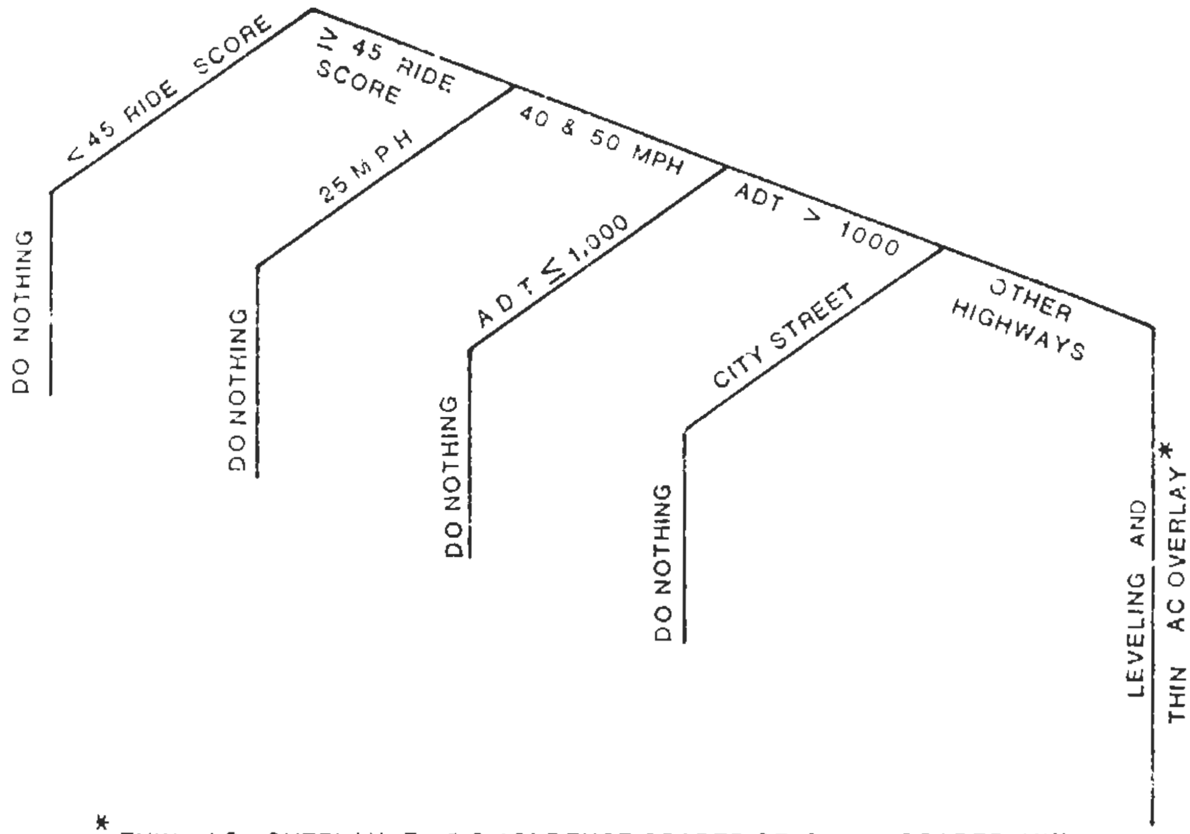
Figure III-5

Example 9: Given - 40% of area with fine raveling.
Repair strategy - Seal coat or rejuvenator seal.

Example 10: Given - 4 occurrences, drip track raveling.
Repair strategy - Special report furnished to district maintenance engineer.

Note: Drip track ravel is a problem in urban areas with stop signs or signals. Field maintenance forces will determine extent and type of repair when the pavement condition survey identifies location. Not a common problem on the rural portion of the California State Highway System.

RIDE QUALITY FLEXIBLE PAVEMENTS



* THIN AC OVERLAY = < 0.10' DENSE GRADED OR OPEN GRADED MIX

Figure III-6

Example 11: Given - 55 ride score measured at 50 mph, average daily traffic = 3,000.
Repair Strategy - Leveling and thin AC overlay.

Dominant Strategy Selection

Assume the road segment being evaluated includes some of the foregoing examples.

Problem	Example Number	Repair Strategy
Alligator Crack	3	Structural overlay based on measured deflections.
Longitudinal Crack	4	Do nothing.
Transverse Crack	None	None.
Rutting	8	Special Report to district.
Raveling	None	None
Ride Quality	11	Leveling and thin AC overla

From the list of the required repair strategies, it can be seen that the structural overlay (California's experience based on the deflection design approach, average thickness 0.20' to 0.25') would correct all of the triggered problems. It is the dominant strategy. Because of the thickness involved, the overlay would also be placed on the shoulders.

C. <u>Pavement Condition Evaluation System for Rigid Pavement</u>

The following pages briefly illustrate the rigid pavement condition evaluation process. The evaluation procedure can be shown conceptually:

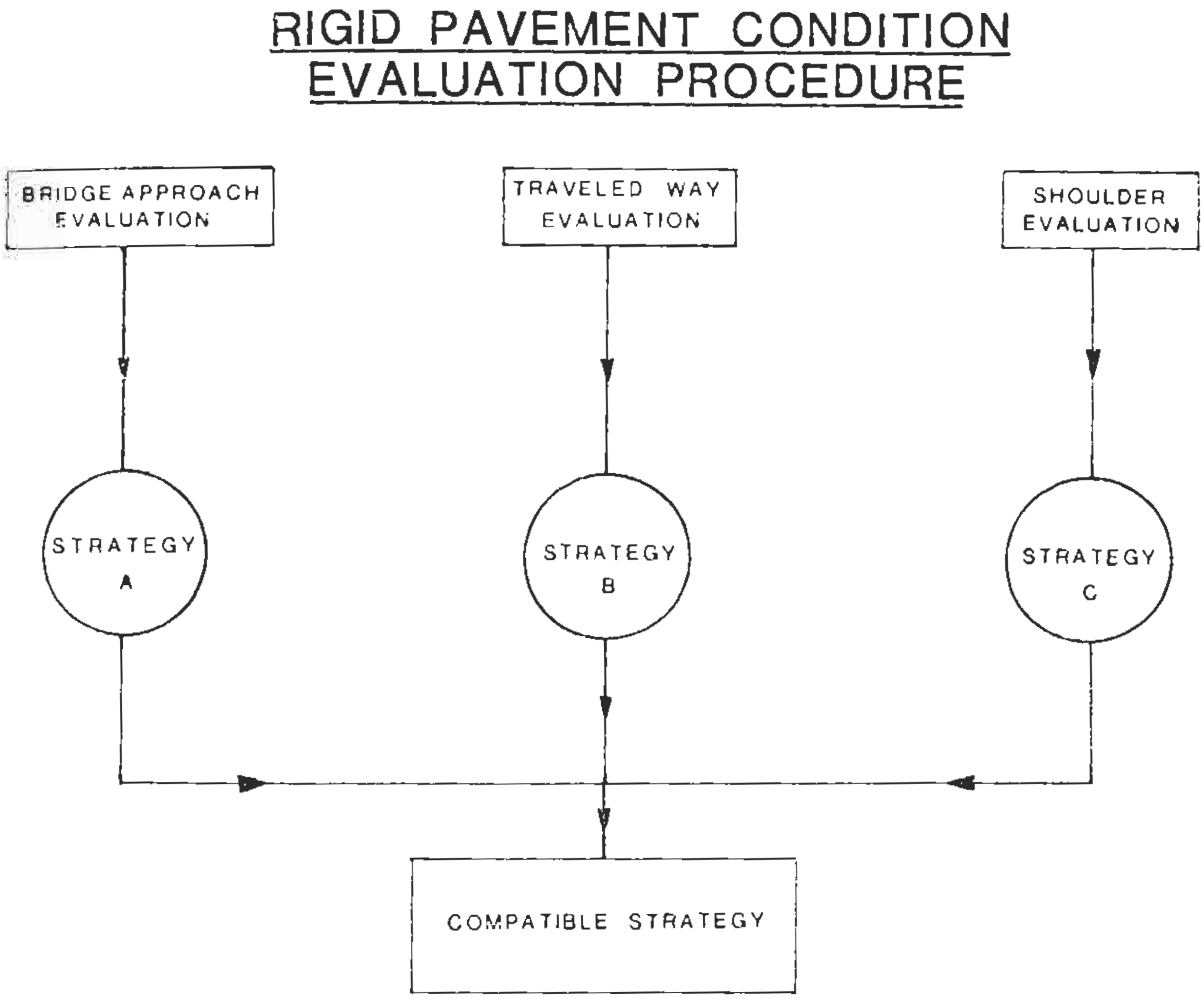


Figure III-7

The rigid pavement conditions are evaluated as follows:

RIGID PAVEMENT TRAVELED WAY EVALUATION

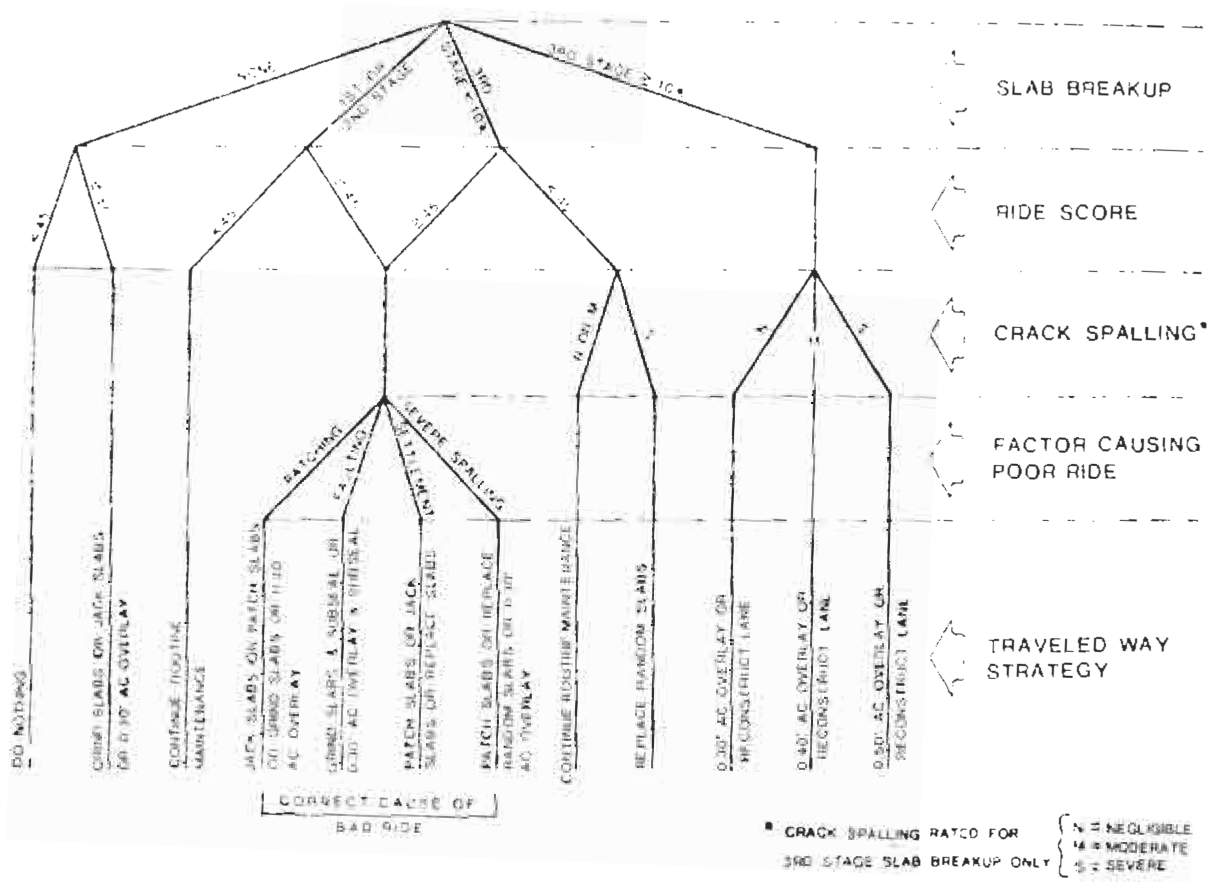


Figure III-8

Example 1: Given - 30% of slabs with 2nd stage cracking, ride score - 40.
Repair strategy - Continue routine maintenance.

Example 2: Given - 20% of slabs with 3rd stage cracking, spalling moderate (factor M), ride score = 50.
Repair strategy - 0.40' AC overlay or reconstruct lane.

Example 3: Given - 20% of slabs with 1st stage cracking, 30% of slabs with 2nd stage cracking, ride score = 55, patching in 10% of slabs.
Repair strategy - Nothing for cracking. Bad ride needs correction. Ride score cause must be determined. If patching is the factor then jack slabs or patch slabs, or grind slabs, or 0.30' AC overlay.

RIGID PAVEMENT SHOULDER EVALUATION

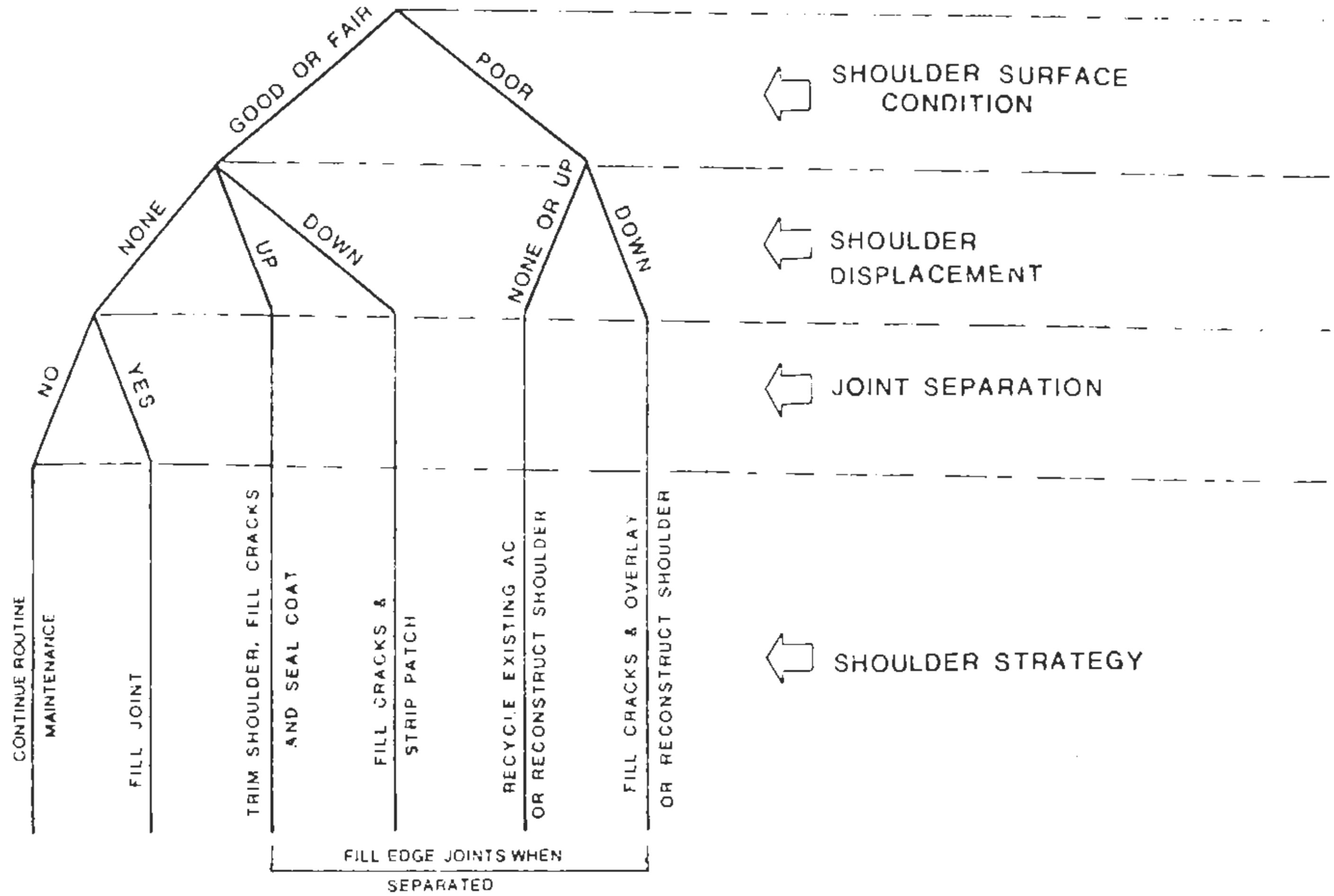


Figure III-9

Example 4: Given - Shoulder condition fair, shoulder displaced down.
Repair Strategy - Fill cracks and strip patch.*

Example 5: Given - Shoulder condition poor, shoulder displaced up.
Repair Strategy - Recycle existing AC shoulder or reconstruct shoulder.*

*Fill edge joint when separated.

RIGID PAVEMENT BRIDGE APPROACH EVALUATION

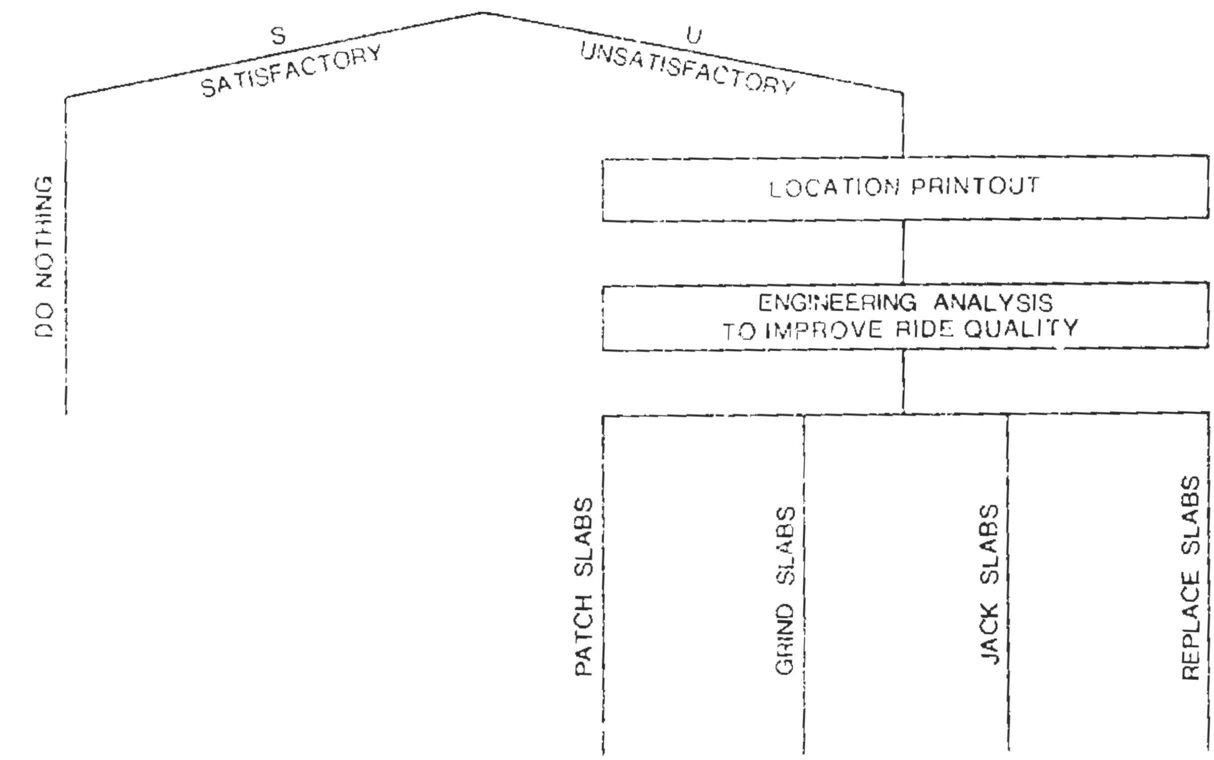


Figure III-10

Example 6: Given - Ride quality unsatisfactory on a bridge approach slab in rigid pavement.

Repair Strategy - Alternatives to improve ride quality.

Patch slab*
Grind slab*
Jack slab*
Replace slab*

*Alternative selection based on engineering evaluation of field conditions. Slab structural integrity, traffic volume, allowable work shift, availability of materials, equipment and funds, should be taken into consideration.

Compatible Strategy Selection

For illustration, assume the rigid pavement segment being evaluated includes some of the foregoing examples:

Problem Location	Example Number	Repair Strategy
Traveled Way	2	0.40' Overlay or lane reconstruction
Shoulder	4	Fill cracks and edge joint and strip patch
Bridge Approach	6	Jack slab (assumed for example)

Compatible strategy alternatives could be:

- Jack bridge approach slab plus 0.40' overlay on traveled way and shoulder.

- Reconstruct lane plus jack or replace bridge approach slab plus fill shoulder cracks and joints and strip patch.

The final alternative selection should also consider the least total cost, traffic volumes, allowable shut down time and funding.

IV. Strategies and Performance

A. Maintenance and Rehabilitation Strategies

Repair strategies have different functions, costs and service lives. Service life is defined as the span of time subsequent to the application of a repair strategy for pavement problems to recur in sufficient extent and severity so as to require re-application of a similar repair strategy. Following is a discussion of various repair strategies currently in use throughout the United States. Some are used little, if at all, in California. The following text and Figures IV-1 and IV-2 describe the functional use of various repair strategies along with recommendations citing when the repair strategy is or is not appropriate; average cost; expected service life and California's level of experience with each strategy.

1. Flexible Pavement Repair Strategies

a. Lane Reconstruction (See Figure IV-1a)

At many locations, the outside (truck lanes) of multi-lane facilities have incurred structural damage from a high incidence of heavy truck loading while the inside lanes have retained their structural adequacy. In these cases, outer lane reconstruction to restore structural adequacy and ride quality may be more cost effective than a structural overlay which must be carried across all adjacent lanes and shoulders. The presence of vertical grade controls, median barriers, drainage facilities, restrictive bridge clearance, etc., can preclude the placement of a structural overlay and thus require lane reconstruction.

b. PCC Overlays (See Figure IV-1a)

In order to restore structural adequacy there are cases where it may be effective to place a nonreinforced PCC overlay over an existing AC pavement. California design practice requires a minimum PCC thickness of 0.55 foot. An AC leveling course is not recommended since the new AC will not attain the compaction of the existing pavement and uneven support could lead to early cracking of the overlay. The minimum thickness of 0.55 foot may be precluded where vertical grade constraints exist. Rigid overlays are not suitable in unstable terrain where flexibility is required. This method has not been used extensively.

c. Asphalt Concrete Overlays (See Figure IV-1a)

This is the most common treatment employed to improve or extend the service life of asphalt concrete pavements. It consists of a variable thickness up to a maximum of 0.6 foot. Overlays are used to correct rough ride, seal or waterproof the surface, improve the skid resistance, or strengthen the structural section.

If the overlay thickness is properly designed by the deflection analysis method, a 10 year average service life can be expected.

Overlays less than 0.10 foot do not add significant structural strength to the pavement section. Thin overlays are probably the most misused strategy when placed over pavements that are structurally deficient. In such instances a thin overlay may have a crack correction service life of only 1 or 2 years.

Many 0.08 foot overlays placed to improve ride quality fail to do so since this thickness is often inadequate to level out the rough locations. A leveling course should be required in conjunction with the blanket in order to materially improve ride roughness.

A common oversight that will lead to short service life of overlays is the failure to remove and replace areas where the underlaying base has weakened due to presence of water and excessive loading. It is important that these areas be excavated and replaced with high quality base and surfacing and that any drainage problems be corrected.

Open graded AC is commonly used to improve skid resistance.

d. Inverted Overlay (See Figure IV-1a)

An open graded AC placed on the existing pavement and overlaid with a dense graded AC has been used experimentally to repair cracked pavement, restore structural adequacy and minimize reflective cracking. A good surface texture can be obtained and in the case of reasonably thick overlays, improvement of ride quality will also result.

Where inverted overlays are used, care must be taken to "daylight" the open graded layer to provide adequate drainage. The open graded layer should be carried across the shoulder if the overlying dense graded AC layer will also cover the shoulder. Since the open graded AC has a tendency to trap water, it is not an appropriate strategy to consider in freeze-thaw areas.

e. Pavement Reinforcing Fabric and Overlay (See Figure IV-1a)

A problem common to AC overlays is the reflection of cracks from the old pavement. These reflected cracks permit water to enter the pavement leading to premature crack widening and spalling. One method that is being used more extensively with good results is the installation of a stress relieving interlayer between the existing pavement and overlay.

Reinforcing fabric material is produced by several companies under various trade names such as: Petromat, Bidim, Mirafi, Typar, and others. These materials properly applied appear to be effective as a waterproofing membrane and as a retardant of reflection cracking and pumping at the cracks, thus extending the service life of the overlay.

Pavement reinforcing fabric is about equivalent in cost to 0.10 foot thickness of AC; thus, an important advantage of using this material is very evident on multilane highways. In these cases, generally, only the outside or truck lanes are in need of a thick overlay. However, if it is desired to maintain the original pavement cross slope, unnecessary thickness of asphalt concrete will be required on the inner lanes. A minimum of 0.10 foot AC thickness can be eliminated from the outer lanes when the fabric is used, thus reducing the overlay thickness by 0.10 foot on the inner lanes and considerable cost savings will be realized.

Recent laboratory testing indicates that reinforcing fabric may be more effective in retarding reflection cracking if placed in the lower third of the overlay rather than directly on the old pavement.

Since reinforcing fabric is used with no less than a 0.10 foot AC overlay, some ride quality improvement and provision of good surface texture normally result.

f. Rubberized Asphalt Interlayer and Overlay (See Figure IV-1a)

Another method used to reduce the incidence of reflection cracking is the application of a rubberized asphalt chip seal prior to placing an overlay. The mixture consists of 25% granulated rubber obtained from reclaimed tires and 75% asphalt cement applied at a rate of approximately 0.60 gal. per square yard. Chips are then rolled into the membrane. As is the case with pavement reinforcing fabric, the total thickness of the AC overlay is generally reduced at least 0.10 foot. This strategy is being used in California on an experimental basis to determine its effectiveness in repairing cracked pavement, restore structural adequacy, provide good surface texture, and improve ride quality.

g. Hot Recycling (See Figure IV-1a)

This is a process in which the existing AC and in some cases the underlying base material is removed, processed, and may be mixed with new aggregate, additional asphalt cement and/or a recycling agent at a central plant and then placed back on the roadway. Strict air pollution requirements must be satisfied. A major problem with this process is the difficulty of heating the mixed material to the initial compaction temperature of 250°F (minimum) required by California Standard Specifications. Production rates for recycling plants tend to be low, again due to the need to handle small quantities to minimize air pollution. There are also problems with maintaining quality control due to the variability of composition of the in place material.

This process has the potential of ultimately saving significant sums of money and critical resources as the supply of natural aggregates diminishes and the price of asphalt products increases. Since material is removed, processed and then reapplied to the roadway it can be an advantage where vertical grade constraints exist as an alternative to lane reconstruction. In general hot recycling has similar functions as AC overlays.

h. Heater Remix (See Figure IV-1a)

This method consists of heating and remixing the upper 3/4± inch of the existing surfacing before placing an overlay to restore structural adequacy, repair cracked pavement or restore surface texture. An asphalt re-juvenating agent, such as Reclamite, is often applied to soften the existing asphalt. This treatment appears to be successful in reducing reflection cracking. This strategy has excellent application under urban conditions where excessive cross slope occurs and it is preferable to remove some of the material to flatten the cross slope. However, air pollution is a potential problem wherever this strategy is used.

i. Cutler Process (See Figure IV-1a)

This process is similar to the heater remix method except that the overlay material is mixed with the heated and scarified existing material in one operation and then rolled.

j. Cold Planing (See Figure IV-1a)

This method can have important applications on urban streets where existing curb and gutter control the grade. Over the years, an undesirable cross slope or high center crown can develop due to the application of successive overlays. The machine planes off a variable thickness of AC at the crown, tapering to generally about 1 inch at the curb. The material can be stockpiled for future recycling or recycled and replaced as the overlay. When cold planing results in reducing the pavement's structural adequacy, consideration should be given to a structural overlay.

k. Rubberized Asphalt Chip Seal Coats (See Figure IV-1b)

The State of Arizona and the city of Phoenix have reported considerable success with the use of an asphalt rubber chip seal as a wearing course, to waterproof pavement, heal hairline cracks, and correct fine aggregate ravel. Materials and method of application are the same as discussed in preceeding item "f". California has experimented with this strategy to a limited extent; however excessive chip loss or whipoff can occur.

As is the case with seal coats (below) this strategy will not correct load associated cracking or improve ride quality. The surface has low resistance to the scrubbing action of tires associated with a high volume of turning movements.

l. Rock Seal Coats (See Figure IV-1b)

These include slurry and chip seals which are used to correct raveling of fine aggregate, waterproof the pavement or "hold" the pavement over a winter or two at the most. Short service lives of 1 to 3 years can be normally expected for a chip seal although a properly placed seal coat on a low volume road may last a longer period of time. Chip seals are not usually placed on high traffic volume roads due to the problem of stone whipoff causing vehicle damage. In some instances, chip seals are placed to improve skid resistance.

m. Open Graded Seal Coat (See Figure IV-1b)

This consists of a plant mixed open graded asphalt concrete which is placed primarily to waterproof or seal the pavement, and improve skid resistance. It has been used in some cases to correct a bleeding pavement and can correct coarse aggregate ravel.

This strategy should not be used in areas where frequent tire chain use or freeze-thaw is experienced. The minimial thickness applied will not correct ride roughness.

n. Slurry Seals (See Figure IV-1b)

Slurry seals consist of mineral aggregate, water and asphaltic emulsion proportioned prior to placing and applied as a mixture. Slurry seals are used to decrease the permeability of an existing pavement and hold the pavement over a winter or two. Short service lives of 1 to 2 years can be normally expected for these seals although a properly placed slurry seal on a low volume roadway may last a longer period of time. Slurry seals are not normally placed to improve skid resistance. However, if this type of seal is being considered for a location where surface texture is needed, a 3/8 inch maximum aggregate size should be used.

o. Seal Coat with Cover (See Figure IV-1b)

This strategy is used to restore binder flexibility, and stop fine aggregate ravel. The cover may be composed of a screening of sand or fine aggregate. This treatment has the potential to reduce skid resistance and should not be used where the existing pavement has a low or moderate skid number.

p. Liquid Seal Coats (See Figure IV-1b)

Liquid or fog seals are used to correct fine raveling, oxidation, and high permeability. Fog seals are a mixture of asphaltic emulsion and water without the application of a cover material. Fog seal coats can be expected to last no more than 1 to 3 years. They are used in many cases to waterproof the surface and hold the road over the winter until a more effective treatment can be applied.

This treatment can cause a reduction in pavement skid resistance and should not be used where the existing pavements have moderate or low skid resistance and wet weather skidding accidents are a concern.

q. Binder-Modifiers (Pavement Rejuvenating Agents) (See Figure IV-1b)

These are products of the petroleum refining process. They are known under trade names such as Reclamite, Gilsabind, Petroset, Satin Black and Astec Pavement Seal. These products are most effective on dry, permeable pavements. The effectiveness of these materials in non-aggregate seals to seal cracks is questionable since penetrations of only 1/4 inch have been identified based on test results. Complete penetration does not occur on impermeable pavement surfaces and a temporary lowered skid resistance will result, possibly requiring the areas to be sanded.

r. Crack Filling (See Figure IV-1c)

Cracks in flexible pavement should be sealed to prevent the entrance of water into the subgrade. In the past, maintenance practices have been such that many cracks are improperly sealed, thus leading to early opening of the cracks since the sealant did not penetrate into the crack. It is preferable that cracks be thoroughly cleaned before application of the sealant to ensure good penetration and bonding to the sides of the crack.

s. Miscellaneous (See Figure IV-1c)

Other interlayers and methods that have been used to reduce reflection cracking are stone dust, metal plates, expanded metal, welded wire fabric and chicken wire. Most of these have not been successful and further testing of them is not recommended.

2. Rigid Pavement Repair Strategies

Fewer strategies are available for the rehabilitation or maintenance of rigid pavements as compared to flexible pavements. Repair techniques for rigid pavements need more study and testing.

a. Lane Reconstruction (See Figure IV-2a)

At many locations, the outside (truck lanes) of multilane facilities have incurred structural damage from a high incidence of heavy truck loading while the inside lanes have retained their structural adequacy. In these cases, outer lane reconstruction to restore structural adequacy and ride quality may be more cost effective than a structural overlay which must be carried across all adjacent lanes and shoulders. As in the case of flexible pavements the impact of vertical grade controls apply and can preclude the placement of a structural overlay, limiting the correction of structural inadequacy to lane reconstruction. Vertical grade constraints are often a serious problem that must be considered in all strategies which involve reasonably thick overlays.

b. PCC Overlays (See Figure IV-2a)

A variety of PCC overlays to restore structural adequacy are available: bonded and unbonded, continuous reinforced, non-reinforced. Several unbonded PCC overlay projects have been constructed in California with good results. The major concerns with PCC overlays are maintaining traffic and vertical grade controls, since a minimum of 0.55 foot thickness of PCC overlay is recommended. As is the case with thick AC overlays over rigid pavement, digouts and replacement of the structural section may be necessary at bridge approach slabs and at overcrossings to maintain the vertical clearance.

There are several test installations of bonded, thin lift (2-3 inches), non-reinforced PCC overlays in other states. In most cases, the conditions under which these overlays are being tested are not comparable to those encountered in California. For instance on one project in Iowa, the ADT was 10,000 with only 4% trucks. Several other projects were on residential streets with no truck traffic. In general there is a lack of reliable performance data and the expense of obtaining a bond to the existing pavement may be too high to warrant use of this method.

c. Asphalt Concrete Overlays (See Figure IV-2a)

This strategy is used to extend the service life of PCC pavements (strengthening the structural section) and to improve ride quality where existing pavement is faulted or cracked. Blankets up to 0.6 foot maximum are used to strengthen the structural section. In order to improve ride quality and prevent reflection cracking, a minimum AC overlay thickness of 0.30 foot is recommended. If slabs are severely broken, rolling with heavy equipment has been done to seat the slabs before the overlay is placed. Thin AC overlays have been placed over rigid pavements but performance generally has not been satisfactory. Thin AC overlays tend to "reflect" cracks quickly, and frequently do not bond adequately to PCC pavement.

Since much of the deteriorating rigid pavement is on urban freeways, the existing pavement may need to be removed and replaced to maintain the vertical clearance of overcrossings and meet other vertical grade controls. If the bridge approach slabs are rocking, it is necessary to subseal or mudjack before placing the overlay to reduce the likelihood of reflection cracking occurring. Fractured bridge approach slabs may need to be replaced to improve the ride quality. Both of the above can lead to severe traffic handling problems.

d. Inverted Overlay (See Figure IV-2a)

As in the case of flexible pavements, this is an open graded AC placed on the existing pavement which is overlaid with a dense graded AC. It has been used experimentally to repair cracked pavement, restore structural adequacy and to minimize reflective cracking. A good surface texture can be obtained and as with reasonably thick overlays, improvement of ride quality will result.

Drainage provisions such as daylighting the open graded layer must be considered in the use of this type of overlay. Since the open graded AC has a tendency to trap water, it is not an appropriate strategy to consider in freeze-thaw areas.

e. Pavement Reinforcing Fabric and Overlay (See Figure IV-2a)

Essentially, the purpose of installing pavement reinforcing fabric between PCC pavement and an AC overlay is to repair badly cracked pavement and reduce reflection cracking. One installation has been made on a PCC state highway in California and more experience is needed to evaluate long term performance of this strategy. Subsequent to further performance evaluation it appears that total AC overlay thickness can be reduced by 0.10 foot where fabric is used. It is believed that an AC leveling course should be placed on the old PCC pavement, followed by reinforcing fabric, and a surface or wearing course of AC. This procedure appears to have better potential for retarding reflection cracking than placing the fabric directly on the old PCC pavement.

f. Slab Replacement (See Figure IV-2a)

PCC slabs have been replaced by removing the concrete and cement treated base and replacing with 12 inches of new PCC directly on the subbase material. Migration of fine particles from the untreated subbase material could lead to rapid faulting. Consideration should be given to providing an impervious barrier between the concrete and untreated subbase to prevent the migration of fines and faulting. In addition, the installation of longitudinal edge drains will greatly reduce the potential pumping problem. The traffic handling problems inherent in a slab replacement project, on a high traffic volume urban freeway, are a significant concern that must be addressed by the design engineer. Evaluation of traffic handling alternatives may indicate an off-peak construction operation or construction on a round-the-clock basis with fast setting concrete to complete the work as rapidly as possible.

g. Mudjacking (See Figure IV-2b)

PCC pavement may be raised to a grade line by mudjacking. Holes are drilled through the pavement at close intervals and special high pressure pumping equipment is used to pump concrete slurry under the slabs to raise them to grade. This strategy is used extensively to correct grade line of faulted and settled pavements, and to raise settled slabs at bridge approaches.

h. Subsealing (See Figure IV-2b)

This strategy is used to fill cavities below PCC pavement to control the progression of faulting and ensuing slab breakup. Holes are drilled through the pavement and hot air blown asphalt is pumped beneath the slab. In California little if any subsealing has been done recently; however, it appears that subsealing is warranted in the case of rocking slabs (not yet badly cracked) that are to be ground or overlaid, since it has proven successful in filling underlying voids and reducing pumping.

i. Grinding (See Figure IV-2b)

This strategy is being increasingly used to improve ride quality since the first cost is less than other PCC repair strategies. In general, grinding costs are approximately $2.50 to $4.00 per square yard. Other strategies such as overlays may be 2 to 4 or more times as expensive since more than one lane needs to be overlaid. The main advantage in grinding faulted pavements is that only the rough riding lane (usually the truck or outer lane) may be ground. The long term performance of ground pavements appears to be highly variable.

j. Pavement Subdrainage (See Figure IV-2b)

Rigid pavements that are faulted and pumping prior to grinding or overlaying are likely to continue to pump unless corrective work is undertaken. Roadway structural sections by their nature are slow draining; therefore, water can be retained under the PCC for days and even months. This water mixed with fines present in the cement-treated base and combined with action of traffic can pump at the joints. Continual pumping can lead to voids under the slabs at the joints. Saturated subbase materials also destroy the supporting value for the PCC slab.

The installation of a longitudinal underdrain pipe or asphalt treated filter material or filter fabric drainage system adjacent to the lower edge of pavement will accelerate the removal of free water trapped under the pavement. An engineered analysis of locations where there is a potential for pumping should be undertaken to identify longitudinal drainage system requirements.

Particular care should be given for sags of vertical curves, low sides of superelevated sections, low flat valley sections where basement soils are impervious, sections adjacent to irrigated landscaping and depressed freeways.

k. Crack Filling (See Figure IV-2b)

Sawed joints in rigid pavement are not generally filled unless excessive spalling occurs. Joints between the rigid pavement and the shoulder are filled when they open one-quarter inch or more. Random cracks should be filled before the winter rains. Cracks and joints should be thoroughly cleaned prior to filling.

l. Grooving (See Figure IV-2b)

Grooving consists of sawing longitudinal grooves in the pavement surface. It is used to reduce hydroplaning and improve vehicle tracking. The grooving equipment does not perform well on badly cracked and spalled pavement.

FLEXIBLE PAVEMENT REPAIR STRATEGY INFORMATION

REPAIR STRATEGY	FUNCTION (OBJECTIVE)	PROPER USE	IMPROPER USE	SERVICE LIFE	*1976/77 COST PER LANE MILE	CALIFORNIA'S EXPERIENCE
1. LANE RECONSTRUCTION	RESTORE STRUCTURAL ADEQUACY	A. WHERE MORE COST EFFECTIVE THAN ALTERNATES B. RIDE SCORE >45 C. VERTICAL GRADE CONSTRAINTS		20 YR	$90,000 (1)	EXTENSIVE
2. PCC OVERLAYS	RESTORE STRUCTURAL ADEQUACY	WHERE MORE COST EFFECTIVE THAN ALTERNATES (0.55' MINIMUM THICKNESS)	A. UNSTABLE TERRAIN B. VERTICAL GRADE CONSTRAINTS	10 YR	$65,000 (2)	LIMITED
3. AC OVERLAYS	A. RESTORE STRUCTURAL ADEQUACY B. REPAIR CRACKED PAVEMENT C. RESTORE SURFACE TEXTURE D. IMPROVE RIDE QUALITY	A. LOAD ASSOCIATED CRACKING B. RIDE SCORE >45 C. RUT DEPTH > 3/4" D. COARSE AGGREGATE RAVEL	A. VERTICAL GRADE CONSTRAINTS	10 YR	$12,500/0.10'	EXTENSIVE
4. INVERTED OVERLAYS	A. RESTORE STRUCTURAL ADEQUACY B. REPAIR CRACKED PAVEMENT C. RESTORE SURFACE TEXTURE D. IMPROVE RIDE QUALITY	A. WHERE MORE COST EFFECTIVE THAN CONVENTIONAL OVERLAY B. PROVIDE DRAINAGE BLANKET	FREEZE-THAW AREAS	10 YR TARGET	$35,000 (3)	LIMITED EXPERIMENTAL INSTALLATIONS
5. PAVEMENT REINFORCING FABRIC & OVERLAY	A. RESTORE STRUCTURAL ADEQUACY B. REPAIR CRACKED PAVEMENT C. RESTORE SURFACE TEXTURE D. IMPROVE RIDE QUALITY E. WATER RESISTANT MEMBRANE	A. WHERE MORE COST EFFECTIVE THAN CONVENTIONAL OVERLAY B. VERTICAL GRADE CONSTRAINTS		10 YR TARGET	$35,000 (4)	LIMITED EXPERIMENTAL INSTALLATIONS
6. RUBBERIZED ASPHALT INTERLAYER & OVERLAY	A. RESTORE STRUCTURAL ADEQUACY B. REPAIR CRACKED PAVEMENT C. RESTORE SURFACE TEXTURE D. IMPROVE RIDE QUALITY E. WATER RESISTANT MEMBRANE	A. WHERE MORE COST EFFECTIVE THAN CONVENTIONAL OVERLAYS B. VERTICAL GRADE CONSTRAINTS		10 YR TARGET	$35,000 (5)	LIMITED EXPERIMENTAL INSTALLATIONS
7. HOT RECYCLING	A. RESTORE STRUCTURAL ADEQUACY B. REPAIR CRACKED PAVEMENT C. RESTORE SURFACE TEXTURE D. CONSERVE NATURAL RESOURCES	A. WHERE MORE COST EFFECTIVE THAN ALTERNATES B. VERTICAL GRADE CONSTRAINTS	AIR QUALITY CONSTRAINT AT PLANT	10 YR	$24,000/0.10	NONE TO DATE
8A. HEATER REMIX 8B. CUTLER PROCESS	A. RESTORE STRUCTURAL ADEQUACY B. REPAIR CRACKED PAVEMENT C. RESTORE SURFACE TEXTURE	A. WHERE MORE COST EFFECTIVE THAN ALTERNATES B. VERTICAL GRADE CONSTRAINTS	AIR QUALITY CONSTRAINT AT SITE	5-10 YR	$25,000 (6)	HEATER REMIX-EXTENSIVE CUTLER PROCESS-NONE TO DATE
9. COLD PLANING	A. CONFORM TO ELEVATION CONTROL B. REMOVE DETERIORATED AND/OR CONTAMINATED LAYER	A. WHERE MORE COST EFFECTIVE THAN ALTERNATIVES B. PREPARE FOR OVERLAY C. AIR QUALITY CONTROLS PRECLUDE HOT PLANING D. VERTICAL GRADE CONTROLS		NOT APPLICABLE	$15,000 (7)	MODERATE

* COSTS DO NOT INCLUDE TRAFFIC HANDLING

Figure IV-1a

RIGID PAVEMENT REPAIR STRATEGY INFORMATION

REPAIR STRATEGY	FUNCTION (OBJECTIVE)	PROPER USE	IMPROPER USE	SERVICE LIFE	*1976-66 COST PER LANE MILE	CALIFORNIA'S EXPERIENCE
1. LANE RECONSTRUCTION	RESTORE STRUCTURAL ADEQUACY	A. > 10% THIRD STAGE CRACKING B. WHERE MORE COST EFFECTIVE THAN ALTERNATES. C. VERTICAL GRADE CONSTRAINTS D. RIDE SCORE > 45		20 YR.	$100,000	LIMITED
2. PCC OVERLAYS	RESTORE STRUCTURAL ADEQUACY	A. > 10% THIRD STAGE CRACKING B. WHERE MORE COST EFFECTIVE THAN ALTERNATES. C. NO VERTICAL GRADE CONSTRAINTS D. WHEN TRAFFIC HANDLING PERMITS E. RIDE SCORE > 45		20 YR.	$ 65,000 (1)	LIMITED
3. AC OVERLAYS	A. RESTORE STRUCTURAL ADEQUACY B. REPAIR CRACKED PAVEMENT C. RESTORE SURFACE TEXTURE D. IMPROVE RIDE QUALITY	A. > 10% THIRD STAGE CRACKING B. WHERE MORE COST EFFECTIVE THAN ALTERNATES. C. FAULTING IF SLABS STABILIZED D. NO VERTICAL GRADE CONSTRAINTS E. RIDE SCORE > 45	ROCKING SLABS	10 YR.	$ 12,500/0.10'	MODERATE
4. INVERTED OVERLAYS	A. RESTORE STRUCTURAL ADEQUACY B. REPAIR CRACKED PAVEMENT C. RESTORE SURFACE TEXTURE D. IMPROVE RIDE QUALITY	A. > 10% THIRD STAGE CRACKING B. WHERE MORE COST EFFECTIVE THAN ALTERNATES. C. FAULTING IF SLABS STABILIZED D. NO VERTICAL GRADE CONSTRAINTS E. RIDE SCORE > 45 F. PROVIDE DRAINAGE BLANKET	FREEZE-THAW AREAS	10 YR.	$ 40,000 (2)	LIMITED
5. PAVEMENT REINFORCING FABRIC & OVERLAY	A. REPAIR BADLY CRACKED PAVEMENT B. WATER RESISTANT MEMBRANE	A. WHERE MORE COST EFFECTIVE THAN ALTERNATES. B. VERTICAL GRADE CONSTRAINTS		10 YR.	$ 35,000 (3)	ONE EXPERIMENTAL INSTALLATION
6. SLAB REPLACEMENT	REPLACE RANDOM SLABS WHICH ARE SEVERELY DISTRESSED	A. LESS THAN 35 SLABS PER MILE B. WHERE MORE COST EFFECTIVE THAN OVERLAY OR RECONSTRUCTION C. SEVERE CRACK SPALLING D. RIDE SCORE > 45		5 YRS.	$ 15,000 (4)	MODERATE

* COST DO NOT INCLUDE TRAFFIC HANDLING

Figure IV-2a

RIGID PAVEMENT REPAIR STRATEGY INFORMATION

REPAIR STRATEGY	FUNCTION (OBJECTIVE)	PROPER USE	IMPROPER USE	SERVICE LIFE	*1976-77 COST PER LANE MILE	CALIFORNIA'S EXPERIENCE
7. MUDJACKING	A. FILL CAVITIES UNDER PAVEMENT B. RESTORE PAVEMENT GRADELINE	A. IMPROVE RIDE SCORE B. FAULTED OR VERTICALLY DISPLACED SLABS C. WHERE MORE COST EFFECTIVE THAN ALTERNATES	BADLY CRACKED	5-10 YR.	$ 55,000 (5)	EXTENSIVE
8. SUBSEALING	FILL CAVITIES UNDER PAVEMENT	FAULTED PAVEMENT	BADLY CRACKED SLABS	5-10 YR.	$55,000	NO RECENT EXPERIENCE
9. GRINDING	A. RELIEVE FAULTING B. IMPROVE RIDE QUALITY	A. FAULTING > 1/4" B. RIDE SCORE > 45	> 10% THIRD STAGE CRACKING	MORE THAN 5 YR.	$20,000	EXTENSIVE
10. PAVEMENT SUBDRAINAGE	DEWATER STRUCTURAL SECTION	A. AT LOWER PAVEMENT EDGE B. IN WET CLIMATE C. INDICATIONS OF FAULTING AND/OR PUMPING		UNKNOWN EST 10-15 YR.	$20,000/MILE	LIMITED EXPERIMENTAL INSTALLATIONS
11. CRACK FILLING	WATERPROOF PAVEMENT	A. CLEAN CRACKS ≥ 1/4" WIDE B. APPROPRIATE SEALANT	A. DIRTY CRACKS B. < 1/4" CRACKS	1-2 YR.	$ 200	EXTENSIVE
12. GROOVING	A. REDUCE HYDRO-PLANING B. IMPROVE VEHICLE TRACKING	A. ABNORMAL RATE OF WET PAVEMENT ACCIDENTS DUE TO HYDROPLANING	BADLY CRACKED PAVEMENT	10-15 YR.	$ 5,000	EXTENSIVE

* COSTS DO NOT INCLUDE TRAFFIC HANDLING

ASSUMPTIONS FOR RIGID PAVEMENT REPAIR COST ESTIMATES

(1) 0.60' PCC
(2) 0.08' O.G PLUS 0.25' AC
(3) REINFORCING FABRIC WITH 0.20' AC
(4) 30 SLABS/MILE @ $500 EACH (12" DEPTH PCC)
(5) $8 PER SQUARE YARD

Figure IV-2b

B. Flexible Pavement Repair Strategies Performance

Pavement repair performance, as experienced in California, was analyzed to establish predictability of service life, so that the value of rehabilitation strategies could be substantiated.

Structural overlays for load associated cracking and overlays for reflection cracking control are designed to achieve a ten-year service life with low maintenance costs.

Sample projects were selected from widening and surfacing projects and from deflection overlay recommendations made by the California Transportation Laboratory. The biennial condition ratings were reviewed and district maintenance departments were contacted to determine if there were any maintenance performed which would invalidate estimated service life. Service life is defined as the span of time subsequent to the application of a repair strategy for pavement problems to recur in sufficient extent and severity so as to require reapplication of a similar repair strategy.

For flexible pavement, the following pavement conditions indicate the end point or failure condition.

a. Rock and Sand Seals or thin blankets -
10% of the area exhibits alligator cracking, or patching, or both.

b. Overlays greater than 0.08 foot thickness - 30% of the area exhibits alligator cracking or patching or both.

The pavement condition information was taken from the "Flexible Pavement Condition Inventory". The flexible pavement portion of the survey has been conducted each two years since 1969. Segregation between load-associated and nonload-associated cracking was initiated in the 1977-78 survey and was not available for these performance models. Pavements exhibiting initial signs of distress were assumed to fail at the next survey. Pavements which had sufficient maintenance work to bias service life were eliminated.

1. Sand Seals

Sand seals were evaluated for their ability to seal cracks. Although the seals may not have been placed solely to seal cracks, most were placed over cracked pavement.

The mean service life of sand seal applications is 14 months with a maximum life of 40 months.

Sand Seal Service Life is shown in Figure IV-3.

CRACK CORRECTION SERVICE LIFE
SAND SEALS

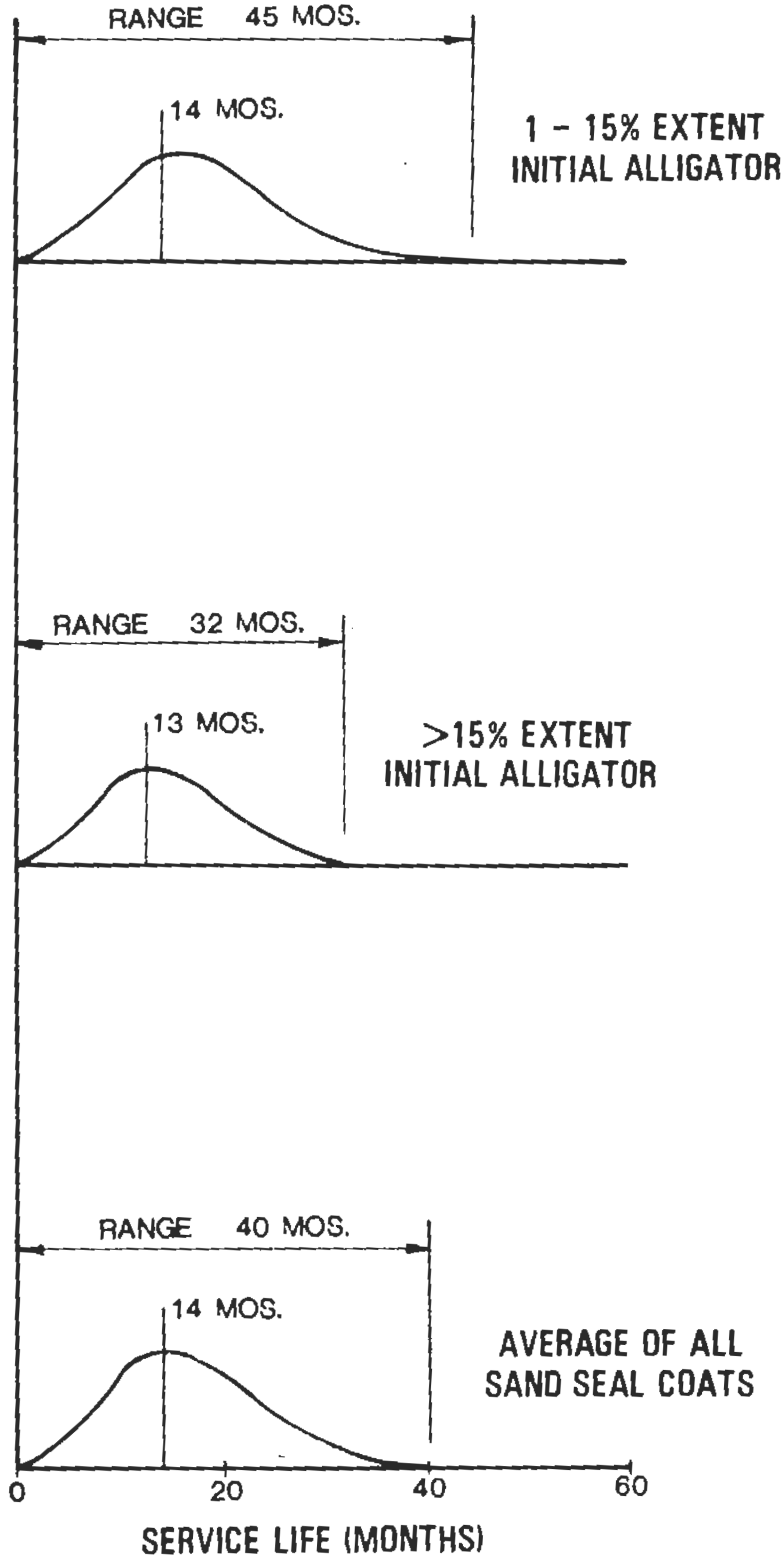


Figure IV-3

2. Rock Seals

Rock seals were also evaluated for their ability to seal cracks. Although the seals may not have been placed solely to seal cracks, most were placed over cracked pavement.

The mean service life of rock seal applications is 16 months with a maximum life of 50 months.

Rock Seal Service Life is shown in Figure IV-4.

3. Thin AC Overlays (0.08 foot)

The performance model for one-inch blanket overlays is based on a geographical-topographical distribution map. The map (Figure IV-5) shows areas of similar environment. The effect of traffic on service life was investigated but no correlation was found to exist between the traffic index or average daily traffic and thin blanket overlay performance.

The mean service life of thin blanket overlays for all geographic areas is 30 months with a maximum life of 75 months as shown in Figure IV-6.

CRACK CORRECTION SERVICE LIFE
ROCK SEAL COATS

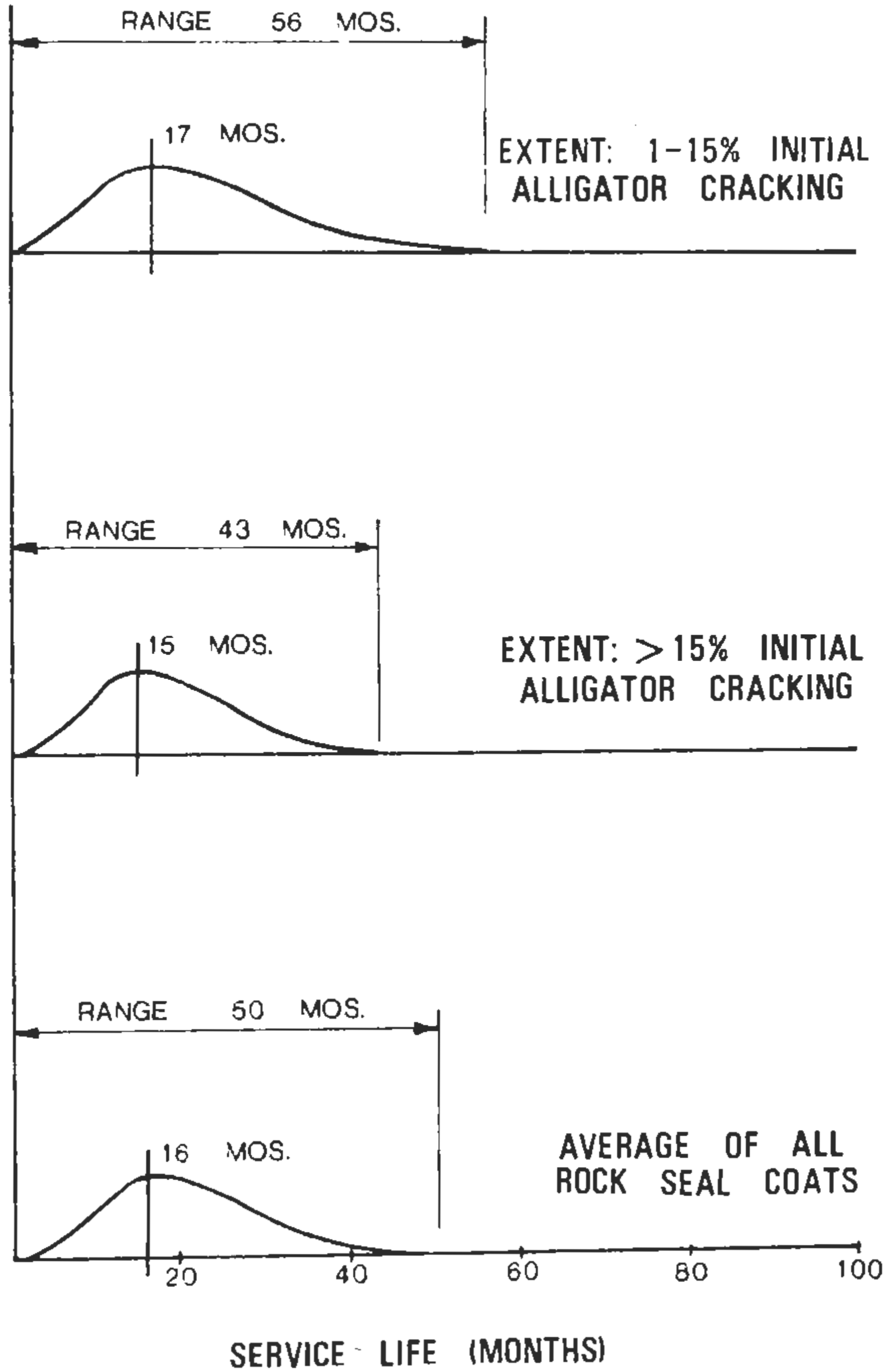


Figure IV-4

ENVIRONMENTAL REGIONS OF CALIFORNIA

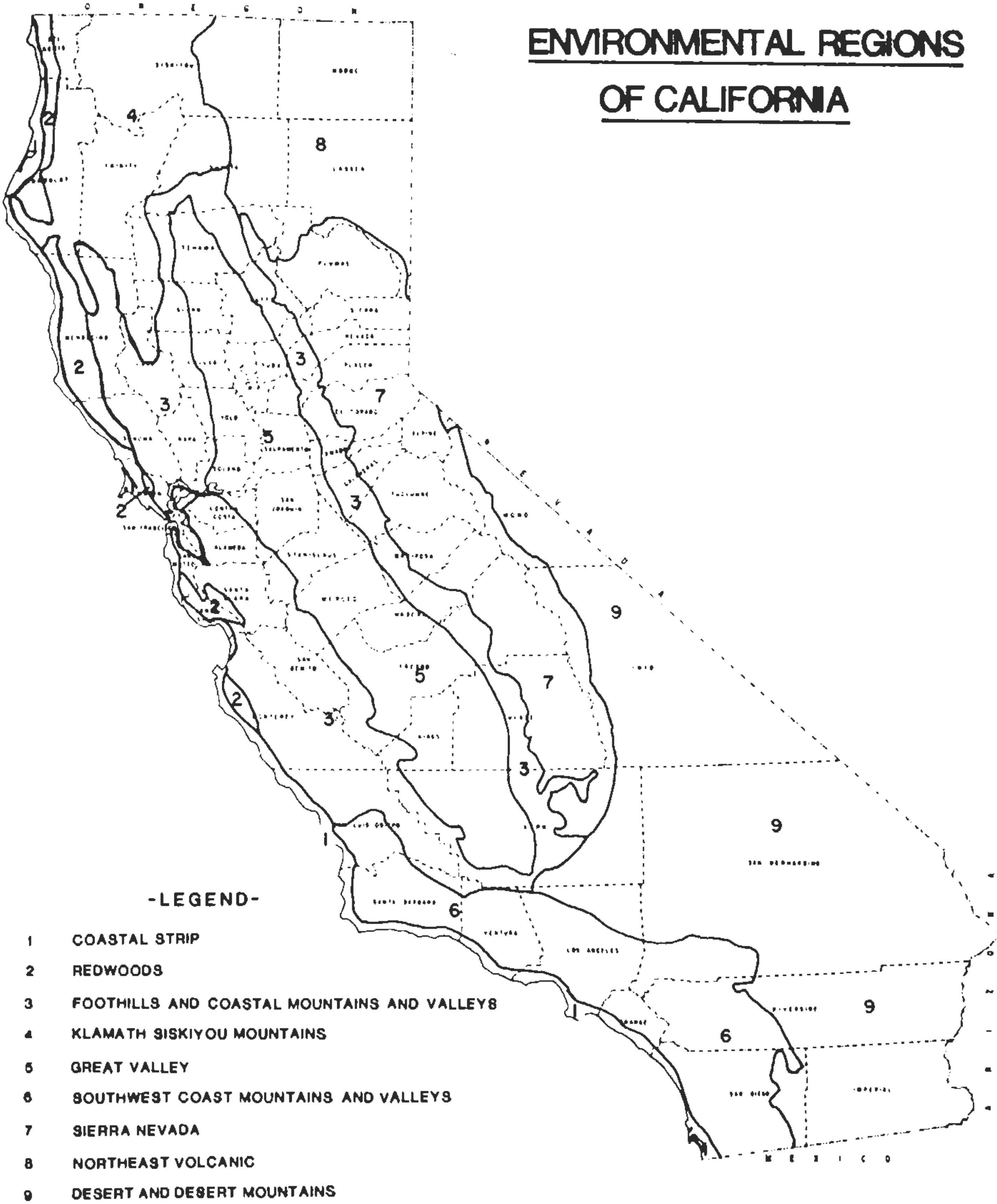


Figure IV-5

CRACK CORRECTION SERVICE LIFE

THIN BLANKETS

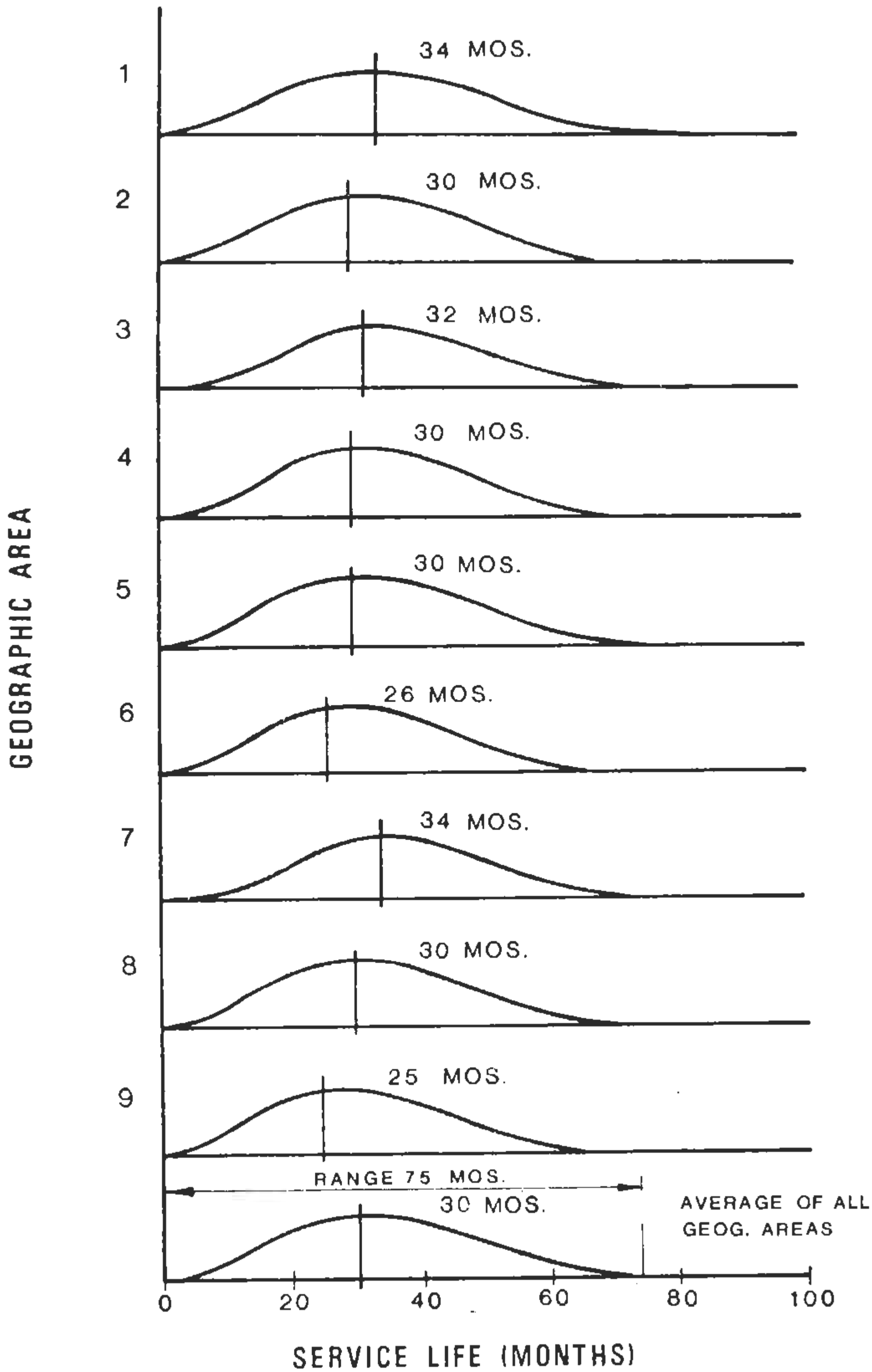


Figure IV-6

4. Thick AC Overlays (0.15 foot or thicker)

The performance of thick overlays was analyzed in four separate categories based on the following design methods.

a. Deflection Analysis Design
b. Gravel Equivalent Design
c. Subjective Judgment
d. Reflection Cracking

Thick AC overlays placed on flexible and rigid pavements were included in the investigation. The thicker overlays were intended to provide structural support necessary to yield a ten-year service life despite the initial pavement condition.

An assumption was made that thick overlays placed over flexible pavements had an initial condition of 30% or more alligator cracking.

The service life for thick overlays over flexible pavement is defined as the recurrence of either alligator cracking and/or patching over 30% of the area.

a. Deflection Analysis Design Method

Overlay thicknesses are designed on the basis of future anticipated traffic loading to add sufficient strength to prevent the pavement from deflecting beyond critical limits.

Because of the feeling that overlay thickness recommendations were excessive, a study of deflection analysis recommendations was made for the five-year period 1972-77.

Figure IV-7 indicates the number of lane miles of each recommended thickness or treatment. It shows that a weighted average of 0.20 foot thickness resulted from all studies. Only about 11 percent of the total resulted in thicknesses greater than 0.35 feet. The results of the study indicate excessive thickness is not being recommended.

Deflection studies do not normally result in a recommendation of a uniform overlay thickness throughout a project. The overlay thickness will vary depending upon the residual strength of existing pavement and projected traffic load repetitions.

Overlay designs using the deflection analysis method were to provide a ten-year service life. A review of projects designed by this method indicates a mean service life of 129 months is attained with a range of 88 to 170 months as shown on Figure IV-8. This exceeds the planned service life criteria.

It is recommended that deflection measurements not be obtained for general inventory purposes. Pavement deflection measurements are best utilized on a timely basis (one year prior to overlay construction) for specific projects.

PAVEMENT DEFLECTION STUDIES
FIVE YEAR HISTORY (1972-1977)

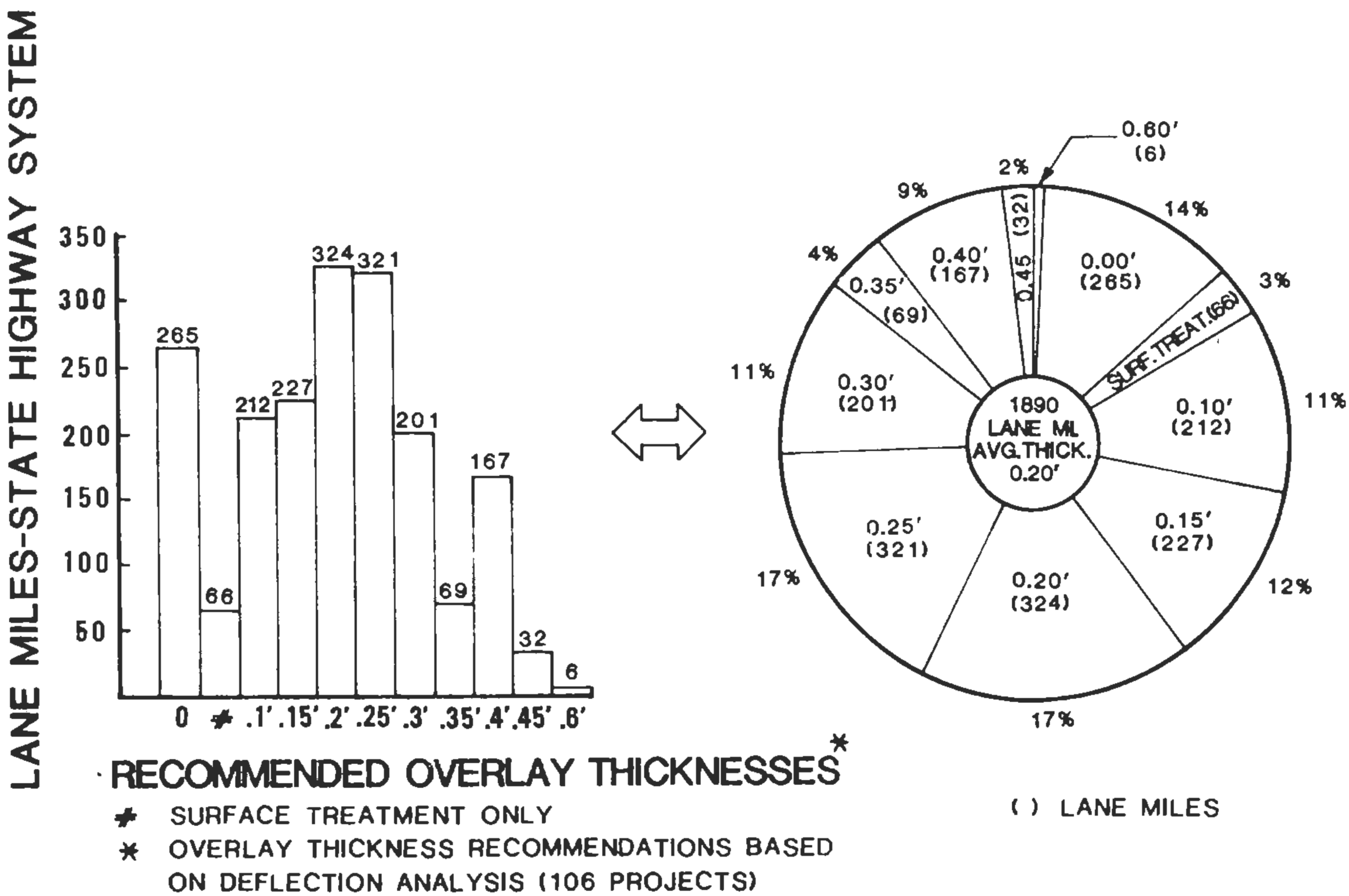
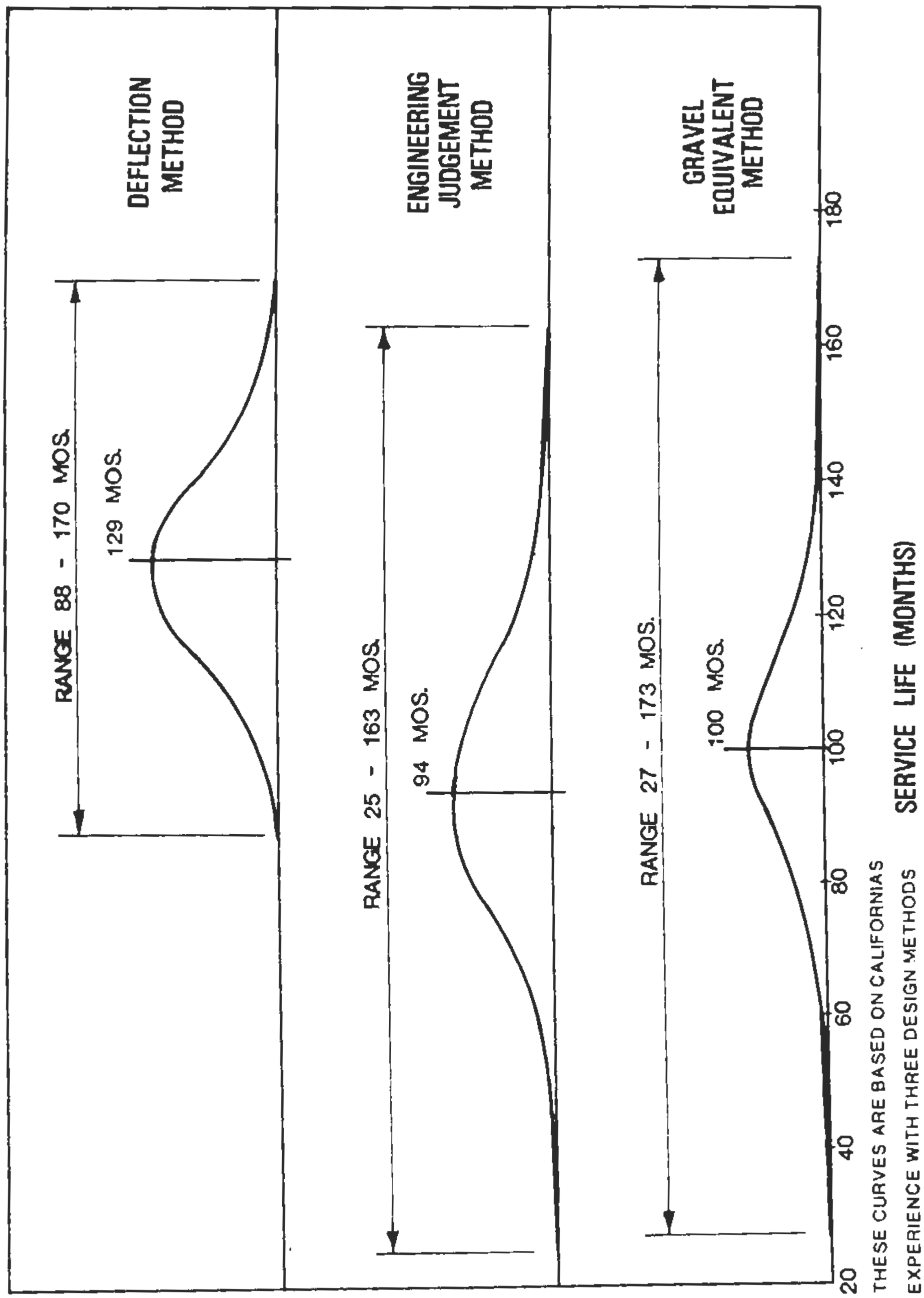


Figure IV-7

CRACK CORRECTION SERVICE LIFE

STRUCTURAL OVERLAYS



* THESE CURVES ARE BASED ON CALIFORNIAS EXPERIENCE WITH THREE DESIGN METHODS FOR STRUCTURAL OVERLAYS OVER FLEXIBLE PAVEMENT.

Figure IV-8

b. Gravel Equivalent Design Method

An overlay thickness is derived from the difference between a gravel equivalent required for a new design and a gravel equivalent determined from the existing structural section.

This design requires the engineer to make a subjective assessment of in-place pavement conditions. An overlay is designed based on predicted future traffic and assumed in-place strength of the existing roadway. This procedure does not truly evaluate the load carrying capacity of the existing pavement.

The performance model indicates that rehabilitation based on gravel equivalent methods attain a mean service life of 100 months with a range of 27 to 173 months (See Figure IV-8). This falls short of the planned ten-year service life target.

When vertical grade controls prohibit the use of a thick overlay or cost effectiveness indicates a composite overlay, reworking the existing structural section, or recycling to be a more economical design, the gravel equivalent method is the only appropriate method to utilize. This method is also of value in investigating instances of premature structural failure.

The FHWA uses the "AASHTO Interim Design Guide" method as an independent check for overlay thickness requirements on federal-aid projects. The required overlay thickness is found by subtracting the existing pavement thickness from the total thickness required by a new design analysis after subjectively assigning layer strength coefficient values for the existing pavement. No physical tests are performed to determine layer coefficients.

This procedure is quite similar to the gravel equivalent method. Basically, the only difference is the nomenclature used to identify the corresponding factors. For example, it is necessary to convert California "R" value to "soil support" value and California's "gravel equivalent" to "structural number".

c. Engineering Judgment Method

Overlay thickness is based on engineering judgments of successful techniques on other pavements with similar conditions, or on financial constraints.

The projects used in this study include all overlays not constructed in accordance with recommendations from deflection analysis design, gravel equivalent design, or reflection cracking criteria.

Overlays based on engineering judgment designs attain a mean service life of 94 months with a range of 25 to 163 months as shown on Figure IV-8. This is less than the planned ten-year service life.

Subjective judgment is the only practical method to address correction of pavement problems such as ravel, low skid resistance, poor surface texture, non-load associated hairline cracking, or ride roughness, when these problems are not accompanied by load associated cracking or block cracking. Flexible pavement overlays based on subjective judgement should be limited to less than 0.10 foot in thickness and used only if expected to provide a minimum five-year service life.

d. Reflection Cracking Method

Reflection cracking is the reappearance of any cracks reflecting from an underlying pavement through a subsequent overlay.

Various overlay thicknesses have been placed, and many experimental fabrics or other materials have been used in efforts to control reflection cracking. Long-range service has not yet been experienced with the latest generation of experimental materials. "Nonreinforced" overlays provide as long a service life as any other materials of equivalent cost tested for reflection cracking control.

General practice, based on experience in California, applies the following minimum overlay thickness to control reflection cracking.

AC pavement over untreated base: One-half the existing AC thickness.
PCC pavement or AC pavement over cement treated base: 0.30 foot minimum.

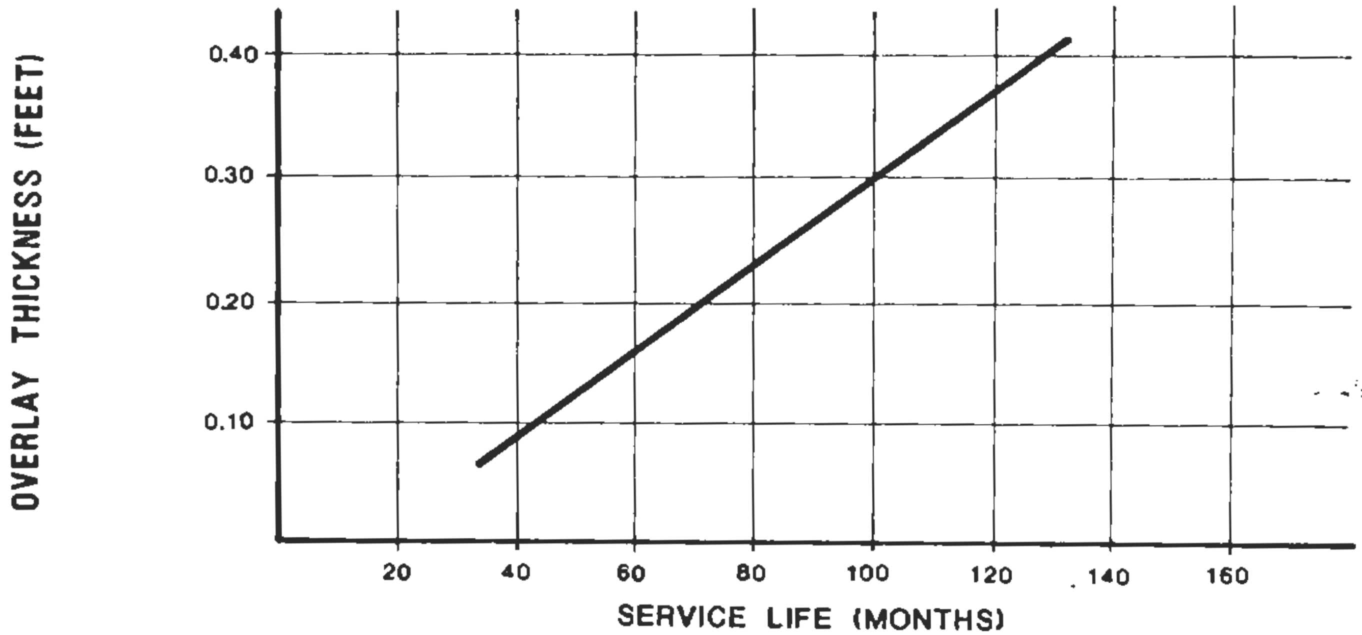
There is insufficient California data to determine the service life of flexible pavement overlays to control reflective cracking.

The service life of thick overlays placed on rigid pavement is defined as the time when more than five transverse cracks or joints per station appear in the overlay. The great variation in performance of these overlays can be explained by their variable thickness.

The current study indicates the service life of reflection cracking overlays over rigid pavement averages 88 months with a range of 5 to 171 months as shown in Figure IV-9.

CRACK CORRECTION SERVICE LIFE
THICK OVERLAYS AC OVER PCC

> 5 TRANSVERSE CRACKS



SERVICE LIFE REFLECTION CRACKING OVERLAYS

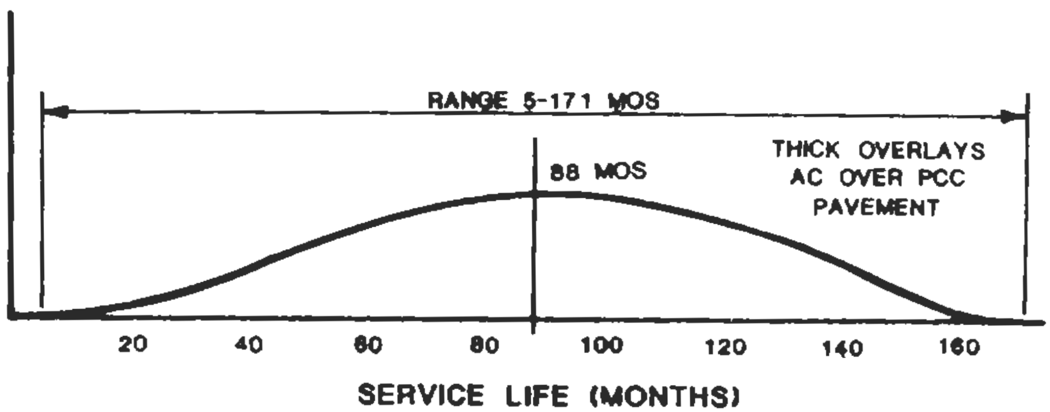


Figure IV-9

5. Findings

Although sand and rock seals may do well for non-crack related pavement repair, they provide a short-lived solution for preventing surface intrusion of water on cracked pavement.

Rock and Sand Seals used for correcting cracking problems are yielding a service life of only one to four years.

Thin blanket overlays are not always being placed where they provide cost-effective rehabilitation.

The mean service life of a one-inch AC overlay is only 30 months before the original cracking condition recurs. Thin blanket overlays should not be used to correct cracking unless warranted by engineering structural analysis, or unless engineering judgment indicates a temporary solution because of time, financial, or other constraints is adequate.

The increased service life and superior predictability of deflection analysis designed overlays indicates this method is superior to either the gravel equivalent or engineering judgment methods. Deflection study field work costs about $1,000 per day (1977 base). On-site production averages 10 lane miles per day. Travel time to remote locations would add to this cost. The cost of a deflection method overlay design is in the range of 1/2 to 1 percent of project construction cost.

There is ample evidence that deflection method overlay designs have often resulted in thinner overlays than subjective judgment overlays. The resultant savings can readily amount to several hundreds of thousands of dollars annually.

This study reflects service life expectancy of current pavement rehabilitation practice. Longer service lives can be expected when rehabilitation practices are implemented in accordance with the findings of this study.

Guidelines for the design of overlays on flexible pavement are given in Figure IV-10.

GUIDELINES FOR THE DESIGN OF OVERLAYS ON FLEXIBLE PAVEMENT

PAVEMENT PROBLEM	RECOMMEND OVERLAY DESIGN METHOD			
	ENGINEERING JUDGEMENT	GRAVEL EQUIVALENT	DEFLECTION ANALYSIS (1)	REFLECTION CRACKING CONTROL (1)
NON LOAD ASSOCIATED CRACKING -- BLOCK OR SHRINKAGE CRACKING. TRANSVERSE AND/OR LONGITUDINAL CRACKING				
1. NO VERTICAL GRADE CONTROLS				X
2. WITH VERTICAL GRADE CONTROLS		X		X (2)
3. COST EFFECTIVENESS INDICATES A COMPOSITE OVERLAY, REWORKING THE EXISTING STRUCTURAL SECTION, OR RECYCLING - (USING R VALUE TEST PROCEDURE)		X		
LOAD ASSOCIATED CRACKING -- ALLIGATOR CRACKING IN THE WHEELPATHS				
1. NO VERTICAL GRADE CONTROLS			X	
2. WITH VERTICAL GRADE CONTROLS		X	X (2)	
3. COST EFFECTIVENESS INDICATES A COMPOSITE OVERLAY, REWORKING THE EXISTING STRUCTURAL SECTION, OR RECYCLING - (USING R VALUE TEST PROCEDURE)		X		
PREMATURE STRUCTURAL FAILURE - INVESTIGATION		X		
RIDE ROUGHNESS -- NOT ACCOMPANIED BY ABOVE CRACKING DEFECTS, < 0.10 FOOT PLUS REQUIRED LEVELING COURSE	X			
RAVEL, LOW SKID RESISTANCE, POOR SURFACE TEXTURE, NON LOAD ASSOCIATED HAIRLINE CRACKING ETC. NOT ACCOMPANIED BY ABOVE CRACKING (<0.10 FOOT)	X			

) WITH BOTH NON LOAD ASSOCIATED AND LOAD ASSOCIATED CRACKING, THE GREATER REQUIRED THICKNESS GOVERNS.

) APPLICABLE IF A REINFORCING FABRIC OR RUBBERIZED INTERLAYER WILL REDUCE OVERALL THICKNESS SUFFICIENTLY TO ACCOMMODATE VERTICAL GRADE CONTROLS.

Figure IV-10

C. Performance of PCC Pavements in California*

The performance of PCC (Portland cement concrete) pavements is currently under study in California. Pavement condition and historical traffic data on rigid pavements is being used to empirically relate the surface characteristics of fractured and faulted slabs to the total accumulated equivalent axle loadings (EAL's). The study findings make it possible to estimate the "remaining life" of rigid pavement sections through surveys of their surface conditions.

Findings based on this study are as follows:

- No correlation between ride score and accumulated EAL's, or ride score and lane number, could be made because of the possibility grinding or other surface maintenance had been performed during the life of the pavement.

- The correlation obtained between road meter ride scores and the faulting index**, suggest that the road meter does measure faulting and that a ride score greater than 40 indicates that faulting is becoming severe.

* For complete details of this study, see reference number 57.

** Faulting index is a number from 0 to 10 subjectively indicating the relative roughness of faulted PCC pavement. 0 is nonfaulted new pavement and 10 is very rough riding heavily faulted old pavement.

- For PCC pavements on cement treated subgrade:
  a. Moderate faulting can be expected after 1.0×10^6 EAL repetitions,
  b. Severe faulting is not expected before 1.5×10^6 EAL repetitions,
  c. On the average, severe faulting can be anticipated at approximately 2.5×10^6 EAL's.

- For PCC pavements on cement treated base:
  a. Moderate faulting can be expected after 1.0×10^6 EAL repetitions,
  b. Severe faulting is not expected before 2.0×10^6 EAL repetitions,
  c. On the average, severe faulting can be anticipated at approximately 4×10^6 EAL's.

- For a highway that has experienced 4×10^6 EAL repetitions the difference in faulting performance between CTB and CTS is about two to three years, based on 1977 traffic figures (500,000 EAL's in 1977).

- PCC pavements fail by cracking from fatigue loading.

- The failure progression of PCC pavement over cement treated subgrade and PCC pavement over cement treated base are similar, but their service lives are different.

- The strength of the cement treated layer directly under the PCC pavement has a significant effect on the fatigue life of PCC pavement.

- There is little time differential between the onset of first stage cracking and third stage cracking.

- Extent of third stage cracking or total cracking can be used to predict the relative remaining life of the pavement. Actual experienced EAL's must be known to predict remaining life in real time.

- When the total percentage of cracked slabs approaches 20 percent, severe cracking distress is likely in the near future. In California, the time span from 20 percent total cracking to severe distress is well within five years.

- The cracking failure model developed in this study proved valid in the various environmental settings tested in California representing coastal, mountain, desert and central valley climates.

D. Performance of Grinding PCC Pavements to Improve Ride Quality

There are many miles of Portland cement concrete pavements in California that have been in service for 15-20 years. Because of the condition of pumping, a step off or faulting can develop at the transverse joints over a period of time. Significantly faulted pavement produces an annoying and noisy ride that generates complaints from truckers and motorists. Faulting can result from base and shoulder erosion creating voids under some parts of the pavement and a buildup of material at other points and lead to rocking slabs due to the presence of voids under the joints. This condition eventually leads to cracking and slab breakup. There is the potential for many thousands of lane miles of PCC pavements to develop faulting followed by structural breakup as they age.

There are several strategies such as patching, mudjacking, asphalt subsealing, overlaying or grinding that have been used in an effort to correct the problem. One strategy that is being used increasingly is grinding of the pavement surface, usually limited to the outside or truck lane providing the pavement is structurally sound (limited cracking). This method can be very expensive. The price of grinding including traffic handling, and supplemental work, was $4 per square yard on recent projects. There is some question as to the long-term performance and cost effectiveness of this strategy from the standpoint of whether or not the causes, and hence continuation of faulting, has been controlled.

At best, grinding alone, without being accompanied by other strategies to correct the cause of faulting or rough ride, appears to be a questionable strategy to improve ride quality of PCC pavement since the service life of improved ride quality seems to be highly variable. This may be due to a lack of sufficient performance data, or other variables.

It has been observed on some projects where grinding alone has been done that the slabs continue to rock under traffic loads. This can be attributed to the presence of voids under the slabs resulting from pumping and/or curling, caused by thermal stresses. Voids could possibly be filled by subsealing or mudjacking prior to grinding. The continued movement of these slabs will probably lead to a short service life and the likelihood of rapid slab breakup. On projects where rocking slabs are encountered, alternate repair strategies could be more effective.

There are other strategies to improve the ride quality of PCC pavement or eliminate faulting that should be tested and evaluated. These include thin PCC overlays (subsealed where badly cracked), subsealing combined with grinding, underdrains, epoxy overlays, overlays combined with pavement reinforcing fabric, and others. These strategies could prove to be more cost effective than either grinding or thick overlays.

On the basis of present data, it appears that a minimum of 4 years of improved ride quality can be expected before the ride score increases to a value equal to or greater than it was prior to grinding. However only one grinding of the pavement surface may be possible since removal of another 0.5 inch of Portland cement concrete could decrease the concrete thickness to a point where the structural strength of the concrete is affected and the slabs could fail due to loading.

Even though AC overlays are 2 to 4 times more expensive than grinding they may be more cost effective since they may last a proportionately longer period of time. It is estimated that a .30-.35' AC (minimum required to minimize reflection cracking) overlay may perform satisfactorily for 10 years. The asphalt concrete overlay has the potential of being recycled when deteriorated, providing another 10 or more years of service. This could become very advantageous in the future as our natural resources diminish or the cost of bituminous material increases significantly.

The performance of grinding rigid pavement to improve ride quality, as experienced in several projects, is shown in Figures IV-11a to IV-11h.

RELATIONSHIP OF GRINDING TO RIDE SCORE

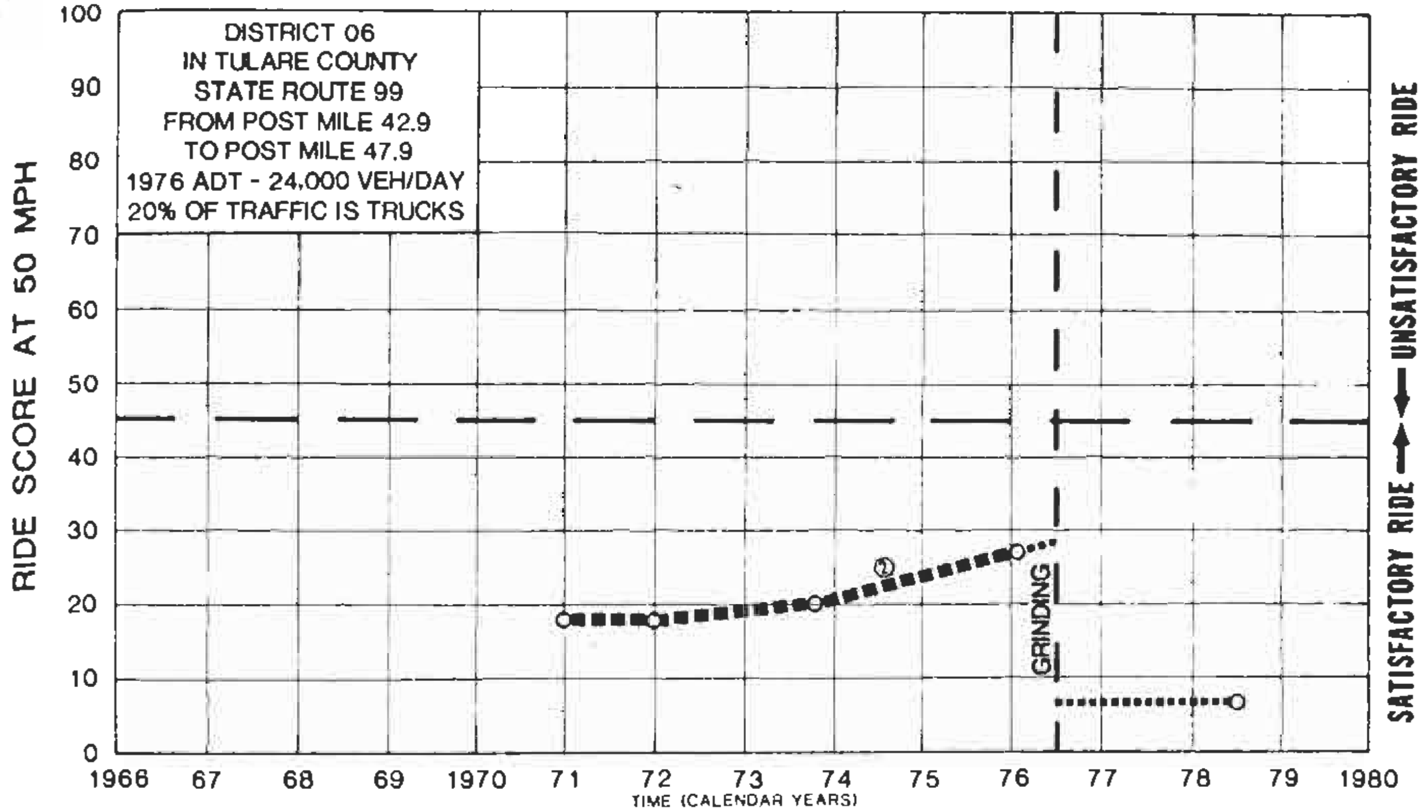
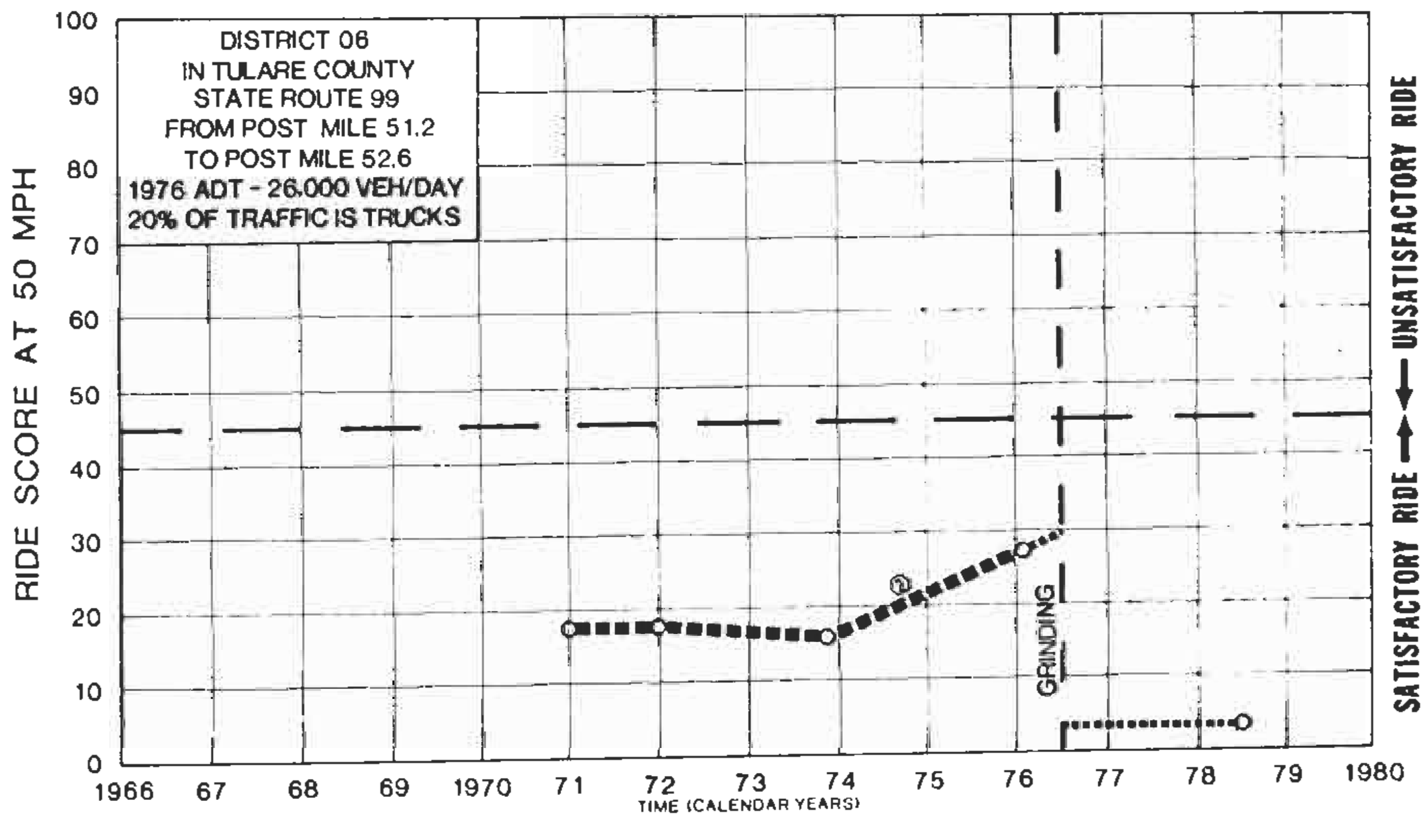


Figure IV-11a



LEGEND:
○ = MEASURED RIDE SCORES
■■■▪▪▪ = LEFT LANES IN DIRECTION OF ASCENDING POST MILES (■■■ INTERPOLATED ; ▪▪▪ ESTIMATED)
◆◆◆•••• = RIGHT LANES IN DIRECTION OF ASCENDING POST MILES (◆◆◆ INTERPOLATED ; •••• ESTIMATED)
①,②,···ⓝ = LANE NO. ① INNERMOST, ⓝ OUTERMOST

Figure IV-11b

RELATIONSHIP OF GRINDING TO RIDE SCORE

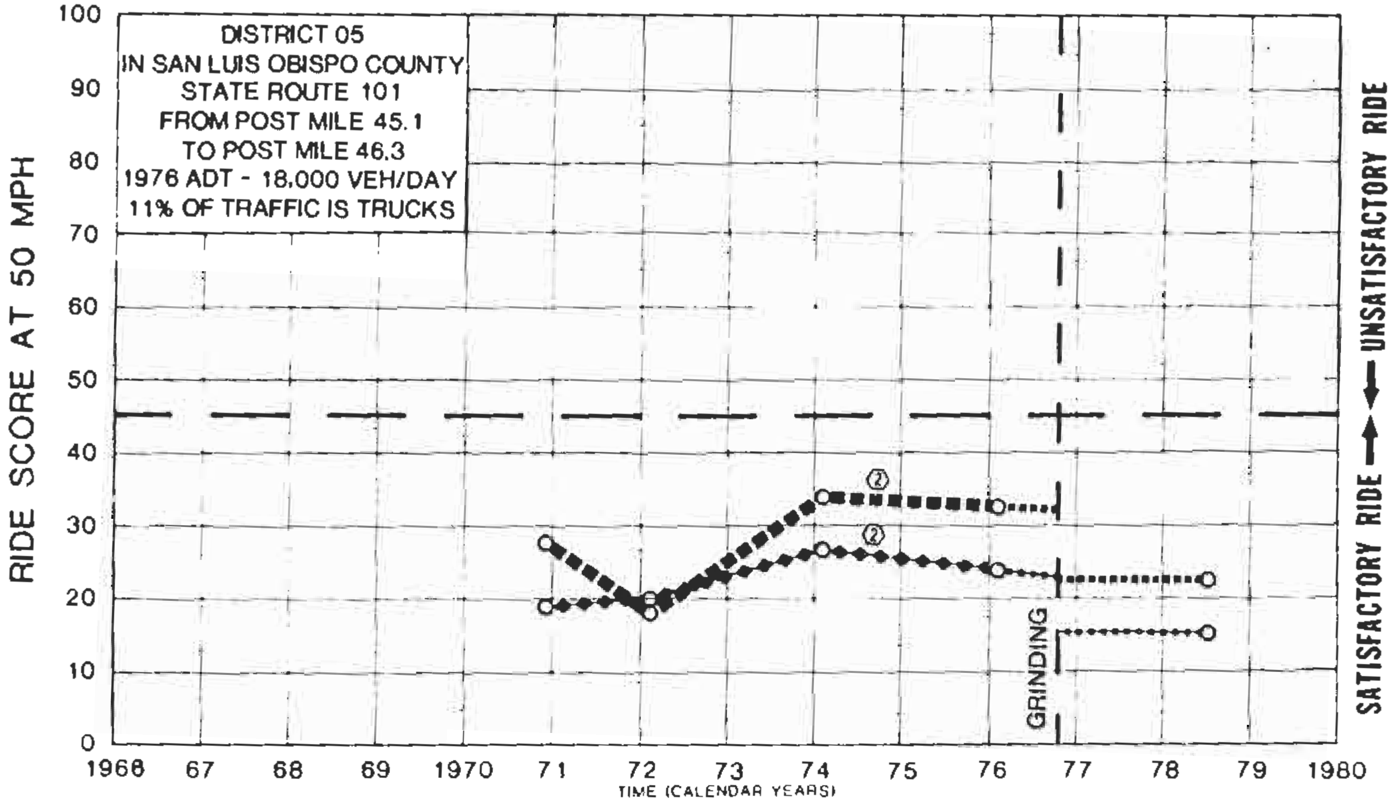


Figure IV-11c

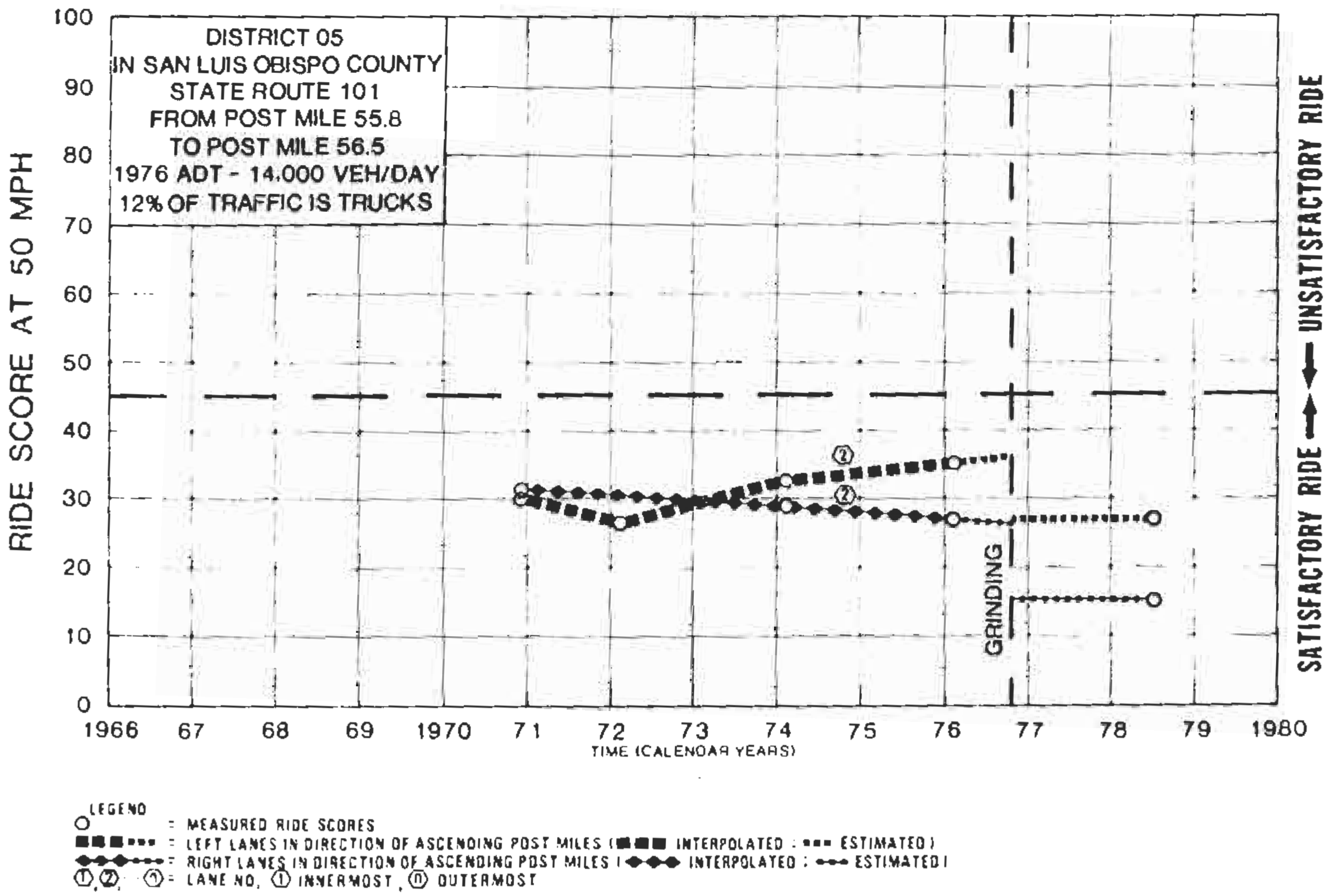


Figure IV-11d

RELATIONSHIP OF GRINDING TO RIDE SCORE

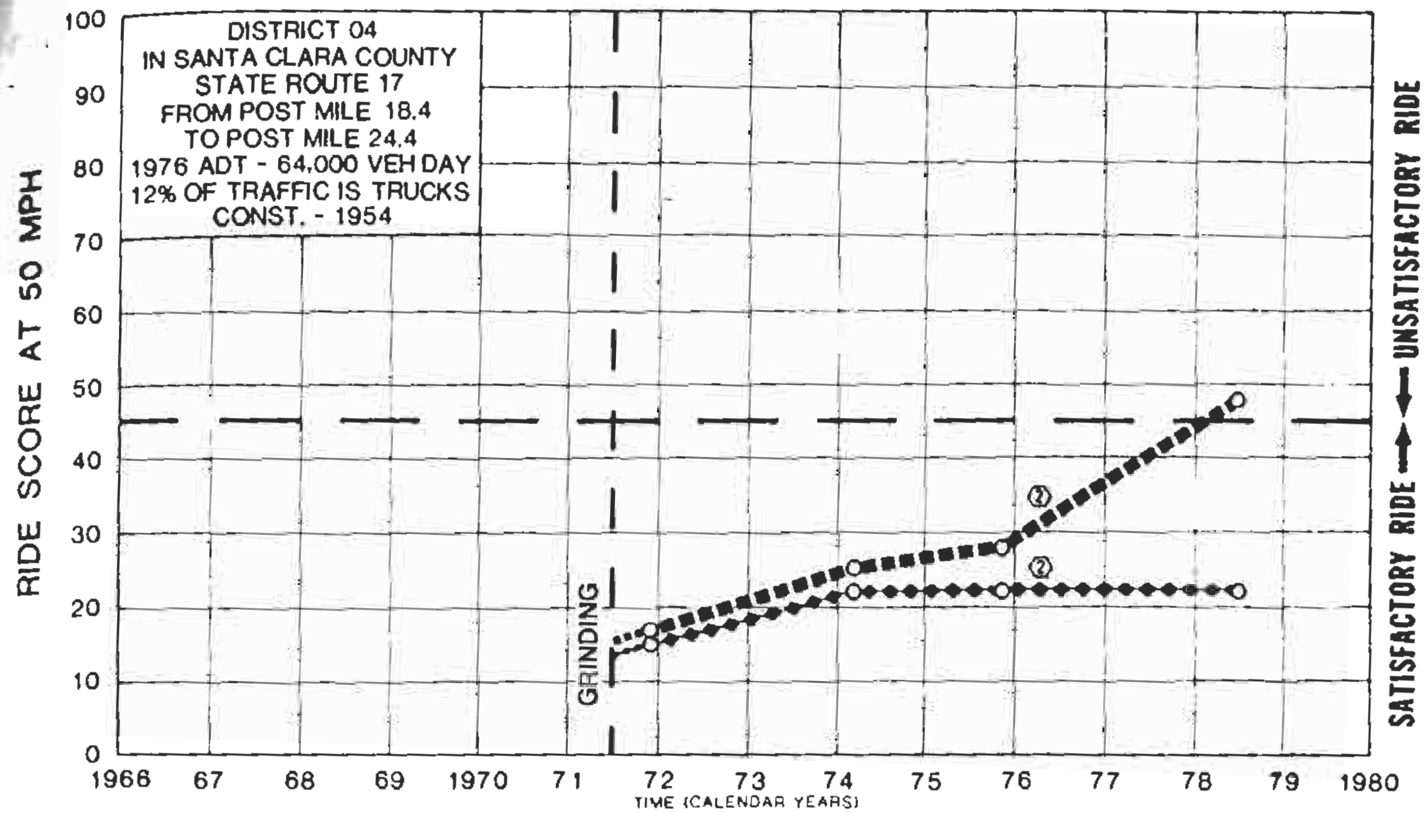


Figure IV-11e

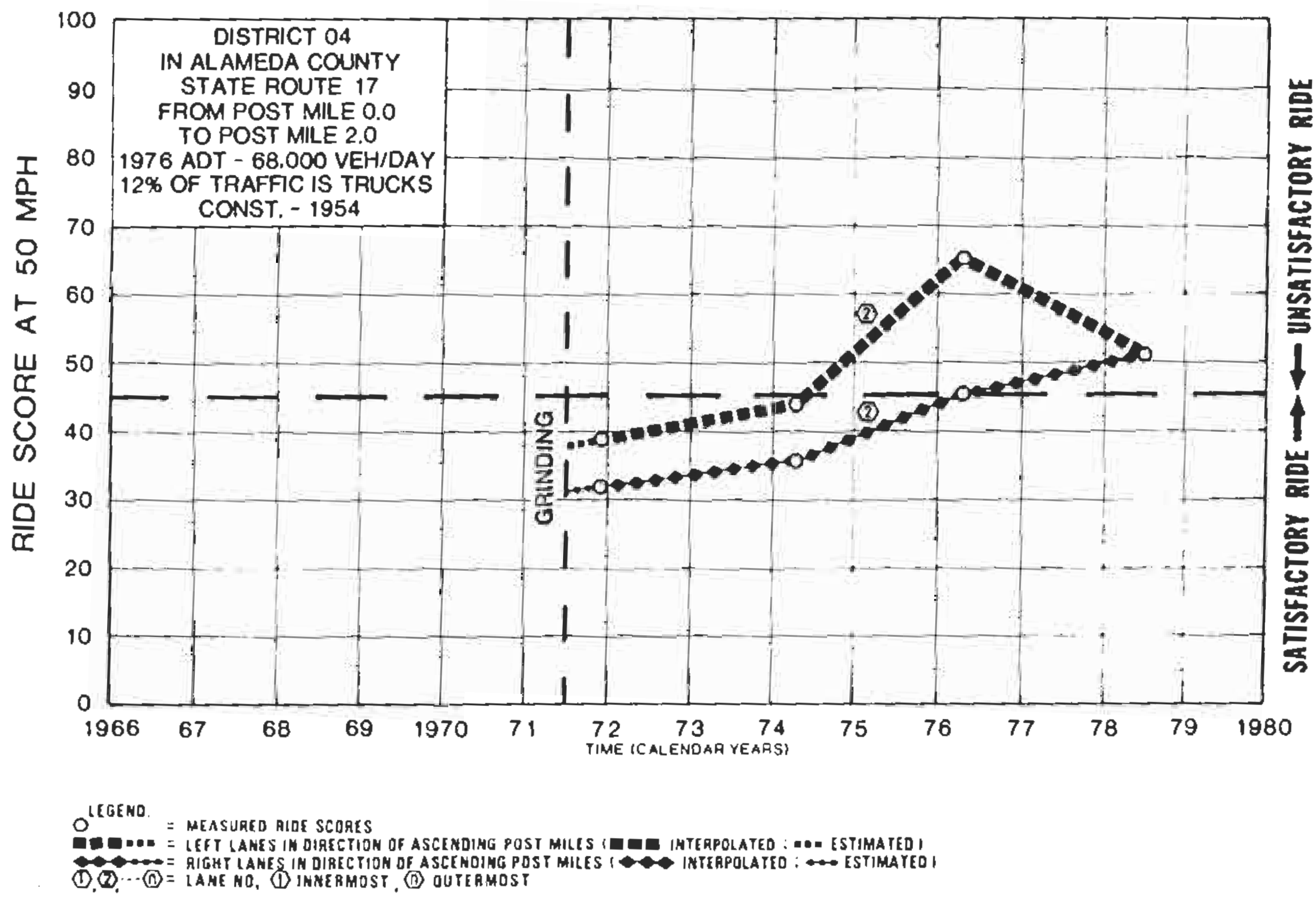


Figure IV-11f

RELATIONSHIP OF GRINDING TO RIDE SCORE

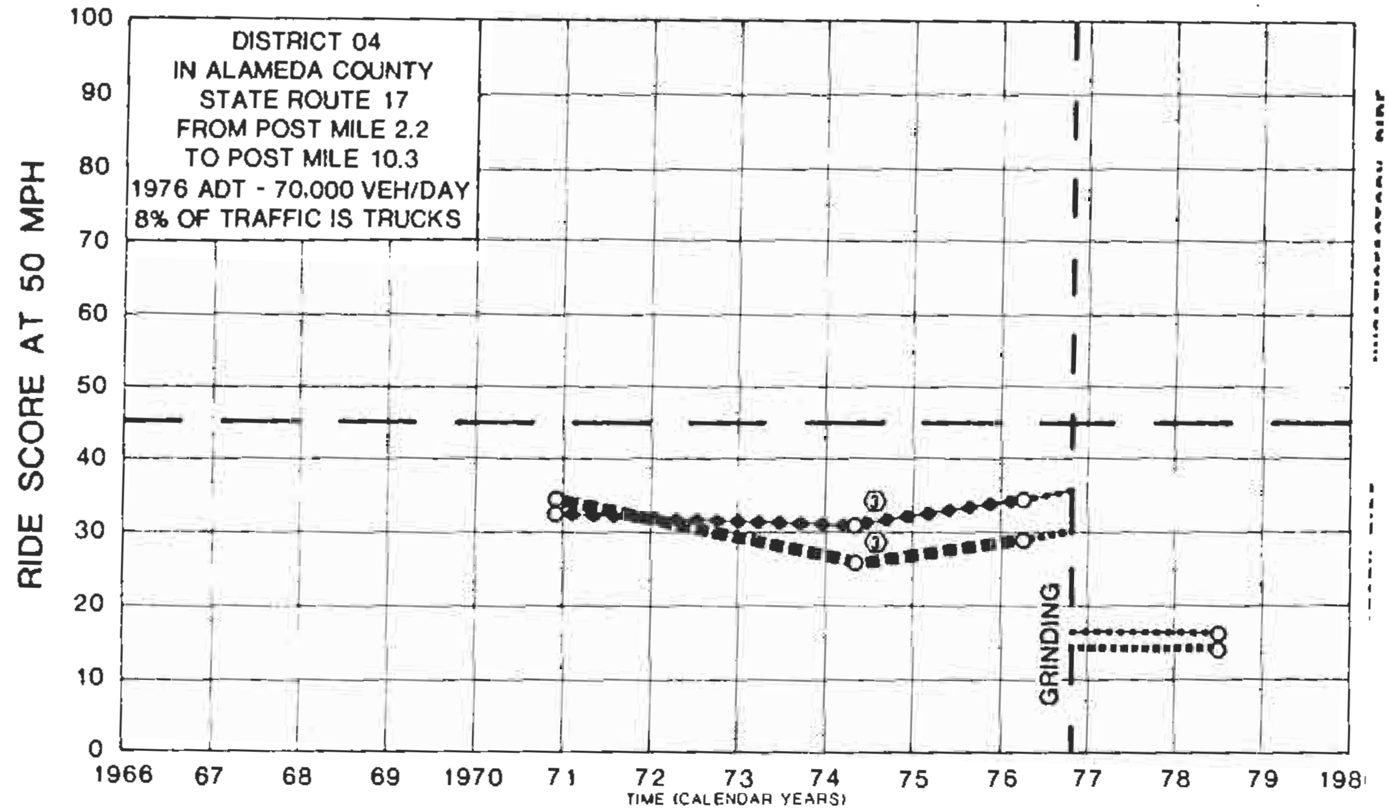
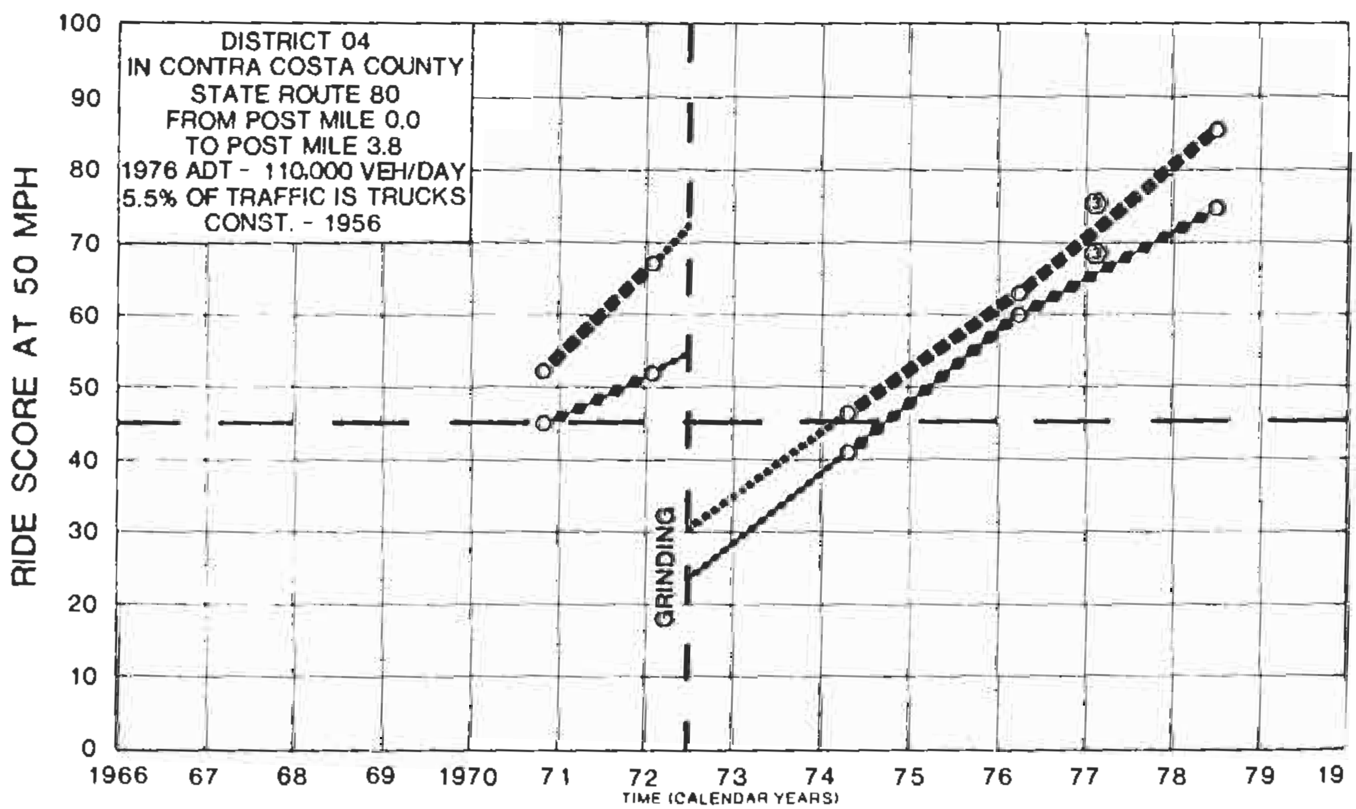


Figure IV-11g



LEGEND
○ = MEASURED RIDE SCORES
■■■▪▪▪ = LEFT LANES IN DIRECTION OF ASCENDING POST MILES (■■■ INTERPOLATED ; ▪▪▪ ESTIMATED)
◆◆◆•••• = RIGHT LANES IN DIRECTION OF ASCENDING POST MILES (◆◆◆ INTERPOLATED ; •••• ESTIMATED)
①,②,···ⓝ = LANE NO. ① INNERMOST , ⓝ OUTERMOST

Figure IV-11h

V. Cost Considerations

A. Repair Strategy Cost Models

1. Usage

The Pavement Management System (PMS) generates for each district a listing of problem pavement locations, the indicated dominant repair strategies, strategy service lifes, and PMS estimated project cost (see Section VII of this report). Lists are reviewed to determine if other planned work conflicts with or supersedes the indicated PMS project. The district selects the appropriate solution among alternatives based on field review, funding constraints, or level of service and adjusts the cost estimate if warranted. PMS cost estimates are used for program level deliberations until superseded by district estimates.

Pavement Management System cost estimates are used for:

- Making cost effectiveness comparisons among repair strategies.

- Determining repair costs for all districts.

- Determining relative pavement repair program mix between routine maintenance, major maintenance, resurfacing, and reconstruction.

- Determining appropriate statewide funding level for maintenance, resurfacing, reconstruction, and other pavement repair programs.

2. Cost Data

The Pavement Management System produces project level cost estimates sufficiently accurate for statewide pavement management decision making. More specific and detailed district estimates are required in order to be sufficiently accurate for "project level" decisions such as project budgeting and contract advertising. The latter are not a part of California's PMS.

Contract Cost Data, Maintenance Management System Cost Data, and engineering judgement were used to develop a computer cost file.

"Contract Cost Data" is published annually. It contains contract item average bid prices by district and statewide. Quite commonly, average prices are not available for all districts. Bid prices recorded vary greatly between districts. Figure V-1 shows the price range and variance of asphalt concrete within districts and statewide. Because of the large range in values these figures require some engineering judgement to develop average prices.

The Maintenance Management System contains unit costs for maintenance program activities by district and statewide. Costs are highly variable among districts. This cost data has the same limitations as "Contract Cost Data", but can be similarly used for PMS.

District staff estimates are the most accurate available. They reflect local knowledge of factors that influence contract prices or maintenance costs. These estimates are

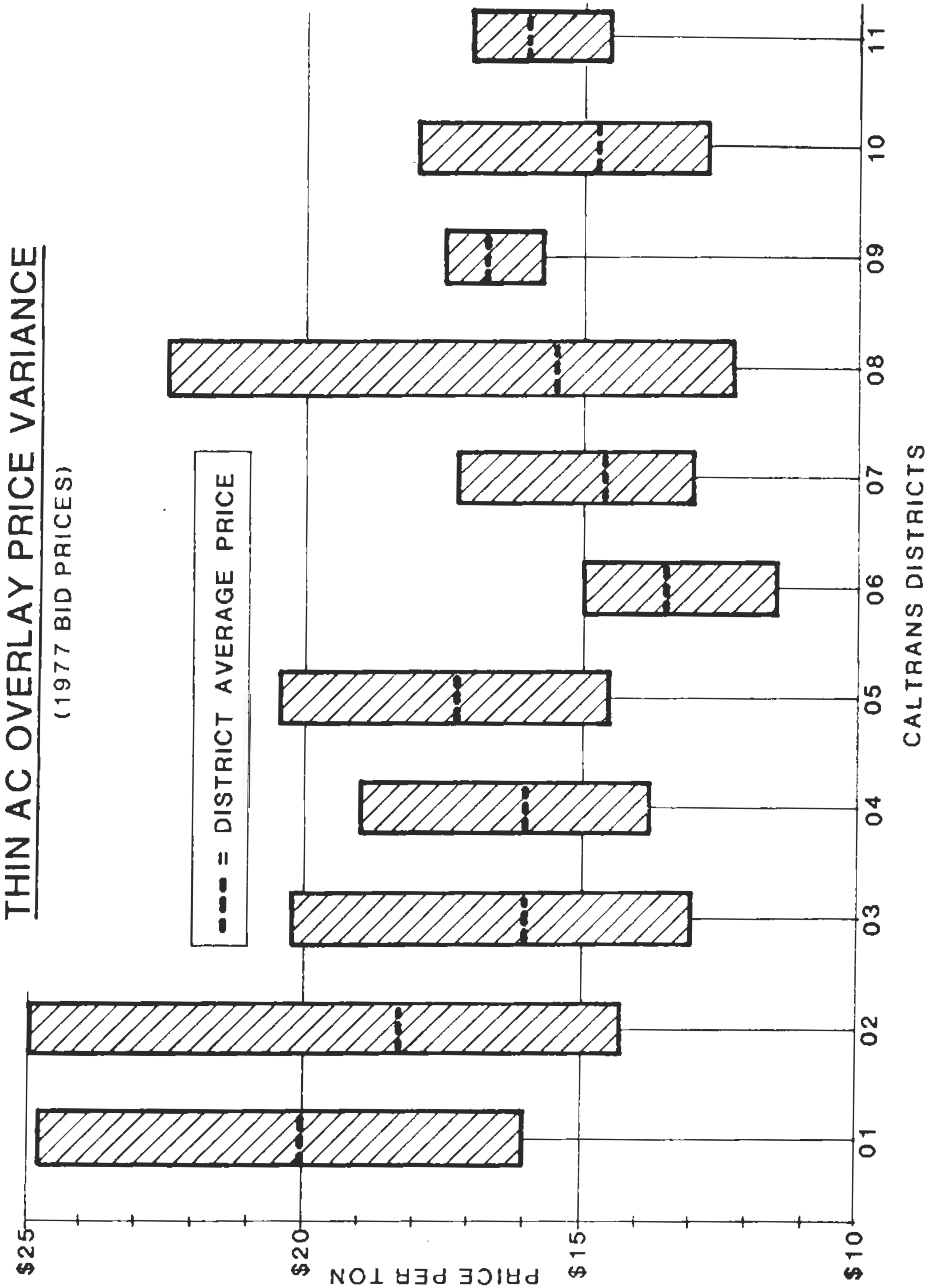

THIN AC OVERLAY PRICE VARIANCE
(1977 BID PRICES)
= DISTRICT AVERAGE PRICE
$25
$20
$15
$10
PRICE PER TON
01
02
03
04
05
06
07
08
09
10
11
CALTRANS DISTRICTS

Figure V-1

suitable for all functions. District staff cost estimates cannot be feasibly made for all projects triggered by the PMS. They will be utilized to supercede the PMS estimates when available.

In comparison to new construction, there is a paucity of cost data for pavement repair and reconstruction work. In order to produce realistic and current cost estimates, the PMS estimates are compared to actual contract costs and the computer price factors adjusted on a periodic basis.

A special cost data base has been developed, comprised of average costs per lane mile of all repair strategies, so that cost estimates are based on current repair work prices.

3. Assumptions for Cost Estimates

Project cost accuracy is significantly influenced by road width, specific repair strategy or thickness, and unit cost factors.

Road width is non-standard and varies considerably within road types. Two-lane roads vary from 20 feet to 40 feet or more depending on shoulder width and channelization. Multi-lane roads also vary substantially, but to a lesser degree. The PMS data base contains the number of lanes, but no shoulder width information. Changes in standards over the years and a variety of geometric configurations within the same road category have resulted in a wide variation in width of existing shoulders. More accurate data concerning shoulder widths is available, but it is not felt that the marginally improved accuracy warrants the computer program interface required with other data systems. For these reasons, average width assumptions are made for two-lane, multilane, and freeway shoulders.

In those cases where the pavement evaluation system indicates a dominant PMS repair strategy with alternatives of an overlay or lane reconstruction, the overlay strategy is used to provide the basis for the PMS cost estimate.

Following are some of the most significant assumptions in developing the cost formulae:

a. A 0.20' AC overlay is assumed when the flexible pavement evaluation system indicates a structural analysis overlay solution. This is the statewide average thickness recommendation by the California Transportation Laboratory based on deflection analyses conducted over the last 10 years.

b. A rubberized asphalt chip seal coat is assumed when the flexible pavement evaluation system indicates a reflection crack analysis solution.

c. Grind slabs, subseal and installation of edge drains is assumed when the rigid pavement evaluation process indicates "correct the cause of bad ride".

d. A 0.30', 0.40' or 0.50' AC overlay is assumed when the Rigid Pavement Traveled Way Evaluation systems indicates an overlay solution. The AC thickness assumed is dependent on the degree of 3rd stage crack spalling, Nominal (N), Moderate (M) or Severe (S).

PMS cost studies do not incorporate user costs. Project development sufficiently considers user delay cost in plan and specification preparation. Nebulous user costs should not be allowed to unduly influence selection of the appropriate repair strategy.

4. Cost Formulae

Each leg of the pavement condition evaluation decision-trees identifying a repair strategy has a separately identified cost formula. This was done in order to simplify the process of making changes in the computer program (even though some formulas have identical form). The formulas are given for rigid pavement on Figure V-2a and V-2b and for flexible pavement in Figure V-3.

There are provisions for geographical variances in costs (factor G_g) which can provide a factor for each of the eleven districts and a statewide average. The cost formulae also include a traffic handling factor for 2-lane, multilane, or freeway facilities.

COST FORMULAE FOR PMS USE
RIGID PAVEMENT (TRAVELED WAY) *

REPAIR STRATEGY	2 LANE FACILITY COST	MULTILANE FACILITY COST	FREEWAY FACILITY COST
AC OVERLAY AND EDGE DRAINS	$(L)(G_z)(T2)\left[(N+0.67)\left(\frac{\text{DN or DM or DS}}{0.10}\right)(CR)+2(CG3)\right]$	$(L)(G_z)(TM)\left[(N+1.33)\left(\frac{\text{DN or DM or DS}}{0.10}\right)(CR)+2(CG3)\right]$	$(L)(G_z)(TF)\left[(N+2.33)\left(\frac{\text{DN or DM or DS}}{0.10}\right)(CR)+2(CG3)\right]$
GRIND SLABS, SUBSEAL, EDGE DRAINS	$(L)(G_z)(T2) \times \left[(n \text{ WHERE RIDE} \geq 45)(CG1+CG2)+2(CG3)\right]$	$(L)(G_z)(TM) \times \left[(n \text{ WHERE RIDE} \geq 45)(CG1+CG2)+2(CG3)\right]$	$(L)(G_z)(TF) \times \left[(n \text{ WHERE RIDE} \geq 45)(CG1+CG2)+2(CG3)\right]$
REPLACE RANDOM SLABS	$(L)\left(\frac{\Sigma \text{ 3rd STAGE CRACKING} < 10\% \text{ "S" SPALL}}{100}\right) \times (CJ)(G_z)(T2)$	$(L)\left(\frac{\Sigma \text{ 3rd STAGE CRACKING} < 10\% \text{ "S" SPALL}}{100}\right) \times (CJ)(G_z)(TM)$	$(L)\left(\frac{\Sigma \text{ 3rd STAGE CRACKING} < 10\% \text{ "S" SPALL}}{100}\right) \times (CJ)(G_z)(TF)$

L=PROJECT LENGTH IN MILES
N=TOTAL NUMBER OF LANES
n=NUMBER OF LANES TRIGGERED
NOTE: FOR OTHER FACTORS IN THE FORMULAS, REFER TO PAGES 100 AND 101

*WHERE PAVEMENT STRATEGIES DICTATE OVERLAY ON SHOULDERS, AVERAGE SHOULDER WIDTHS ARE ASSUMED.

Figure V-2a

COST FORMULAE FOR PMS USE
RIGID PAVEMENT (SHOULDERS)

REPAIR STRATEGY	2 LANE FACILITY COST	MULTILANE FACILITY COST	FREEWAY FACILITY COST
RECONSTRUCT	$(L)(G_z)(CP)(T2)(1/2)$	$(L)(G_z)(CP)(TM)$	$(L)(G_z)(CP)(TF)$
FILL JOINTS, CRACKS AND AC OVERLAY	$(L)(G_z)(T2)[(CX)+(CY)+(0.33)(CW)]$	$(L)(G_z)(TM)[(CX)+(CY)+(0.67)(CW)]$	$(L)(G_z)(TF)[(CX)+(CY)+(0.67)(CW)]$
TRIM, FILL JOINTS, CRACKS AND SEAL COAT	$(L)(G_z)(T2)[(CT)+(CX)+(CY)+(0.33)(CS)]$	$(L)(G_z)(TM)[(CT)+(CX)+(CY)+(0.67)(CS)]$	$(L)(G_z)(TF)[(CT)+(CX)+(CY)+(0.67)(CS)]$
FILL JOINTS, CRACKS AND STRIP PATCH	$(L)(G_z)(T2)[(CX)+(CY)+(CV)]$	$(L)(G_z)(TM)[(CX)+(CY)+(CV)]$	$(L)(G_z)(TF)[(CX)+(CY)+(CV)]$
FILL JOINTS	$(L)(G_z)(T2)(CX)$	$(L)(G_z)(TM)(CX)$	$(L)(G_z)(TF)(CX)$

L=PROJECT LENGTH IN MILES
N=TOTAL NUMBER OF LANES
NOTE: FOR OTHER FACTORS IN THE FORMULAS, REFER TO PAGES 100 AND 101

Figure V-2b

COST FORMULAE FOR PMS USE

FLEXIBLE PAVEMENT (INCLUDING SHOULDERS)

REPAIR STRATEGY	2 LANE FACILITY COST	MULTILANE FACILITY COST	FREEWAY FACILITY COST
STRUCTURAL ANALYSIS	$(L)(N+0.67)\left(\frac{DA}{0.10}\right)(CA)(G_z)(T2)$	$(L)(N+1.33)\left(\frac{DA}{0.10}\right)(CA)(G_z)(TM)$	$(L)(N+2.33)\left(\frac{DA}{0.10}\right)(CA)(G_z)(TF)$
THIN OVERLAY AND LOCAL DIGOUTS	$(L)(N+0.67)(CJ)(G_z)(T2)$ + $(L)(N)(0.10)(CE)(G_z)(T2)$	$(L)(N+1.33)(CJ)(G_z)(TM)$ + $(L)(N)(0.10)(CE)(G_z)(TM)$	$(L)(N+2.33)(CJ)(G_z)(TF)$ + $(L)(N)(0.10)(CE)(G_z)(TF)$
THIN OVERLAY AND LEVELING *	$(L)(N+0.67)(F2)(CJ)(G_z)(T2)$	$(L)(N+1.33)(FM)(CJ)(G_z)(TM)$	$(L)(N+2.33)(FF)(CJ)(G_z)(TF)$
REFLECTION CRACKING ANALYSIS	$(L)(n)(CK)(G_z)(T2)$	$(L)(n)(CK)(G_z)(TM)$	$(L)(n)(CK)(G_z)(TF)$
BASE REPAIR AND PATCH	$(L)(0.75)\left(\frac{\Sigma \text{"B" CRACKING}}{100}\right)(CE)(G_z)(T2)$	$(L)(0.75)\left(\frac{\Sigma \text{"B" CRACKING}}{100}\right)(CE)(G_z)(TM)$	$(L)(0.75)\left(\frac{\Sigma \text{"B" CRACKING}}{100}\right)(CE)(G_z)(TF)$
MAINTENANCE OVERLAY *	$(L)(N+0.87)(0.75CJ)(G_z)(T2)$	$(L)(N+1.33)(0.75CJ)(G_z)(TM)$	$(L)(N+2.33)(0.75CJ)(G_z)(TF)$
SEAL COAT	$(L)(n)(CL)(G_z)(T2)$	$(L)(n)(CL)(G_z)(TM)$	$(L)(n)(CL)(G_z)(TF)$

L = PROJECT LENGTH IN MILES

N = TOTAL NUMBER OF LANES

n = NUMBER OF LANES TRIGGERED

NOTE: FOR OTHER FACTORS IN THE FORMULAS, REFER TO PAGES 100 AND 101

* WHERE PAVEMENT STRATEGIES DICTATE OVERLAY ON SHOULDERS. AVERAGE SHOULDER WIDTHS ARE ASSUMED

Figure V-3

Cost factors, overlay thickness assumptions, traffic handling factors etc. although handled as constants are "tabled" in the computer system and can be changed with ease in the light of new or more accurate information or for the purposes of simulation studies.

Following is a description of the factors used in the PMS cost equations:

a. Geographic factor

$G_g = G_1, G_2$ ----- G_{13}. Used to provide for geographical cost variances for each district. G_{13} is the statewide average and will equal 1.00. District factors can vary above or below the statewide average.

b. Traffic Handling factor

	Present Value
T2 = two-lane facilities	1.25
TM = multilane facilities	1.15
TF = freeway facilities	1.15

c. Flexible Pavement Repair factors

	Present Value
DA = Structural Analysis, depth of overlay	0.20'
CA = 0.10' AC Overlay	$ 12,500/Ln-mi
CJ = 0.08' Thin AC Overlay	$ 10,000/Ln-mi
CK = Reflection Cracking Analysis	$ 10,000/Ln-mi
CE = Base Repair and patch	$140,000/Ln-mi
CL = Rock Seal Coat	$ 3,000/Ln-mi
CP = Fill Cracks	$ 1,000/Ln-mi

F2 = ride leveling course factor, 2-lane facility		1.30
FM = ride leveling course factor, multilane facility		1.15
FF = ride leveling course factor, freeway facilities		1.15

d. Rigid Pavement Repair factors

Traveled Way factors:	Present Value
DN = AC Overlay depth for "N" spall	0.30'
DM = AC Overlay depth for "M" spall	0.40'
DS = AC Overlay depth for "S" spall	0.50'
CR = 0.10' AC Overlay	$ 12,500/Ln-mi
CJ = Replace random slabs	$175,000/Ln-mi
CG1 = Grind slabs	$ 20,000/Ln-mi
CG2 = Subseal slabs	$ 15,000/Ln-mi
CG3 = Edge drains	$ 20,000/Ln-mi

Shoulder factors:	Present Value
CV = Strip patch	$ 700/mi
CT = Trim	$ 1,500/mi
CX = Fill joint	$ 400/mi
CP = Reconstruct	$ 30,000/mi
CY = Fill cracks	$ 400/mi
CS = Seal coat	$ 300/mi
CW = 0.08' AC Overlay	$ 10,000/mi

B. Roadbed Maintenance Cost

In evaluating alternatives for repair of a particular section of highway, a comparison should be made between pavement maintenance expenditures and the cost of a capital improvement project. This provides the decision maker or program advisor with realistic information to determine whether it is more cost effective to continue to provide routine maintenance or to proceed with a capital outlay project.

Other factors such as functional classification of highway, level of service, ride quality, public demands, financial program levels, and district minimums need to be considered along with maintenance expenditures in arriving at a decision.

In order to make this analysis, it is necessary to have reasonably accurate pavement maintenance expenditures for particular segments of highways. For this reason, California's Maintenance Management System has now incorporated the reporting of these expenditures on a post mile basis in a computer file which will be accessible to the PMS in about one year.

An additional benefit will be the ability to produce an exception report when pavement maintenance expenditures on individual highway sections show a marked increase often associated with deteriorating pavement.

In the PMS context, it is important to compare the cost of continued maintenance to the cost of rehabilitation in determining respective program levels. A detailed theoretical procedure relating age and type of pavement, structural defects, ride quality, traffic volume, environmental conditions, and other parameters and which supposedly can predict future maintenance costs and the optimum time to do a specific maintenance operation or a rehabilitation project is infeasible. The factors are too variable to provide reliable data. A simple straight forward approach that compares the past and anticipated pavement maintenance expenditures and other factors with the cost of a rehabilitation project is more realistic.

C. Cost Effectiveness Considerations

The major purpose for developing a Pavement Management System is to improve the cost effectiveness of pavement maintenance and rehabilitation expenditures. This can only be achieved by defining an acceptable level of service and then minimizing expenditures to produce that quality of service.

Because of the scope, complexity, and diversity of cost effective considerations it is impractical to incorporate an automated cost effectiveness assessment in the PMS.

Overall cost effectiveness is addressed in several phases of the management decision making process for existing pavements.

1. Determining relative program levels:

Relative program levels (i.e. Maintenance vs reconstruction, etc.) should be based on repair costs, program effectiveness and sound engineering practice. The PMS produces a summary report of repair costs by program and by geographic location in terms of District, County, Route, etc. (See Section VII of this report). The historic pavement condition inventory and past program expenditures will be evaluated over time to determine the program levels needed to match pavement deterioration rates. Other studies will address the cost effectiveness (e.g. service life extension vs cost) of resurfacing vs reconstruction. These types of cost effectiveness studies can and will be made within the scope of the pavement management system. However, they are infrequent periodic analyses that can best be addressed as special studies and need not be incorporated in the automated functions.

2. Determining relative project priorities:

The role of cost effectiveness and other considerations are presently being formulated to reflect departmental prioritizing policies.

3. Determining appropriate strategies among alternatives:

The selection of an appropriate repair strategy will be based on an evaluation of feasible alternatives. The PMS includes a research of the state of the art for pavement repair strategies (function of strategy, proper and improper applications, approximate cost and estimated service life). The evaluation of alternatives at a specific location is a function of specific engineering design which is not a component of PMS. The final strategy selection should consider site restrictions (vertical grade controls, environmental constraints, etc.), material and resource availability, traffic handling constraints, safety and appearance characteristics, as well as an evaluation of cost effectiveness of feasible alternatives. The cost effectiveness analysis should take into account the initial cost of the repair, the service life of the repair, and the time value of money (interest rate) in a conventional engineering economic analysis. The PMS will supply the majority of the needed information, but the analysis is the responsibility of the design engineer. The conclusions reached in an alternatives evaluation should be documented in requests for project concept approval and in program priority lists of projects.

4. Cost effectiveness reassessment:

New and innovative repair materials and techniques are developed from time to time. Recycling and stress relieving interlayers for overlays are some relatively recent examples. Such new techniques may be more cost effective in some instances than the old standard remedies. Market price fluctuations in aggregates, cement, asphalt and other basic materials may also change the relative cost effectiveness of strategies. Periodic reassessment of the state of the art of repair methods and techniques should be made to determine if economic conditions warrant changes in policies governing pavement maintenance, resurfacing and reconstruction. The implementation phase of PMS includes an ongoing monitoring and evaluating process to improve total program cost effectiveness.

VI. Pavement Management System Applications

A. Pavement Management System Implementation

1. Information Available

The PMS described in this report has been implemented in California to manage pavement repairs statewide. This system will enhance and support the decision making processes with meaningful information applied through a structured process that is based on sound engineering practice (See Figure VI-1).

Following is a partial listing of the types of information produced by the system:

- Meaningful pavement condition data for each lane throughout the entire state highway system.

- Measureable pavement quality levels of service.

- A structured process for evaluating pavement conditions and identifying the appropriate level of repair commensurate with the assigned level of service.

PAVEMENT MANAGEMENT SYSTEM APPLICATIONS

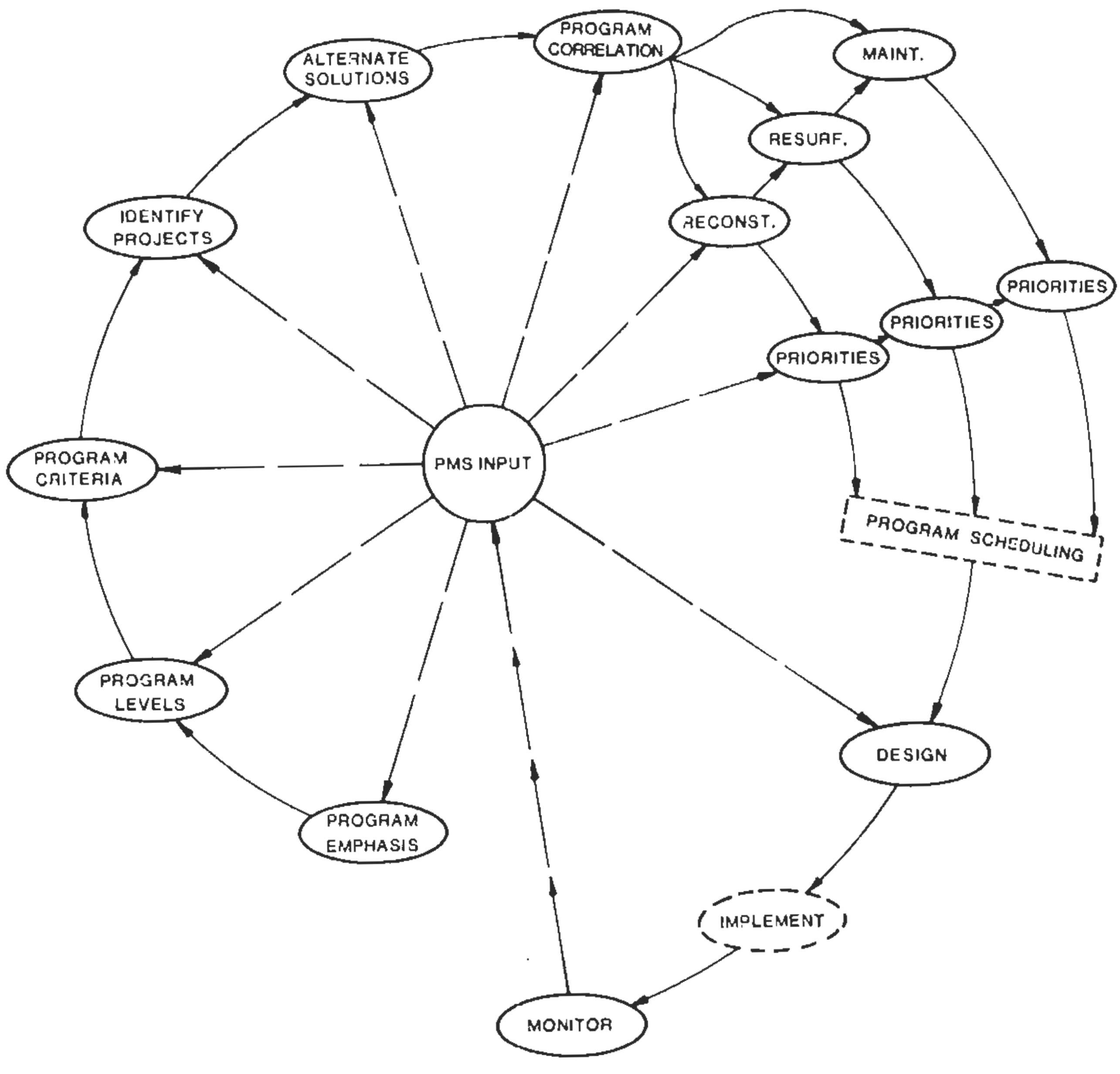


Figure VI-1

- Listings for each lane that identify all triggered problems and their corresponding repair strategies for developing alternate designs.

- State of the art type information for repair strategies (function, proper and improper application, cost and service life estimates).

- Project cost estimates for the most desirable repair solution.

- Information for determining the relative cost effectiveness of alternate solutions.

- A correlation of available repair strategies with the highway program funding structure.

- Project eligibility guidelines for the Federal R-R-R Program.

- Listings of candidate projects for each funding program component.

- Repair cost summaries for each funding program component.

- Information for prioritizing projects in each district and statewide.

2. Use by Headquarters Function

The information produced by the PMS has several applications for headquarters functions:

- Program Funding Levels.

  The PMS will provide the information to develop a periodic statewide "state of the pavement" report that will quantify the level of effort that would be required to maintain the entire state highway system at a prescribed level of service. The report will include a historic assessment of pavement conditions and evaluate the short range and longer term implications of current and alternate program funding levels. Comparisons will be made between highway system components (by functional classification and federal-aid systems) to determine if different levels of service would be appropriate and address their funding implications. The cost effectiveness of the highway program funding components will be evaluated to determine the appropriateness of each. Cost estimates of funding alternatives would be used to recommend funding level adjustments to top management. These analyses would also provide a basis for modifying program criteria to improve the over-all cost effectiveness of maintenance and rehabilitation expenditures.

- Project Priorities

  The PMS pavement condition data and other parameters will be used to define departmental prioritizing policies. A structured process reflecting those policies will be used to determine project priorities in each district and statewide. Project priorities will then be used in conjunction with legislative, fiscal and other controls to schedule improvements in the 5-year State Transportation Improvement Program.

- Administrative Communication

  PMS information will aid liaison communication between the districts, headquarters and the FHWA. It will provide a consistent basis for evaluating project proposals, setting project priorities, determining federal funding eligibility and aid in making project tradeoffs within and between districts.

3. Use by District Functions

The information produced by the PMS can be sorted and reported by district, route, county, maintenance cost center, federal-aid system and functional classification. It can also be sorted and reported by problem type, severity, repair strategy type and project cost range. This provides a wide range of applications within the districts like:

- Identifying locations where repair work should be considered.

- Identifying all problems and corresponding repair strategies for each lane of a project to aid developing project alternatives.

- Providing repair cost and service life information on alternative repair strategies for cost effectiveness evaluations.

- Correlating repair strategies and funding program components for project alternates.

- Determining project priorities within the district for each funding program component.

- Providing information to justify projects for headquarters approval.

- Providing repair cost estimates to assess maintenance, resurfacing and reconstruction costs within the district to aid distribution of discretionary funds geographically by program.

- Providing a basis for balancing discretionary funds between programs within the district.

- Providing a basis for assessing the impact on maintenance workload when resurfacing and reconstruction projects are postponed in the prioritizing and scheduling process.

4. Implementation Plan

System development is beyond the conceptual phase. The PMS computer system is complete and is presently producing user reports.

PMS findings, processes and products are being implemented as a structured decision making process. The PMS will be used throughout the project development process for Caltrans' reconstruction, resurfacing and maintenance programs. A new cycle of the annual planning, programming and budgeting process began in the fall of 1978. The following describes how PMS is implemented and integrated in the overall project development process.

- Repair strategy state of the art findings have been used to modify criteria for each program to ensure that appropriate project solutions appear in each program.

- The system has produced cost estimates for each program to correct all triggered problems. These cost estimates represent the funding required to provide a prescribed level of service. This information will be used by top management to aid in setting program funding levels for the 5-year State Transportation Improvement Program.

- Each district has been furnished the complete series of PMS user reports for their area:

  - Flexible Pavement Condition Inventory
  - Rigid Pavement Condition Inventory
  - Bridge Approach Condition Inventory
  - Candidate Projects Report

    - Reconstruction Program
    - Resurfacing Program
    - Flexible Pavement Maintenance Program
    - Rigid Pavement Maintenance Program

  - Corrective Strategies For All Triggered Lanes Report

- Guidelines have been developed for selecting candidate projects in each transportation district for each program.

- Prioritizing guidelines for each program have been developed that define Caltrans' prioritizing policies. Candidate projects for each program will be prioritized by each district. All district priority lists for each program will be aggregated into a statewide priority list by the statewide program advisor as information to aid programming and budgeting projects in the 5-year State Transportation Improvement Program.

- Instructions have been developed to assist users in accessing all information in the computer files. This includes the capability of modifying level of service trigger values to play "what if" games for special studies.

B. Pavement Management System User Reports

PMS is a management information and evaluation system to improve the pavement rehabilitation decision-making process.

A considerable effort has been made to involve users in the development of computer reports to make them responsive to district and headquarters user needs. These reports have been designed to provide a limited array of report formats, minimize the volume of information furnished, and provide maximum capability and flexibility for selecting and sorting information.

The information reported through the PMS describes pavement condition in meaningful understandable terms. It identifies where rehabilitation should be considered, indicates the appropriate level of repair, reports repair cost and expected service life, quantifies rehabilitation costs, supports program funding levels, and aids in determining program and project priorities for programming improvements.

Three basic kinds of reports have been developed to meet these information needs:

1. Pavement Condition Inventory

   Flexible pavement
   Rigid pavement
   Bridge Approach Ride Rating

2. Candidate Project Lists (Dominant Strategy)

   Resurfacing Program (HA3)
   Reconstruction Program (HA22)
   Flexible Pavement Maintenance Program (HA1101)
   Rigid Pavement Maintenance Program (HA1102)

3. Corrective Strategies For All Triggered Lanes

   All triggered problems and their appropriate repair strategies for each lane.

The format and content of each of the user reports are displayed in Figures VI-2a to VI-2f. The locations or projects listed in these reports can reflect all information in the data base, or only projects triggered by PMS levels of service criteria, or only those locations that meet the selection criteria prescribed by any user from a wide variety of available selection parameters.

PMS220-A RUN: 05/07/79
CALIFORNIA DEPARTMENT OF TRANSPORTATION
DIVISION OF MAINTENANCE
OFFICE OF HIGHWAY MAINTENANCE

PAVEMENT MANAGEMENT SYSTEM
FLEXIBLE PAVEMENT CONDITION INVENTORY
1977-78 DATA

DISTRICT: 07 ROUTE: 072 COUNTY: LA

PM 6.6 TO PM 7.0 LOCKHEED ST.-WHITTIER, TO
GREGG ROAD-PICO RIVERA.
WHITTIER CITY LIMITS PM 6.8 JUAREZ ST.
SAN GABRIEL RIVER BRIDGE PM 6.9.
PICO-RIVERA CITY LIMITS PM 6.9(E.B.)
AC OVERLAY-BADLY BROKEN UP.
ESTIMATED EVALUATION DUE TO TRAFFIC

LOG LENGTH : .4
TOTAL LANES: 4
COST CENTER: 653
SURVEY DATE: 05-78
INCHES RAIN: 10

ADT : 33,000
% TRUCKS :
FUNCTIONAL CLASS:
FEDERAL AID :
RSS :

DIR & LANE	ROADTYPE	RIDE SPEED	RIDE SCORE	SKID	PSI	ALLIGATOR CRACK TYPE A	TYPE B	TYPE C	BLOCK CRACK	TRANS CRACK	LONG CRACK	RAVEL	DRIP TRACK	RUT >3/4"	PATCH	SHLDR
L 1	CITY ST.	40 MPH	88			10%	10%		15%	4/STA 1/8"-1/4"	100'/STA 1/8"-1/4"		1 EA		80% POOR	
L 2	CITY ST.		33			15%	15%		15%	4/STA 1/8"-1/4"	100'/STA 1/8"-1/4"		2 EA		80% POOR	
R 1	CITY ST.	40 MPH	60			10%	10%		15%	4/STA 1/8"-1/4"	100'/STA 1/8"-1/4"		1 EA		80% POOR	
R 2	CITY ST.	25 MPH	52			15%	15%		15%	4/STA 1/8"-1/4"	100'/STA 1/8"-1/4"		2 EA		80% POOR	

PM 8.4 TO PM 10.7 VAN NORMAN RD-CITY OF PICO RIVERA, TO
GARFIELD AVE-MONTEBELLO CITY LIMITS.
RIO HONDO RIVER BRIDGE PM 8.5 TO 8.6,
EB = PICO RIVERA/MONTEBELLO C/L

LOG LENGTH : 2.3
TOTAL LANES: 4
COST CENTER: 651
SURVEY DATE: 05-78
INCHES RAIN: 10

ADT : 28,000
% TRUCKS :
FUNCTIONAL CLASS:
FEDERAL AID :
RSS :

DIR & LANE	ROADTYPE	RIDE SPEED	RIDE SCORE	SKID	PSI	ALLIGATOR CRACK TYPE A	TYPE B	TYPE C	BLOCK CRACK	TRANS CRACK	LONG CRACK	RAVEL	DRIP TRACK	RUT >3/4"	PATCH	SHLDR
L 1	CITY ST.	25 MPH	15							1/STA <1/8"			2 EA			
L 2	CITY ST.	25 MPH	20			01%	01%			1/STA <1/8"	100'/STA <1/8"		6 EA			
R 1	CITY ST.	40 MPH	25							1/STA <1/8"			4 EA			
R 2	CITY ST.	25 MPH	17			01%	01%			1/STA <1/8"	100'/STA <1/8"		7 EA			

Figure VI-2a

PMS225-A
RUN DATE: 05/16/79
CALIFORNIA DEPARTMENT OF TRANSPORTATION
DIVISION OF MAINTENANCE

PAVEMENT MANAGEMENT SYSTEM
RIGID PAVEMENT CONDITION INVENTORY
BASED ON 77/78 SURVEY

DISTRICT: 07 ROUTE: 005 COUNTY: ORA

PM 2.3 TO PM 2.7 BEGIN L4 PM 2.5
SL FAULTING #2 LNS

LOG LENGTH : .4
TOTAL LANES: 7
COST CENTER: 617
SURVEY DATE: 01-78
INCHES RAIN: 10

ADT : 73000
% TRUCKS :
FUNCTIONAL CLASS: NON ARTERIAL
FEDERAL AID :
RSS :

DIR & LANE	ROADTYPE	RIDE SPEED	RIDE SCORE	SKID	PSI	SLAB BREAKUP 1ST STAGE	2ND STAGE	3RD STAGE	3RD STAGE SPALL	PATCHES % AREA	COND	FAULTING	PAVE/SHOULD JOINT SEP	DISPL	RT SHLD COND
L 1	FREEWAY	50	59									NO	NO		
L 2	FREEWAY	50	49									NO	NO		
L 3	FREEWAY	50	31			4%		8%	MOD			YES	YES		
L 4	FREEWAY	50	57			5%		3%	MOD			NO	YES		FAIR
R 1	FREEWAY	50	84							05%	FAIR	NO	NO		
R 2	FREEWAY	50	62			20%	4%	4%		05%	FAIR	NO	NO		
R 3	FREEWAY	50	66			29%	4%	10%	MOD	10%	FAIR	YES	YES		GOOD

PM 2.7 TO PM 3.4 JT SPALL (M) L-1, SOME FINE
DAMAGE L-4 WITH SEVERE RAVEL & SPALL
END L-4 @ P M 3.1
SL SETTLEMENT R-3 WITH VERT DISPL
WITH R2

LOG LENGTH : .7
TOTAL LANES: 7
COST CENTER: 617
SURVEY DATE: 01-78
INCHES RAIN: 10

ADT : 76000
% TRUCKS :
FUNCTIONAL CLASS: NON ARTERIAL
FEDERAL AID :
RSS :

DIR & LANE	ROADTYPE	RIDE SPEED	RIDE SCORE	SKID	PSI	SLAB BREAKUP 1ST STAGE	2ND STAGE	3RD STAGE	3RD STAGE SPALL	PATCHES % AREA	COND	FAULTING	PAVE/SHOULD JOINT SEP	DISPL	RT SHLD COND
L 1	FREEWAY	50	83							04%	GOOD	NO	NO		
L 2	FREEWAY	50	73			1%				04%	GOOD	NO	NO		
L 3	FREEWAY	50	65			1%				04%	GOOD	NO	YES		GOOD
L 4	FREEWAY	50	57			3%				04%	GOOD	NO	NO		
R 1	FREEWAY	50	80			1%	1%			02%	FAIR	NO	NO		
R 2	FREEWAY	50	72			5%	2%			02%	FAIR	YES	NO		
R 3	FREEWAY	50	65			8%	1%	1%	MOD	03%	FAIR	YES	NO	UP	FAIR

Figure VI-2b

PMS245-A
RUN DATE: 05/18/79
CALIFORNIA DEPARTMENT OF TRANSPORTATION
DIVISION OF MAINTENANCE

PAVEMENT MANAGEMENT SYSTEM
BRIDGE APPROACH CONDITION INVENTORY
BASED ON 77-78 SURVEY

PAGE 1

DISTRICT: 07   ROUTE: 405   COUNTY: LA

POST MILE			DIR & LANE	BRIDGE RIDE SCORE
34.2	BEGIN BRIDGE	CHALON RD BR 53-738	L 1	14
	RIDESCORE DATE: 09-78	ALL LANES - STEPPED	L 2	0
	COST CENTER: 722	RT LANES - RANDOM CRACKING	L 3	8
	ADT: 180,000	LT LANES - DIFFERENTIAL AT PN	L 4	0
			R 1	18
			R 2	0
			R 3	6
			R 4	0
34.2	END BRIDGE	CHALON RD BR 53-738	L 1	23
	RIDESCORE DATE: 09-78	ALL LANES-STEPPED	L 2	16
	COST CENTER: 722	L3-CORNER CRACKS	L 3	24
	ADT: 180,000	R3,R4 - RANDOM CRACKS	L 4	14
			R 1	10
			R 2	7
			R 3	7
			R 4	5
38.6	BEGIN BRIDGE	SEPULBEDA BLVD BR. 53-740	L 1	18
	RIDESCORE DATE: 09-78	ALL LANES- STEPPED	L 2	6
	COST CENTER: 772	L1,L2-MUDJACKED	L 3	0
	ADT: 180,000	L4- TRANS. CRACKING	L 4	5
			L 5	16
			R 1	14
			R 2	12
			R 3	14
			R 4	16
39.0	END BRIDGE	VENTURA BLVD. BR 53-741	L 1	18
	RIDESCORE DATE: 09-78	ALL LANES- STEPPED AND MUDJACKED	L 2	7
	COST CENTER: 772	L1,L2,R1,R3 - TRANSVERSE CRACKING	L 3	7
	ADT: 180,000	L3 - 2ND STAGE CRACKING	R 1	0
			R 2	6
			R 3	7

Figure VI-2c

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PMS210-B                                               PAVEMENT MANAGEMENT SYSTEM                                              PAGE    1
RUN DATE: 05/21/79                                   CANDIDATE LOCATIONS (FLEXIBLE)
CALIFORNIA DEPT OF TRANSPORTATION           PMS HIGHWAY PROGRAM MA22    BASED ON 77/78 SURVEY
DIVISION OF MAINTENANCE

DIST     ROUTE     COUNTY            PM  TO  PM
 07       072        LA              6.6     7.0        COST CENTER 653     ADT        33,000     ROAD TYPE: FLEXIBLE-CITY STREET
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED            PROGRAM MA22        COST      $61,200     SERVICE LIFE:  10 YEARS
DIST STRATEGY:                                          PROGRAM             COST                  PROGRAMMED:          BUDGETED:
C/L MILES    .4     LANE MILES     1.6       ANNUAL MAINT. COST/MILE: LAST F.Y.          LAST F.Y.-1            LAST F.Y.-2

DIST     ROUTE     COUNTY            PM  TO  PM
 07       091        LA              6.0     6.5        COST CENTER 721     ADT        43,000     ROAD TYPE: FLEXIBLE-CITY MAINTAINED
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED            PROGRAM MA22        COST                  SERVICE LIFE:  10 YEARS
DIST STRATEGY:                                          PROGRAM             COST                  PROGRAMMED:          BUDGETED:
C/L MILES    .5     LANE MILES     3.0       ANNUAL MAINT. COST/MILE: LAST F.Y.          LAST F.Y.-1            LAST F.Y.-2

DIST     ROUTE     COUNTY            PM  TO  PM
 07       091        LA              6.5     6.7        COST CENTER 721     ADT        43,000     ROAD TYPE: FLEXIBLE-CITY MAINTAINED
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED            PROGRAM MA22        COST                  SERVICE LIFE:  10 YEARS
DIST STRATEGY:                                          PROGRAM             COST                  PROGRAMMED:          BUDGETED:
C/L MILES    .2     LANE MILES     1.2       ANNUAL MAINT. COST/MILE: LAST F.Y.          LAST F.Y.-1            LAST F.Y.-2

DIST     ROUTE     COUNTY            PM  TO  PM
 07       101        VEN             4.3     5.0        COST CENTER 743     ADT        73,000     ROAD TYPE: FLEXIBLE-FREEWAY
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED            PROGRAM MA22        COST     $127,300     SERVICE LIFE:  10 YEARS
DIST STRATEGY:                                          PROGRAM             COSY                  PROGRAMMED:          BUDGETED:
C/L MILES    .7     LANE MILES     2.8       ANNUAL MAINT. COST/MILE: LAST F.Y.          LAST F.Y.-1            LAST F.Y.-2

DIST     ROUTE     COUNTY            PM  TO  PM
 07       101        VEN             5.0     5.4        COST CENTER 743     ADT        74,000     ROAD TYPE: FLEXIBLE-FREEWAY
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED            PROGRAM MA22        COST      $72,700     SERVICE LIFE:  10 YEARS
DIST STRATEGY:                                          PROGRAM             COST                  PROGRAMMED:          BUDGETED:
C/L MILES    .4     LANE MILES     1.6       ANNUAL MAINT. COST/MILE: LAST F.Y.          LAST F.Y.-1            LAST F.Y.-2

DIST     ROUTE     COUNTY            PM  TO  PM
 07       101        VEN             5.4     6.9        COST CENTER 743     ADT        59,000     ROAD TYPE: FLEXIBLE-FREEWAY
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED            PROGRAM MA22        COST     $636,900     SERVICE LIFE:  10 YEARS
DIST STRATEGY:                                          RROGRAM             COST                  PROGRAMMED:          BUDGETED:
C/L MILES   3.5     LANE MILES    14.0       ANNUAL MAINT. COST/MILE: LASY F.Y.          LAST F.Y.-1            LAST F.Y.-2
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Figure VI-2d

PMS210-B
RUN DATE: 05/21/79
CALIFORNIA DEPT OF TRANSPORTATION
DIVISION OF MAINTENANCE

PAVEMENT MANAGEMENT SYSTEM
CANDIDATE LOCATIONS (FLEXIBLE)
PMS HIGHWAY PROGRAM MA22 BASED ON 77/78 SURVEY

DISTRICT 07

DISTRICT TOTALS (PMS)

C/L MILES	-	8.8
LANE MILES	-	36.6
MA1101	-	
MA1102	-	
MA22	-	$1,462,100
MA3	-	
COST TOTAL	-	$1,462,100

DISTRICT ESTIMATES

MA1101	-	
MA1102	-	
MA22	-	
MA3	-	
MX	-	
COST TOTAL	-	

COUNTY	ROUTE	C/L MILES	LANE MILES	COST
DISTRICT 07				
LA	072	.4	1.6	$61,200
	091	.7	4.2	
LA	TOTALS	1.1	5.8	$61,200
VEN	101	7.7	30.8	$1,400,900
VEN	TOTALS	7.7	30.8	$1,400,900
DISTRICT 07	TOTALS	8.8	36.6	$1,462,100

Figure VI-2e

PMS230-B
RUN DATE: 05/16/79
CALIFORNIA DEPARTMENT OF TRANSPORTATION
DIVISION OF MAINTENANCE

PAVEMENT MANAGEMENT SYSTEM
CORRECTIVE STRATEGIES FOR ALL TRIGGERED LANES (FLEXIBLE)
BASED ON 77/78 SURVEY

DISTRICT 07 ROUTE 072 COUNTY LA

• DOMINANT STRATEGY FOR PROJECT CONCEPT

PM 6.6 TO PM 7.0 TOTAL LANES: 04

ROAD TYPE: FLEXIBLE-CITY STREET

ADT: 33,000

COST CENTER: 653

ANNUAL MAINT. COST/MILE: LAST FY

LAST FY-1

LAST FY-2

LANE	PROBLEM	REPAIR STRATEGY
L1	ALLIG. A CRACK	FILL CRACKS
	ALLIG. B CRACK	THIN OVERLAY & LOCAL DIGOUTS
L2	ALLIG. A CRACK	FILL CRACKS
	ALLIG. B CRACK	•STRUCTURAL ANALYSIS REQUIRED
R1	ALLIG. A CRACK	FILL CRACKS
	ALLIG. B CRACK	THIN OVERLAY & LOCAL DIGOUTS
R2	ALLIG. A CRACK	FILL CRACKS
	ALLIG. B CRACK	•STRUCTURAL ANALYSIS REQUIRED

DISTRICT 07 ROUTE 091 COUNTY LA

• DOMINANT STRATEGY FOR PROJECT CONCEPT

PM 6.0 TO PM 6.5 TOTAL LANES: 06

ROAD TYPE: FLEXIBLE-CITY MAINTAINED

ADT: 43,000

COST CENTER: 721

ANNUAL MAINT. COST/MILE: LAST FY

LAST FY-1

LAST FY-2

LANE	PROBLEM	REPAIR STRATEGY
L2	ALLIG. A CRACK	FILL CRACKS
	ALLIG. B CRACK	THIN OVERLAY & LOCAL DIGOUTS
L3	ALLIG. A CRACK	FILL CRACKS
	ALLIG. B CRACK	•STRUCTURAL ANALYSIS REQUIRED
R2	ALLIG. A CRACK	FILL CRACKS
	ALLIG. B CRACK	BASE REPAIR & PATCH
R3	ALLIG. A CRACK	FILL CRACKS
	ALLIG. B CRACK	THIN OVERLAY & LOCAL DIGOUTS

PM 6.5 TO PM 6.7 TOTAL LANES: 06

ROAD TYPE: FLEXIBLE-CITY MAINTAINED

ADT: 43,000

COST CENTER: 721

ANNUAL MAINT. COST/MILE: LAST FY

LAST FY-1

LAST FY-2

LANE	PROBLEM	REPAIR STRATEGY
L2	ALLIG. B CRACK	•STRUCTURAL ANALYSIS REQUIRED
L3	ALLIG. B CRACK	STRUCTURAL ANALYSIS REQUIRED
R2	ALLIG. B CRACK	THIN OVERLAY & LOCAL DIGOUTS
R3	ALLIG. B CRACK	•STRUCTURAL ANALYSIS REQUIRED

Figure VI-2f

C. Repair Strategy Correlation With The California Highway Program Structure

California's financial resources are allocated to several programs: Aeronautics, Mass Transportation, General Support, Highways and Transportation Planning. Pavement maintenance and rehabilitation are included in the Highways program.

The resources allocated to each program are influenced by a variety of factors such as: statutory requirements, program emphasis, departmental policies, Federal-aid allocations, public desires, and political realities. For PMS purposes, departmental policies have been used as the sole criterion for correlating repair strategies with program elements and components.

Pavement maintenance and rehabilitation in California is accomplished under four highway funding components:

- Flexible Pavement Maintenance Program
- Rigid Pavement Maintenance Program
- Reconstruction Program
- Resurfacing Program

The PMS correlation of strategies to program components reflects current Caltrans policies. This data is incorporated into the PMS information system and used in the process of summarizing systemwide pavement maintenance and rehabilitation costs. These costs may be used to develop recommendations for appropriate program funding levels and for determining the allocation of various program funds to the several transportation districts in California.

D. Repair Strategy Correlation With The Federal "Resurfacing, Restoration and Rehabilitation Program"

Pavement repair projects on the Federal-Aid Highway Systems may be eligible for federal-aid financing through the "Resurfacing, Restoration and Rehabilitation (R-R-R) Program" under provisions of the Federal-Aid Highway Act of 1976.

California's understanding of federal-aid financing eligibility for the various pavement repair strategies is portrayed in Figures VI-3a to VI-3c. These tables summarize the general conditions of federal-aid eligibility for the various repair strategies, as jointly determined by Caltrans and the FHWA California Division Office, based on the following documents:

- o Draft memorandum from FHWA California Division Administrator to District Engineers and Bridge Engineer dated January 21, 1977, regarding "The R-R-R Program, FHWA Notice N5040.19, June 28, 1976.
- o "Resurfacing, Restoration, and Rehabilitation (R-R-R) Work", FHWA Notice N5040.19, June 28, 1976.
- o "Federal-Aid Highway Program Manual, Volume 6, Chapter 2, Section 1, Subsection 1: Design Standards For Federal Aid Projects", November 18, 1975.

The tables provide general policy guidelines for planning and programming eligible R-R-R projects. They provide guidance regarding the required degree of conformance to geometric and safety standards and the project design thickness justification required. These policies are subject to frequent change.

Proposed minimum geometric design standards for R-R-R projects on non-freeways have been developed by FHWA. Those standards have been published in the Federal Register, Vol. 43, No. 164, August 23, 1978 (pages 37556 through 37568).

GUIDELINES FOR THE CORRELATION OF REPAIR STRATEGIES WITH FHWA R-R-R PROGRAM

	REPAIR STRATEGY	R-R-R PROGRAM ELIGIBILITY	THICKNESS (1)	FHPM 6-2-1-1 GEOMETRIC DESIGN STANDARDS (2)	FHWA SAFETY STANDARDS COMPLIANCE REQUIREMENTS (2)	THICKNESS JUSTIFICATION	COMMENTS
FLEXIBLE PAVEMENT REPAIRS	LANE RECONSTRUCTION	YES	VARIABLE	CONFORM	CONFORM	DESIGN OF PAVEMENT STRUCTURE REQUIRED	
	PCC OVERLAY	YES	VARIABLE	CONFORM	CONFORM	DESIGN OF PAVEMENT STRUCTURE REQUIRED	
	AC OVERLAY	NO	< 0.06'	N/A	N/A	N/A	MAINTENANCE - NOT ELIGIBLE
		YES	0.06' - 0.10'	REASONABLE DEVIATIONS	EVALUATE & UPGRADE TO EXTENT POSSIBLE	NONE. STATE LETTER WILL COVER BLANKET APPROVAL	
		YES	> 0.10' - 0.25'	SUBSTANTIAL CONFORMITY	SUBSTANTIAL CONFORMITY	DESIGN OF PAVEMENT STRUCTURE REQUIRED	
		YES	> 0.25'	CONFORM	CONFORM	DESIGN OF PAVEMENT STRUCTURE REQUIRED	
	INVERTED OVERLAY	YES	≤ 0.25'	SUBSTANTIAL CONFORMITY	SUBSTANTIAL CONFORMITY	DESIGN OF PAVEMENT STRUCTURE REQUIRED	EXAMPLE: 0.20' DENSE AC OVER 0.04' OPEN GRADED AC
		YES	> 0.25'	CONFORM	CONFORM	DESIGN OF PAVEMENT STRUCTURE REQUIRED	EXAMPLE: 0.20' DENSE AC OVER 0.08' OPEN GRADED AC
	PAVEMENT REINFORCING FABRIC & OVERLAY	YES	≤ 0.15'	SUBSTANTIAL CONFORMITY	SUBSTANTIAL CONFORMITY	DESIGN OF PAVEMENT STRUCTURE REQUIRED	EXAMPLE: 0.15' AC ON FABRIC
		YES	> 0.15'	CONFORM	CONFORM	DESIGN OF PAVEMENT STRUCTURE REQUIRED	EXAMPLE: 0.20' AC ON FABRIC ON 0.10' AC
	RUBBERIZED ASPHALT INTERLAYER & OVERLAY	YES	≤ 0.15'	SUBSTANTIAL CONFORMITY	SUBSTANTIAL CONFORMITY	DESIGN OF PAVEMENT STRUCTURE REQUIRED	EXAMPLE: 0.03' INTER-LAYER & 0.10' AC
		YES	> 0.15'	CONFORM	CONFORM	DESIGN OF PAVEMENT STRUCTURE REQUIRED	EXAMPLE: 0.03' INTER-LAYER & 0.25' AC
	HOT RECYCLE AC	YES	> 0.10' - 0.25'	SUBSTANTIAL CONFORMITY	SUBSTANTIAL CONFORMITY	DESIGN OF PAVEMENT STRUCTURE REQUIRED	EXAMPLE: RECYCLE 0.15' PLUS 0.10' AC OVERLAY
		YES	> 0.25'	CONFORM	CONFORM	DESIGN OF PAVEMENT STRUCTURE REQUIRED	EXAMPLE: RECYCLE 0.25' PLUS 0.08' AC OVERLAY

NOTES: (1) 5 YEAR MINIMUM SERVICE LIFE REQUIRED FOR ELIGIBILITY

(2) EXCEPTIONS MAY BE GRANTED UNDER EXTREME CONDITIONS

Figure VI-3a

GUIDELINES FOR THE CORRELATION OF REPAIR STRATEGIES WITH FHWA R-R-R PROGRAM

FLEXIBLE PAVEMENT REPAIRS

REPAIR STRATEGY	R-R-R PROGRAM ELIGIBILITY	THICKNESS (1)	FHPM 6-2-1-1 GEOMETRIC DESIGN STANDARDS (2)	FHWA SAFETY STANDARDS COMPLIANCE REQUIREMENTS (2)	THICKNESS JUSTIFICATION	COMMENTS
HEATER REMIX & CUTLER PROCESS	YES	0.06'-0.10'	REASONABLE DEVIATIONS	EVALUATE & UPGRADE TO EXTENT POSSIBLE	NONE. STATE LETTER WILL COVER BLANKET APPROVAL	EXAMPLE: REMIX 0.04' PLUS REJUVENATING AGENT PLUS 0.06' AC OVERLAY
	YES	>0.10'-0.25'	SUBSTANTIAL CONFORMITY	SUBSTANTIAL CONFORMITY	DESIGN OF PAVEMENT STRUCTURE REQUIRED	EXAMPLE: REMIX 0.08' PLUS REJUVENATING AGENT PLUS 0.10' AC OVERLAY
COLD PLANING	NO	VARIABLE	N/A	N/A	N/A	SEE NOTE (3)
RUBBERIZED ASPHALT CHIP SEAL COAT	NO	<0.06'	N/A	N/A	N/A	MAINTENANCE - NOT ELIGIBLE
ROCK SEAL COAT	NO	<0.06'	N/A	N/A	N/A	MAINTENANCE - NOT ELIGIBLE
OPEN GRADED SEAL COAT	NO	<0.06'	N/A	N/A	N/A	MAINTENANCE - NOT ELIGIBLE
SEAL COAT WITH COVER	NO	<0.06'	N/A	N/A	N/A	MAINTENANCE - NOT ELIGIBLE
LIQUID SEAL COAT	NO	<0.06'	N/A	N/A	N/A	MAINTENANCE - NOT ELIGIBLE
BINDER MODIFIERS (REJUVENATING AGENT)	NO	<0.06'	N/A	N/A	N/A	MAINTENANCE - NOT ELIGIBLE
CRACK FILLING	NO	N/A	N/A	N/A	N/A	MAINTENANCE - NOT ELIGIBLE
BASE REPAIR & PATCH	NO	VARIABLE	N/A	N/A	N/A	MAINTENANCE - SEE NOTE (3)
DEFERRED SEAL COAT	YES	<0.06'	N/A	N/A	N/A	STAGE CONSTRUCTION - FIRST SEAL COAT AFTER CONSTRUCTION

NOTES: (1) 5 YEAR MINIMUM SERVICE LIFE REQUIRED FOR ELIGIBILITY
(2) EXCEPTIONS MAY BE GRANTED UNDER EXTREME CONDITIONS
(3) MAY BE ELIGIBLE WHEN COMBINED WITH OTHER ELIGIBLE STRATEGIES

Figure VI-3b

GUIDELINES FOR THE CORRELATION OF REPAIR STRATEGIES WITH FHWA R-R-R PROGRAM

RIGID PAVEMENT REPAIRS

REPAIR STRATEGY	R-R-R PROGRAM ELIGIBILITY	THICKNESS (1)	FHPM 6-2-1-1 GEOMETRIC DESIGN STANDARDS (2)	FHWA SAFETY STANDARDS COMPLIANCE REQUIREMENTS (2)	THICKNESS JUSTIFICATION	COMMENTS
SINGLE LANE RECONSTRUCTION	YES	VARIABLE	CONFORM	CONFORM	DESIGN OF PAVEMENT STRUCTURE REQUIRED	
PCC OVERLAY	YES	>0.25'	CONFORM	CONFORM	DESIGN OF PAVEMENT STRUCTURE REQUIRED	
AC OVERLAY	NO	≤0.25'	N/A	N/A	N/A	RECOMMENDED MINIMUM = 0.30' AC
	YES	>0.25'	CONFORM	CONFORM	DESIGN OF PAVEMENT STRUCTURE REQUIRED	
INVERTED AC OVERLAY	NO	≤0.25'	N/A	N/A	N/A	RECOMMENDED MINIMUM = 0.25' DENSE AC OVER 0.08' OPEN GRADED AC
	YES	>0.25'	CONFORM	CONFORM	DESIGN OF PAVEMENT STRUCTURE REQUIRED	
PAVEMENT REINFORCING FABRIC & OVERLAY	NO	<0.25'	N/A	N/A	N/A	RECOMMENDED MINIMUM 0.25' THICK
	YES	≥0.25'	CONFORM	CONFORM	EXPERIMENTAL TEST SECTION LENGTH ONE MILE MAXIMUM	EXAMPLE: 0.20' AC ON FABRIC ON 0.10' AC
SLAB REPLACEMENT	NO	VARIABLE	N/A	N/A	N/A	<5% OF SLABS
	YES	VARIABLE	REASONABLE DEVIATIONS	EVALUATE & UPGRADE TO EXTENT POSSIBLE	NONE. DICTATED BY EXISTING PCC & CTB	EXAMPLE: REPLACE 0.67' PCC AND 0.33' CTB WITH 1.00' PCC
MUDJACKING	NO	VARIABLE	N/A	N/A	N/A	WHEN DONE ALONE
	YES	VARIABLE	ELIGIBLE STRATEGY REQUIREMENTS GOVERN		N/A	SEE NOTE (3)
SUBSEALING	NO	VARIABLE	N/A	N/A	N/A	WHEN DONE ALONE
	YES	VARIABLE	ELIGIBLE STRATEGY REQUIREMENTS GOVERN		N/A	SEE NOTE (3)
GRINDING	YES	VARIABLE	REASONABLE DEVIATIONS	EVALUATE & UPGRADE TO EXTENT POSSIBLE	N/A	
PAVEMENT SUBDRAINAGE	YES	N/A	N/A	N/A	N/A	
CRACK SEALING	NO	N/A	N/A	N/A	N/A	MAINTENANCE-NOT ELIGIBLE
GROOVING	NO	N/A	N/A	EVALUATE & UPGRADE TO EXTENT POSSIBLE	N/A	ELIGIBLE IN TRAFFIC SAFETY PROGRAM, BUT NOT ELIGIBLE IN R-R-R PROGRAM

NOTES: (1) 5 YEAR MINIMUM SERVICE LIFE REQUIRED FOR ELIGIBILITY

(2) EXCEPTIONS MAY BE GRANTED UNDER EXTREME CONDITIONS

(3) MAY BE ELIGIBLE WHEN COMBINED WITH OTHER ELIGIBLE STRATEGIES

Figure VI-3c

VII. Computer Usage

A. PMS Computer System Design in Concept

The computer system is comprised of four basic component processes shown in Figure VII-1. The schematic and subsequent text describes the flow of information from data collection to the production of computer reports that support pavement management decision making.

COMPUTER SYSTEM OVERVIEW

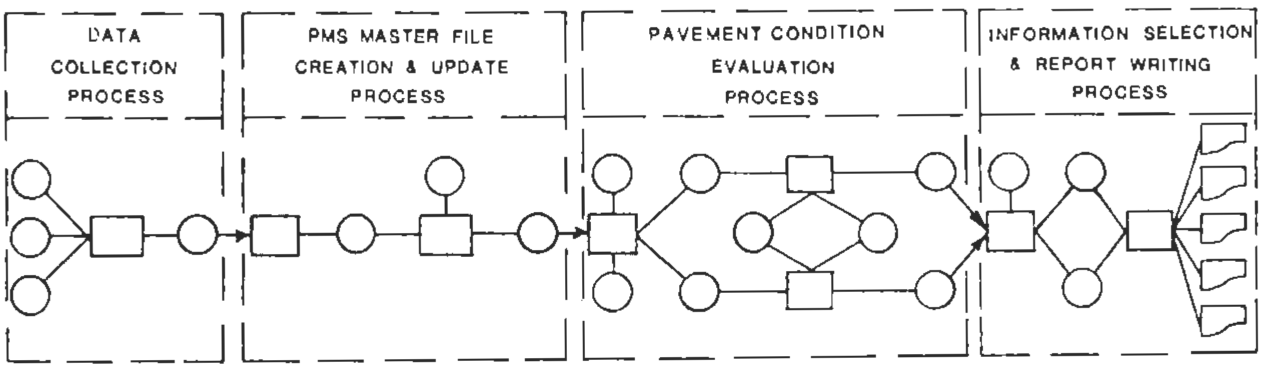


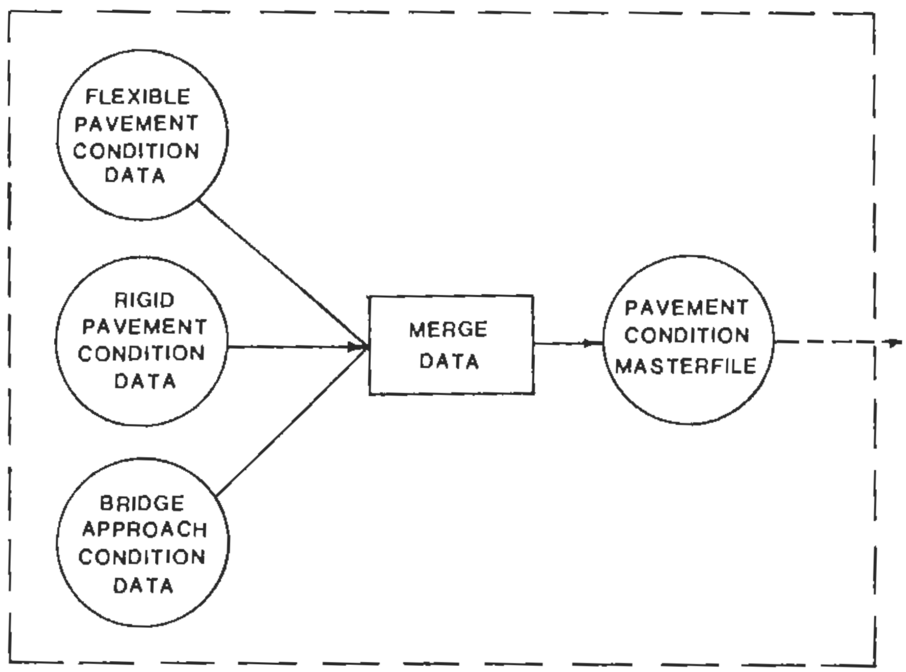
Figure VII-1

1. Data Collection Process

Pavement condition data from field surveys is collected and stored in flexible, rigid, and bridge approach subfiles because the information in each category is unique. The three subfiles are merged to create the Pavement Condition Masterfile.

Figure VII-2 also shows the type of data collected and stored in each of the three categories.

DATA COLLECTION PROCESS



FLEXIBLE PAVEMENT CONDITION DATA:

SEGMENT LOCATION
ALLIGATOR CRACKING
TRANSVERSE CRACKING
LONGITUDINAL CRACKING
RUTTING
RAVELING & WEATHERING
PATCHING
RIDE QUALITY
SKID NUMBER
% TRUCKS
MAINTENANCE TERRITORY I.D.
ANNUAL RAINFALL
RATER'S SPECIAL COMMENTS
CONDITION SURVEY DATE

RIGID PAVEMENT CONDITION DATA:

SEGMENT LOCATION
SLAB BREAKUP
RIDE QUALITY
SHOULDER CONDITIONS
JOINT SEPARATION
SHOULDER DISPLACEMENT
SHOULDER CONDITION
SKID NUMBER
% TRUCKS
MAINTENANCE TERRITORY I.D.
ANNUAL RAINFALL
RATER'S SPECIAL COMMENTS
CONDITION SURVEY DATE

BRIDGE APPROACH CONDITION DATA:

BRIDGE LOCATION
BRIDGE IDENTIFICATION
BRIDGE APPROACH RIDE RATING
MAINTENANCE TERRITORY I.D.
CONDITION SURVEY DATE

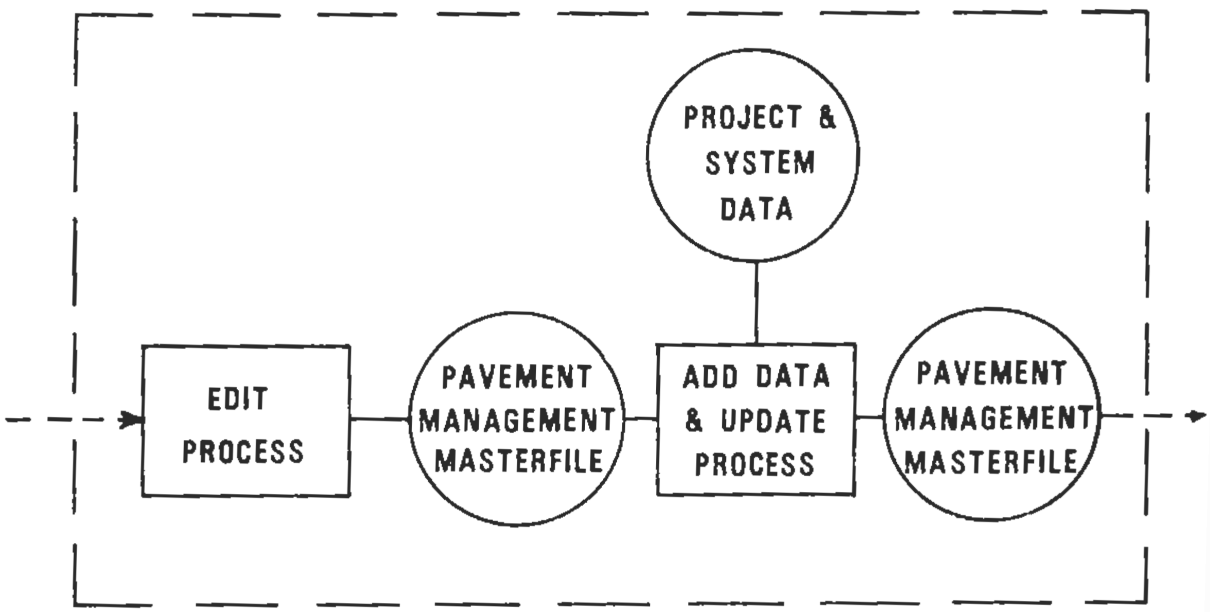
Figure VII-2

2. PMS Masterfile Creation and Update Process

Data from the Pavement Condition Masterfile is edited and translated to initiate the Pavement Management Masterfile. Project and system data are then added to complete the Pavement Management Masterfile. This process also includes the capability to update or correct the file.

Figure VII-3 also shows the kind of project and system data added in this process.

PMS MASTERFILE CREATION AND UPDATE PROCESS



PROJECT AND SYSTEM DATA:

- TRAFFIC VOLUME
- ROAD SEGMENT LENGTH
- FUNCTIONAL CLASSIFICATION
- FEDERAL AID SYSTEM
- ROUTES OF STATEWIDE SIGNIFICANCE
- MAINTENANCE COST
- PAVEMENT SERVICEABILITY INDEX
- PROGRAMMED & BUDGETED REPAIRS
- DISTRICT PLANNED REPAIRS

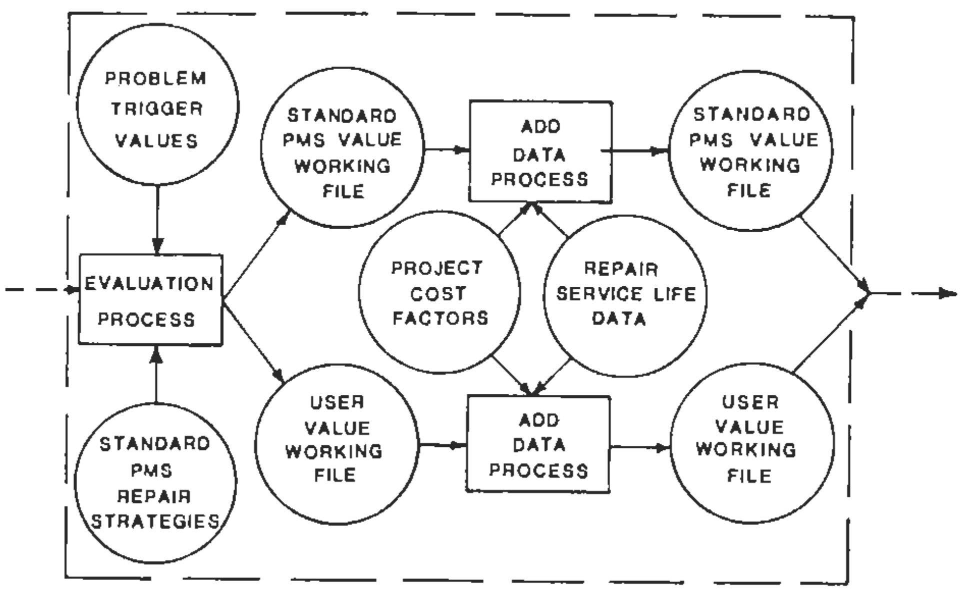
Figure VII-3

3. Pavement Condition Evaluation Process

Data from the Pavement Management Masterfile is screened by the pavement condition evaluation process against problem trigger values (levels of service) in the same decision-tree evaluation process described in Section III and matched with appropriate standard PMS repair strategies. In this process the user can use standard trigger values or define an alternate range of values for special studies or more selective sorting. A Working File is thus established using either standard values or user specified values. The Working File is then supplemented with project cost estimating factors and repair service life data to complete the working file.

Figure VII-4 also describes the added inputs to this process.

PAVEMENT CONDITION EVALUATION PROCESS



PROBLEM TRIGGER VALUES:

RIDE QUALITY
ALL PAVEMENT PROBLEMS

PROJECT COST FACTORS:

UNIT COST VARIABLES

STANDARD PMS REPAIR STRATEGIES:

STRATEGY/PROBLEM CORRELATION
FOR PROJECT COST ESTIMATES

REPAIR SERVICE LIFE DATA:

SERVICE LIFE FOR ALL STRATEGIES

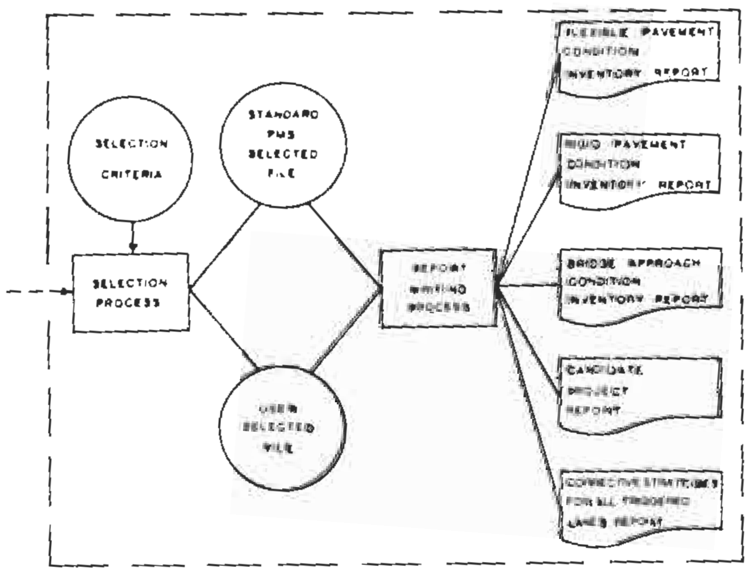
Figure VII-4

4. Information Selection and Report Writing Process

The working file created in the pavement condition evaluation process is input to the selection process. Data from the working file is tested against the selection criteria specified by the user (either standard PMS values or user designated values) to create the selected file (standard or user designated). This procedure produces a file of highway segments (projects) desired by the user.

The selected file is the input to the report writing process to produce the desired information in one or more of the reports shown in Figure VII-5. Examples of the user reports are shown in Figures VI-2a through VI-2f.

INFORMATION SELECTION AND REPORT WRITING PROCESS



SELECTION CRITERIA:

LOCATION
PAVEMENT CONDITION VALUES
REPAIR / MAINTENANCE COST
SYSTEM DESIGNATIONS
TRAFFIC VOLUMES
HIGHWAY SUB PROGRAMS
SCHEDULE FOR IMPROVEMENT
ETC.

CONDITION INVENTORY REPORTS:

LOCATION
PAVEMENT CONDITION INFORMATION
MAINTENANCE TERRITORY I.D.
TRAFFIC VOLUME
% TRUCKS
SYSTEM DESIGNATIONS
ANNUAL RAINFALL
CONDITION SURVEY DATE
RATER'S SPECIAL COMMENTS

CANDIDATE PROJECT REPORT:

LOCATION
MAINTENANCE TERRITORY I.D.
TRAFFIC VOLUME
ROAD TYPE
PMS REPAIR STRATEGY
HIGHWAY SUB PROGRAM
PMS PROJECT COST
REPAIR SERVICE LIFE
PLANNED REPAIR STRATEGY
PLANNED PROJECT COST
PLANNED HIGHWAY SUB PROGRAM
SCHEDULE FOR IMPROVEMENT
ANNUAL MAINTENANCE COST

CORRECTIVE STRATEGIES FOR ALL TRIGGERED LANES REPORT:

LOCATION
MAINTENANCE TERRITORY I.D.
TRAFFIC VOLUME
ROAD TYPE
LANE I.D.
PROBLEM TYPE / LANE
STRATEGY FOR EACH TRIGGERED LANE
ANNUAL MAINTENANCE COST

Figure VII-5

B. Description of Computer Programs

A flow chart of the computer system is shown in Figure VII-6.

With some exceptions noted below all programs come in matched pairs. These are described, for example, as MMS601/650. The first number refers to that program which deals with flexible pavement and the second number refers to the program for rigid pavement.

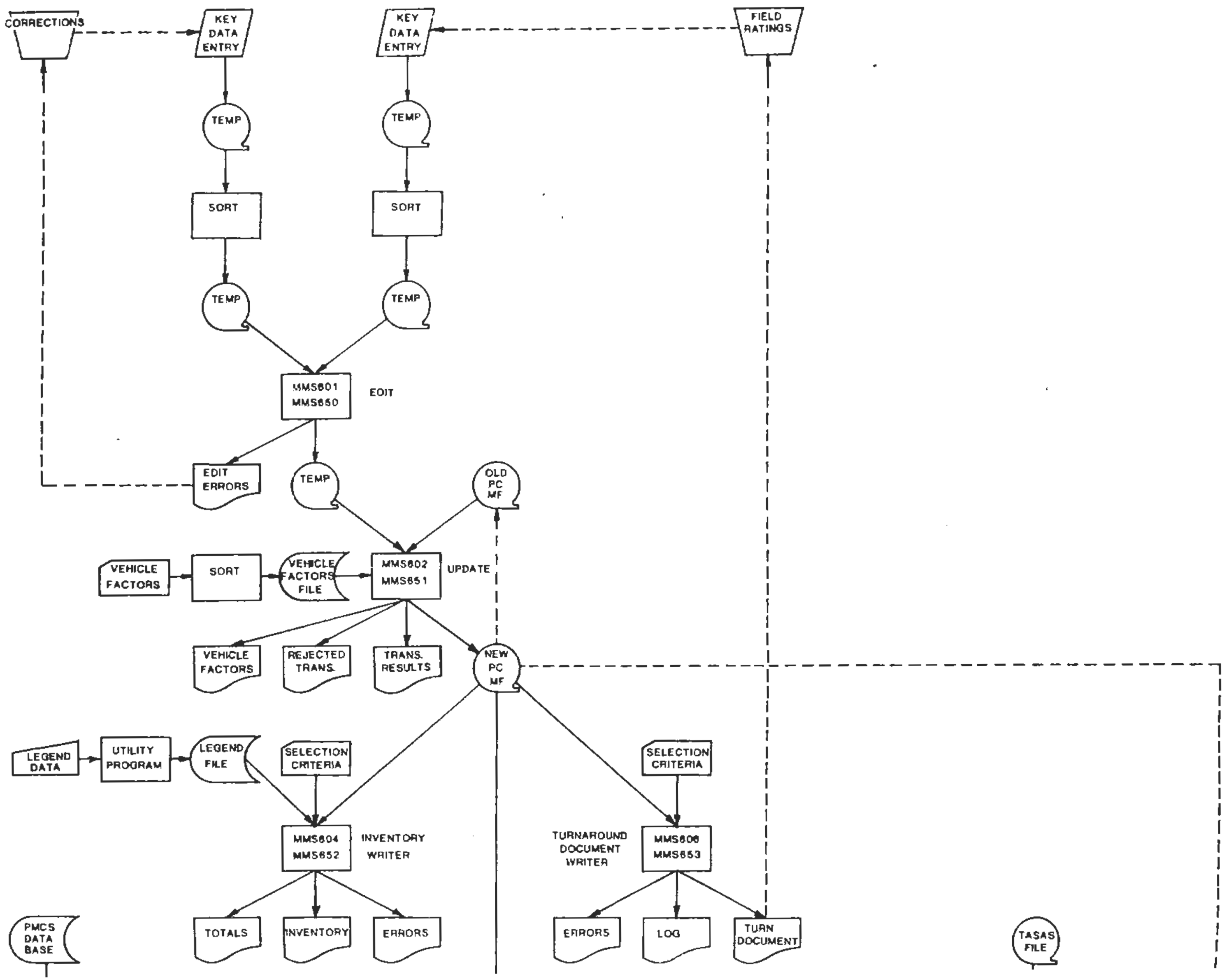
Each program in the system has an 'errors and controls' listing printed out. The errors portion tells what went wrong if a job failed. The controls portion enable those who run the system to see that the proper number of records are being passed from program to program.

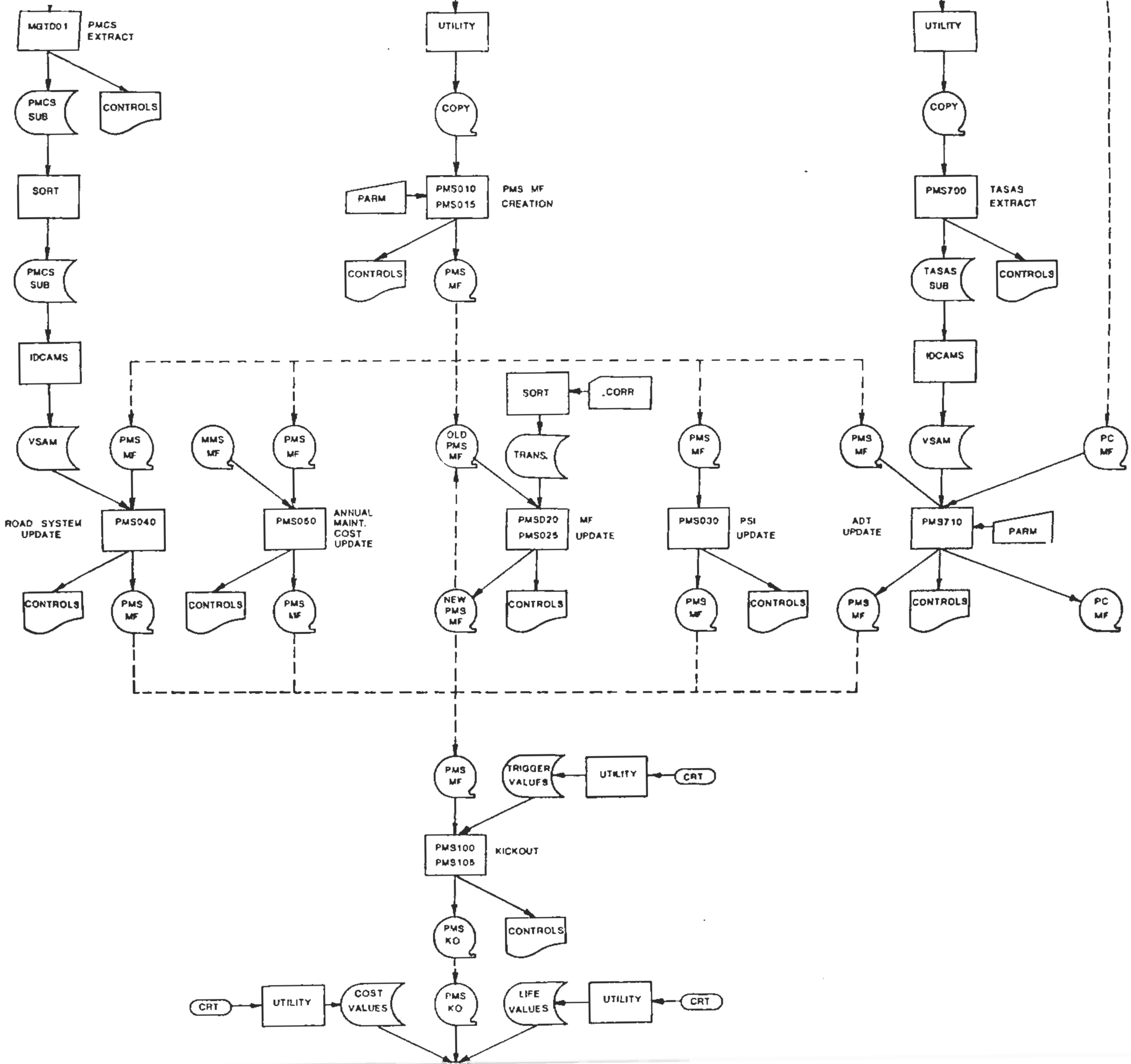
All programs in the system have been programmed by the 'top down structured' method. This means that the functions of each program have been placed into a hierarchy and are self-contained in modules that are 'called' by higher functions.

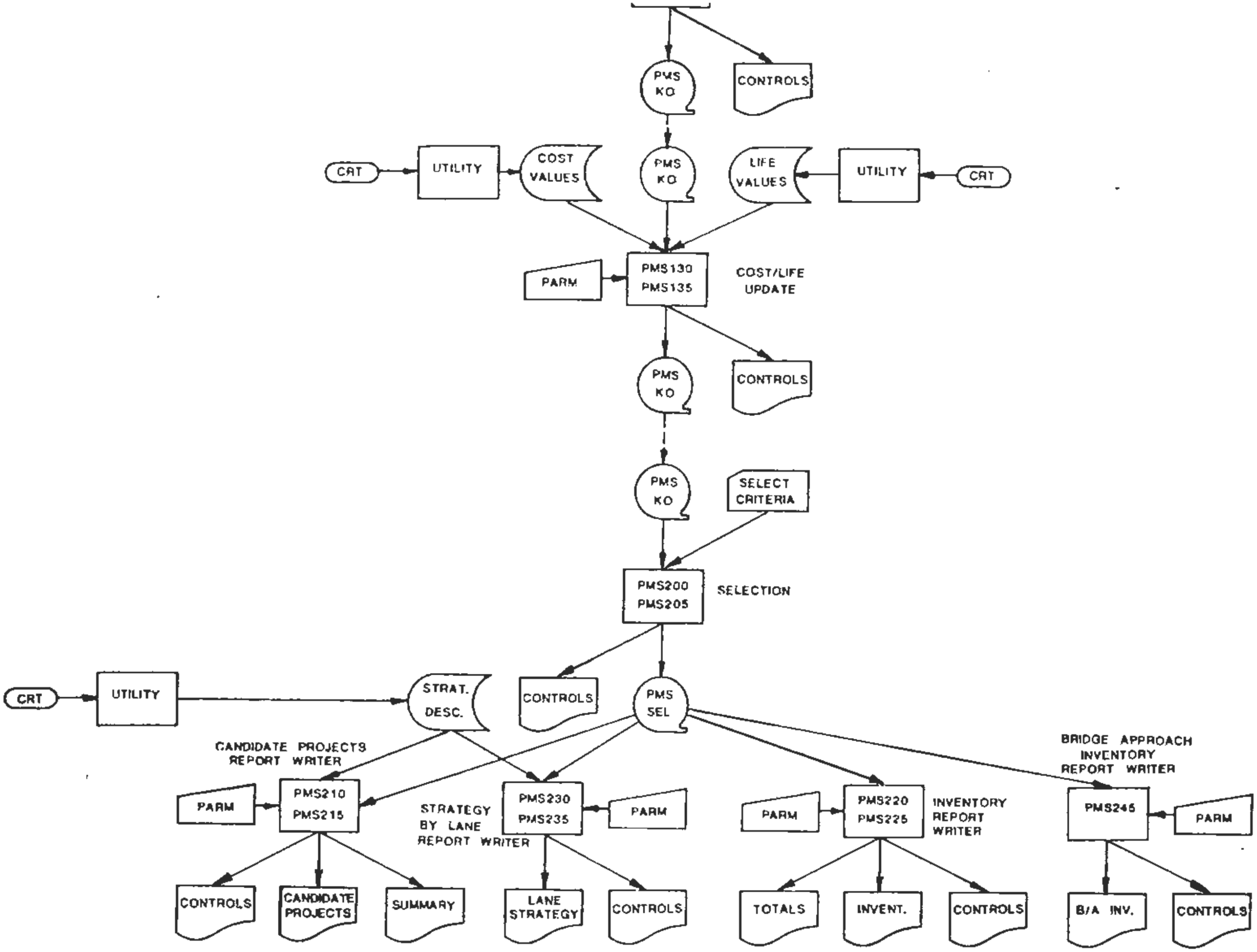
A program may be added in the future if the federal government requires the use of the 'pavement serviceability index'. This would be calculated by an equation from pavement condition data, and added to the PMS masterfile.

A future program or subsystem will select cost data from the Maintenance Management System and compute the annual maintenance costs per mile for each section of road in the state highway system. This will then be used to add maintenance cost information to the PMS masterfile. Data of this type is just beginning to be collected in conjunction with the 77-78 pavement condition survey.

Another future program may be written to provide performance data on the various PMS repair strategies. This data might be in the form of statistical tables or plotted curves and will give us the average expected life of the strategies. From this and initial project costs it may be possible to determine when the next repair should be made. The performance life file presently used by other programs in the system would be updated. This program could also be used as a basis for managing the various maintenance programs.


CORRECTIONS
KEY DATA ENTRY
KEY DATA ENTRY
FIELD RATINGS
TEMP
TEMP
SORT
SORT
TEMP
TEMP
MMS601 MMS650
EOIT
EDIT ERRORS
TEMP
OLD PC MF
VEHICLE FACTORS
SORT
VEHICLE FACTORS FILE
MMS602 MMS651
UPDATE
VEHICLE FACTORS
REJECTED TRANS.
TRANS. RESULTS
NEW PC MF
LEGEND DATA
UTILITY PROGRAM
LEGEND FILE
SELECTION CRITERIA
SELECTION CRITERIA
MMS604 MMS652
INVENTORY WRITER
TURNAROUND DOCUMENT WRITER
MMS606 MMS653
PMCS DATA BASE
TOTALS
INVENTORY
ERRORS
ERRORS
LOG
TURN DOCUMENT
TASAS FILE


MGTD01
PMCS EXTRACT
PMCS SUB
CONTROLS
SORT
PMCS SUB
IDCAMS
VSAM
UTILITY
COPY
PARM
PMS010 PMS015
PMS MF CREATION
CONTROLS
PMS MF
UTILITY
COPY
PMS700
TASAS EXTRACT
TASAS SUB
CONTROLS
IDCAMS
VSAM
PC MF
PMS MF
MMS MF
PMS MF
OLD PMS MF
SORT
.CORR
TRANS.
PMS MF
PMS MF
ROAD SYSTEM UPDATE
PMS040
PMS050
ANNUAL MAINT. COST UPDATE
PMS020 PMS025
MF UPDATE
PMS030
PSI UPDATE
ADT UPDATE
PMS710
PARM
CONTROLS
PMS MF
CONTROLS
PMS MF
NEW PMS MF
CONTROLS
PMS MF
CONTROLS
PMS MF
CONTROLS
PC MF
PMS MF
TRIGGER VALUES
UTILITY
CRT
PMS100 PMS105
KICKOUT
PMS KO
CONTROLS
CRT
UTILITY
COST VALUES
PMS KO
LIFE VALUES
UTILITY
CRT



COMPUTER SYSTEM FLOW CHART
PAVEMENT MANAGEMENT SYSTEM
(OCT. 1978)

1. Pavement Condition Subsystem

The pavement condition subsystem is the part of the Pavement Management System that collects pavement condition information. It has four programs. These programs edit incoming data, update the pavement condition masterfile, create an inventory report, and print a turnaround document for inputting the next survey data with the same postmile sections that are on the current masterfile.

MMS601/650. This program edits incoming field data from turnaround documents and corrections submitted from headquarters staff. Data which fails the edit are listed on an error report. Accepted data are used to create transactions updating the pavement condition masterfile.

INPUTS:

Field ratings (See Files - items 1)
Headquarters corrections (See Files - items 2 and 3)

OUTPUTS:

Good transactions file (See Files - items 4 and 5)
Error report

MMS602/651. This program updates the pavement condition masterfile with transactions from the edit program. The disposition of each transaction (after it is matched against the masterfile) is printed out. An additional input to this program is the vehicle factors file. This file contains factors used to standardize all ride comfort data regardless of the vehicle used to gather that data. The factors used are printed out by the program.

INPUTS:

Pavement condition masterfile (See Files - items 6 and 7)
Good transactions file (See Files - items 4 and 5)
Vehicle factors (See Files - item 8)

OUTPUTS:

Pavement condition masterfile (See Files - items 6 and 7)
Transaction application report
Rejected transactions report
Vehicle factors listing

MMS604/652. This program writes a report which is used internally by those personnel who perform the pavement condition survey. It is replaced for PMS users by the report from PMS220/225 and PMS245. A legend file provides information which is printed at the beginning of each district's listing and a selection criteria file specifies which records are to be selected from the pavement condition masterfile for printing. Its major outputs are the inventory report which lists information from the selected records and totals pages showing route, district, and statewide totals of centerline miles and lane miles for the selected records.

INPUTS:

Pavement condition masterfile (See Files - items 6 and 7)
Legend file (See Files - item 9)
Selection criteria (See Files - item 10)

OUTPUTS:

Inventory listing
Totals
Errors

MMS606/653. This program creates a turnaround document used by field crews to rate sections of pavement. It provides location data (district, county, postmiles) as a basis on which to start a new survey and provides an organized format for inputting new data. A selection criteria specifies which records are to be printed on the document. It's major outputs are the turnaround document, a log to be used to keep track of the status of each section of pavement to be rated, and a listing of the selection criteria and any errors found in it.

INPUT:

Pavement condition masterfile (See Files - items 6 and 7)
Selection criteria (See Files - item 10)

OUTPUT:

Turnaround document
Log
Errors

2. Masterfile Creation/Update Subsystem

The creation/update subsystem establishes the PMS masterfile from the pavement condition subsystem, and then adds data derived from other sources. It also provides for making corrections or other changes.

PMS010/015. This program reads the pavement condition masterfile, selects certain records (one survey only, flexible or rigid only, etc.) selects certain portions of each record, and creates a PMS masterfile. Space is provided in the new file for additional data to be inserted by other programs.

INPUT:

Pavement condition masterfile (See Files - items 6 and 7)
Selection parameter (for year of survey)

OUTPUT:

PMS masterfile (See Files - items 11 and 12)
Controls

PMS020/025. This program updates the PMS masterfile to either make changes or to add data. The need for updating can be caused by one or more of the following reasons:

- o An error may have been made.
- o A project's limits may have been changed.
- o It may be desirable to place a 'hold' on certain projects because of duplicate projects.
- o Districts may decide to use repair strategies that differ from PMS strategies.
- o A project's funding highway program may change.

INPUT:

PMS masterfile (See Files - items 11 and 12)
Update transactions (See Files - item 13)

OUTPUT:

PMS Masterfile (See Files - items 11 and 12)
Errors
Controls

PMS040. This program adds information about the road system or systems to which any particular section belongs. Such systems include the federal aid system, routes of statewide significance, and the functional classification system. The necessary information comes from the project management and control system (PMCS) which is not under the jurisdiction of PMS and is maintained by a different unit. MGT001 creates a subfile of information which is used in part by PMS040 to update the PMS masterfile.

INPUT:

PMS masterfile (See Files - items 11 and 12)
PMCS subfile (See Files - item 15)

OUTPUT:

PMS masterfile (See Files - items 11 and 12)
Controls

MGT001. This is an existing program which accesses the Project Management and Control System (PMCS) data base. This data base consists of a large number of different record types, each containing data on various aspects of a highway project. MGT001 was designed to select desired data from the data base for other existing EDP systems and has been modified to get the data needed by PMS040. It creates a subfile of data required for several systems.

INPUT:

PMCS data base (See Files - item 14)

OUTPUT:

PMCS subfile (See Files - item 15)
Controls

PMS700. The Traffic Accident Surveilance and Analysis System (TASAS) is a system which is not under the jurisdiction of the Pavement Management System. It contains data on traffic volumes and is the official source for the accurate length of all state highways. There are several different files in the system. This program reads the TASAS current highway file and selects records with which to create a subfile of ADT and length information. It also does some reformatting of the TASAS data. This subfile is used for both the PMS flexible and rigid masterfiles and the flexible and rigid pavement condition masterfiles. The length of a section of road is obtained from this file because the difference between start and end postmile limits does not necessarily give a true length.

INPUT:

TASAS current highway projects file (See Files - item 16)

OUTPUT:

TASAS subfile (See Files - item 17)
Controls

PMS710. This program uses the TASAS subfile created by PMS700 to determine the average daily traffic (ADT) and length for projects on either of four different files:

- The pavement management system flexible masterfile
- The pavement management system rigid masterfile
- The flexible pavement condition masterfile
- The rigid pavement condition masterfile

The program uses those records from the TASAS file which are within the postmile limits of the PMS record and calculates an average ADT and a length for the section. This data is added to whichever file is being updated.

INPUT:

Flexible pavement condition masterfile (See Files - item 6)
Rigid pavement condition masterfile (See Files - item 7)
Flexible PMS masterfile (See Files - item 11)
Rigid PMS masterfile (See Files - item 12)
TASAS subfile (See Files - item 17)
File selection parameter (to select input pavement file)

OUTPUT:

Flexible pavement condition masterfile (See Files - item 6)
Rigid pavement condition masterfile (See Files - item 7)
Flexible PMS masterfile (See Files - item 11)
Rigid PMS masterfile (See Files - item 12)
Controls

3. Kickout Subsystem

The kickout subsystem determines which pavement sections on the PMS masterfile merit repair. The determination is based on the problem trigger values submitted by the user. These trigger values are easily changed, thus allowing a user to test a variety of assumptions. The kickout subsystem also determines strategy(s) needed to 'cure' noted problem(s). Cost and performance data are added to the kicked out problem pavement locations.

PMS100/105. This program reads the PMS masterfile and creates a subfile or 'kickout' file of all those pavement sections which did not meet the values fed into the program from a file of 'standard trigger values'. Each pavement section also has strategies assigned based on which problem(s) failed the assigned values. Sometimes only one strategy is appropriate and at other times there may be more than one, in which case all would be added to the exception file. The strategies come from a list of 'standard strategies'. The logic to get from problem(s) to strategy(s) is in the program. The trigger values may be changed by reading in a different trigger value file thus giving the user the ability to experiment with different values of his costs or needs.

INPUT:

PMS masterfile (See Files - items 11 and 12)
Trigger values file (see Files - item 19)

OUTPUT:

PMS kickout file (See Files - items 20 and 21)
Controls

PMS130/135. This program reads the PMS kickout file and determines the dominant strategy for each pavement section. It then computes the first cost for that strategy using the file of standard cost factors. It adds this data plus the performance life of the strategy and the highway program which funds the dominant strategy to the kickout file. Non-standard cost and life files may also be read in order to play 'what-if' games to determine the potential effects of changes to either costs or service life estimates.

INPUT:

PMS kickout file (See Files - items 20 and 21)
Cost factors file (See Files - item 22)
Performance life files (See Files - item 23)
Parameter (to select district or headquarters cost factor)

OUTPUT:

PMS kickout file (See Files - items 20 and 21)
Controls

4. Report Subsystem

The report subsystem provides reports in any one or all of five fixed formats. The data to be reported comes from the kickout file, or any portion of it, selected by a program within the report subsystem. By using this program in conjunction with changes to trigger values in the kickout program PMS100/105, an almost unlimited degree of flexibility is provided in the system. This flexibility is necessary in order to determine funding levels, set priorities, determine the overall condition of any given route, or to determine the amount and type of work indicated in any particular district, county, superintendent territory, etc.

PMS200/205. This program selects records from the PMS kickout file of problem pavement sections and creates a subfile to be used later by the report writing programs. An input document is used for providing the selection criteria and can use essentially any field on the kickout record. Common selection criteria would be location data (district, route, county, cost center, etc.), problem data, highway funding program data, or strategy data.

INPUT:

PMS kickout file (See Files - items 20 and 21)
Selection criteria (See Files - item 24)

OUTPUT:

Selected kickout file (See Files - items 20 and 21)
Selection criteria and edit errors
Other edit errors
Controls

PMS210/215. This program uses either the PMS kickout file or a selected portion of it from PMS200/205 to write reports showing dominant strategies and other information of selected pavement sections. Reports are lists of candidate projects of the various highway funding programs that involve pavement maintenance or rehabilitation.

INPUT:

PMS kickout file (See Files - items 20 and 21)
Strategy Description file (See Files - item 24)
Parameter (for report heading purposes)

OUTPUT:

Detailed report (See Figure VII-7a)
Summary report (See Figure VII-7b)
Controls

```
                                                        PAVEMENT MANAGEMENT SYSTEM
PMS210-B                                              CANDIDATE LOCATIONS (FLEXIBLE)
RUN DATE: 05/21/79                         PMS HIGHWAY PROGRAM MA22    BASED ON 77/78 SURVEY
CALIFORNIA DEPT OF TRANSPORTATION
DIVISION OF MAINTENANCE

                                     PM  TO  PM                                  33,000   ROAD TYPE: FLEXIBLE-CITY STREET
DIST     ROUTE     COUNTY                                 COST CENTER 653    ADT           SERVICE LIFE:  10 YEARS
 07       072       LA               6.6      7.0         PROGRAM MA22       COST  $61,200  PROGRAMMED:            BUDGETED:
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED              PROGRAM            COST        LAST F.Y.-1        LAST F.Y.-2
DIST STRATEGY:                               ANNUAL MAINT. COST/MILE: LAST F.Y.
C/L MILES    .4    LANE MILES    1.6

                                     PM  TO  PM                                  43,000   ROAD TYPE: FLEXIBLE-CITY MAINTAINED
DIST     ROUTE     COUNTY                                 COST CENTER 721    ADT           SERVICE LIFE:  10 YEARS
 07       091       LA               6.0      6.5         PROGRAM MA22       COST          PROGRAMMED:            BUDGETED:
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED              PROGRAM            COST        LAST F.Y.-1        LAST F.Y.-2
DIST STRATEGY:                               ANNUAL MAINT. COST/MILE: LAST F.Y.
C/L MILES    .5    LANE MILES    3.0

                                     PM  TO  PM                                  43,000   ROAD TYPE: FLEXIBLE-CITY MAINTAINED
DIST     ROUTE     COUNTY                                 COST CENTER 721    ADT           SERVICE LIFE:  10 YEARS
 07       091       LA               6.5      6.7         PROGRAM MA22       COST          PROGRAMMED:            BUDGETED:
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED              PROGRAM            COST        LAST F.Y.-1        LAST F.Y.-2
DIST STRATEGY:                               ANNUAL MAINT. COST/MILE: LAST F.Y.
C/L MILES    .2    LANE MILES    1.2

                                     PM  TO  PM                                  73,000   ROAD TYPE: FLEXIBLE-FREEWAY
DIST     ROUTE     COUNTY                                 COST CENTER 743    ADT           SERVICE LIFE:  10 YEARS
 07       101       VEN              4.3      5.0         PROGRAM MA22       COST $127,300  PROGRAMMED:            BUDGETED:
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED              PROGRAM            COST        LAST F.Y.-1        LAST F.Y.-2
DIST STRATEGY:                               ANNUAL MAINT. COST/MILE: LAST F.Y.
C/L MILES    .7    LANE MILES    2.8

                                     PM  TO  PM                                  74,000   ROAD TYPE: FLEXIBLE-FREEWAY
DIST     ROUTE     COUNTY                                 COST CENTER 743    ADT           SERVICE LIFE:  10 YEARS
 07       101       VEN              5.0      5.4         PROGRAM MA22       COST  $72,700  PROGRAMMED:            BUDGETED:
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED              PROGRAM            COST        LAST F.Y.-1        LAST F.Y.-2
DIST STRATEGY:                               ANNUAL MAINT. COST/MILE: LAST F.Y.
C/L MILES    .4    LANE MILES    1.6

                                     PM  TO  PM                                  59,000   ROAD TYPE: FLEXIBLE-FREEWAY
DIST     ROUTE     COUNTY                                 COST CENTER 743    ADT           SERVICE LIFE:  10 YEARS
 07       101       VEN              5.4      6.9         PROGRAM MA22       COST $636,900  PROGRAMMED:            BUDGETED:
 PMS STRATEGY:  STRUCTURAL ANALYSIS REQUIRED              PROGRAM            COST        LAST F.Y.-1        LAST F.Y.-2
DIST STRATEGY:                               ANNUAL MAINT. COST/MILE: LAST F.Y.
C/L MILES   3.5    LANE MILES   14.0
```

Figure VII-7a

PMS210-8
RUN DATE: 05/21/79
CALIFORNIA DEPT OF TRANSPORTATION
DIVISION OF MAINTENANCE

PAVEMENT MANAGEMENT SYSTEM
CANDIDATE LOCATIONS (FLEXIBLE)
PMS HIGHWAY PROGRAM MA22 BASED ON 77/78 SURVEY

PAGE 3

DISTRICT 07

DISTRICT TOTALS (PMS)		
C/L MILES	-	8.8
LANE MILES	-	36.6
MA1101	-	
MA1102	-	
MA22	-	$1,462,100
MA3	-	
COST TOTAL	-	$1,462,100

DISTRICT ESTIMATES	
MA1101	-
MA1102	-
MA22	-
MA3	-
MX	-
COST TOTAL	-

COUNTY	ROUTE	C/L MILES	LANE MILES	COST
DISTRICT 07				
LA	072	.4	1.6	$61,200
	091	.7	4.2	
LA	TOTALS	1.1	5.8	$61,200
VEN	101	7.7	30.8	$1,400,900
VEN	TOTALS	7.7	30.8	$1,400,900
DISTRICT 07	TOTALS	8.8	36.6	$1,462,100

Figure VII-7b

PMS220/225. This program uses the PMS kickout file or a selected portion of it from PMS200/205 to produce an inventory report on all sections of road in the state highway system. It contains essentially all the information in the pavement condition file but has the data translated into more usable forms and includes project length, average daily traffic and functional classification data from the Pavement Management System.

INPUT:

PMS kickout file (See Files - items 20 and 21)

OUTPUT:

Inventory (See Figures VII-7c and VII-7d)
Totals
Controls

PMS220-A RUN: 05/07/79
CALIFORNIA DEPARTMENT OF TRANSPORTATION
DIVISION OF MAINTENANCE
OFFICE OF HIGHWAY MAINTENANCE

PAVEMENT MANAGEMENT SYSTEM
FLEXIBLE PAVEMENT CONDITION INVENTORY
1977-78 DATA

DISTRICT: 07 ROUTE: 072 COUNTY: LA

PM 6.6 TO PM 7.0 LOCKHEED ST.-WHITTIER, TO GREGG ROAD-PICO RIVERA.
-WHITTIER CITY LIMITS PM 6.8 JUAREZ ST.
SAN GABRIEL RIVER BRIDGE PM 6.9.
PICO-RIVERA CITY LIMITS PM 6.9(F.R.)
AC OVERLAY-BADLY BROKEN UP.
ESTIMATED EVALUATION DUE TO TRAFFIC

LOG LENGTH : .4
TOTAL LANES: 4
COST CENTER: 653
SURVEY DATE: 05-78
INCHES RAIN: 10

ADT : 33.000
% TRUCKS :
FUNCTIONAL CLASS:
FEDERAL AID :
RSS :

DIR & LANE	ROADTYPE	RIDE SPEED	RIDE SCORE	SKID	PSI	ALLIGATOR CRACK TYPE A	TYPE B	TYPE C	BLOCK CRACK	TRANS CRACK	LONG CRACK	RAVEL	DRIP TRACK	RUT >3/4"	PATCH	SHLDR
L 1	CITY ST.	40 MPH	86			10%	10%		15%	4/STA 1/8"-1/4"	100'/STA 1/8"-1/4"		1 EA		80% POOR	
L 2	CITY ST.		33			15%	15%		15%	4/STA 1/8"-1/4"	100'/STA 1/8"-1/4"		2 EA		80% POOR	
R 1	CITY ST.	40 MPH	60			10%	10%		15%	4/STA 1/8"-1/4"	100'/STA 1/8"-1/4"		1 EA		80% POOR	
R 2	CITY ST.	25 MPH	52			15%	15%		15%	4/STA 1/8"-1/4"	100'/STA 1/8"-1/4"		2 EA		80% POOR	

PM 8.4 TO PM 10.7 VAN NORMAN RD-CITY OF PICO RIVERA, TO GARFIELD AVE-MONTEBELLO CITY LIMITS.
RIO HONDO RIVER BRIDGE PM 8.5 TO 8.6,
FB = PICO RIVERA/MONTEBELLO C/L

LOG LENGTH : 2.3
TOTAL LANES: 4
COST CENTER: 651
SURVEY DATE: 05-78
INCHES RAIN: 10

ADT : 28.000
% TRUCKS :
FUNCTIONAL CLASS:
FEDERAL AID :
RSS :

DIR & LANE	ROADTYPE	RIDE SPEED	RIDE SCORE	SKID	PSI	ALLIGATOR CRACK TYPE A	TYPE B	TYPE C	BLOCK CRACK	TRANS CRACK	LONG CRACK	RAVEL	DRIP TRACK	RUT >3/4"	PATCH	SHLDR
L 1	CITY ST.	25 MPH	13							1/STA <1/8"			2 EA			
L 2	CITY ST.	25 MPH	20			01%	01%			1/STA <1/8"	100'/STA <1/8"		6 EA			
R 1	CITY ST.	40 MPH	25							1/STA <1/8"			4 EA			
R 2	CITY ST.	25 MPH	17			01%	01%			1/STA <1/8"	100'/STA <1/8"		7 EA			

Figure VII-7c

PMS225-A
RUN DATE: 05/16/79
CALIFORNIA DEPARTMENT OF TRANSPORTATION
DIVISION OF MAINTENANCE

PAVEMENT MANAGEMENT SYSTEM
RIGID PAVEMENT CONDITION INVENTORY
BASED ON 77/78 SURVEY

DISTRICT: 07   ROUTE: 005   COUNTY: LA

PM 2.3 TO PM 2.7   BEGIN LA PM 2.5
SL FAULTING #2 LNS

LOG LENGTH : .4
TOTAL LANES: 7
COST CENTER: 617
SURVEY DATE: 01-78
INCHES RAIN: 10

ADT : 73000
% TRUCKS :
FUNCTIONAL CLASS: NON ARTERIAL
FEDERAL AID :
RSS :

DIR & LANE	ROADTYPE	RIDE SPEED	RIDE SCORE	SKID	PSI	SLAB BREAKUP 1ST STAGE	SLAB BREAKUP 2ND STAGE	SLAB BREAKUP 3RD STAGE	3RD STAGE SPALL	PATCHES % AREA	PATCHES COND	FAULT-ING	PAVE/SHOULD JOINT SEP	PAVE/SHOULD JOINT DISPL	RT SHLD COND
L 1	FREEWAY	50	59									NO	NO		
L 2	FREEWAY	50	49									NO	NO		
L 3	FREEWAY	50	31			4%		8%	MOD			YES	YES		
L 4	FREEWAY	50	57			5%		3%	MOD			NO	YES		FAIR
R 1	FREEWAY	50	84							05%	FAIR	NO	NO		
R 2	FREEWAY	50	62			20%	4%	4%		05%	FAIR	NO	NO		
R 3	FREEWAY	50	66			29%	4%	10%	MOD	10%	FAIR	YES	YES		GOOD

PM 2.7 TO PM 3.4   JT SPALL (M) L-1. SOME FIRE
DAMAGE L-4 WITH SEVERE RAVEL & SPALL
END L-4 @ P M 3.1
SL SETTLEMENT R-3 WITH VERT DISPL
WITH R2

LOG LENGTH : .7
TOTAL LANES: 7
COST CENTER: 617
SURVEY DATE: 01-78
INCHES RAIN: 10

ADT : 76000
% TRUCKS :
FUNCTIONAL CLASS: NON ARTERIAL
FEDERAL AID :
RSS :

DIR & LANE	ROADTYPE	RIDE SPEED	RIDE SCORE	SKID	PSI	SLAB BREAKUP 1ST STAGE	SLAB BREAKUP 2ND STAGE	SLAB BREAKUP 3RD STAGE	3RD STAGE SPALL	PATCHES % AREA	PATCHES COND	FAULT-ING	PAVE/SHOULD JOINT SEP	PAVE/SHOULD JOINT DISPL	RT SHLD COND
L 1	FREEWAY	50	83							04%	GOOD	NO	NO		
L 2	FREEWAY	50	73			1%				04%	GOOD	NO	NO		
L 3	FREEWAY	50	65			1%				04%	GOOD	NO	YES		GOOD
L 4	FREEWAY	50	57			3%				04%	GOOD	NO	NO		
R 1	FREEWAY	50	80			1%	1%			02%	FAIR	NO	NO		
R 2	FREEWAY	50	72			5%	2%			02%	FAIR	YES	NO		
R 3	FREEWAY	50	65			8%	1%	1%	MOD	03%	FAIR	YES	NO	UP	FAIR

Figure VII-7d

PMS230/235. This program uses either the PMS kickout file or a selected portion of it from PMS200/205 to write a report showing the dominant strategy and other appropriate strategies for each lane of selected pavement sections. The report provides appropriate strategies to 'cure' the observed problems when the dominant strategy is not used because of cost or other restraints.

INPUT:

PMS kickout file (See Files - items 20 and 21)
Strategy description files (See Files - item 25)
Parameter (for report heading purposes)

OUTPUT:

Strategy by lane report (See Figure VII-7e)
Controls

PMS230-B
RUN DATE: 05/16/79
CALIFORNIA DEPARTMENT OF TRANSPORTATION
DIVISION OF MAINTENANCE

PAVEMENT MANAGEMENT SYSTEM
CORRECTIVE STRATEGIES FOR ALL TRIGGERED LANES (FLEXIBLE)
BASED ON 77/78 SURVEY

• DOMINANT SYRATEGY FOR PROJECT CONCEPT

DISTRICT 07 ROUTE 072 COUNTY LA

PM 6.6 TO PM 7.0 TOTAL LANES: 04
ROAD TYPE: FLEXIBLE-CITY STREET
ADT: 33,000
COST CENTER: 653
ANNUAL MAINT. COST/MILE: LAST FY
LAST FY-1
LAST FY-2

LANE	PROBLEM	REPAIR STRATEGY
L1	ALLIG. A CRACK ALLIG. B CRACK	FILL CRACKS THIN OVERLAY & LOCAL DIGOUTS
L2	ALLIG. A CRACK ALLIG. B CRACK	FILL CRACKS •STRUCTURAL ANALYSIS REQUIRED
R1	ALLIG. A CRACK ALLIG. B CRACK	FILL CRACKS THIN OVERLAY & LOCAL DIGOUTS
R2	ALLIG. A CRACK ALLIG. B CRACK	FILL CRACKS •STRUCTURAL ANALYSIS REQUIRED

• DOMINANT STRATEGY FOR PROJECT CONCEPT

DISTRICT 07 ROUTE 091 COUNTY LA

PM 6.0 TO PM 6.5 TOTAL LANES: 06
ROAD TYPE: FLEXIBLE-CITY MAINTAINED
ADT: 43,000
COST CENTER: 721
ANNUAL MAINT. COST/MILE: LAST FY
LAST FY-1
LAST FY-2

LANE	PROBLEM	REPAIR STRATEGY
L2	ALLIG. A CRACK ALLIG. B CRACK	FILL CRACKS THIN OVERLAY & LOCAL DIGOUTS
L3	ALLIG. A CRACK ALLIG. B CRACK	FILL CRACKS •STRUCTURAL ANALYSIS REQUIRED
R2	ALLIG. A CRACK ALLIG. B CRACK	FILL CRACKS BASE REPAIR & PATCH
R3	ALLIG. A CRACK ALLIG. B CRACK	FILL CRACKS THIN OVERLAY & LOCAL DIGOUTS

PM 6.5 TO PM 6.7 TOTAL LANES: 06
ROAD TYPE: FLEXIBLE-CITY MAINTAINED
ADT: 43,000
COST CENTER: 721
ANNUAL MAINT. COST/MILE: LAST FY
LAST FY-1
LAST FY-2

LANE	PROBLEM	REPAIR STRATEGY
L2	ALLIG. B CRACK	•STRUCTURAL ANALYSIS REQUIRED
L3	ALLIG. B CRACK	STRUCTURAL ANALYSIS REQUIRED
R2	ALLIG. B CRACK	THIN OVERLAY & LOCAL DIGOUTS
R3	ALLIG. B CRACK	•STRUCTURAL ANALYSIS REQUIRED

Figure VII-7e

PMS245. This program uses the rigid PMS kickout file or a portion of it from PMS205 to write a report providing information on bridge approach slabs. This is necessary because those records applying to bridge approach slabs were eliminated from the PMS225 report in order to improve it's readability. This report supplements the inventory of pavement conditions for rigid pavements.

INPUT:

Rigid PMS kickout File (See Files - item 21)

OUTPUT:

Bridge approach report (See Figure VII-7f)
Controls

PMS245-4
RUN DATE: 05/18/79
CALIFORNIA DEPARTMENT OF TRANSPORTATION
DIVISION OF MAINTENANCE

PAVEMENT MANAGEMENT SYSTEM
BRIDGE APPROACH CONDITION INVENTORY
BASED ON 77-78 SURVEY

DISTRICT: 07 — ROUTE: 405 — COUNTY: LA

POST MILE			DIR & LANE	BRIDGE RIDE SCORE
34.2	BEGIN BRIDGE RIDESCORE DATE: 09-78 COST CENTER: 722 ADT: 180,000	CHALON RD BR 53-738 ALL LANES - STEPPED RT LANES - RANDOM CRACKING LT LANES - DIFFERENTIAL AT PN	L 1	14
			L 2	0
			L 3	8
			L 4	0
			R 1	18
			R 2	0
			R 3	6
			R 4	0
34.2	END BRIDGE RIDESCORE DATE: 09-78 COST CENTER: 722 ADT: 180,000	CHALON RD BR 53-738 ALL LANES-STEPPED L3-CORNER CRACKS R3,R4 - RANDOM CRACKS	L 1	23
			L 2	16
			L 3	24
			L 4	14
			R 1	10
			R 2	7
			R 3	7
			R 4	5
38.6	BEGIN BRIDGE RIDESCORE DATE: 09-78 COST CENTER: 772 ADT: 180,000	SEPULBEDA BLVD BR. 53-740 ALL LANES- STEPPED L1,L2-MUDJACKED L4- TRANS. CRACKING	L 1	18
			L 2	6
			L 3	0
			L 4	5
			L 5	16
			R 1	14
			R 2	12
			R 3	14
			R 4	16
39.0	END BRIDGE RIDESCORE DATE: 09-78 COST CENTER: 772 ADT: 180,000	VENTURA BLVD. BR 53-741 ALL LANES- STEPPED AND MUDJACKED L1,L2,R1,R3 - TRANSVERSE CRACKING L3 - 2ND STAGE CRACKING	L 1	18
			L 2	7
			L 3	7
			R 1	0
			R 2	6
			R 3	7

Figure VII-7f

C. Description of Computer Files

Because of the difference in pavement types, flexible and rigid pavement information is generally kept in separate files.

There are three major files for each pavement type in the pavement management system. These are:

- o Pavement condition masterfile
- o Pavement management system masterfile
- o Pavement management system kickout file

Because of their large size these files are stored on magnetic tape. Since these files are used by many programs in the system the definitions of their contents have been placed in a special library where they may be called in by any program using them. This allows the definitions to be changed once for the system rather than once for each program.

There are six subsidiary files for each pavement type in the system. These are:

- o Vehicle factors file
- o Inventory legend file
- o Trigger value file
- o Cost factors file
- o Performance life file
- o Strategy description file

Since these are very small files they are stored on magnetic disk.

In addition there are two files from other systems within the Department of Transportation which contain information of use to PMS:

- o Traffic accident and surveillance access system file (TASAS)
- o Project management and control system file (PMCS)

For PMS purposes, information is excerpted from those files to create the TASAS and PMCS subfiles.

There are also several files of a temporary nature which are passed between programs or used for selection purposes. These are:

- o Pavement condition ratings file
- o Pavement condition corrections file
- o Pavement condition transaction file
- o Flexible pavement condition selection file
- o Rigid pavement condition selection file
- o Pavement management system update transactions file
- o Pavement management system selection file

Following are descriptions of the twenty-four files that comprise the PMS data base:

1. Name: Pavement Condition Ratings File
   Record length: 192
   Volume: 100-30,000 records
   File organization: Sequential

   The pavement condition ratings files are created by key data entry from turnaround documents completed by pavement raters. Records from this file are used to create transactions which update the pavement condition masterfile.

2. Name: Flexible Pavement Condition Corrections File
Record Length: 164
Volume: 1-500 records
File organization: Sequential

The flexible pavement condition corrections files are created by key data entry from correction documents submitted by the headquarters PMS staff. Records from this file are used to create transactions which add, delete, or modify records in the pavement condition masterfile. These corrections are made necessary because of errors in filling out the turn-around document or key punch errors.

3. Name: Rigid Pavement Condition Correction File
Record length: 192
Volume: 1-500 records
File organization: Sequential

The rigid pavement condition corrections files are created by key data entry from correction documents submitted by the headquarters PMS staff. Records from this file are used to create transactions which add, delete, or modify records in the pavement condition masterfile. These corrections are made necessary because of errors in filling out the turnaround document or key punch errors.

4. Name: Flexible Pavement Condition Transactions File
   Record length: 152
   Volume: 100-30,000 records
   File organization: Sequential

The flexible pavement condition transactions files consist of ratings or corrections which have passed the edit program. These records are used to add, delete, or modify data in the pavement condition masterfile.

5. Name: Rigid Pavement Condition Transactions File
   Record length: 225
   Volume: 100-30,000 records
   File organization: Sequential

The rigid pavement condition transactions files consist of ratings or corrections which have passed the edit program. These records are used to add, delete, or modify data in the pavement condition masterfile.

6. Name: Flexible Pavement Condition Masterfile
   Record length: 104-2080
   Volume: 70,000 records
   File organization: Sequential

The flexible pavement condition masterfile is a file of variable length records. There are two different types of records in the file. Type 1 records contain a base segment which has information about the entire roadway being rated. In addition, there are from 1 to 18 lane segments containing data which refers only to an individual lane. The number of lane segments in the record depends on the number of lanes on the road. Type 2 records have a base segment for identification purposes and up to 15 comment segments. These segments provide space for the raters more subjective comments about things which are not covered by specific data. This file is also used outside the Pavement Management System for historical purposes so it contains data taken in all surveys. PMS uses only one survey at a time (usually the latest) and a selection process provides data from the desired survey.

7. Name: Rigid Pavement Condition Masterfile
   Record length: 78-2154
   Volume: 25,000 records
   File organization: Sequential

The rigid pavement condition masterfile is a file of variable length records. There is a base segment which contains information about the entire roadway being rated. There are from 1 to 18 lane segments containing data which refers only to an individual lane. The number of lane segments in the record depends on the number of lanes on the road. There are also up to 15 comment segments which contain the raters more subjective comments about things which are not covered by specific data. Since this file is also used outside the Pavement Management System for historical purposes it contains the data taken in all surveys. The Pavement Management System uses only one survey at a time (usually the latest) and a selection process provides data from the desired survey.

8. Name: Pavement Condition Vehicle Factors File
   Record length: 80
   Volume: 30 records maximum
   File organization: Sequential

The pavement condition vehicle factors files contain factors which, when multiplied by the ride scores, yield results which are compatible, even though different vehicles were used to obtain the ride scores. This is necessary because softer riding vehicles would produce higher ride scores than those with harder suspensions even on the same pavement.

9. Name: Pavement Condition Legend File
   Record length: 133
   Volume: 250 records maximum
   File organization: NA

The pavement condition legend files produce a legend which appears on the front of the inventory report to make it more understandable. Among other things it explains in english the meaning of some of the results which are printed out in numeric form.

10. Name: Pavement Condition Selection File
    Record length: 80
    Volume: 1-3 records
    File organization: NA

The pavement condition selection file provides a method of selecting only certain records from the masterfile for reporting or producing a turnaround document. The selection criteria is usually location (district, route, county, cost center, etc.), or survey year.

11. Name: Flexible Pavement Management System Masterfile
    Record length: 680-1870
    Volume: 7,000 records
    File organization: Sequential

The flexible PMS masterfile is a file of variable length records. It contains records from the pavement condition file which are from the desired survey. There is a base segment which contains information applicable to the entire roadway, and up to 18 lane segments containing information pertaining to each individual lane only. Most of the data from the pavement condition record are copied to the records in this file.

12. Name: Rigid Pavement Management System Masterfile
    Record length: 680-1870
    Volume: 15,000 records
    File organization: Sequential

The rigid PMS masterfile is a file of variable length records. It contains records from the pavement condition file which are from the desired survey. There is a base segment which contains information applicable to the entire roadway, and up to 18 lane segments containing information pertaining to each individual lane only. Most but not all of the data from the pavement condition record are copied to the records in this file.

13. Name: PMS Update Transactions File
Record length: 80
Volume: 1-500 records
File organization: Sequential

The PMS update transactions file contains corrections and updates to the PMS masterfile. It is usually coded by the headquarters PMS users. The major usage will be to change project limits and to add district strategy data.

14. Name: Project Management and Control System (PMCS) Data Base
Record length: Variable
Volume: 160,000 records
File organization: Indexed Sequential

The PMCS data base is an enormous file of data covering every mile of highway in the state highway system, both existing and proposed. The data base is 'online' meaning that it can be accessed, for updating or reading, immediately via cathode ray tube terminals, as well as by batch processing. Because it is an indexed sequential file it can be accessed either randomly (go directly to the desired record) or sequentially (take the next record in order). A number of access routines have been developed to enable users of the file to take advantage of this flexibility.

Data on this file have been organized into several groups or record types. Each record type contains data of a similar nature (safety items, dimensional items, dates, etc.). There are 21 of these record types. Each pavement section contains all 21 record types. Users of the data base can select only those record types containing the data they want and ignore the other record types.

15. Name: Project Management and Control System Subfile
    Record length: 150
    Volume: 14,000 records
    File organization: VSAM

Because the PMCS data base is so large, a subfile has been created which contains only certain desired information. At present five different systems use data from this file which is updated monthly from the PMCS data base. The file is organized so that it can be accessed randomly (to the start of a highway district, for example) and then read sequentially. The Pavement Management System uses this file to obtain road system data.

16. Name: TASAS Current Highway File
    File organization: Sequential

The TASAS current highway file contains average daily traffic (ADT) and road length information amoung other things. It is our source for ADT figures and correct roadway lengths. Roadway lengths are changeable due to realignment and to renumbering which occurs at district or county boundaries.

17. Name: TASAS Subfile
    Record length: 50
    Volume: 42,000 records
    File organization: VSAM

The TASAS subfile is a file of ADT and road length information derived from the TASAS file. Only certain data has been selected and some of it has been reformatted to make it more usable to PMS. The file is organized so that it can be entered randomly at a desired point (the start of a particular route within a given county within a given highway district, for example) and then read sequentially from that point on.

18. Name: Pavement Management System Trigger Values File
    Record length: 30
    Volume: 50 Records maximum
    File organization: NA

The PMS trigger value file (one each for flexible and rigid) is actually a number of files which can be used at will. This provides a method of changing problem trigger values without changing a program. It allows 'standard' trigger values to be updated and allows the user to play 'what if' games to determine the effect of changes in problem trigger values on his budget or on his mix of projects. The file consists of mnemonic names and values which are associated with those names. The file is copied into the program when a job is run. When the name is encountered in the program the associated value is used to make a comparison with the appropriate problem.

19. Name: Flexible Pavement Management System Kickout File
Record length: 730-2090
Volume: 7,000 records
File organization: Sequential

The flexible PMS kickout file is a file of variable length records derived from the flexible PMS masterfile. There is a root segment containing information applicable to the entire roadway and up to 18 lane segments containing information concerning one particular lane only. Only those records from the masterfile which contain pavement condition data exceeding specific trigger values are copied to the kickout file. Highway program, project cost, and repair strategy information is also added to the file.

20. Name: Rigid Pavement Management System Kickout File
Record length: 730-2090
Volume: 10,000 records
File organization: Sequential

The rigid PMS kickout file is a file of variable length records which is derived from the rigid PMS masterfile. There is a root segment containing information applicable to the entire roadway and up to 18 lane segments containing information concerning one particular lane only. Only those records from the masterfile which contain pavement condition data exceeding specific trigger values are copied to the kickout file. Highway program, project cost and repair strategy information is also added to the file.

21. Name: Pavement Management System Cost Factors File
    Record Length: 20
    Volume: 50 records
    File organization: NA

The PMS cost factors file (one each for flexible and rigid) is actually a number of files which can be used to revise cost estimates without altering a program. It allows 'standard' cost values to be updated and allows the user to play 'what if' games to determine the effect of cost changes on his budget or on his mix of highway programs. The file consists of factor names and cost values which are associated with those names. The file is copied into the program when the job is run. When the name is encountered in the program the associated value is used in computing costs.

22. Name: Pavement Management System Performance Life File
    Record length: 20
    Volume: 50 records
    File organization: NA

The PMS performance life file (one each for flexible and rigid) is also a group of files which can be used to change performance life estimates without altering the program. The performance life file consists of a strategy code and a performance life value which is associated with that code. The file is copied into the program when a job is run, and when the code is encountered in the program the associated value is used. Normally the 'standard' values on this file would only be changed at infrequent intervals (2-5 years).

23. Name: Pavement Management System Selection File

Record length: 80

Volume: 1-10 records

File organization: NA

The PMS selection file contains selection criteria which enables the Pavement Management System users to obtain only those pavement sections from the PMS kickout file which they want at any given time or for any given purpose. There is selection capability on virtually every field in the PMS kickout record.

24. Name: Pavement Management System Strategy Description File

Record length: 80

Volume: 50 records maximum

File organization: Sequential

The strategy description file (one each for flexible and rigid) is a file of strategy codes and the descriptions that correlate with them. It also contains problem descriptions that go with each code. The sequence of the strategy codes determines the dominance of the strategies. Each strategy is dominant to all other strategies below it in the file. By placing this information on a file instead of coding it into a program, changes are much easier to make. The file is copied into the program when it is needed and when the codes are encountered the associated problem description and strategy description are printed. The dominant strategy for the road section is also determined from the file.

VIII. Correlation of California Pavement Rating System And AASHTO* Road Test Present Serviceability Index (PSI)

A single number rating system was developed at the AASHTO Test Road to measure pavement serviceability. A panel of raters was first used to assess test road serviceability strictly on a subjective basis and their averaged ratings were described as Present Serviceability Ratings (PSR). The Present Serviceability Index (PSI) was later developed to correlate certain physical measurements to the subjective ratings. The PSI system is based on pavement roughness (riding qualities), cracking, and patching, while rutting is also considered for flexible pavements. The roughness or ride quality factor dominates the PSI ratings whereas cracking and patching influence PSI values to a lesser extent. PSI ratings vary from 0 (impassable) to 5 (perfect).

Using an altogether different approach the California Department of Transportation has completed four biennial condition surveys on all flexible pavements in the state system since 1969. In 1976, California completed the first condition survey of rigid pavements on its highway system. Biennial condition surveys for both pavement types are continuing with the current condition survey to be completed in the fall of 1978. (See Section I of this report for a description of California's current Pavement Condition Rating Systems.)

A primary reason for developing a correlation of the two systems is the possibility that FHWA criteria for R-R-R (Resurfacing, Restoration and Rehabilitation) project warrants will involve use of PSI ratings or its proxy.

*Throughout this report the current acronym AASHTO is used in lieu of the former acronym AASHO.

Although a correlation between the California rating system and PSI system has been developed there are major disadvantages to the use of the single number PSI rating system.

- The propagation of alligator cracks in wheelpath areas of an AC pavement indicates lack of structural strength needing immediate attention to support imposed traffic loads. However, this condition may not necessarily be reflected in poor ride quality measurements for some undetermined period of time.

- Since the ride quality measurement dominates the PSI value, such a roadway would not indicate the more immediate need for rehabilitation if PSI values are used to establish levels of acceptability.

- California's jointed PCC pavement develops 1st, 2nd and 3rd stage slab breakup indicating structural deterioration. Acceptable ride quality can and does exist on such a pavement. However, since ride quality dominates the PSI value, such a pavement would not indicate the need for rehabilitation.

- A single number rating system does not assist in identification of proper repair strategies. A rating system which considers ride quality information along with both extent and severity measurements of each pavement condition is considered superior to a single number rating system such as PSI. A primary advantage is that it permits retention of information which assists in the selection of an appropriate rehabilitation strategy.

- A single number rating system such as PSI does not provide sufficient data to permit performance evaluation. Information relative to severity and extent of each pavement condition is essential to accurately assess performance and assist in the study of performance trends.

A. Conversion System for Rigid Pavements

The PSI formula for PCC pavement as developed at the AASHTO Road Test is given below:

$$PSI = 5.41 - 1.78 \log (1+ \overline{SV}) - 0.09 \sqrt{C+P}$$

PSI = Present Serviceability Index
$\overline{SV}$ = mean slope variance
C = extent of cracking (lin. ft. per 1000 sq. ft.)
P = extent of patching (sq. ft. per 1000 sq. ft.)

PSI values range from 0 to 5, with a value of 0 indicating an impassable condition. A PSI value of 2.5 or less indicates a pavement eligible for rehabilitation for the level of service expected on the Interstate Highway System.

The corresponding formula using data from California's pavement rating system for PCC pavements to convert to equivalent PSI values is as follows:

$$\text{Equivalent PSI} = \frac{1}{0.1926 + 0.0045RS} - 0.09 \sqrt{0.36L+0.72M+1.44S+10P}$$

RS = Ride Score as determined from PCA Road Meter
L = Extent of first stage* cracking (% of slabs)
M = Extent of second stage* cracking (% of slabs)
S = Extent of third stage* cracking (% of slabs)
P = Extent of patching (% of area)

*Refer to Table 1 for a definition of 1st, 2nd & 3rd stage cracking.

California's first rigid pavement rating inventory was made in the 1975-76 Fiscal Year. Data obtained from this first survey did not include an actual extent measurement of slab breakup. The present rigid pavement condition inventory uses extent as well as severity of pavement conditions.

In the PSI formula, ride quality has more influence on PSI ratings than either cracking or patching.

The AASHTO Road Test Profilometer was used to measure slope variance (pavement roughness) in the earlier days of the road test. Later, a Bureau of Public Roads Roughometer was developed for use to measure roughness. The CHLOE* Profilometer was conceived and developed at still a later date, too late for use at the test road. In more recent years, high speed ride quality measuring equipment such as the PCA Road Meter has been developed and utilized with very good success by many public agencies. California has been using PCA Road Meters to inventory ride qualities on the State Highway System biennially since 1969. Caltrans first attempt to correlate ride quality and PSI was done in 1969. The correlation was determined on PCC pavements of varying roughness and was based on ride qualities only (no deductions for cracking and patching). The California Transportation Laboratory established a correlation between California's first PCA Road Meter and the slope variance as determined with the CHLOE Profilometer. Slope variance data was converted to equivalent PSI values using the AASHTO Test Road formula.

The PSI values were then plotted against summation of roughness counts per mile with the PCA Road Meter to provide a direct correlation. In 1976 another correlation study for rigid pavements was performed by the California Transportation Laboratory when PCA Road Meter equipment was placed in a new vehicle (1975

*Developed by Carey, Huckins, Leathers and Other Engineers

Plymouth Station Wagon). Figure VIII-1 shows the results of this study and the results of a later correlation on flexible pavements. For rigid pavements, a computerized, best fit equation yields the expression.

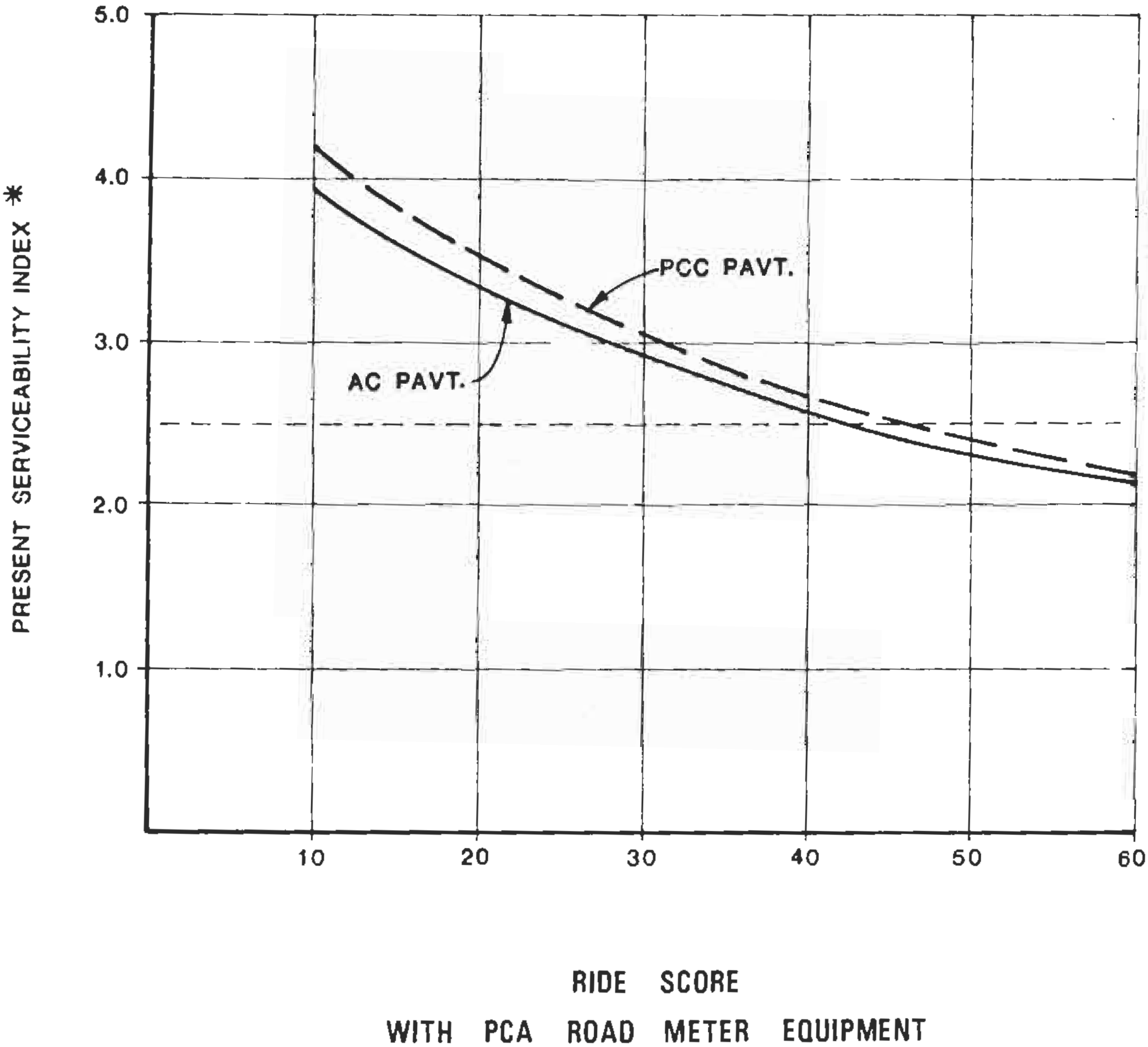
$$PSI = \frac{1}{0.1926 + 0.0045RS}$$

RS = Ride Score as measured by the PCA Road Meter

This term replaces the $5.41 - 1.78 \log (1+\overline{SV})$ portion of the PSI equation for PCC pavement. Figure VIII-2 shows correlation curves as adopted by several states for the purpose of converting ride measurements to equivalent PSI. Brokaw developed the PCA Road Meter and the results of his work are also shown for comparison purposes. Overall correlation variance is undoubtedly due to different suspension systems on the various vehicles used.

Pavement cracking does not have as much influence on PSI values as does ride quality. Loss of structural integrity in pavements would seem to warrant more of an impact on PSI ratings than it does. Examples are given in Table 2 of specific cases to illustrate this point. The examples clearly show cases where the rate of structural deterioration is not reflected in ride qualities in sufficient time to permit a relatively inexpensive rehabilitation. Nevertheless, a means of converting data from the California rating system to equivalent PSI values as determined by the AASHTO formula has been developed. If no patching exists, the PSI reduction due to pavement cracking is represented by the term $0.09\sqrt{C}$ in the AASHTO equation. Four classes of cracking in rigid pavements were defined at the AASHTO Road Test, as follows:

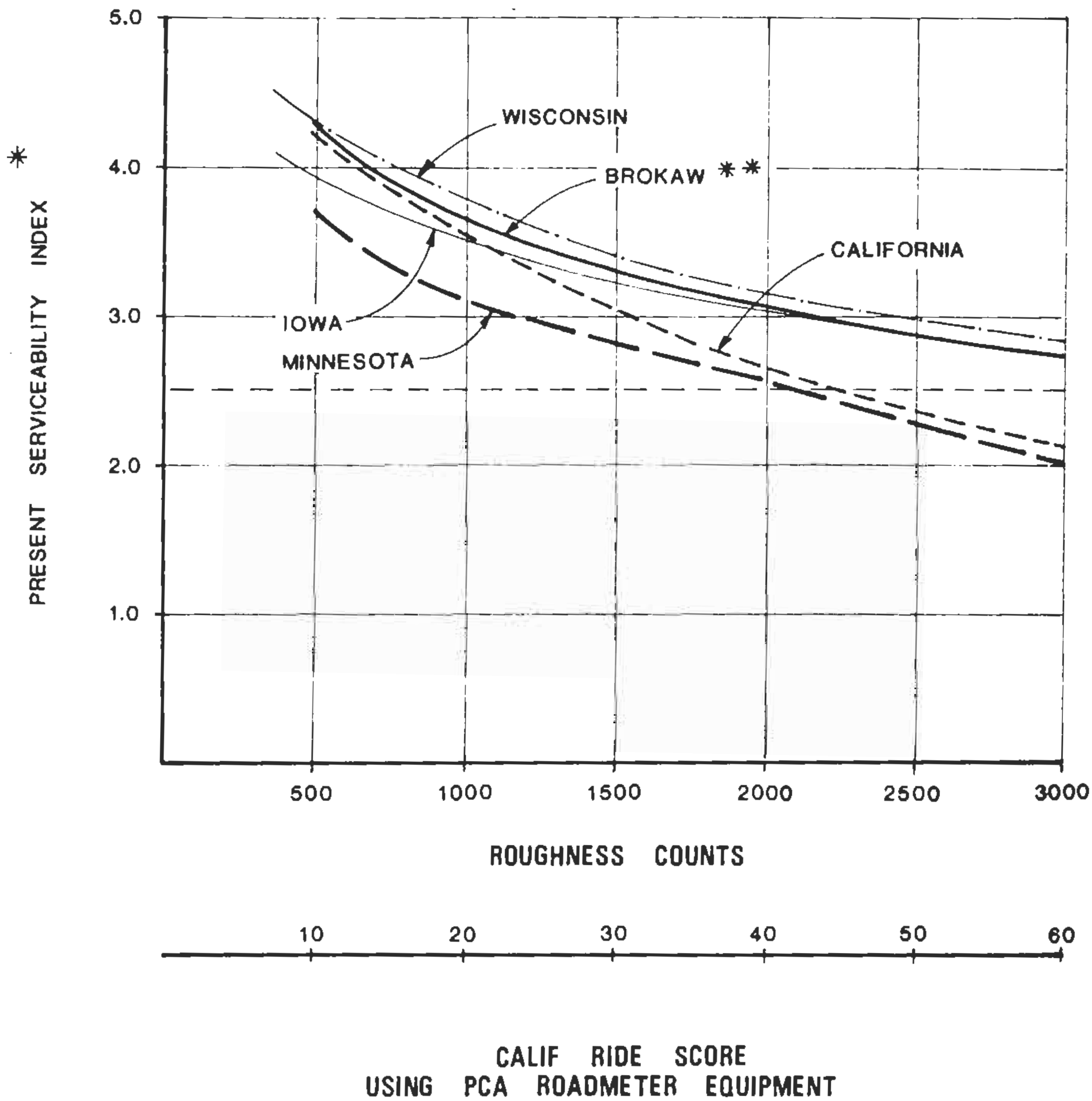
PRESENT SERVICEABILITY VS. ROUGHNESS



* NO CONSIDERATION FOR CRACKING, PATCHING OR RUTTING

Figure VIII-1

PRESENT SERVICEABILITY VS. ROUGHNESS
PCC PAVEMENTS



* NO CONSIDERATION FOR CRACKING AND PATCHING

** DEVELOPER OF PCA ROADMETER

Figure VIII-2

Class 1 - "Hairline" cracking not visible at 15 feet.

Class 2 - Cracking visible at 15 feet with spalling (or slab separation) less than 1/4 inch wide at the pavement surface.

Class 3 - Cracking 1/4 inch or greater in width.

Class 4 - All sealed cracking.

By AASHTO definition, only Class 3 and 4 cracking are included in the PSI formula.

The term C in the PSI equation is total lin. ft. of Class 3 and Class 4 cracks per 1000 sq. ft. of pavement.

The California rating system does not include crack width measurements or crack length measurements because this is impractical for inventory purposes. It is reasoned that it is necessary to work with average conditions of relatively long segments. For example, one lane mile is over 63 times greater than the standard 1000 sq. ft. section of pavement used at the AASHTO Test Road.

To demonstrate the correlation between the two rating systems, consider the condition of one full lane width crack 1/4" wide or wider in each slab (5.38 slabs in 1000 square feet). For the lane being rated the length of cracking is 12 x 5.38 or 64.5. The PSI reduction in the AASHTO equation gives a value of $0.09 \sqrt{64.5} = 0.72$.

To convert from the California system to equivalent PSI deduction assuming 99% second stage cracking, ($0.09 \sqrt{0.72M}$), we obtain $0.09 \sqrt{0.72 \times 99} = 0.76$, to assist in relating the California rating data to PSI values. Note that L = first, M = second, and S = third stage cracking extent percentage.

Figure VIII-3 shows a comparison of PSI deduction values for first, second, and third stage cracking, calculated by the California and AASHTO methods.

Figure VIII-4 shows a comparison of combined cracking PSI deduction values using an AASHTO Road Test case history.

As shown by these figures, it was found that the expression $0.09 \sqrt{0.36L + 0.72M + 1.44S}$ (California Rating System) yields a close approximatation to the AASHTO term of $0.09 \sqrt{C}$ to determine the deduction in PSI value attributable to pavement cracking.

If no pavement cracking exists, the PSI reduction due to patching is expressed as $0.09 \sqrt{P}$ in the AASHTO formula. The value of P represents square feet of patching for 1000 square feet of pavement in the section being rated. It includes all patches whether full lane width or not.

To convert from California's patch code ratings to equivalent PSI deductions the following expression is used.

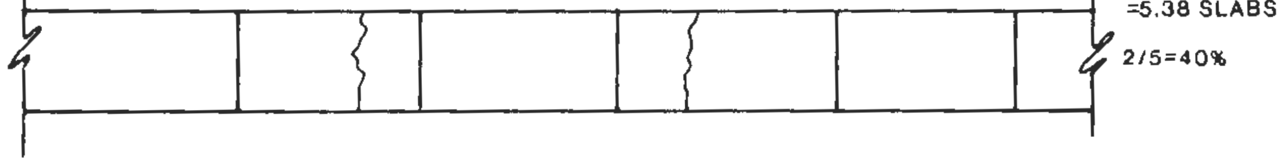
$$0.09 \sqrt{10P}$$

P = percent area of patching in the section being rated.

For a detailed comparison, refer to Table 3.

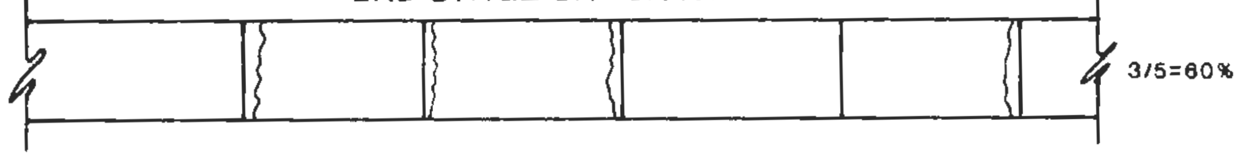
CALCULATION OF PSI DEDUCTION VALUES FOR FIRST, SECOND AND THIRD STAGE CRACKING USING CALIFORNIA AND AASHTO METHODS

1ST STAGE CRACKING



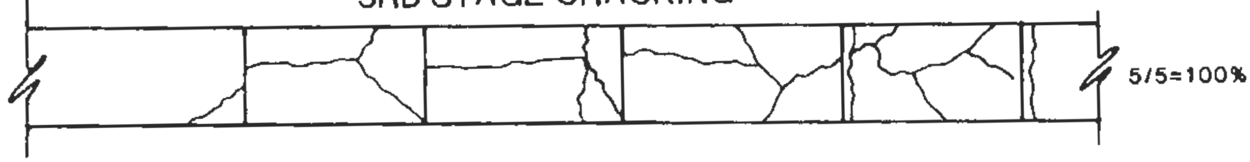
CALIF. PSI DEDUCTION	L40=40% 1ST STAGE CRACKING	$0.09\sqrt{0.36 \times 40}=0.34$
AASHTO PSI DEDUCTION	LINEAR FT. CRACKING=24'	$0.09\sqrt{24}=0.44$

2ND STAGE CRACKING



CALIF. PSI DEDUCTION	M60=60% 2ND STAGE CRACKING	$0.09\sqrt{0.72 \times 60}=0.59$
AASHTO PSI DEDUCTION	LINEAR FT. CRACKING=48'	$0.09\sqrt{48}=0.62$

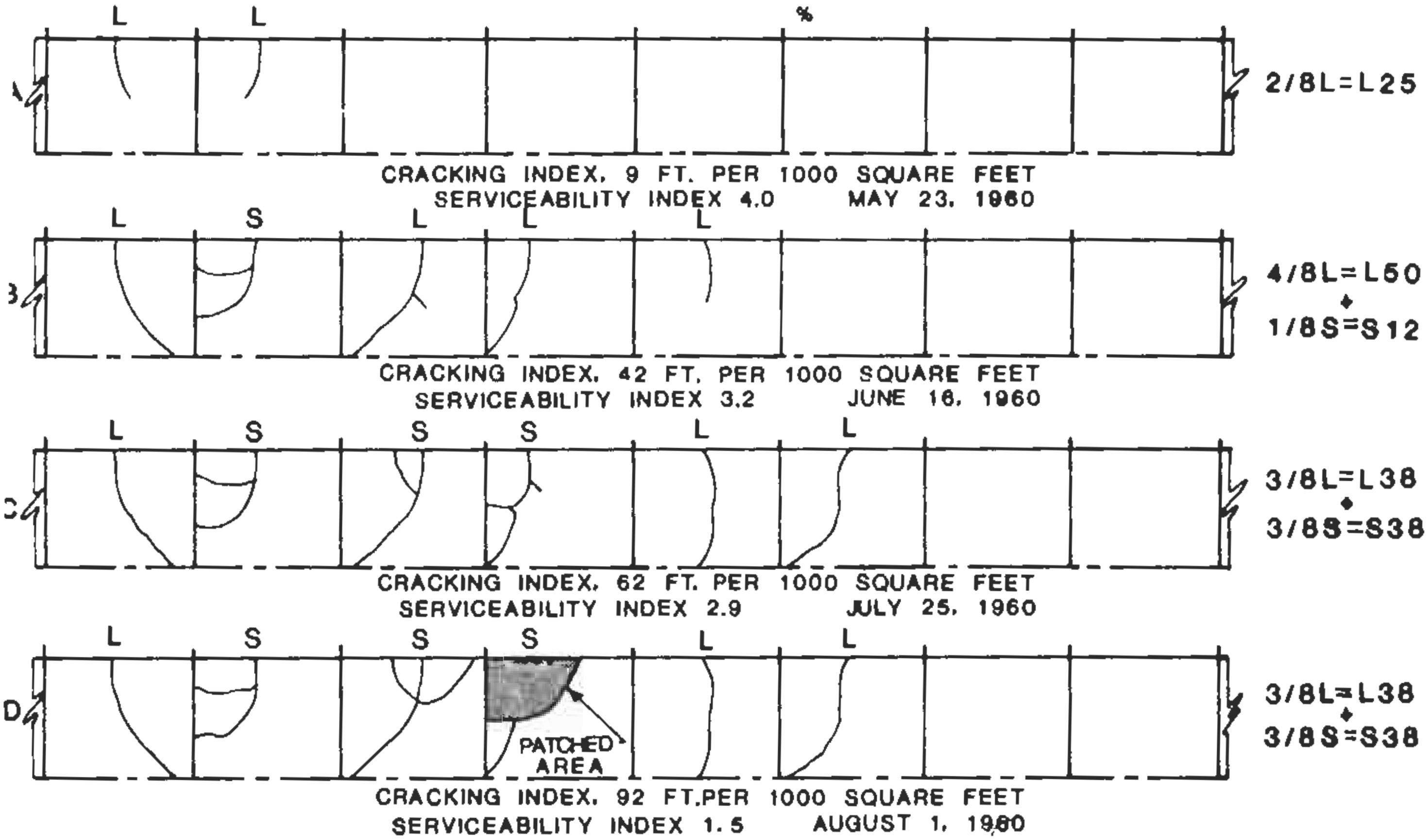
3RD STAGE CRACKING



CALIF. PSI DEDUCTION	S99=100% 3RD STAGE CRACKING	$0.09\sqrt{1.44 \times 99}=1.07$
AASHTO PSI DEDUCTION	LINEAR FT. CRACKING=120'	$0.09\sqrt{120}=0.99$

Figure VIII-3

CALCULATION OF PSI DEDUCTION VALUES FOR COMBINED CRACKING USING CALIFORNIA AND AASHTO METHODS



STATE OF CONDITION	LENGTH OF CRACKS "C"	AASHTO PSI REDUCTION	CALIF. RATING	CALIF. PSI REDUCTION
A	9	0.27	L25	0.27
B	42	0.58	L50 + S12	0.53 *
C	62	0.71	L38 + S38	0.74
D	92	0.86	L38 + S38	0.74

*EXAMPLE: $0.09\sqrt{0.36L+0.72M+1.44S} = 0.09\sqrt{0.36 \times 50 + 0.72 \times 0 + 1.44 \times 12} = 0.53$

Figure VIII-4

B. Conversion System For Flexible Pavements

The PSI formula developed at the AASHTO Test Road is as follows for flexible pavements:

$$PSI = 5.03 - 1.91 \log (1 + \overline{SV}) - 0.01\sqrt{C+P} - 1.38\ \overline{RD}^2$$

PSI = Present Serviceability Index

$\overline{SV}$ = mean slope variance

C = cracking, $ft^2/1000\ ft^2$

P = patching, $ft^2/1000\ ft^2$

$\overline{RD}$ = mean rut depth, inches

The corresponding formula using data from California's pavement rating system for AC pavements to convert to equivalent PSI values is as follows:

$$\text{Equivalent PSI} = \frac{1}{0.2093 + 0.0445RS} - 0.01\sqrt{5B+10B'+10P} - \frac{L}{100}\overline{RD}$$

PSI = Present Serviceability Index.

RS = Ride Score from PCA Road Meter.

B = Percent of wheelpath length which exhibits alligator cracking (Values 1 through 99).

B' = Same as above except use pavement length of block cracking.

P = Percent area of pavement patched (Values 1 through 99).

L = Percent length of rutting (Values 1 through 99).

$\overline{RD}$ = Rut depth code where 3/4" or greater ruts are identified.

Table 4 shows the pertinent details of California's flexible pavement condition rating system.

Figure VIII-5 shows the correlation between ride scores and PSI as developed by several states. It should be noted that Utah uses the PCA Road Meter, while Wisconsin uses the Mays Meter which is quite similar. Minnesota has utilized the PCA Road Meter. Iowa also has used the PCA Road Meter, but for whatever reason found AC pavements to be more difficult than PCC pavements to correlate.

Balmer also found good correlation between roughness measurements and PSI for rigid pavements, but did not find as good a correlation for AC pavements.

Five points plotted on this family of curves, (Figure VIII-5) indicate the results of slope variance data, considering ride quality only, as it was measured by CHLOE equipment on various flexible pavements in California. Ride score data was obtained from our biennial condition survey from these same locations within about the same time frame. These roughness counts vs PSI values plot rather closely to the correlation curves developed by Brokaw.

Three classifications of cracking in flexible pavements were utilized at the AASHTO Test Road:

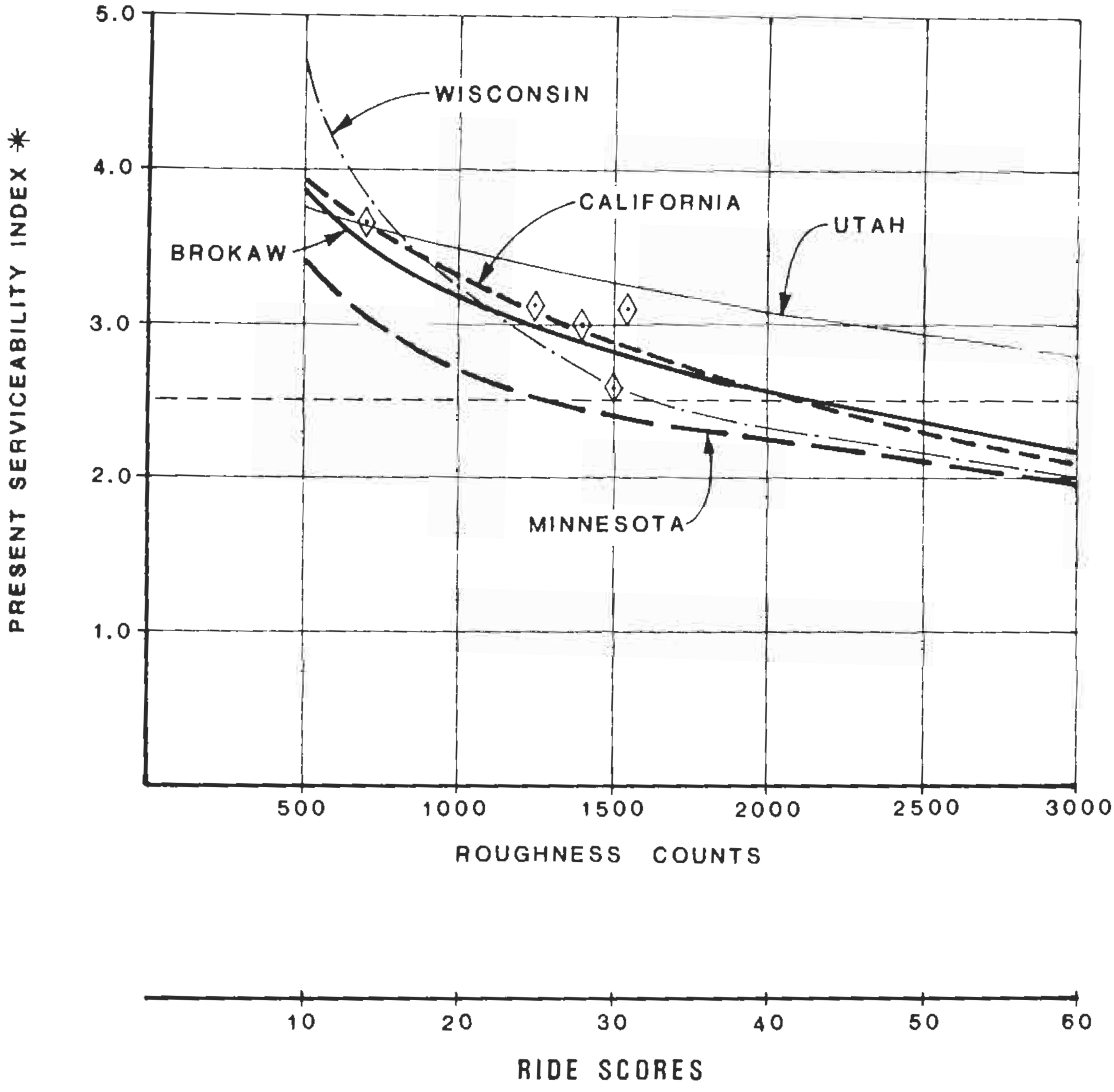
Class 1 cracks - single line cracks.

Class 2 cracks - cracks which have progressed to the stage where cracks have connected together to form a grid type pattern, regardless of crack width.

Class 3 cracks - cracking in which the bituminous surfacing segments have become loose.

Only Class 2 and 3 cracking is included in the PSI formula for flexible pavements. The extent of cracking is measured in square feet per 1000 square feet of pavement surface. If alligator cracking is the only problem, the maximum PSI reduction which is

PRESENT SERVICEABILITY VS ROUGHNESS
AC PAVEMENTS



◊ COMPARISON BETWEEN CHLOE (SLOPE VARIANCE) & PCA ROADMETER ON AC PAVEMENTS IN CALIF. USING THE AASHTO FORMULA $PSI=5.03-1.91 \log(1+\overline{SV})$ COMPARED TO RIDE SCORES

* NO CONSIDERATION FOR PATCHING, CRACKING AND RUTTING

Figure VIII-5

possible using the AASHTO formula is 0.31 when 100% of the pavement area being rated has alligator cracking. Structural condition of this type would appear to warrant much greater consideration.

Table 5 shows examples as documented from specific projects to illustrate this point. It is obvious from these examples how use of the PSI system can result in a "Do Nothing" policy when in fact, some form of relatively minor structural repair performed on a timely basis can be most cost effective.

California AC pavement condition rating data for cracking and patching can be converted to equivalent PSI deduction by use of the following expression:

$$0.01 \sqrt{C+P} = 0.01 \sqrt{5B+10B' + 10P}$$

Table 6 shows the details needed for conversion of crack ratings from the California flexible pavement rating system to the PSI system.

Table 7 provides the needed data to convert from California patch ratings to equivalent PSI deductions.

Rut depth influence on PSI values in the AASHTO formula is expressed as $-1.38\ \overline{RD}^2$, $\overline{RD}$ being the average rut depth as measured in inches.

The California rating system for flexible pavements includes only locations of rut depth 3/4" or greater.

Continuous 3/4 inch rutting in both wheelpaths results in a PSI deduction of 1.38 $(.75)^2$ or 0.78. Where rut depths of $\geq$ 3/4 inch are encountered, the PSI deduction can be made based on % length of rutting in the section being rated, but it is then impossible to compute a PSI deduction less than 0.78 because $<$ 3/4 inch rut depths are not measured in the California rating system.

Where rutting exists, it may occur in both wheelpaths. However, 100% continuous rutting only in the outside wheelpath can occur due to lack of lateral (shoulder support) and this would result in only a 0.19 reduction in PSI.

Table 8 shows the details needed to perform the conversion for rutting. The conversion formula is given at the bottom of this Table.

TABLE 1

RIGID PAVEMENT DEFINITIONS*

Slab Breakup (Cracking)

Severity

First stage cracking	Transverse, longitudinal or diagonal cracks in a slab which divide the slab into 2 or 3 large pieces. It consists of minor distress cracks which are more than 2' apart or more than 2' from planned joints and cracks.
Second stage cracking	Transverse, longitudinal or diagonal cracks which develop within 2' of planned or unplanned cracks or joints.
Third stage cracking	Interconnected cracks developing between first stage or second stage cracks, and joints or other cracks. Third stage cracking, as opposed to first or second stage cracking, divides the slab into at least 3 pieces and usually 4 or more.

Extent

1 through 99	Percent of slabs in a lane segment that exhibit each stage of distress cracking described above (Values 1 through 99).

Patching

Condition

G	Good condition, performing satisfactorily.
F	Fair condition, somewhat deteriorated and affects ride quality to some extent.
P	Poor condition, badly deteriorated and affects ride quality significantly.

Extent

1 through 99	Percent area that is patched (Values 1 through 99).

*Taken from California's "Manual of Rating Instructions for Pavement Condition Surveys".

TABLE 2

EXAMPLES OF PCC PAVEMENTS WITH EXCELLENT RIDE QUALITIES BUT HAVING OBVIOUS STRUCTURAL PROBLEMS

Example 1:

Date of Rating	District	County	Route	Post Miles	Lane	Ride Score	PSI*	Structural Condition
1976	03	Sac.	99	19/20	R2	18	3.65	25%-1st Stage Cracks 25%-2nd Stage Cracks 25%-3rd Stage Cracks

*PSI shown is based on ride quality conversion only. When cracking is also considered, the PSI is reduced to 2.95 which is above the 2.50 critical value.

Example 2:

Date of Rating	District	County	Route	Post Miles	Lane	Ride Score	PSI*	Structural Condition
1976	10	S.J.	99	34/35	R2	19	3.60	60%-1st Stage Cracks 30%-2nd Stage Cracks 10%-3rd Stage Cracks

*PSI based on ride score conversion only. When cracking is also considered the PSI is reduced to 2.9 which still does not indicate any rehabilitation needs based on the PSI criterion.

TABLE 3

PATCHING IN PCC PAVEMENTS
CONVERSION OF CALIFORNIA PAVEMENT RATING DATA

Patching $ft^2/1000\ ft^2$	PSI Deduct. Using AASHTO Formula	Extent (Calif.) Percent	Using Calif. Conversion Formula*
20	0.40	02	0.40
100	0.90	10	0.90
150	1.10	15	1.11
170	1.17	17	1.17
250	1.42	25	1.42

*Conversion formula

Equivalent PSI Reduction = $0.09\sqrt{10P}$

TABLE 4

FLEXIBLE PAVEMENT DEFINITIONS*

Alligator Cracking

Severity

Class A	single or parallel longitudinal cracking in wheelpath(s), regardless of crack width.
Class B	polygon connected alligator cracking in wheelpath(s) regardless of crack width.
Class C	unusual alligator cracking (i.e. pavt. surface widening which has subsequently cracked).

Extent

1 through 99	Percent of length of segment showing type of alligator cracking described above (50% = one continuous wheelpath for Class A or B).

Block Cracking

Class B'	polygon connected cracking nearly full lane width, regardless of crack width.

Extent

1 through 99	Percent of pavement length showing nearly full lane width of block cracking.

Patching

Quality of Patching (Visual rating only)

G = Good
F = Fair
P = Poor

Extent

1 through 99	Percent of pavement area having patches.

*Taken from California's "Manual of Rating Instructions for Pavement Condition Surveys".

TABLE 5

EXAMPLES OF AC PAVEMENTS WITH EXCELLENT RIDE QUALITIES BUT HAVING OBVIOUS STRUCTURAL PROBLEMS

Date of Rating	District	County	Route	Post Miles	Lane	Ride Score	PSI*	Structural Condition
12/73	10	SJ	88	19.2/ 20.6	R1	20	3.35 3.00	Alligator Cracking > 1/4" wide over > 45% of pavement area. Many patches and pumping.
1/76	3	Glenn	32	8.7/ 9.0	R1	17	3.50 3.30	Alligator Cracking 1/4" wide over > 45% of pavement area. No patching recorded.
2/76	3	ED	50	22.8/ 25.9	R2	13	3.75 3.50	Alligator Cracking 1/4" wide over more than 45% of pavement area. Patching recorded in 4%-8% of area.

*Upper PSI value is based on Ride Quality conversion alone. Lower PSI value also considers cracking and patching. Since all PSI values are well above the critical 2.50 level, none of these projects would "qualify" for rehabilitation based on the PSI criterion.

TABLE 6

PSI CONVERSION
CRACKING IN AC PAVEMENTS

AASHTO Class 2 and Class 3 cracking includes all cracking which has formed a grid pattern (alligator cracking) regardless of crack width.

Condition	Calif.Rating	PSI Reduction from Calif.Conversion	C*	PSI Reduction AASHTO Form
Class B cracks over 20% of length of one 3' wheelpath.	B10	0.07	50	0.07
Class B cracks over 50% of one 3' wheel-path.	B25	0.11	125	0.11
Class B cracks continuous in 3' outer wheel-path only. No cracks in inner wheelpath.	B50	0.16	250	0.16
Class B' cracks over 50% of length.	Block 50	0.22	500	0.22

California Conversion

Equivalent PSI reduction = $0.01\sqrt{5B+10B'}$

B = Calif. rating code for extent of wheelpath alligator cracking.

B'= Calif. rating code for extent of full lane width cracking (block cracking).

AASHTO System

AASHTO PSI reduction = $0.01\sqrt{C}$

C* = sq. ft. of cracking per 1000 sq. ft. of pavement.

TABLE 7

PSI CONVERSION
PATCHING IN AC PAVEMENTS

Area of Patching, sq.ft. per/1000 sq.ft. of Pavement	Calif. Rating Patching Extent	PSI Reduction from Calif. Conversion System	PSI Reduction Using AASHTO Formula
10	01	0.03	0.03
100	10	0.10	0.10
300	30	0.17	0.17
900	90	0.30	0.30

California Conversion

Equivalent PSI reduction = $0.01 \sqrt{10P}$

P = Calif. rating code for patching extent.

AASHTO System

AASHTO PSI reduction = $0.01 \sqrt{P}$

P = Patching extent in sq. ft. per 1000 sq. ft. pavement.

TABLE 8

PSI CONVERSION
RUTTING IN AC PAVEMENTS

Condition	Calif. Rating	Mean Rut Depth	PSI Reduction Calif.Conversion	PSI Reduction AASHTO Form
3/4" Rutting in 20% outer wheelpath length. None in inner wheelpath.	R10	0.07"	0.01	0.01
3/4" Rutting in 30% outer wheelpath length. None in inner wheelpath.	R15	0.11"	0.02	0.02
3/4" Rutting in 100% outer wheelpath length. None in inner wheelpath.	R50	0.37"	0.19	0.19
3/4" Rutting continuous in outer wheel-path plus 50% of inner wheelpath.	R75	0.56"	0.42	0.43
Continuous 3/4" ruts in both wheel-paths.	R99	0.75"	0.74	0.78

TABLE 8 (Continued)

California Conversion

Equivalent PSI reduction = $\frac{L}{100}\overline{RD}$

$\overline{RD}$ = Mean rut depth in section being rated.

L = factor for percent of wheelpath length where 3/4" rutting has occurred.

(one continuous wheelpath = 50% of length or L = 50)

AASHTO System

AASHTO PSI reduction = $1.38\ \overline{RD}^2$

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