TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
TX-90/930-1		

4. Title and Subtitle	5. Report Date
MicroPES Release 1.01 A User's Manual	June 1989
	6. Performing Organization Code: Texas Transportation Institute
7. Author(s)	8. Performing Organization Report No.
Scullion, T., Paredes, M., Fowler, J., Fernando, E.	Research Report 930-1
9. Performing Organization Name and Address: Texas Transportation Institute, Texas A & M University, College Station, TX 77843	10. Work Unit No.
	11. Contract or Grant No.: 2-18-87-0930
	13. Type of Report and Period Covered: Interim- September 1986 January 1989
12. Sponsoring Agency Name and Address: Texas State Department of Highways and Public Transportation; Safety & Maintenance Div., P.O. Box 5051, Austin, Texas 78763	14. Sponsoring Agency Code

15. Supplementary Notes

Research performed for the State of Texas
Research Study Title: District Level Pavement Management System

16. Abstract

This report describes a microcomputer system for analyzing the information collected by state forces in their annual network-level Pavement Evaluation System (PES). Included in the MICRO-PES are the following three subsystems:

a) A one-year Maintenance and Rehabilitation (M&R) estimation system, which contains a series of decision trees developed by experienced engineers from the Maintenance and Pavement Design Divisions. The trees relate pavement distress to the appropriate M&R strategy and have been developed for Flexible, Jointed and Continuously Reinforced Concrete Pavements,

b) The RAMS-District Optimization Program which selects as optimum combination of projects within a fixed budget level. Optimization uses 0-1 Integer Programming techniques and uses maintenance effectiveness as an Objective Function,

c) A Routine Maintenance Estimate system which permits estimates of type, amount and cost of routine maintenance requirements for any highway or network of highways.

The software package requires an IBM-XT on AT or compatible microcomputer with at least a 1.2 MB floppy disc drive, a 10 MB hard disk, 640 KB of RAM, an EGA graphics adaptor, and a dot matrix printer.

17. Key Words	18. Distribution Statement
Pavement Management, Decision Trees, Optimization, Microcomputer, RAMS	No restrictions. This document is available to the public through the National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	94	

Form DOT F 1700.7 (8-69)

MICRO-PES RELEASE 1.01

A USER'S MANUAL

by

Tom Scullion
Miguel Paredes
John Fowler
Emmanuel Fernando

Research Report 930-1

Research Study 2-18-87-0930

District Level Pavement Management Systems

Sponsored by

Texas Department of Highways and Public Transportation

Texas Transportation Institute
The Texas A&M University System
College Station, Texas

June 1989

METRIC (SI*) CONVERSION FACTORS

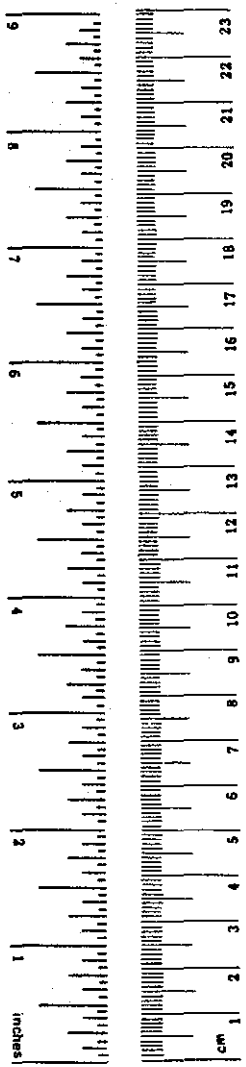
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in²	square inches	645.2	millimetres squared	mm²
ft²	square feet	0.0929	metres squared	m²
yd²	square yards	0.836	metres squared	m²
mi²	square miles	2.59	kilometres squared	km²
ac	acres	0.395	hectares	ha
MASS (weight)				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft³	cubic feet	0.0328	metres cubed	m³
yd³	cubic yards	0.0765	metres cubed	m³

NOTE: Volumes greater than 1000 L shall be shown in m³.

TEMPERATURE (exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

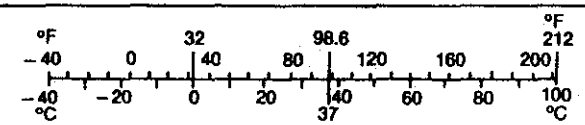


APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm²	millimetres squared	0.0016	square inches	in²
m²	metres squared	10.764	square feet	ft²
km²	kilometres squared	0.39	square miles	mi²
ha	hectores (10 000 m²)	2.53	acres	ac
MASS (weight)				
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m³	metres cubed	35.315	cubic feet	ft³
m³	metres cubed	1.308	cubic yards	yd³

TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

TABLE OF CONTENTS

		page
ABSTRACT		iv
DISCLAIMER		v
LISTS OF REPORTS		vi
ACKNOWLEDGEMENTS		vi
IMPLEMENTATION STATEMENT		vii
Section 1	Introduction	1
Section 2	Getting Started	7
Section 3	Menu MICRO-PES	10
Section 4	Option 0 "Create a Subset Section File"	13
Section 5	Option 1 "One-Year M&R Estimates"	23
Section 6	Option 2 "RAMS-D01"	33
Section 7	Option 3 "Routine Maintenance Estimates"	38

Appendices

A.	An Overview of the RAMS-D01	48
B.	RAMS-D01 Output Files	61
C.	Decision Trees for One-Year M&R Estimates	68
C.1	Decision trees for rehabilitation and maintenance of Rigid pavements (types 1, 2, and 3)	69
C.2	Decision trees for rehabilitation and maintenance of Flexible pavements (types 4 through 10)	75

ABSTRACT

This report describes a microcomputer system for analyzing the information collected by state forces in their annual network-level Pavement Evaluation System (PES). Included in the system are the following three subsystems:

a) A one-year Maintenance and Rehabilitation (M&R) estimation system, which contains a series of decision trees developed by experienced engineers from the Maintenance and Pavement Design Divisions. The trees relate pavement distress to the appropriate M&R strategy and have been developed for Flexible, Jointed and Continuously Reinforced Concrete Pavements,

b) The RAMS-District Optimization Program which selects an optimum combination of projects within a fixed budget level. Optimization uses 0-1 Integer Programming techniques and uses maintenance effectiveness as an Objective Function,

c) A Routine Maintenance Estimate system which permits estimates of type, amount and cost of routine maintenance requirements for any highway or network of highways.

The software package requires an IBM-XT or AT or compatible microcomputer with at least a 1.2 MB floppy disc drive, a 10 MB hard disk, 640 KB of RAM, an EGA graphics adaptor, and a dot matrix printer.

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas State Department of Highway and Public Transportation. This report does not constitute a standard, specification, or regulation.

LIST OF REPORTS

Research Report 930-1 "Micro-PES Release 1.0, User Manual" describes a microcomputer based program for analyzing the information collected in the annual Network Level Pavement Evaluation System. Included in the system are the following three subsystems: (a) One year M&R Estimates, which contains a series of decision trees developed by experienced engineers in the Maintenance and Design Divisions, (b) RAMS-District Optimization Program which selects an optimum combination of projects within a fixed budget level, and (c) Routine Maintenance Estimates.

Research Report 903-2 "Pavement Management: Where Do We Go From Here" provides an implementation plan for expanding the current PES System to meet both Departmental and Federal PMS requirements.

"Research Report 903-3 RAMS-D01: As a Decision Analysis Tool" presents a study of using the RAMS-01 Program and compares its recommendations for project priorities with those established by District personnel.

ACKNOWLEDGEMENTS

This system was developed under the guidance of Bob Guinn, Pavement Management Engineer for the State of Texas. The contributions of Bryan Stampley D-18PM, Jim L. Brown D-8 and Jerry Daleiden D-8 are acknowledged.

The RAMS optimization system was developed for mainframe computer by Dr. R.L. Lytton of TTI under project 207.

IMPLEMENTATION STATEMENT

The Texas State Department of Highways and Public Transportation has been operating its Pavement Evaluation System since the early 1980's. To date, the information has been used largely at the central division level to track trends in overall network condition; little use has been made of the data by the districts who are responsible for project selection. In an attempt to make the pavement condition data more accessible to district personnel, the MICRO-PES system was developed. This system has been implemented within the Pavement Management section in Austin. District forces are being encouraged to participate in this effort. Complete implementation will only occur once District personnel have customized the system to their particular needs.

SECTION 1 INTRODUCTION

In the early 1980's the Texas Department of Highways and Public Transportation implemented its network level Pavement Management System (PES). Initially, only a small portion of the state's road segments were inspected. Recently the sample size has increased considerably; for the past two years every mile of Interstate pavement has been inspected. Several districts also take 100% samples for their own internal use. However, in general, the main user of the PES data has been the Austin Office in its efforts to track network condition and estimate overall funding requirements. The district offices, despite expending considerable effort to collect the data, are generally not users of the information generated.

In an attempt to address this problem, Study 930 was initiated in September 1987. The aim of the project was to attempt to develop and implement applications at the district level. It was acknowledged that the PES database was an excellent source of current pavement condition data that could be used by the districts to assist with the maintenance and rehabilitation operations. Study 930 was therefore focused on building a "user-friendly" micro-computer package that could readily be implemented within district offices.

The information available within the PES system is shown in Table 1. Each record represents an approximate two-mile section of highway. Separate records are provided for divided highways and frontage roads. The key items in Table 1 are discussed below; a complete description is given in Reference 1.

Columns 1-24	Location information including district, county, highway name, beginning and ending milepost.
Column 25	Directional Code.
Columns 27-47	Visual distress data for either Flexible, Jointed or Continuously Reinforced Pavement. (pavement type given in columns 57-58).
Columns 48-49	Average Mays Ride Value for section.
Columns 50-51	Average Skid Value for section
Columns 52-54	Average Structural Strength Index (deflection based index).
Columns 55-56	Posted Speed Limit.
Columns 57-58	Pavement Types.

1987/1988 REHAB FILE FORMAT

VARIABLE	TYPE: (A)lpha or (N)umeric	COLUMNS	DECIMAL PLACES
DISTRICT	N	1 - 2	
COUNTY	N	3 - 5	
PREFIX	A	6 - 7	
MUMBER	A	8 - 11	
SUFFIX	A	12	
BPOST	N	13 - 15	
BDISP	N	16	
BDIST	N	17 - 18	1
EPOST	N	19 - 21	
EDISP	N	22	
EDIST	N	23 - 24	1
LANE	A	25	
SEGCOUNT	N	26	
RUT/SPALL/FAILSLAB	N	27 - 29	
BLOCK/PCPATCH/FAILSLAB	N	30 - 32	
PATCH/PUNCHOUT/JCPFAIL	N	33 - 35	
FAILURE/AQCPATCH/(blank)	N	36 - 38	
ALLIGATOR/CRACKSPC/LONG	N	39 - 41	
LONGITUD/(blank)/PCPAT	N	42 - 44	
TRANSVER/(blank)/JOINTSPC	N	45 - 47	
RIDE(PSI)	N	48 - 49	1
SKID	N	50 - 51	
SSI	N	52 - 54	
SPEED	N	55 - 56	
PTYPE	N	57 - 58	
FCLASS	N	59	
NUMBERML	N	60 - 61	
SURWIDTH	N	62 - 64	
ADT	N	65 - 70	
KIPS	N	71 - 75	
LENGTH	N	76 - 77	1
UVU	N	78 - 80	
AVU	N	81 - 83	
WVU	N	84 - 86	
PS	N	87 - 89	
UPS	N	90 - 92	
SIUC	N	93 - 95	
SKUC	N	96 - 98	
RMUC	N	99 - 101	
ROADWAY	A	102 - 108	
BEGVALUE	N	109 - 112	
REQUEST	N	113 - 115	
HWYDSN	N	116	
MANDFLAG	A	117	
OTHRFLAG	A	118	
FOREMAN	N	119 - 120	
COMMENT	N	121 - 122	
(filler)	A	123 - 153	

Table 1. Record Layout of PES Masterfile.

Code	Description
1	Continuously Reinforced Concrete Pavement
2	Jointed Reinforced Concrete Pavement
3	Jointed Plain Concrete Pavement
4	Thick Asphaltic Concrete Pavement (greater than 5 1/2")
5	Intermediate Thickness Asphaltic Concrete Pavement (2 1/2" to 5 1/2")
6	Thin Surfaced Flexible Base Pavement (less than 2 1/2")
7	Composite Pavement (Asphalt Surfaced Concrete Pavement)
8	Overlaid and/or Widened Old Concrete Pavement
9	Overlaid and/or Widened Old Flexible Pavement
10	Thin Surfaced Flexible Base Pavement (Surface Treatment-Seal Coat Combination)
Column 59	Functional Class.
Columns 60-61	Number of Lanes.
Columns 62-64	Surface Width.
Columns 65-70	Current Annual Average Daily Traffic (all lanes).
Columns 71-75	Estimated accumulative 18-kip equivalencies for next twenty years.
Columns 76-77	Length of section in miles.
Columns 78-101	Numerous Pavement Score indicators including unweighted visual utility score, weighted pavement score and others.

This file is updated annually. Data collection begins in September and is usually completed by the end of December. This file is typically available for use on February 1, which is adequate for selection of seal coat and overlay projects for the following year.

This report presents a users manual for a microcomputer system MICRO-PES, Release 1.0, which accesses and processes the PES Master File. The purpose of this system is to present the district personnel with a set of tools for generating reports from the PES Master File. These applications are aimed at identifying projects for consideration for maintenance and rehabilitation. Once the district forces become familiar with the system, it is anticipated that other customized reports will be generated. The current system consists of the following four application programs:

Program 0 Create a Subset File

This program allows the district personnel to flexibly access the master PES data file and extract a subset for later processing. By creating this small work file, the later analysis programs run much more efficiently.

Program 1 One Year M&R Estimates

This program contains a series of decision trees developed by experienced engineers from D-18 (Maintenance) and D-8 (Design) to aid the district personnel in selecting appropriate Maintenance and Rehabilitation Strategies. The decision trees relate the existing pavement distresses, pavement type and traffic level for a given road segment to an appropriate M&R strategy. Separate trees have been developed for CRCP, Jointed and Flexible Pavements.

These trees are aimed at supplying the district with "first-cut" estimates of network needs. They are not design systems, but rather indications of the level of effort an individual section requires. Details of these decision trees are shown in Appendix C.

Program 2 RAMS-D01

This program is the RAMS District Optimization Program documented in TTI Research Report 207-3[2]. The program allows the districts to select the optimum combination of projects within a fixed budget level. The program generates the most cost-effective series of projects using a "M&R effectiveness" index, or "benefits." The "benefit" for a particular strategy for a given road segment is a weighted measure of how the strategy performs in eliminating existing distresses over the planning horizon (usually 10 years). The program maximizes benefits within the fixed budget level and drops from consideration projects which do not yield enough benefit. The program can be rerun at different budget levels to evaluate the best budget level for competing maintenance sections, or to identify an optimum budget level for the entire district.

Details of the optimization procedure are given in Appendix A and reference 2.

Program 3 Routine Maintenance Estimates

This is a simple program which permits the District Maintenance Engineer to estimate the amount and cost of routine maintenance required on any particular highway or network of highways. For example, the engineer may wish to apply crack seals to every highway carrying more than 500 vehicles per day which has excessive amounts of longitudinal and/or transverse cracking. This program lets

the engineer specify the criteria and then proceeds to search for sections which meet the criteria. The program then calculates area and maintenance cost for each of the selected sections.

The layout of this report is as follows. Section 2 contains information on "getting started" with the software package, including installation instruction. Section 3 describes the main menu. Sections 4, 5, 6, and 7 describe each of the four application programs. Each of these programs is documented in a similar manner. The first page "PROGRAM TITLE" contains a description of the program with objectives, input/output file info and running instructions. The next pages show the reader each of the INPUT and OUTPUT screens generated by the program with appropriate instructions or discussion.

Supporting documentation for each of these programs is presented in the Appendices. Appendix A presents a discussion of the RAMS optimization procedure, and the output reports generated from the microcomputer version of this program are shown in Appendix B. The decision trees (developed largely by Texas SDHPT personnel) are shown in Appendix C.

Any district wishing to use this system will need to contact Mr. Bryan Stampley of D-18PM, SDHPT, Austin, Texas, for the computer disks containing the system and data files.

References

1. "1986 Pavement Evaluation System Raters Manual," Texas State Department of Highways and Public Transportation, Austin, Texas, August 1986.

2. Ahmed, N.V., Lu, D.Y., Lytton, R.L., Mahoney, J.P., and Phillips, D.T., "The Texas Rehabilitation and Maintenance District Optimization System," Texas Transportation Institute Research Report 207-3, Nov 1978.

SECTION 2

GETTING STARTED

Hardware Requirements

The MICRO-PES software package requires an IBM-XT or AT or compatible microcomputer with at least one 1.2 MB 5 1/4 in. floppy disk drive, a 10 MB hard disk drive, 640 KB of RAM, an EGA graphics adaptor, and a dot matrix printer.

Currently, all the programs in the package and their required data files and other utility files take up about 400 KB of storage space. The space for district data can vary from 120 KB to 200 KB or more per district, so it is advisable to have at least 800 KB of free storage space in the hard disk in order to install and run the programs.

Installation

To install MICRO-PES, turn the computer on, wait for the DOS command prompt to show, insert the MICRO-PES diskette into Drive A, go to the A: Drive, and then type INSTALL at the DOS A: command prompt. Then follow the instructions and the programs will be automatically loaded into your computer's drive C, under a subdirectory named C:MICROPES. To run the programs, you need to make the MICROPES directory the active one by using the CD MICROPES (change directory) command. Once in the MICROPES directory, you are ready to start.

The Program Screen

All programs use the same type of display screen (Fig. 1) to present input options, output tables and program information:

- The title frame: displays the identifier for each screen.
- The screen input/output: displays all input options, status information, and all output except for those that are directly routed to the line printer.
- The command line: displays all prompts with their respective input alternatives, error messages and the corrective action to be taken to recover from them, and is used to edit information. All user input is done from this line.

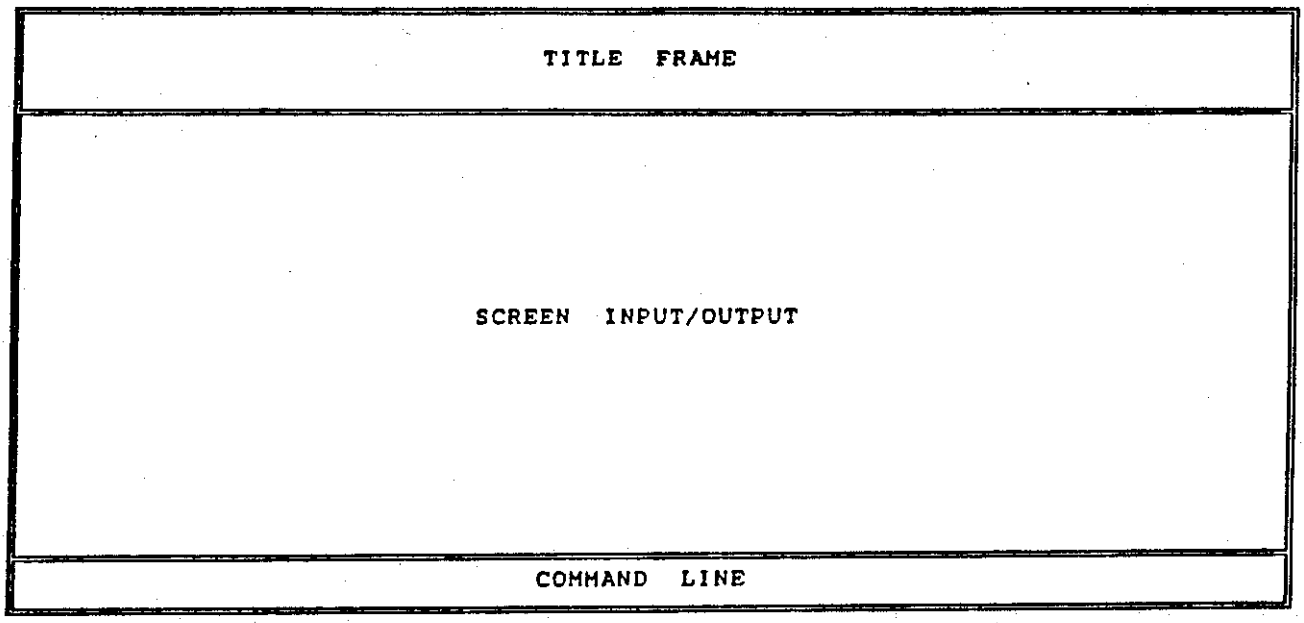


Fig. 1

SECTION 3

MICRO-PES MENU

PROGRAM TITLE:

Menu

OBJECTIVE:

This is a single screen which acts as the main menu for the entire system. Currently only options 0, 1, 2, 3, and 9 are valid. Others will be added once deflection data is added to the system.

Using this screen, the user selects the required program. The usual sequence is to run option 0 "Create a Subset Section File" to create a work file FLATDATA.DAT. Then run either options 1, 2, or 3 to perform the desired analysis. Exits from each program will return to this screen.

INPUT FILE:

The following files must be located on the hard disk drive, under the same drive designation and subdirectory if the latter is used:

BRUN40.EXE	RAMSD01.EXE
BUDGET.EXE	ROADSELE.EXE
M&REST.EXE	DISTDATA.DAT
MENU.EXE	MISC.DAT
PAVMAINT.EXE	INSTPES.BAT

All of the above files are contained in the release 1.0 disk.

OUTPUT FILE:

None

RUNNING INSTRUCTIONS:

Under the DOS command prompt, type **MENU** and press the "Return" or [ENTER] key.

PROGRAM

Menu

INPUT SCREEN

MICRO-PES PROGRAM SELECTION MENU

The following programs are available:

0 . Create a Subset Section File
1 . One-year M&R estimates
2 . RAMS-DO1
3 . Routine Maintenance estimates
4 . FPS design
5 . Remaining Life estimate
6 . Modulus back calculation
7 . Load rating
8 . HPMS
9 . EXIT to DOS

Please enter the desired Option number:

INSTRUCTIONS:

This is the main menu screen of the system. The User inputs the option number required. As of January 1988, only options 0, 1, 2, 3, and 9 are available. Other options will be made available once deflection data is collected within the Texas network level pavement management system.

SECTION 4

OPTION 0, "CREATE A SUBSET SECTION FILE"

PROGRAM TITLE:

Create a Subset Section File

OBJECTIVE:

Typically the PES master file has over 1,000 records for each district. This program permits the user to create a subset of this file for efficient data processing by later analysis programs. The user can extract data by Route (section along a particular highway) or Network (a subset of the master file, for example, all IH pavements). The extracted records are placed in a work file called FLATDATA.DAT for subsequent analysis by the available programs.

INPUT FILE:

DISTDATA.DAT: This file contains the district's PES data for a given year.

If the user desires to analyze other PES files, they need to rename them to DISTDATA.DAT before they can be used with the programs in this package.

OUTPUT FILE:

FLATDATA.DAT: This is the name given to the work file that will be created by the subset program; FLATDATA.DAT must be created before any of the analysis programs can be executed.

RUNNING INSTRUCTIONS:

1. Enter option 0 from the main menu
2. The prompt line will ask if you have selected the correct option
3. Type Y for yes
4. A title screen will be displayed, and after a few seconds, replaced by input screen 1 (see next page).

PROBLEMS/QUESTIONS **Contact: Bryan E. Stampley, P.E. TEXAN: 241-3676**

PROGRAM

Create a Subset Section File

INPUT SCREEN

DISTRICT AND COUNTY INFORMATION

Select the required District and County:

1. District Number (0 means ALL): 11

2. County Code (0 means ALL):

NOTE: Selected counties must be located within District 11

Enter the County Code (1 to 254; 0 for ALL) and press ENTER: 0

INSTRUCTIONS:

This screen prompts the user to select districts and counties. A prompt is displayed in the command line asking the user to enter a district number. If 0 is entered, i.e., all districts are selected, the program assumes that all counties are also required and immediately continues with the next screen. If a single district is selected (1 to 25), a second prompt will be displayed in the command line asking the user to select either a specific county (1 to 254) or all counties (0).

Note that the county of choice must belong to the selected district.

PROGRAM

Create a Subset Section File

INPUT SCREEN

ROAD AND HIGHWAY SELECTION CRITERIA

Select sections of roads or highways by:

1 . ROUTE

2 . NETWORK

Please enter the desired selection criteria number:

INSTRUCTIONS:

When identifying sections, two options are available: the Route option allows the user to select any individual highway for analysis, and input screen 0.3 prompts for highway name, milepost limits, lane, etc.

The Network option allows the user to select a subset of the district file (for example, all Interstate Pavements carrying more than 10,000 ADT). If this option is selected, two input screens (0.4 and 0.5) follow which allow the user to specify Network, Foreman, Pavement Score, ADT levels. A review screen then permits a final check of the input information before the program proceeds to create the subset PES file. If the input information is not correct, the user presses R and the program returns to input screen 0.1.

PROGRAM

Create a Subset Section File

INPUT SCREEN

```
ROUTE  SEARCH  CRITERIA  MISCELLANEOUS  INFORMATION


    Please enter the following information:

1. Highway Prefix:   US

2. Highway Number:   59

3. Suffix letter (N means no Suffix): N

4. Length of section to search for, FROM:   0.0
                                     TO:  50.0

5. Roadway (C means ALL): C


    Is the above information correct? (Y/N):
```

INSTRUCTIONS:

The user inputs the Route of interest:

1. Highway Prefix (options IH, US, SH, FM, PR)
2. Highway Number (numerics only, max = 9999)
3. Suffix Letter (L = Loop, S = Spur, N = None)
4. Milepost Limits (numeric)
5. Roadway (Options A, X, L, R, C where C = all roadways)

PROGRAM

Create a Subset Section File

INPUT SCREEN 0.4

NETWORK TYPE

The following Network Types are available:

1 . INTERSTATE HIGHWAY (IH)

2 . U.S. HIGHWAY (US)

3 . STATE HIGHWAY (SH)

4 . FARM TO MARKET ROAD (FM)

5 . PARK ROAD (PR)

6 . IH, US, AND SH

7 . ALL

Please enter the desired Network Type number:

INSTRUCTIONS:

The user selects the network of interest.

PROGRAM

Create a Subset Section File

INPUT SCREEN

NETWORK SEARCH CRITERIA MISCELLANEOUS INFORMATION

Please enter the following information:

1. Foreman Number (0 for ALL): 0

2. Pavement Score range, MIN: 30
MAX: 80

3. Minimum Annual Average Daily Traffic (AADT): 5,000

Is the above information correct? (Y/N):

INSTRUCTIONS:

The user specifies:

1. Foreman Number (1, 2, 3,...18 or 0 which means all foremen),
2. PES pavement score range (values 0 to 100), and
3. Minimum ADT; the program will only select sections which have higher ADT than that specified.

```
                    SEARCH  CRITERIA  REVIEW


The search for Highway or Road sections for:

        District (0 means ALL) ->  11
        County (0 means ALL) --->  0

Will be performed by -> NETWORK

For sections that satisfy the following:

        Network -> U.S. HIGHWAY (US)
        Foreman (0 means ALL) -->  0
        Pavement Score range --->  50  to  70
        Minimun AADT ----------->   5,000


Enter C to CONTINUE the search or R to RETRY a new criteria (C/R):
```

INSTRUCTIONS:

This screen shows the user the search criteria specified and permits changes before final submission. Entering C will cause the program to run, searching the master file for the specified sections.

A similar screen will be displayed if the Route search options are selected.

PROGRAM

Create a Subset Section File

INPUT SCREEN 0.7

SEARCHING SECTIONS UNDER GIVEN CRITERIA

Number of Sections Searched -> 1,571
Number of Sections Found ----> 52

SEARCHING DATABASE... PLEASE WAIT

INSTRUCTIONS:

Once the Route or Network is specified and reviewed, the complete master file is searched. This screen shows how many sections are located that meet the specified criteria.

Once "search completed" appears, the user presses any key to continue.

PROGRAM

Create a Subset Section File

INPUT SCREEN 0.8

SEARCHING SECTIONS UNDER GIVEN CRITERIA

The 52 selected files are stored in:

FLATDATA.DAT

Enter Q to QUIT or R to RETRY the search under a new criteria (Q/R):

INSTRUCTIONS:

The extracted records are stored in a work file called FLATDATA.DAT. Note each time option 0 ("Create a Subset Section File") is run, a new work file is built.

This is the last screen in the "Create a Subset Section File" program. The work file FLATDATA.DAT has been built and the user is ready to select one of the data analysis programs. To get back to the main menu press Q. All analysis will now be performed on the sections stored in the FLATDATA.DAT file. Pressing R allows the user to rerun the subsetting program and replace the working file just created with a new one.

SECTION 5

OPTION 1, "ONE-YEAR M&R ESTIMATES"

PROGRAM TITLE:

One Year M&R Estimates

OBJECTIVE:

This program contains a series of simple decision trees which relate pavement distresses to maintenance and rehabilitation treatments. Consideration is made for pavement type and traffic level as well as distresses. The trees were developed by senior engineers in the Maintenance and Pavement Design Divisions.

INPUT FILE:

FLATDATA.DAT: Subset PES file created by running option 0 of the MICRO-PES menu.

OUTPUT FILE:

MAINT.DAT: Internal file containing all sections selected for maintenance.

REHAB.DAT: Internal file containing all sections selected for rehabilitation.

RUNNING INSTRUCTIONS:

Select option 1 from the MICRO-PES menu.

PROBLEMS/QUESTIONS **Contact: Bryan E. Stampley, P.E. TEXAN: 241-3676**

PROGRAM

One Year M&R Estimates

INPUT SCREEN 1.1

ONE YEAR M&R ESTIMATE PROGRAM MENU

The following options are available:

1 . REVIEW/UPDATE MAINTENANCE COSTS

2 . RUN DECISION TREE

3 . QUIT

Please enter the desired option number:

INSTRUCTIONS:

This is the menu screen for this program. The usual sequence is to first "review/update maintenance cost" data and then to "run decision trees." Each subprogram returns the user to this menu.

Entering the "Quit" option will return the user to the main system menu.

UNIT MAINTENANCE AND REHABILITATION STRATEGY COST

The default cost parameters for the following strategies are:

CRCP (Type 1)

		URBAN	RURAL
1. PCC Patch ($/patch)	-->	2,500.00	2,000.00
2. 3 in. Overlay ($/square-yd)	-->	11.83	7.17
3. 6 in. Overlay ($/square-yd)	-->	26.40	16.00

JRCP & JPCP (Types 2 and 3)

		URBAN	RURAL
1. Seal Cracks ($/linear-ft.)	-->	0.50	0.50
2. Joint Repair ($/joint)	-->	3,500.00	2,500.00
3. Slab Replace ($/slab)	-->	7,500.00	5,000.00
4. PCC Patch ($/patch)	-->	1,500.00	1,000.00
5. 3 in. Overlay ($/square-yd)	-->	11.83	7.17
6. Crack/Seat + 6 in. Overlay ($/square-yd)	-->	28.70	20.80

Would you like to change NONE, URBAN, or RURAL costs? (N/U/R):

INSTRUCTIONS:

Three strategies are considered for CRCP and six for jointed concrete pavement. In this screen, the user can update unit cost information.

A similar table for flexible pavement rehabilitation costs follows this table.

PROGRAM

One Year M&R Estimates

INPUT SCREEN 1.3

UNIT MAINTENANCE AND REHABILITATION STRATEGY COST

The default costs for Asphalt Manitenance are:

1.	Seal Cracks ($/linear-ft)	-->	0.25
2.	Partial Patch ($/square-yd/in)	-->	1.50
3.	Full Depth Patch ($/square-yd/in)	-->	2.50
4.	Fog Seal ($/square-yd)	-->	0.50
5.	Strip Seal ($/square-yd)	-->	0.50
6.	Seal Coat ($/square-yd)	-->	0.95
7.	Asphalt-Rubber Seal ($/square-yd)	-->	1.20
8.	Slurry Seal ($/square-yd)	-->	0.60
9.	Level-Up ($/square-yd)	-->	1.50
10.	Thin Overlay ($/square-yd)	-->	2.40
11.	Rotomill ($/square-yd)	-->	1.70
12.	Spot Seal ($/square-yd)	-->	0.50
13.	Rotomill + Seal Coat ($/square-yd)	-->	2.65
14.	Rotomill + Thin Overlay ($/square-yd)	-->	4.10

Would you like to change NONE, SOME or ALL values? (N/S/A):

INSTRUCTIONS:

These are the 14 maintenance strategies considered within the decision trees. The user is required to update the unit cost information.

Maintenance is considered only when the decision trees (see Appendix C) indicate that rehabilitation is not warranted.

SEARCHING SECTIONS FROM DATABASE

Number of Sections Searched	---------->	52
REHABILITATION: Urban CRCP sections	---------->	0
Rural CRCP sections	---------->	0
Urban JRCP/JPCP sections	---------->	0
Rural JRCP/JPCP sections	---------->	0
Urban Flexible Pavement sections	---------->	0
Rural Flexible Pavement sections	---------->	6
Total number of sections for Rehabilitation	-->	6
MAINTENANCE: Urban Flexible Pavement sections	---------->	0
Rural Flexible Pavement sections	---------->	46
Total number of sections for Maintenance	----->	46

SEARCH COMPLETED... PRESS ANY KEY TO CONTINUE.

INSTRUCTIONS:

Once the decision tree program starts execution, the above table is built in the screen. It shows the number of sections being routed to either maintenance or rehabilitation.

SUMMARY OF URBAN CRCP REHABILITATION COST PER COUNTY

COUNTY	PCC Patching	3 in. Overlay	6 in. Overlay
43	0.	0.	809,589.
57	65,000.	11,717,573.	26,642,836.
85	0.	1,335,696.	1,655,977.
102	245,000.	5,532,420.	47,926,740.
TOTALS	310,000.	18,585,688.	77,035,136.

Please enter the desired strategy number:

DISCUSSION:

A summary table showing total estimated rehabilitation cost per county per rehabilitation treatment is displayed for each of the rehabilitation schemes chosen by the decision trees.

The example above shows a summary table for urban CRCP sections.

PROGRAM

One Year M&R Estimates

PRINTER OUTPUT1.6

Page: 1

FLEXIBLE PAVEMENT REHABILITATION COST ESTIMATES

DIST NUM	COUNTY CODE	HIGHWAY NUMBER	FROM	TO	LN	ROADWAY	PAVE. TYPE	PSI	AADT/ LANE	R/U	CAP	DISTRESS/SECTION
11	003	US0059	010+00	010+12	R	R-L	08	2.6	7000	R	N	RT=100 BC=000 PT=100 FA=000 AC=100 LC=100 TC=100 TREATMENT AREA(sq. yds) COST 3 in. Overlay 43,212 $161,179.
11	003	US0059	010+12	014+00	R	R-V	08	3.6	7000	R	N	RT=002 BC=000 PT=000 FA=000 AC=000 LC=000 TC=100 TREATMENT AREA(sq. yds) COST 6 in. Overlay 42,282 $315,426.
11	174	US0059	022+00	022+20	L	L-P	05	3.3	3350	R	N	RT=020 BC=000 PT=000 FA=000 AC=000 LC=100 TC=000 TREATMENT AREA(sq. yds) COST 3 in. Overlay 27,878 $103,986.
11	174	US0059	028+00	030+00	L	L-P	08	3.3	4800	R	N	RT=020 BC=000 PT=010 FA=000 AC=000 LC=100 TC=100 TREATMENT AREA(sq. yds) COST 3 in. Overlay 27,878 $103,986.
11	174	US0059	030+00	032+09	L	L-P	08	3.4	3800	R	N	RT=020 BC=000 PT=000 FA=000 AC=100 LC=100 TC=100 TREATMENT AREA(sq. yds) COST 3 in. Overlay 40,424 $150,780.

DISCUSSION:

Once a set of summary tables is displayed for a given road surface type, the program prompts the user if he wants a printout (hardcopy) of cost estimates per section.

An example for CRCP sections is presented above.

Besides presenting area and cost estimates per treatment, this printout also gives other useful section information such as district number and county code, beginning and ending mileposts, lane and roadway, pavement type, PSI value, AADT per lane, whether the section is classified as urban or rural, and if it has a capacity problem (based on AAM per lane value), and the type and number of distresses it has.

FLEXIBLE PAVEMENT MAINTENANCE COST SUMMARY
(in 1000's of Dollars)

COUNTY CODE	SEAL CRACKS	PARTIAL PATCH	FULL DPTH. PATCH	FOG SEAL	STRIP SEAL	SEAL COAT	ASPH/RUB SEAL	SLURRY SEAL	LEVEL-UP	THIN OVERLAY	ROTOMILL	SPOT SEAL	ROTOMILL+ SEAL COAT	ROTOMILL+ THIN OVER
3	80.	84.	0.	0.	0.	57.	0.	0.	694.	0.	9.	7.	0.	0.
20	34.	0.	25.	0.	0.	0.	0.	0.	33.	0.	0.	1.	0.	0.
43	46.	96.	3.	0.	0.	0.	0.	0.	479.	0.	0.	0.	0.	0.
57	89.	0.	39.	0.	0.	16.	0.	0.	688.	0.	22.	2.	0.	0.
61	182.	0.	5.	0.	0.	0.	0.	0.	193.	0.	121.	1.	0.	0.
71	93.	72.	15.	0.	0.	93.	0.	0.	447.	0.	40.	3.	0.	0.
80	32.	31.	12.	0.	0.	0.	0.	0.	31.	0.	0.	0.	0.	0.
85	60.	0.	0.	0.	0.	62.	0.	0.	0.	0.	0.	1.	0.	0.
102	140.	0.	62.	0.	0.	100.	0.	0.	336.	0.	6.	0.	0.	0.
114	0.	0.	0.	0.	0.	0.	0.	0.	84.	0.	0.	0.	0.	0.
130	42.	0.	0.	0.	0.	65.	0.	0.	264.	0.	0.	2.	0.	0.
170	75.	0.	40.	0.	0.	53.	0.	0.	91.	0.	0.	0.	0.	0.
174	68.	0.	5.	0.	0.	0.	0.	0.	307.	0.	0.	5.	0.	0.
175	53.	31.	26.	0.	0.	0.	0.	0.	245.	0.	0.	1.	0.	0.
187	75.	69.	3.	0.	0.	0.	0.	0.	245.	0.	6.	6.	0.	0.
199	7.	0.	0.	0.	0.	23.	0.	0.	12.	0.	0.	1.	0.	0.
204	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.
210	16.	63.	19.	0.	0.	0.	0.	0.	237.	0.	0.	1.	0.	0.
228	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
237	0.	0.	18.	0.	0.	0.	0.	0.	38.	0.	0.	2.	0.	0.
TOTALS	1096.	445.	271.	0.	0.	468.	0.	0.	4424.	0.	204.	34.	0.	0.

DISCUSSION:

If flexible road sections are selected for maintenance, a summary table similar to the one previously described for rehabilitation, is produced by the program. However, since the maintenance table needs more than 80 columns to present all pertinent information, its output is directed to the printer. In this case, the user has the capability of deciding whether or not he wants to see this output.

PROGRAM

One Year M&R Estimates

PRINTER OUTPUT1.8

Page: 1

FLEXIBLE PAVEMENT MAINTENANCE COST ESTIMATES

DIST NUM	COUNTY CODE	HIGHWAY NUMBER	FROM	TO	LN	ROADWAY	PAVE. TYPE	PSI	AADT/ LANE	R/U	CAP	DISTRESS/SECTION		
11	003	SH0094	006+00	008+00	L	R-L	06	3.7	2750	R	N	RT=100 BC=000 PT=000 FA=000 AC=000 LC=010 TC=010		
												TREATMENT	AREA	COST ($)
												Level-Up	9,757 (sq-yds)	14,636.
												Seal Cracks	83,635 (ln-ft.)	20,909.
11	003	SH0103	010+19	012+06	R	R-V	06	3.0	2550	R	N	RT=200 BC=000 PT=100 FA=000 AC=000 LC=000 TC=000		
												TREATMENT	AREA	COST ($)
												Level-Up	10,571 (sq-yds)	15,856.
11	003	SH0103	018+00	020+00	L	R-L	05	4.2	2725	R	N	RT=100 BC=100 PT=000 FA=000 AC=000 LC=000 TC=000		
												TREATMENT	AREA	COST ($)
												Level-Up	8,364 (sq-yds)	12,545.
11	003	SH0287	000+00	002+00	L	L-P	05	3.9	3800	R	N	RT=100 BC=000 PT=000 FA=000 AC=100 LC=100 TC=100		
												TREATMENT	AREA	COST ($)
												Level-Up	4,182 (sq-yds)	6,273.
11	003	SH0287	002+00	004+00	L	L-P	05	3.6	3600	R	N	RT=200 BC=000 PT=100 FA=000 AC=100 LC=100 TC=100		
												TREATMENT	AREA	COST ($)
												Level-Up	4,356 (sq-yds)	6,534.

DISCUSSION:

As for rehabilitation (printer output 1.6), the user can also obtain a section by section area and cost estimate listing for maintenance, as shown above. The only difference is that these tables do not give the number of distresses per section, but the distress area codes as presented in the Highway Department's Rater's Manual.

SECTION 6

OPTION 2 "RAMS-D01"

PROGRAM TITLE:

RAMS-D01

OBJECTIVE:

The RAMS District Optimization (RAMS-D01) program selects the optimum rehabilitation or maintenance strategy to apply to each road segment within a given set of road segments within a fixed budget level. The set of road segments to be considered is determined by the "Create a Subset Section File" program (i.e. option 0 of the Menu Program). The optimum solution is that solution which maximizes the overall "M&R effectiveness" index (also called the overall "benefit"). The "benefit" for applying a given strategy to a road segment is a function of the area of the road segment and the amount that applying the strategy will improve the segment for six distress types (i.e., rutting, alligator cracking, longitudinal cracking, transverse cracking, failures/mile, and PSI). Appendix A describes this program in more detail.

INPUT FILE:

BUDGET.DAT: This file is created after the user answers questions concerning 1) the number of years that will be considered when determining the "benefit" of each strategy on each road segment; 2) the cost in dollars per mile-foot for each strategy; and 3) the total funds available.

FLATDATA.DAT: This file is created by running the "Create a Subset Section File" option of the menu program. It contains the PES information (including length, width, pavement conditions, etc.) for each road segment to be considered in the current analysis.

MISC.DAT: This file contains information that is seldom changed by the user. This information includes the resource requirements of each strategy, the minimum required pavement ratings, the survivor curves, etc.

OUTPUT FILE:

RESULTS.TMP: This file contains the optimal maintenance decisions as determined by the RAMS-D01. This is an internal file (i.e., does not need to be printed).

RESULTS.SUM: This file contains a summary of the most recent analysis using RAMS-D01. It contains 1) the inputs supplied by the user; 2) the road segments considered; 3) the optimal maintenance decisions; and 4) the condition of each road segment before and after the optimal strategies have been applied. A sample of this report is found in Appendix B.1.

RESULTS.DET: This file contains a detailed report of the most recent analysis using RAMS-D01. In addition to the information contained in RESULTS.SUM, it contains intermediate results of the analysis procedure. A sample of this report is found in Appendix B.2.

RUNNING INSTRUCTIONS:

Select option 2 from the Menu Program. The user is then prompted for the required input data. In order to accept the default value for any of the prompts, the user may simply hit the [ENTER] key. After answering all of the questions, the RAMS-D01 is performed. Upon completion, the results are displayed on the screen, one page at a time. After viewing the results, the user is allowed to print either the summary or detailed report, rerun RAMS-D01 with new input parameters, or return to the Menu Program.

PROBLEMS/QUESTIONS **Contact: Bryan E. Stampley, P.E. TEXAN: 241-3676**

PROGRAM RAMS-D01 **INPUT SCREEN 2.1**

```
                    RAMS-D01 INPUT PARAMETERS MENU

1. Problem Title ( enter below:75 characters max)
CASE STUDY

2. No. of Time Periods (MAX <= 20) for this run..  10

          Strategy                Aver. Cost per Mile-Foot
3.        FOG SEAL.............      120.00
4.        SEAL COAT............      460.00
5.        OGPMS................     2040.00
6.        THIN OVERLAY.........     1990.00
7.        MOD. OVERLAY.........     4300.00
8.        HEAVY OVERLAY........     7630.00
9.        L. DUTY RECONST......     2030.00
10.       H. DUTY RECONST......     5590.00

11. Budget Available.................      1,000,000

                Is the above information correct ? (Y/N):
```

INSTRUCTIONS:

On this screen, the user is prompted for:

1. A title to the RAMS-D01 run (i.e., a brief description of the run),
2. The number of years to be considered in the determination of the "benefit" for each strategy on each road segment,
3. The cost per mile-foot of each of the eight maintenance and rehabilitation strategies, and
4. The total budget available for use to maintain and rehabilitate the road segments selected in the "Create a Subset Section File" option of the Menu Program.

For each of these queries, the default value is shown and can be selected by simply hitting the "Return" or [ENTER] key. After answering the last inquiry, the user is given an opportunity to edit his/her choices. When the user is satisfied with his/her selections, the RAMS-D01 analysis will proceed. When RAMS-D01 has determined the optimal solution, the decisions will appear on the screen. The next page shows the results of a RAMS-D01 analysis and briefly discusses the content of the output screen. It should be noted that the values given by the user to the queries described above, become the default values for the next run.

PROGRAM RAMS-D01 OUTPUT SCREEN 2.2

OPTIMAL MAINTENANCE DECISIONS

SEG NO	NAME	FROM	TO	STRATEGY	BENEFIT	% BUDGET
17	US0059	018+00	020+00	SEAL COAT	3828.	2.21
37	US0059	022+00	022+20	THIN OVERLAY	18235.	9.55
41	US0059	002+00	004+00	OGPMS	21427.	9.79
43	US0059	004+00	006+00	OGPMS	27469.	9.79
45	US0059	006+00	008+04	OGPMS	22547.	11.75
58	US0059	020+00	020+17	OGPMS	15674.	8.32
74	US0059	010+00	012+00	OGPMS	18094.	9.79
79	US0059	000+06	002+06	OGPMS	68104.	26.11
81	US0059	002+06	002+11	SEAL COAT	240.	.55
89	US0059	010+16	012+00	THIN OVERLAY	1380.	1.43
91	US0059	014+00	016+00	OGPMS	23956.	10.61
				TOTALS:	220954.	99.91

Press any key to continue

DISCUSSION:

This table gives the optimal decisions made by RAMS-D01. The first seven columns identify the road segment. The eighth column identifies the strategy that should be applied to the road segment. Columns nine and ten give the "benefit" derived from, the application of the strategy to the road segment, and the percentage of the budget required for the road segment, respectively. Only those segments that have been selected to have a strategy be applied are listed. If there are more than 14 segments, the first 14 are shown and the user is instructed to press any key to continue. After the last road segment has been displayed, the total "benefit" and the total percentage of the budget used are displayed. Sections are listed in numerical order; they are <u>not</u> ranked in order of decreasing benefit.

PROGRAM RAMS-D01 INPUT SCREEN

RAMS-D01 OUTPUT OPTIONS

The following options are available:

1 . PRINT THE SUMMARY REPORT

2 . PRINT THE DETAILED REPORT

3 . RERUN RAMS-D01 WITH NEW INPUT PARAMETERS

4 . RETURN TO MAIN MENU

Please enter the desired Option number:

INSTRUCTIONS:

After the user has examined the optimal decisions on the screen, the menu given above is displayed. The first option prints the summary report (RESULTS.SUM) to the printer and the second option prints the detailed report (RESULTS.DET) to the printer.* The third option will allow the user to rerun RAMS-D01 by taking them back to the first input screen. The fourth option on this screen will return the user to the Menu Program where any one of the menu program options may be selected.

*On both of these options, the user is prompted to get the printer ready and press the [ENTER] key to begin printing. In general the user should only use the first option; option 2 is used only when changes are made internally to the system. Option 2 prints about 50 pages of information, and is useful only if you are planning to costomize RAMS-D01 to your particular District or County.

SECTION 7

OPTION 3, "ROUTINE MAINTENANCE ESTIMATES"

PROGRAM TITLE:

Routine Maintenance Estimates

OBJECTIVE:

This program permits the Maintenance Engineer to estimate routine maintenance requirements for any highway or network of highways. The Engineer inputs which distresses require maintenance, and the program locates sections and makes area and cost estimates.

INPUT FILE:

FLATDATA.DAT: PES subset file created by running option 0 of the MICRO-PES menu.

OUTPUT FILE:

RESULTS.DAT: Internal file used to store sections selected for routine maintenance.

RUNNING INSTRUCTIONS:

Select option 3 from the MICRO-PES menu.

PROBLEMS/QUESTIONS **Contact: Bryan E. Stampley, P.E. TEXAN: 241-3676**

MAINTENANCE STRATEGY

The following Maintenance Strategies are available:

1 . SEAL CRACKS

2 . PATCHING

3 . SEAL COAT

4 . SQUEEGY SEAL

5 . QUIT TO MENU

Please enter the desired strategy number:

INSTRUCTIONS:

The user specifies which maintenance treatment he wishes to make estimates for. All options are valid.

PAVEMENT CONDITION LEVEL PER DISTRESS TYPE

For each of the following distress types enter the corresponding pavement condition level that you would like to see based on the area of the section covered by the distress in question.
EXAMPLE: To see MODERATE & LARGE areas for SLIGHT RUTTING, enter C at the prompt.

AREA LEVEL	DISTRESS TYPE	AREA OF DISTRESS
[N]ONE	1 . SLIGHT RUTTING	NONE
[S]MALL AREA	2 . SEVERE RUTTING	NONE
[M]ODERATE AREA	3 . MAINTENANCE PATCHING	NONE
[L]ARGE AREA	4 . BLOCK CRACKING	MODERATE
[C]OMBINED	5 . ALLIGATOR CRACKING	MODERATE
[A]LL	6 . LONGITUDINAL CRACKING	MOD. & LARGE
	7 . TRANSVERSAL CRACKING	SMALL

Are all of the above area levels correct? (Y/N):

INSTRUCTIONS:

In this screen, the user specifies which distresses he wants to treat with the specified Maintenance Strategy selected on screen 1. For example, seal cracks could be specified for all pavements with Moderate or Large Transversal cracking; to achieve this, a C would be entered alongside the transverse cracking distress.

The Small, Moderate and Large area levels correspond to the 100, 010 and 001 rating in the Pavement Evaluation System rating procedure. For rutting, the area breaks are 1-25%, 26-50% and >50%. For patching, block and alligator cracking, the breaks are 1-10%, 11-50%, and >50%. For longitudinal cracking, 10-99, 100-200, >200 linear feet per 100 ft. For transverse cracking, 1-4, 5-10, or >10 full transverse cracks per 100 ft. These flexible pavement distresses and rating codes are described in greater detail by the latest version of the "PES Rater's Manual," available from D-18PM.

PROGRAM

Routine Maintenance Estimates

INPUT SCREEN 3.3

MISCELLANEOUS INFORMATION

Please enter the following information:

1. Unit Maintenance Cost ($/linear ft.):

Enter the Unit Maintenance cost ($/linear ft.) and press ENTER: .50

INSTRUCTIONS:

The user inputs the unit cost for the strategy selected in screen 1. In this example, crack seals were selected and a unit cost in dollars per linear foot must be input in this screen. Other strategies would require cost in dollars per square yard.

If the selected strategy is "seal coat," the program will also prompt the user to enter, in addition to the cost, the maximum skid value that, regardless of distress, would warrant a seal coat. If no skid data are available, this input value will be ignored.

SEARCHING SECTIONS FROM DATABASE

Number of Sections Searched -> 52
Number of Sections Found ----> 34

SEARCH COMPLETED... PRESS ANY KEY TO CONTINUE.

INSTRUCTIONS:

Once the unit costs are entered, the FLATDATA.DAT file (created under option 0 or preexisting) is searched for pavement sections with the distress conditions specified in input screen 3.2, and in the case of "seal coat," the file is also searched for pavement sections having skid values that are less than or equal to the value input in input screen 3.3.

SEARCHING SECTIONS FROM DATABASE

The 34 selected files are stored in:

RESULTS.DAT

Enter C to CONTINUE or R to RETRY the search with new criteria (C/R):

INSTRUCTIONS:

The sections found with the matching criteria are placed into RESULTS.DAT. Entering C will cause the program to execute the routines that will calculate the maintenance estimates for the selected sections. Entering R will permit the user to reenter the selection criteria.

SUMMARY TABLE

GIVEN: Maintenance Strategy ----------> SEAL CRACKS
Maintenance Cost($/linear ft.) ----> .5

NETWORK TYPE	ESTIMATED AREA (Linear-ft.)	ESTIMATED COST (Dollars)
INTERSTATE HIGHWAY (IH)	0.	0.
U.S. HIGHWAY (US)	657,518.	328,759.
STATE HIGHWAY (SH)	0.	0.
FARM TO MARKET ROAD (FM)	0.	0.
TOTAL	657,518.	328,759.

Would you like a hardcopy of this table? (Y/N):

DISCUSSION:

This is the summary table showing the estimate amount of linear cracking for all of the pavement sections selected and stored in RESULTS.DAT.

The printout of this table can be obtained by entering Y at the prompt.

PROGRAM

OUTPUT SCREEN 3.7

SECTION TABLE

DIST NUM	COUNTY CODE	HIGHWAY NUMBER	FROM	TO	LN	ROADWAY	LEN (Mi)	WD (ft)	AREA (Line-ft)	COST ($)
11	003	US0059	004+00	006+00	S	R-V	2.0	26	10,560	5,280
11	003	US0059	004+00	006+00	L	L-P	2.0	26	10,560	5,280
11	003	US0059	006+00	006+16	R	R-V	1.6	30	8,448	4,224
11	003	US0059	006+00	006+16	L	L-P	1.6	30	8,448	4,224
11	003	US0059	006+16	010+00	R	R-L	2.4	63	25,344	12,672
11	003	US0059	020+00	022+00	L	L-P	2.0	24	10,560	5,280
11	003	US0059	022+00	022+20	R	R-V	2.0	24	10,560	5,280
11	174	US0059	002+00	004+00	R	R-L	2.0	48	21,120	10,560
11	174	US0059	014+24	018+13	L	L-P	2.9	32	15,312	7,656

Would you like a hardcopy of this table? (Y/N):

DISCUSSION:

This is a section by section listing, showing project specific cracking estimates.

DISTRESS SEVERITY CRITERIA TO REPAIR ROADS IS:

DISTRESS	AREA AFFECTED	CODED AS:
SLIGHT RUTTING	NONE	000
SEVERE RUTTING	NONE	000
MAINTENANCE PATCHING	NONE	000
BLOCK CRACKING	MODERATE	010
ALLIGATOR CRACKING	MODERATE	010
LONGITUDINAL CRACKING	MOD. & LARGE	010 OR 001
TRANSVERSAL CRACKING	SMALL	100

DISCUSSION:

If a printout of the section by section information shown in output screen 2 is desired, a table (see above) documenting the distress criteria chosen to make the routine maintenance estimates will be printed first in a separate page.

After the print job has been submitted, the user has the option of either running the program with other distress criteria or going back to the main menu.

APPENDIX A

AN OVERVIEW OF THE RAMS-D01 PROGRAM

Introduction

In many highway jurisdictions, maintenance and rehabilitation requirements exceed the resources available. Thus, highway engineers are faced with the problem of allocating limited resources among several competing alternatives - sections of roadways in need of maintenance or rehabilitation. The highway engineer is then confronted with the task of establishing a set of maintenance and rehabilitation activities that most effectively addresses the needs of the pavement network with the limited resources at his disposal.

The Rehabilitation and Maintenance System (RAMS) is a set of computer programs developed at the Texas Transportation Institute for managing highways in the State of Texas. The RAMS package operates at two distinct levels: The district level and the state level. One of the programs for application at the district level is the RAMS District Optimization program (1), hereafter referred to as the RAMS-D01 program. RAMS-D01 was developed to aid District engineers in the selection of maintenance and rehabilitation activities that would make the best possible use of the resources available for a particular fiscal year. Categories of resources considered include materials, equipment, manpower and budget constraints.

Figure A-1 provides an overview of RAMS-D01. The program has been implemented on a microcomputer and is referred to as MICRO-RAMS-D01 in the figure. Program inputs include: (1) pavement section characteristics (i.e., pavement condition, section length and width); (2) resource requirements and constraints (i.e., budget, materials, equipment, and manpower); (3) maintenance and rehabilitation strategies; (4) traffic and environmental conditions; (5) analysis period; (6) minimum rating requirements; and (7) pavement performance information. The input variables are those that are normally considered by a highway engineer during the decision process of allocating limited resources for preserving highways under his jurisdiction.

As may be inferred from Figure A-1, RAMS-D01 provides a highway engineer with an analytical tool for evaluating the effects of different budget levels, and for drawing a budget versus benefit profile. The effects of changes in unit costs for manpower, equipment and materials, or of different minimum rating requirements can also be evaluated. This capability for evaluating different scenarios should facilitate budget preparation, and help justify funding requests

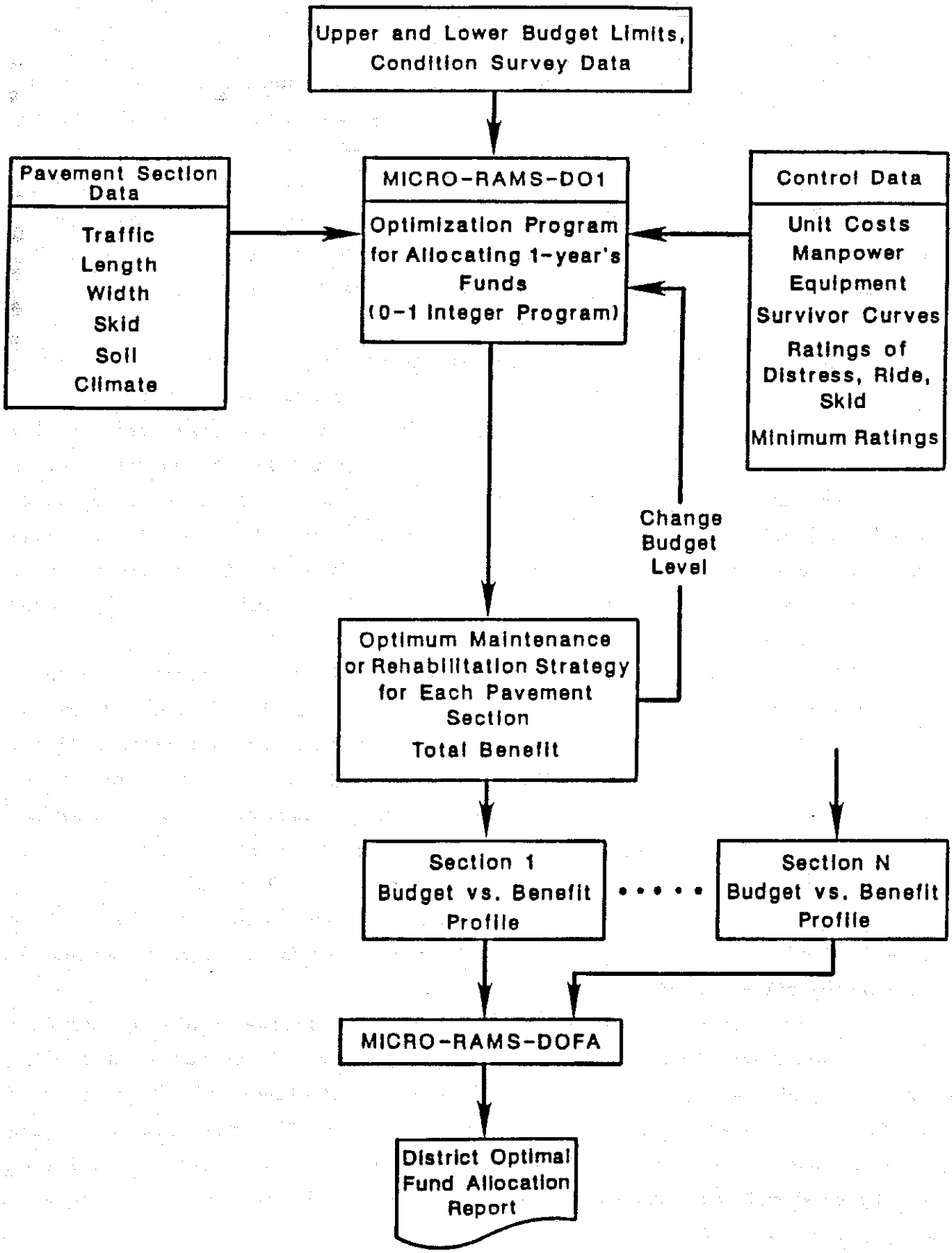


Figure A-1. Overview of Micro-RAMS-DO1.

by the districts in the state. In addition, the rational allocation of state funds among the various districts is encouraged. It is emphasized, however, that RAMS-D01 is only a decision analysis tool. The program is intended to help a highway engineer allocate funds judiciously, particularly when there is a host of competing alternatives to consider, which is usually the case in practice. RAMS-D01 was never intended to dictate the decisions for the highway engineer.

In the sections that follow, the essential features of the optimization program are discussed. Technical details on the objective function and optimization algorithm are presented elsewhere (1, 2, 3) and will not be repeated here. Only the important concepts underlying the program are explained with the purpose of providing the user with a general understanding of RAMS-D01.

The Resource Allocation Problem

In order to illustrate the problem of allocating limited resources among several competing alternatives, consider the hypothetical situation presented in Table A-1.

Table A-1. Hypothetical Resource Requirements and Profits for Various Projects.

	Resource Requirements		
Project	A	B	Profit
1	3	5	150
2	8	3	300
3	2	7	200
4	5	8	600
5	3	1	150
6	7	6	700
7	5	7	400
8	6	8	650
9	9	5	700
TOTAL	48	50	
AVAILABLE	38	38	
EXCESS NEEDED	10	12	

The table shows nine different projects together with the resource requirements and profit associated with each project. For simplicity, only two resources, A and B, are considered. If the quantities available for resources A and B were sufficient to do all projects, then the resource allocation problem becomes trivial. The obvious decision would be to select all projects. However, this is not usually the case. Often, the resources available are limited. In the present example, the total requirements for resource A exceed the amount available by 10 units. Similarly, there is a deficit of 12 units for resource B. Obviously, therefore, not all projects can be selected, and the problem is to determine the set of projects that will yield the most profit while at the same time satisfying the resource constraints.

Problems of this nature are best resolved in an operations research framework. An important element of this framework is the definition of the objective of the optimization process. In the preceding example, the objective was to maximize profits subject to the given resource constraints. Similarly, in the development of RAMS-D01, the objective was defined to be the maximization of the overall effectiveness of maintenance and rehabilitation activities, subject to resource constraints and minimum requirements of pavement quality and service life (1).

An explanation of the concept of maintenance effectiveness is important to understanding the optimization algorithm in RAMS-D01. What is to be optimized must be clearly defined. In many resource allocation problems, for example, profit is the controlling factor. In this instance, profit is usually defined as the difference between revenues and costs, where revenues are generated from the sale of projects from a manufacturing process, and costs are incurred in the manufacture of the said products. Similarly, the concept of maintenance effectiveness must be defined. In order to accomplish this, however, it is first necessary to have a basic understanding of the concept of pavement performance.

Pavement Performance

In order to design pavements, and to select appropriate remedial measures for maintaining or rehabilitating pavement structures, a model is required for predicting the trend in pavement condition over time or with increasing axle

load applications. This trend in pavement condition defines the performance of a particular pavement structure over a given time period. The trend is influenced by several factors, such as (1) the materials the pavement is made of; (2) the thicknesses of the various pavement layers; (3) the traffic loads imposed on the pavement; (4) environmental variables; and (5) maintenance activities performed during the lifetime of the pavement structure. In addition, the trend is relative to a pavement condition indicator such as roughness, cracking or rutting. These pavement condition indicators are measures of the condition of a pavement section at a particular point in time. When considered individually and/or collectively, such indicators provide an estimate of the current overall adequacy of a particular roadway, and identify deficiencies which can lead to accelerated pavement deterioration with additional traffic.

For the RAMS-D01 program, prediction of pavement performance is accomplished using pavement survival curves. Figure A-2 shows a conceptual illustration of a survival curve which shows the probability that a given pavement will not require additional maintenance or rehabilitation at a particular point in time. If the probability of survival at some time t is denoted by R(t), the probability of failure is given by:

$$F(t) = 1 - R(t) \qquad \text{(A-1)}$$

where,

F(t) = probability of failure at time t

R(t) = probability of survival at time t

In Figure A-2, for example, there is a 50 percent probability that a given pavement will require some form of treatment after approximately 6.5 years. Phrased another way, if there were 100 pavement sections, it can be predicted that 50 would require some form of maintenance or rehabilitation work after 6.5 years.

In the development of RAMS-D01, survival curves for various pavement distress types, and maintenance and rehabilitation activities, were determined from the collective judgement and experience of various Texas SDHPT personnel. It is pointed out that survival curves may vary from one highway jurisdiction to another. Differences in traffic and environmental conditions, and in design

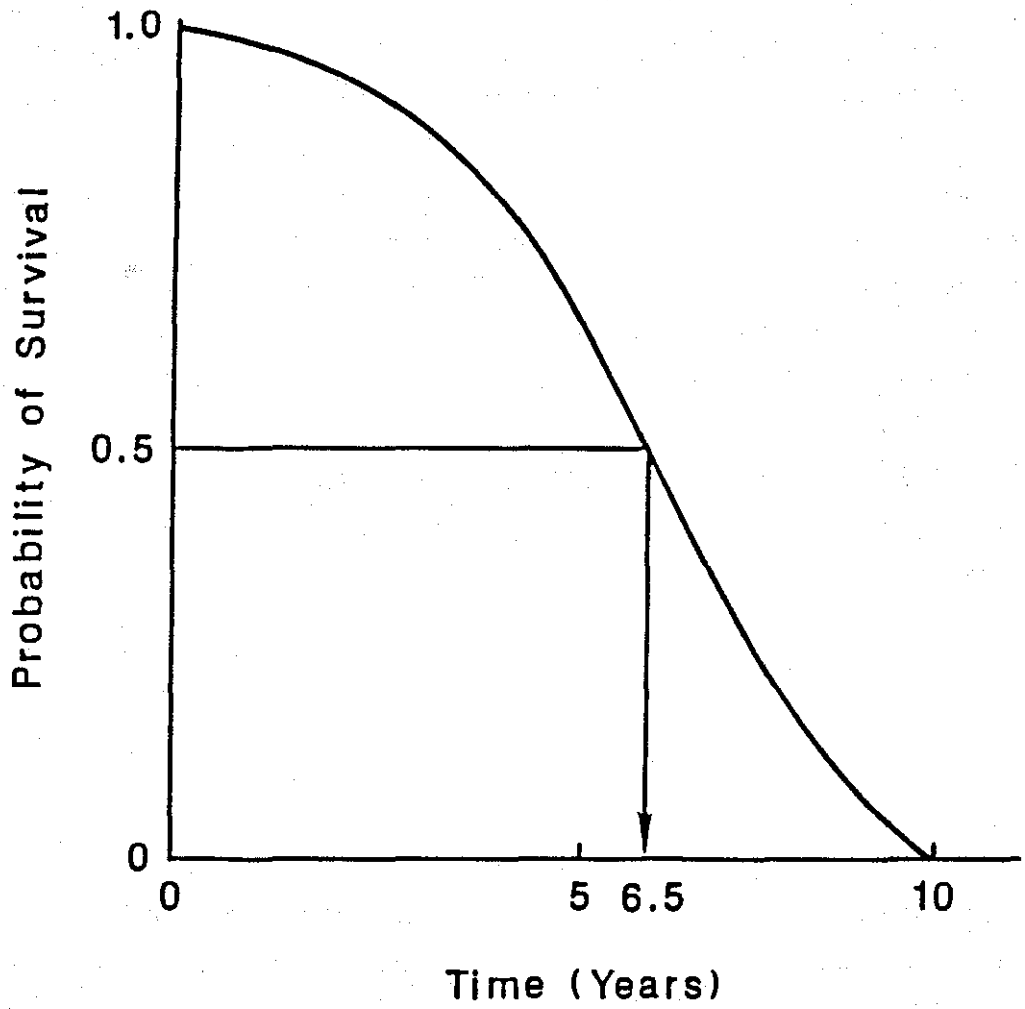


Figure A-2. Conceptual Illustration of a Survival Curve.

and construction practices contribute to variations in pavement performance. Consequently, in the application of the RAMS-D01 program, pavement survival curves applicable to a particular locality should be established and used.

Maintenance Effectiveness

Previously, it was indicated that the objective, which the RAMS-D01 program was to serve, is the maximization of the overall effectiveness of maintenance and rehabilitation activities. The concept of maintenance effectiveness is important to the understanding of what the program does. In order to explain maintenance effectiveness, it is necessary to refer back to the pavement survival curves discussed in the preceding section. As indicated previously, the survival curves are influenced by the types of maintenance or rehabilitation activities performed, and by the types of distress considered. In the RAMS-D01 program, the survival curve for a particular maintenance or rehabilitation treatment, and a given distress type, is multiplied by a weighting factor that reflects the importance attached to the given distress type. This process merely transforms the ordinate scale of the survival curve. Instead of the ordinate values ranging from 0 to 1, as is shown in Figure A-2, the values will subsequently range from zero to the value of the weighting factor associated with a given distress type. Since the weighting factor is an upper limit, its value may be interpreted as the maximum rating that is possible for a given distress type. Table A-2 shows the maximum ratings established for different distresses. Please note that these values are not the same as the utility factors used in PES (in fact, some of the PES distresses are not even included). The microcomputer version of RAMS-D01 converts PES distress ratings into the Table A-2 scale internally.

Table A-2. Maximum Ratings for Different Distress Types (1).

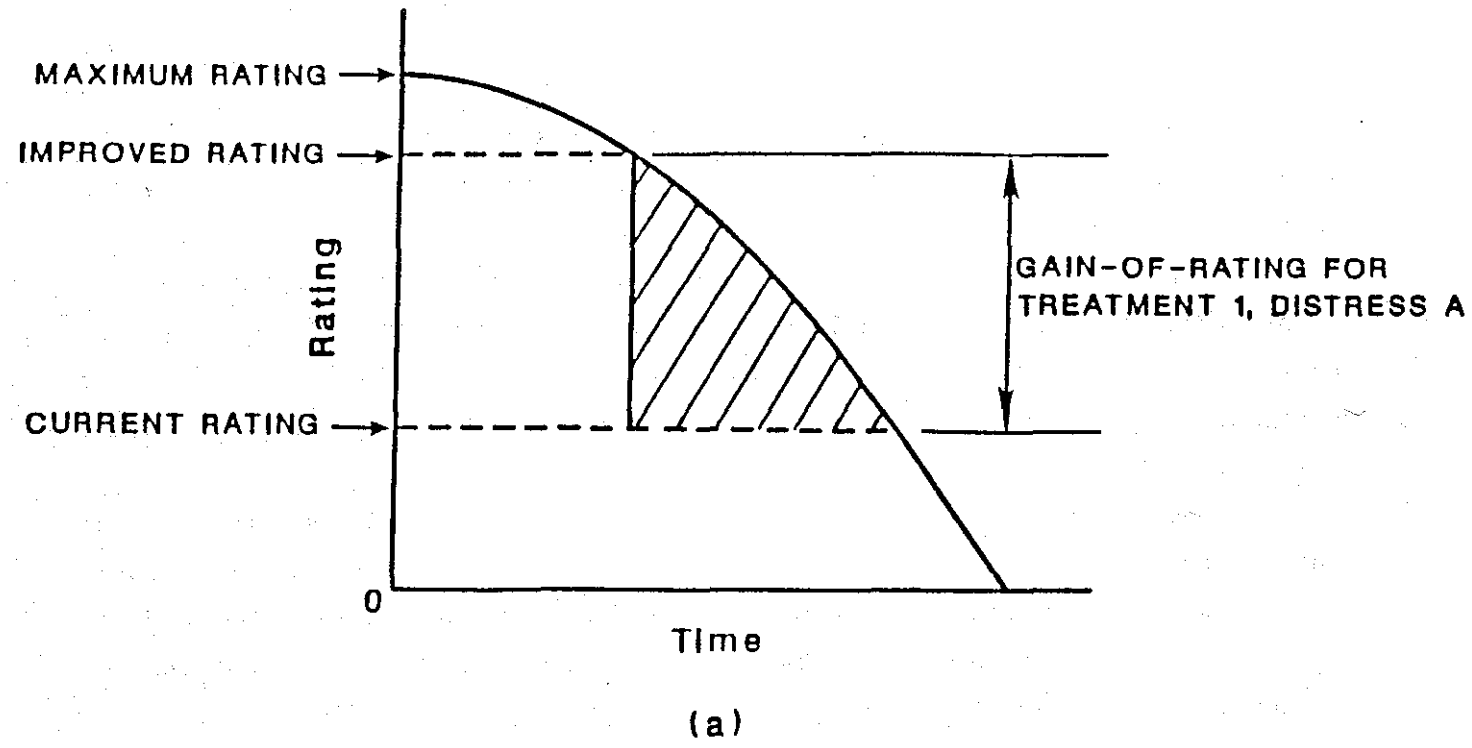
DISTRESS TYPE	MAXIMUM RATING
Rutting	15
Alligator Cracking	25
Longitudinal Cracking	25
Transverse Cracking	20
Failures/Mile	40
Serviceability Index	50

The values shown were established form the collective judgement of Texas SDHPT engineers.

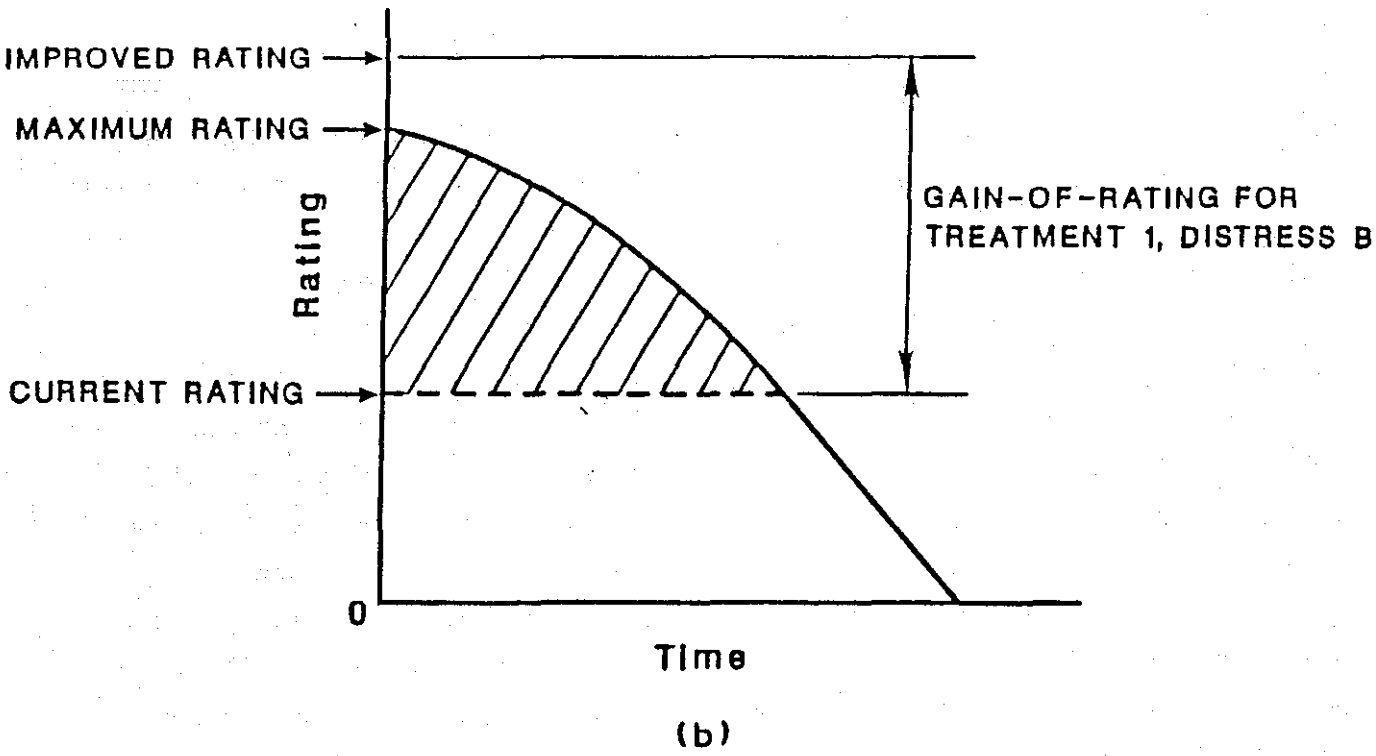
When some form of treatment is applied to a particular pavement, the condition of the pavement will most likely improve, assuming that an appropriate treatment has been applied. Consequently, the condition rating of the pavement is expected to increase, the amount of increase being dependent on the type of distress considered and the maintenance or rehabilitation strategy applied. In the development of RAMS-D01, maximum gain-of-rating points were established using the collective judgement and experience of Texas SDHPT engineers. The maximum gain-of-rating reflects the maximum improvement that can be achieved when a given maintenance strategy is used to treat a specific distress. It should be clear that the maximum possible value for gain-of-rating for a distress type is the maximum rating for the distress type.

The gain-of-rating concept is illustrated in Figure A-3. Figure A-3(a) illustrates a situation where a given strategy significantly improves the rating of a given pavement relative to a certain distress but not enough to achieve the maximum rating associated with the given distress. Figure A-3(b) shows the opposite case where the strategy applied raises the condition rating to a level greater than the maximum rating associated with the given distress. Both of these situations are possible in practice.

Figure A-3 also illustrates the concept of maintenance effectiveness. The hatched area shown for each curve in the figure is a measure of the effectiveness of a particular maintenance activity in treating a given type of pavement distress. In Figure A-3(a), for example, the maintenance effectiveness of Treatment 1 on Distress Type A is quantified by the hatched area. Note that the calculation of the area starts at the point on the curve whose ordinate is the improved pavement condition rating after application of the maintenance treatment. This reflects the fact that the particular treatment did not raise the condition rating to the maximum level associated with the given distress. The maintenance effectiveness calculated is therefore only a fraction of the total area bounded by the curve and the horizontal line passing through the condition rating prior to treatment. In contrast, the maintenance effectiveness for the situation illustrated in Figure A-3(b) is calculated as the entire area bounded by the curve and the horizontal line through the current condition



(a)



(b)

Figure A-3. Illustration of Maintenance Effectiveness.

rating. This is how the program calculates maintenance effectiveness when the improved condition rating exceeds the maximum rating associated with the given distress.

The area under the survival or performance curve is one component of the maintenance effectiveness calculated by the RAMS-D01 program. Essentially, the area provides a measure of the 'benefit' obtained due to the application of a particular maintenance or rehabilitation treatment. The larger the area under the curve, the greater the benefit.

However, another factor that should be considered is cost, since maintenance and rehabilitation activities that provide greater benefits usually require more of the limited resources available, in particular, the budget. Consequently, a ratio, known as the effective gradient of maintenance effectiveness, is evaluated in the RAMS-D01 optimization procedure.

For a given pavement, the total benefit attributable to a particular maintenance or rehabilitation strategy is calculated as the sum of the areas determined for the different distresses considered. This sum is multiplied by the pavement section area to account for this factor in the optimization process. Thus, the pavement area is like a weighting factor that is applied to the total benefit calculated. So, the larger a road segment is, the more total benefit it will have. This weighted benefit divided by the sum of the resource requirements associated with a given treatment being applied to a particular pavement is the effective gradient of maintenance effectiveness.

The effective gradient is essentially a benefit-cost ratio and is a controlling factor in the optimization process. Highway segments with high effective gradients are more likely to be selected for maintenance and rehabilitation treatments than those with lower effective gradients. This is only logical, since a high effective gradient indicates a more efficient use of resources; i.e., more benefits are accrued per unit outlay of resources.

The details of the computational algorithm used to select optimum maintenance and rehabilitation activities are discussed elsewhere (1,3) and will not be repeated at length here. Essentially, the program uses an integer programming technique to maximize the overall benefit that may be achieved with the available resources. At each iteration, the program looks at the calculated effective gradients for the set of maintenance and rehabilitation (M&R)

activities considered for each highway segment. The effective gradient is used to select the set of maintenance and rehabilitation activities considered at each step of the analysis. Iterations continue until a set of M&R activities is obtained that maximizes the overall maintenance effectiveness and satisfies the given constraints.

REFERENCES

1. Ahmed, N.V., et al., "The Texas Transportation and Maintenance District Optimization System," Research Report 207-3, Texas Transportation Institute, Texas A&M University, College Station, Texas, November 1978.

2. Danny, Y. Lu, and Lytton, R.L., "Strategic Planning for Pavement Rehabilitation and Management System," Transportation Research Record 598, Transportation Research Board, Washington, D.C., 1976, pp. 29-35.

3. Senju, S., and Toyoda, Y., "An Approach to Linear Programming with 0-1 Variables," Management Science, Vol. 15, No. 4, December 1968, pp. B-196-207.

APPENDIX B

RAMS-D01 OUTPUT FILES

This appendix presents the summary report (Option 1 on Screen 2-3) from the RAMS-D01 Program. These input and output reports are generated each time the RAMS-D01 Program is run.

RAMS-DOI ANALYSIS

PROBLEM DESCRIPTION : CASE STUDY

NO. OF HIGHWAY SEGMENTS= 94 NO. OF ANALYSIS PERIODS = 10

BUDGET REQUIREMENTS AND AVAILABILITY

STRATEGY	COST PER FOOT-MILE
FOG SEAL	120.00
SEAL COAT	460.00
OGPMS	2040.00
THIN OVERLAY	1990.00
MOD. OVERLAY	4300.00
HEAVY OVERLAY	7630.00
L.D. RECONSTRT.	2030.00
H.D. RECONSTRT.	5590.00
AVAILABLE	1000000.00

Figure B-1. Input screen (user modifiable) showing cost per strategy and total available budget.

SEGM NUM	DIST NUM	COUNTY CODE	HIGHWAY NUMBER	FROM	TO	LN	ROADWAY	LENGTH	WIDTH
1	11	003	US0059	000+00	002+00	S	R-V	2.0	24.0
2	11	003	US0059	000+00	002+00	M	L-P	2.0	24.0
3	11	003	US0059	002+00	004+00	R	R-V	2.0	24.0
4	11	003	US0059	002+00	004+00	M	L-P	2.0	24.0
5	11	003	US0059	004+00	006+00	S	R-V	2.0	26.0
6	11	003	US0059	004+00	006+00	L	L-P	2.0	26.0
7	11	003	US0059	006+00	006+16	R	R-V	1.6	30.0
8	11	003	US0059	006+00	006+16	L	L-P	1.6	30.0
9	11	003	US0059	006+16	010+00	R	R-L	2.4	63.0
10	11	003	US0059	010+00	010+12	R	R-L	1.2	62.0
11	11	003	US0059	010+12	014+00	R	R-V	2.8	26.0
12	11	003	US0059	010+12	014+00	L	L-P	2.8	26.0
13	11	003	US0059	014+00	016+00	R	R-V	2.0	24.0
14	11	003	US0059	014+00	016+00	L	L-P	2.0	24.0
15	11	003	US0059	016+00	018+00	R	R-V	2.0	24.0
16	11	003	US0059	016+00	018+00	L	L-P	2.0	24.0
17	11	003	US0059	018+00	020+00	R	R-V	2.0	24.0
18	11	003	US0059	018+00	020+00	L	L-P	2.0	24.0
19	11	003	US0059	020+00	022+00	R	R-V	2.0	24.0
20	11	003	US0059	020+00	022+00	L	L-P	2.0	24.0
21	11	003	US0059	022+00	022+20	R	R-V	2.0	24.0
22	11	003	US0059	022+00	022+20	L	L-P	2.0	24.0
23	11	174	US0059	000+00	002+00	R	R-L	2.0	48.0
24	11	174	US0059	002+00	004+00	R	R-L	2.0	48.0
25	11	174	US0059	004+00	006+00	L	R-L	2.0	26.0
26	11	174	US0059	006+00	008+00	R	R-L	2.0	26.0
27	11	174	US0059	008+00	010+00	R	R-L	2.0	26.0
28	11	174	US0059	010+00	012+00	R	R-L	2.0	26.0
29	11	174	US0059	012+00	014+00	R	R-L	2.0	26.0
30	11	174	US0059	014+00	014+24	R	R-L	2.4	26.0
31	11	174	US0059	014+24	018+13	R	R-V	2.9	32.0
32	11	174	US0059	014+24	018+13	L	L-P	2.9	32.0
33	11	174	US0059	018+13	020+00	L	R-L	.7	64.0
34	11	174	US0059	020+00	022+00	R	R-V	2.0	24.0
35	11	174	US0059	020+00	022+00	L	L-P	2.0	24.0
36	11	174	US0059	022+00	022+20	R	R-V	2.0	24.0
37	11	174	US0059	022+00	022+20	L	L-P	2.0	24.0
38	11	174	US0059	022+20	024+20	M	R-L	2.1	72.0
39	11	187	US0059	000+00	002+00	R	R-V	2.0	24.0
40	11	187	US0059	000+00	002+00	L	L-P	2.0	24.0
41	11	187	US0059	002+00	004+00	S	R-V	2.0	24.0
42	11	187	US0059	002+00	004+00	L	L-P	2.0	24.0
43	11	187	US0059	004+00	006+00	S	R-V	2.0	24.0
44	11	187	US0059	004+00	006+00	L	L-P	2.0	24.0
45	11	187	US0059	006+00	008+04	S	R-V	2.4	24.0
46	11	187	US0059	006+00	008+04	L	L-P	2.4	24.0
47	11	187	US0059	008+04	008+19	S	R-L	1.5	70.0
48	11	187	US0059	008+19	012+00	R	R-V	2.1	24.0
49	11	187	US0059	008+19	012+00	L	L-P	2.1	24.0
50	11	187	US0059	012+00	014+00	R	R-V	2.0	24.0

Figure B-2. Location information for each section in the analysis.

RAMS-D01 ROAD SEGMENT INPUT DATA (cont.)

SEGM NUM	DIST NUM	COUNTY CODE	HIGHWAY NUMBER	FROM	TO	LN	ROADWAY	LENGTH	WIDTH
51	11	187	US0059	012+00	014+00	L	L-P	2.0	24.0
52	11	187	US0059	014+00	016+00	R	R-V	2.0	34.0
53	11	187	US0059	014+00	016+00	L	L-P	2.0	34.0
54	11	187	US0059	016+00	018+00	R	R-V	2.0	24.0
55	11	187	US0059	016+00	018+00	L	L-P	2.0	24.0
56	11	187	US0059	018+00	020+00	R	R-V	2.0	24.0
57	11	187	US0059	018+00	020+00	L	L-P	2.0	24.0
58	11	187	US0059	020+00	020+17	R	R-V	1.7	24.0
59	11	187	US0059	020+00	020+17	L	L-P	1.7	24.0
60	11	187	US0059	020+17	022+11	M	R-L	1.4	70.0
61	11	187	US0059	022+11	026+00	S	R-V	2.8	24.0
62	11	187	US0059	022+11	026+00	L	L-P	2.8	24.0
63	11	204	US0059	000+00	002+00	R	R-V	2.0	24.0
64	11	204	US0059	000+00	002+00	L	L-P	2.0	24.0
65	11	204	US0059	002+00	004+00	S	R-V	2.0	24.0
66	11	204	US0059	002+00	004+00	L	L-P	2.0	24.0
67	11	204	US0059	004+00	006+00	R	R-V	2.0	24.0
68	11	204	US0059	004+00	006+00	L	L-P	2.0	24.0
69	11	204	US0059	006+00	008+00	R	R-V	2.0	28.0
70	11	204	US0059	006+00	008+00	L	L-P	2.0	28.0
71	11	204	US0059	008+00	010+00	R	R-V	2.0	24.0
72	11	204	US0059	008+00	010+00	L	L-P	2.0	24.0
73	11	204	US0059	010+00	012+00	R	R-V	2.0	24.0
74	11	204	US0059	010+00	012+00	L	L-P	2.0	24.0
75	11	204	US0059	012+00	012+14	R	R-V	1.4	24.0
76	11	204	US0059	012+00	012+14	L	L-P	1.4	24.0
77	11	210	US0059	000+00	000+06	R	R-V	.6	24.0
78	11	210	US0059	000+00	000+06	L	L-P	.6	24.0
79	11	210	US0059	000+06	002+06	L	R-L	2.0	64.0
80	11	210	US0059	002+06	002+11	R	R-V	.5	24.0
81	11	210	US0059	002+06	002+11	L	L-P	.5	24.0
82	11	210	US0059	002+11	006+00	L	R-L	2.6	48.0
83	11	210	US0059	006+00	008+00	R	R-L	2.0	48.0
84	11	210	US0059	008+00	010+00	R	R-L	2.0	48.0
85	11	210	US0059	010+00	010+14	R	R-L	1.4	48.0
86	11	210	US0059	010+14	010+16	R	R-V	.2	24.0
87	11	210	US0059	010+14	010+16	L	L-P	.2	24.0
88	11	210	US0059	010+16	012+00	R	R-V	.3	24.0
89	11	210	US0059	010+16	012+00	L	L-P	.3	24.0
90	11	210	US0059	012+00	014+00	L	R-L	1.9	64.0
91	11	210	US0059	014+00	016+00	L	R-L	2.0	26.0
92	11	210	US0059	016+00	016+16	L	R-L	1.6	26.0
93	12	170	US0059	000+00	000+05	S	R-V	.5	24.0
94	12	170	US0059	000+00	000+05	M	L-P	.5	24.0

Figure B-2. Continued.

HIGHWAY TYPE - STRATEGY RESTRICTIONS

FOR HIGHWAY TYPE	1	L.D. RECONSTRT.	IS INFEASIBLE
FOR HIGHWAY TYPE	2	THIN OVERLAY	IS INFEASIBLE
FOR HIGHWAY TYPE	2	MOD. OVERLAY	IS INFEASIBLE
FOR HIGHWAY TYPE	2	HEAVY OVERLAY	IS INFEASIBLE
FOR HIGHWAY TYPE	2	H.D. RECONSTRT.	IS INFEASIBLE

Figure B-3. User supplied restrictions on strategy selection. Type 1 is thick asphalt. Type 2 is surface treated pavements.

OPTIMAL MAINTENANCE DECISIONS

SEGM NUM	DIST NUM	COUNTY CODE	HIGHWAY NUMBER	FROM	TO	LN	STRATEGY	BENEFIT	COST	% BUDGET
17	11	003	US0059	018+00	020+00	R	SEAL COAT	3828.	22080.00	2.21
37	11	174	US0059	022+00	022+20	L	THIN OVERLAY	18235.	95520.00	9.55
41	11	187	US0059	002+00	004+00	S	OGPMS	21427.	97920.00	9.79
43	11	187	US0059	004+00	006+00	S	OGPMS	27469.	97920.00	9.79
45	11	187	US0059	006+00	008+04	S	OGPMS	22547.	117504.00	11.75
58	11	187	US0059	020+00	020+17	R	OGPMS	15674.	83232.00	8.32
74	11	204	US0059	010+00	012+00	L	OGPMS	18094.	97920.00	9.79
79	11	210	US0059	000+06	002+06	L	OGPMS	68104.	261120.00	26.11
81	11	210	US0059	002+06	002+11	L	SEAL COAT	240.	5520.00	.55
89	11	210	US0059	010+16	012+00	L	THIN OVERLAY	1380.	14328.00	1.43
91	11	210	US0059	014+00	016+00	L	OGPMS	23956.	106080.00	10.61
							TOTALS:	220954.	999144.00	99.91

Figure B-4. Optimal selections. These sections produced the maximum benefit for the budget level specified.

RATINGS BEFORE AND AFTER STRATEGIES APPLIED

SEGM NUM	DIST NUM	COUNTY CODE	HIGHWAY NUMBER	FROM	TO	LN	RUTTING		ALLIG CRKNG		LONG CRKNG		TRANS CRKNG		FAILURE/MILE		SERVICEAB INDEX	
							BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
17	11	003	US0059	018+00	020+00	R	5.00	5.00	25.00	25.00	13.00	25.00	10.00	20.00	40.00	40.00	45.54	47.54
37	11	174	US0059	022+00	022+20	L	5.00	15.00	25.00	25.00	25.00	25.00	20.00	20.00	40.00	40.00	5.82	50.00
41	11	187	US0059	002+00	004+00	S	15.00	15.00	10.00	25.00	13.00	25.00	10.00	20.00	40.00	40.00	13.08	50.00
43	11	187	US0059	004+00	006+00	S	15.00	15.00	15.00	25.00	13.00	25.00	10.00	20.00	20.00	40.00	9.99	50.00
45	11	187	US0059	006+00	008+04	S	10.00	15.00	10.00	25.00	13.00	25.00	10.00	20.00	40.00	40.00	21.95	50.00
58	11	187	US0059	020+00	020+17	R	10.00	15.00	25.00	25.00	18.00	25.00	10.00	20.00	40.00	40.00	9.99	50.00
74	11	204	US0059	010+00	012+00	L	15.00	15.00	25.00	25.00	18.00	25.00	13.00	20.00	40.00	40.00	5.82	50.00
79	11	210	US0059	000+06	002+06	L	5.00	15.00	25.00	25.00	18.00	25.00	13.00	20.00	20.00	40.00	9.99	50.00
81	11	210	US0059	002+06	002+11	L	15.00	15.00	25.00	25.00	18.00	25.00	20.00	20.00	40.00	40.00	45.54	47.54
89	11	210	US0059	010+16	012+00	L	15.00	15.00	25.00	25.00	25.00	25.00	20.00	20.00	40.00	40.00	17.03	50.00
91	11	210	US0059	014+00	016+00	L	3.00	15.00	15.00	25.00	18.00	25.00	10.00	20.00	20.00	40.00	27.79	50.00

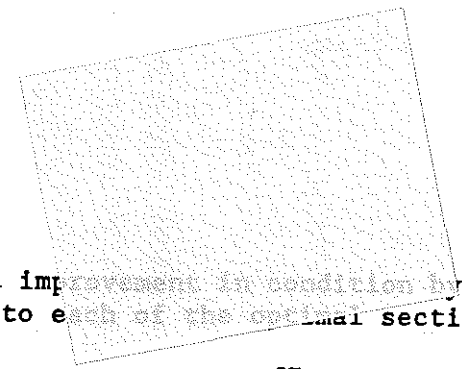


Figure B-5. Estimated improvement in condition by applying the selected strategy to each of the original sections.

APPENDIX C

DECISION TREES FOR ONE-YEAR M&R ESTIMATES

This appendix presents the Maintenance and Rehabilitaion Decision Trees that were developed in cooperation with Texas State Department of Highways and Public Transportation Design (D-8PD) and Maintenance (D-18PM) personnel.

APPENDIX C-1

DECISION TREES FOR REHABILITATION AND MAINTENANCE OF RIGID PAVEMENTS (TYPES 1, 2, AND 3)

MAIN PROGRAM LOGIC DECISION TREE

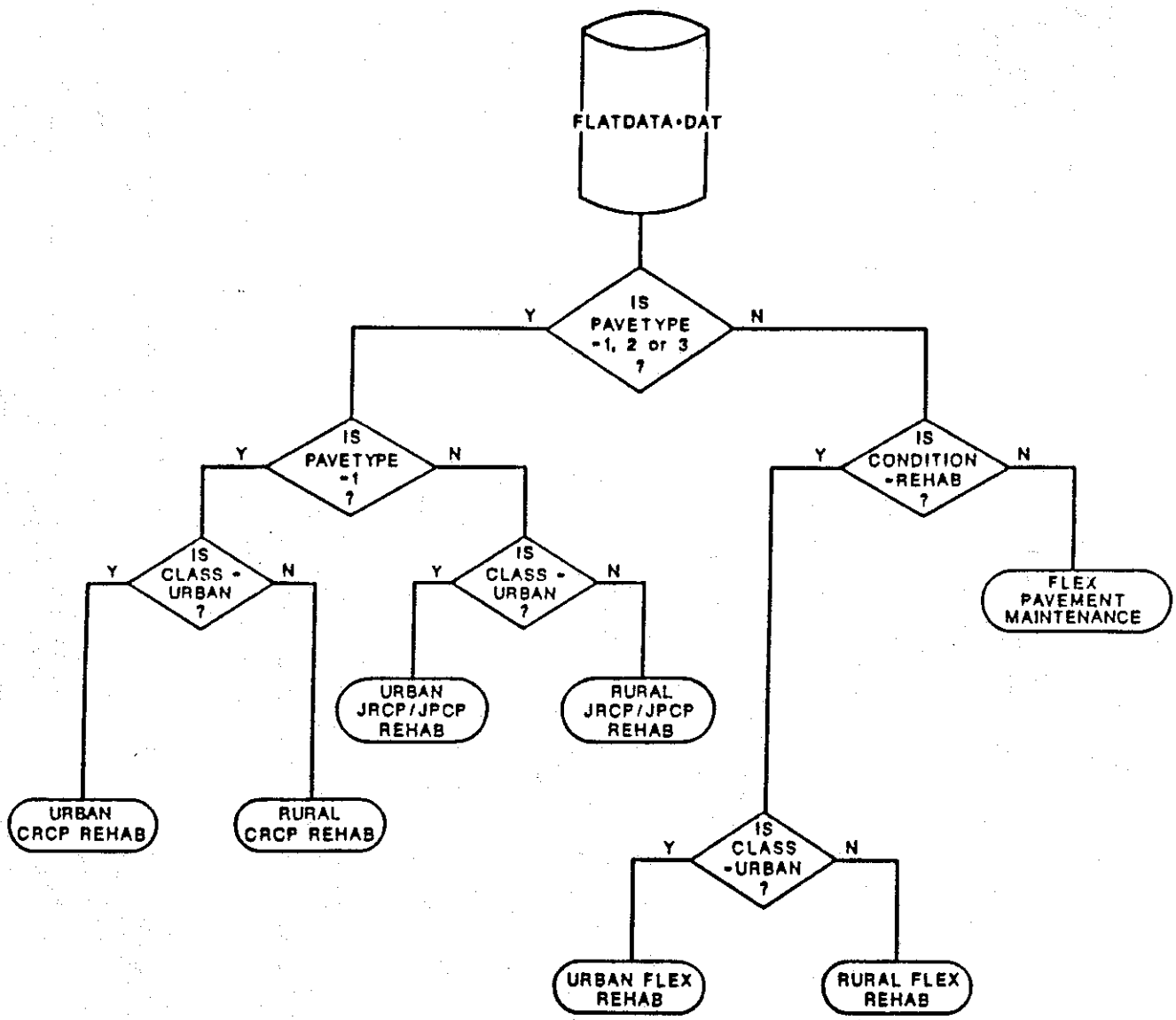


Figure C-1. Overall logic pavement types 1, 2, 3 are rigid pavements (CRCP, JRCP and FPCP respectively). Decision trees are presented for each of the pavement groups at the end of each branch.

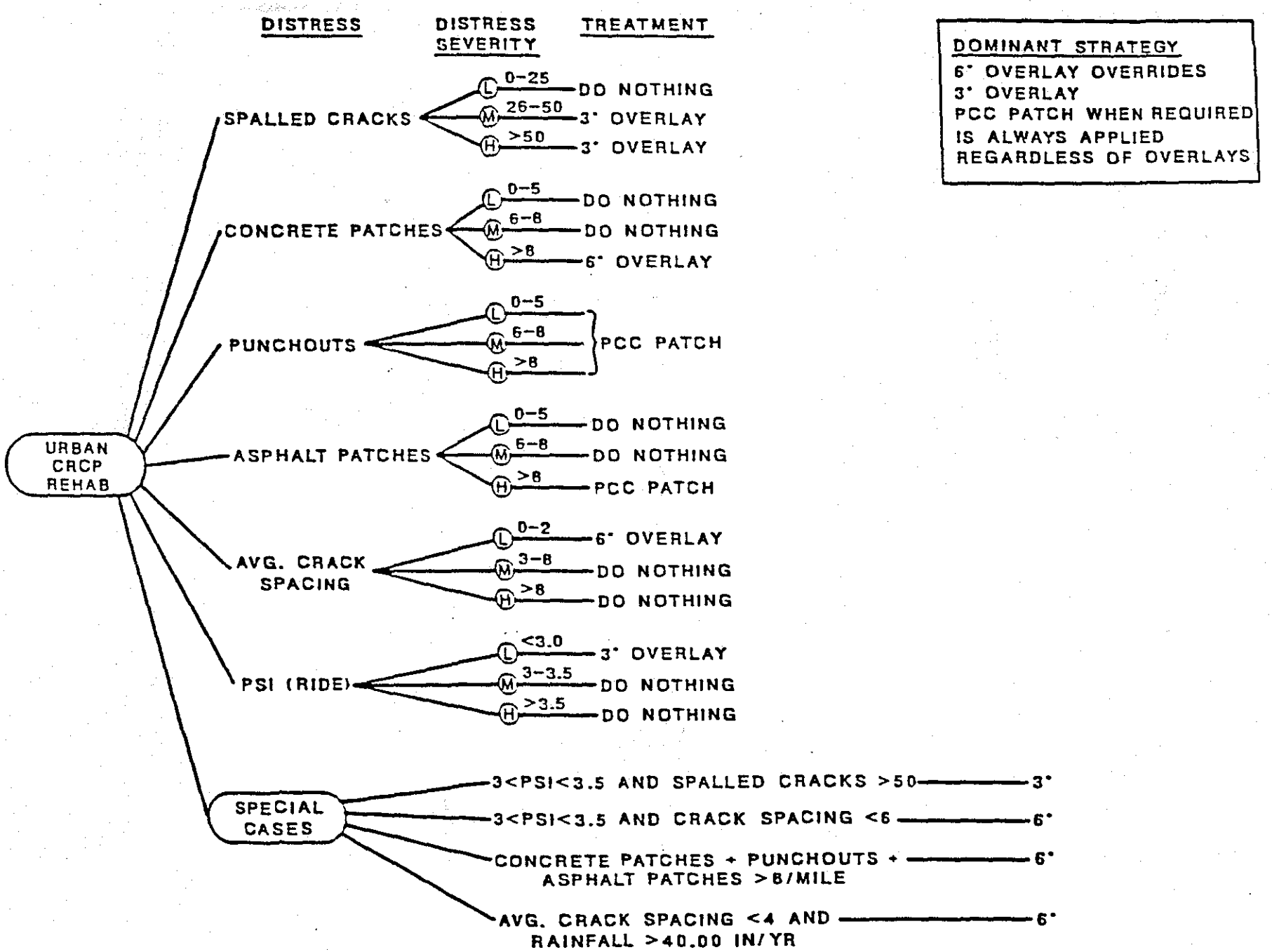


Figure C-2. Decision Tree for Urban CRCP Maintenance and Rehabilitation.

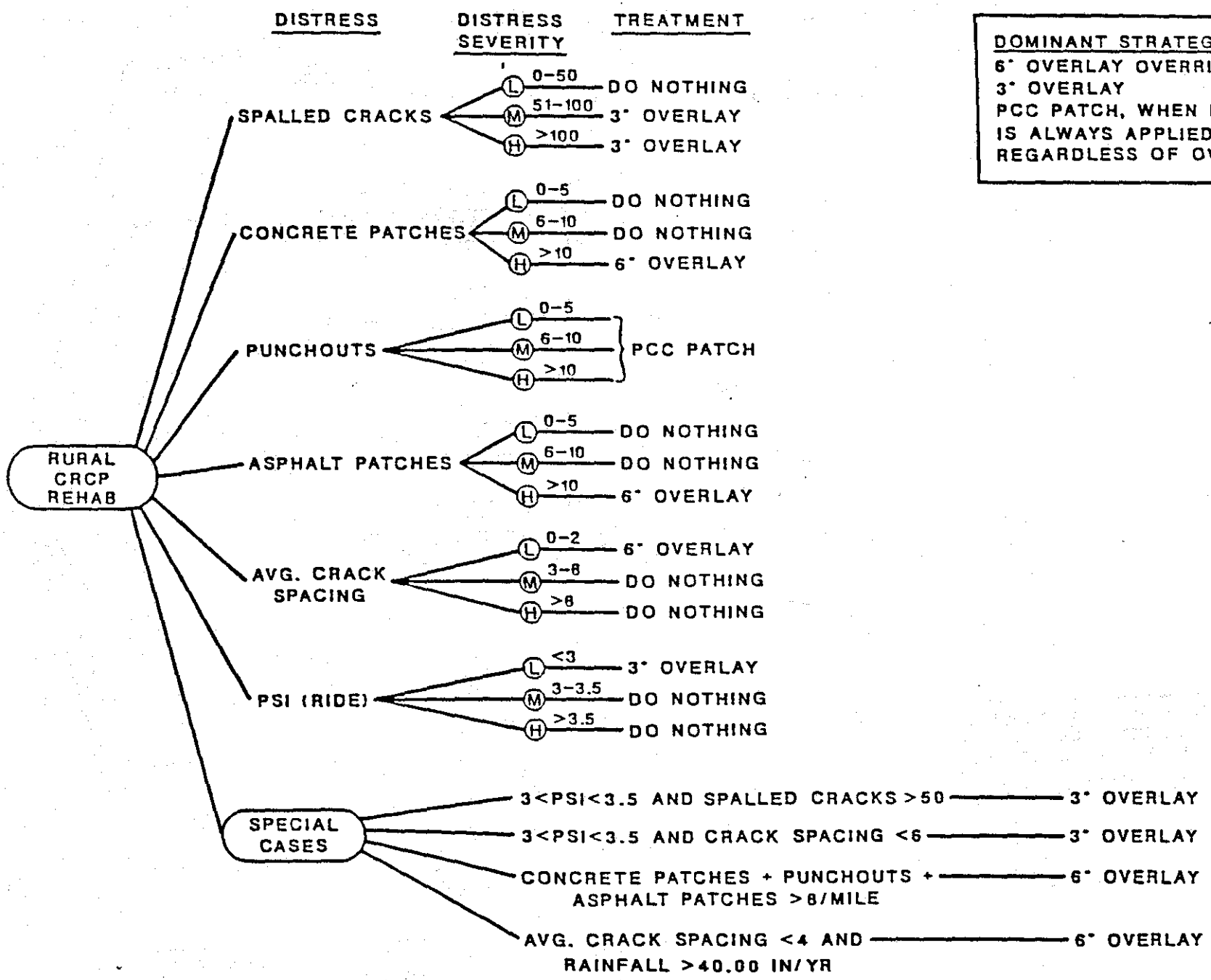


Figure C-3. Decision Tree for Rural CRCP Maintenance and Rehabilitation.

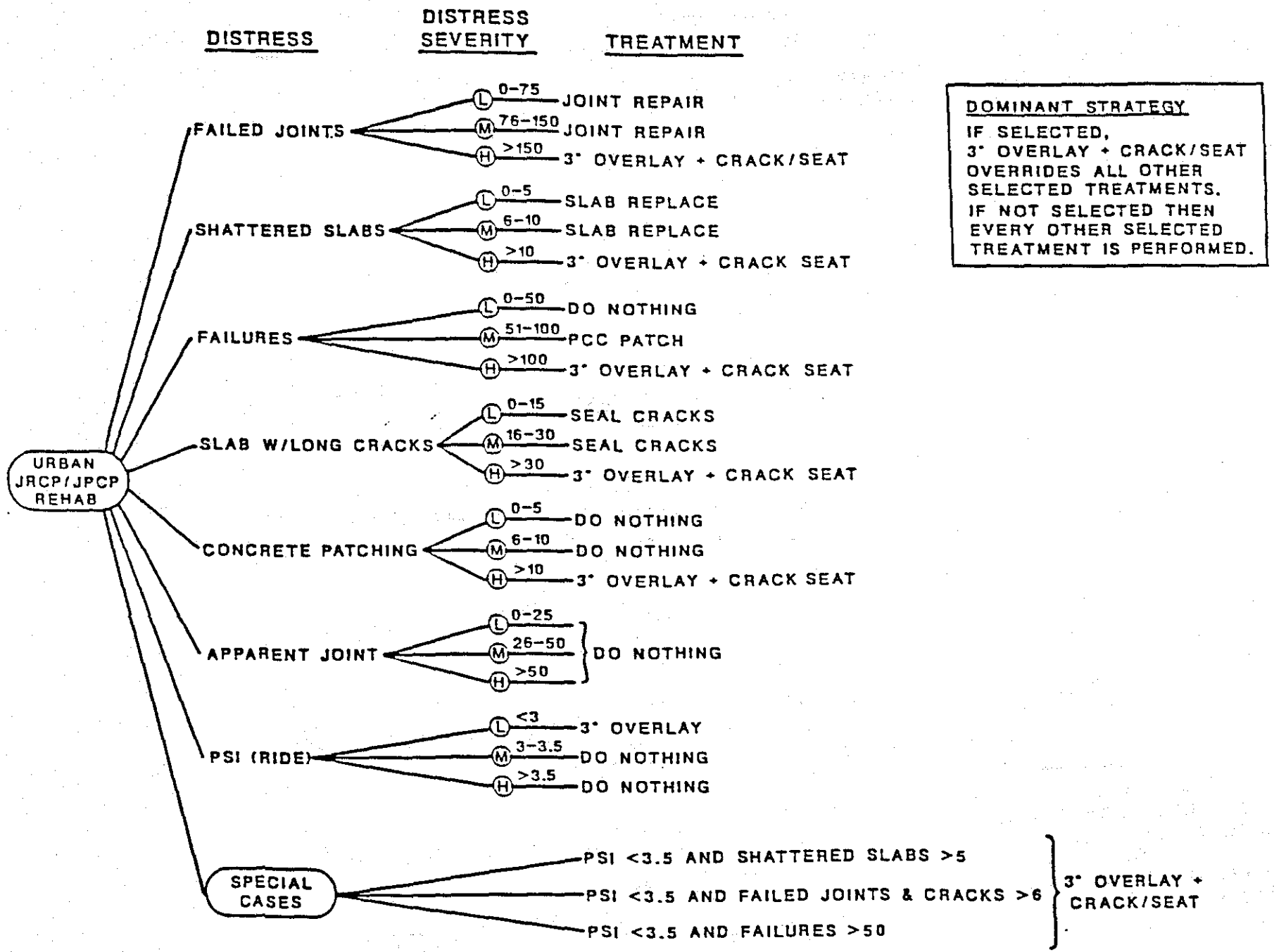


Figure C-4. Decision Tree for Urban JRCP/JPCP Maintenance and Rehabilitation.

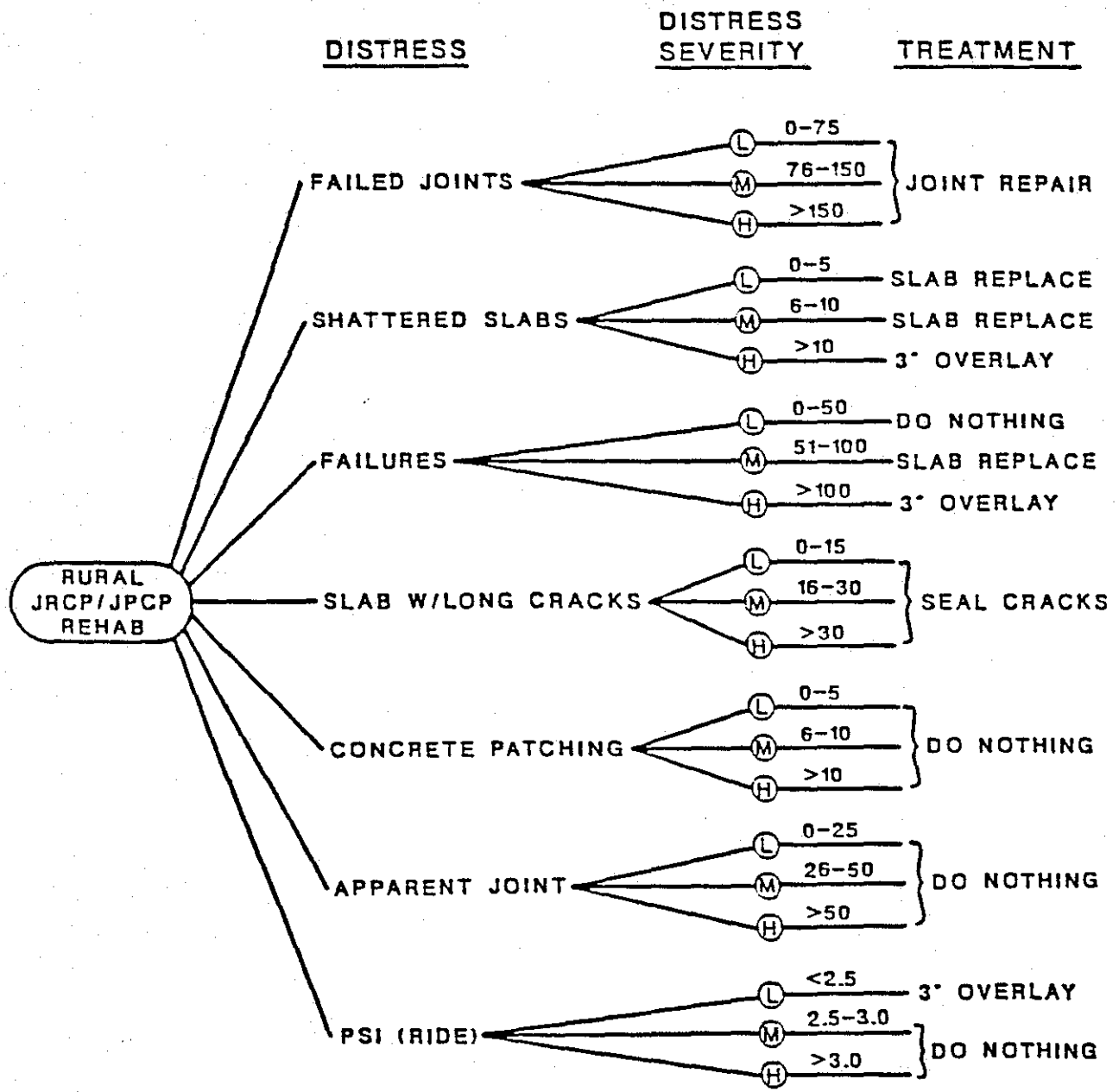


Figure C-5. Decision Tree for Rural JRCP/JPCP Maintenance and Rehabilitation.

APPENDIX C-2

DECISION TREES FOR REHABILITATION AND MAINTENANCE OF FLEXIBLE PAVEMENTS (TYPES 4 THROUGH 10)

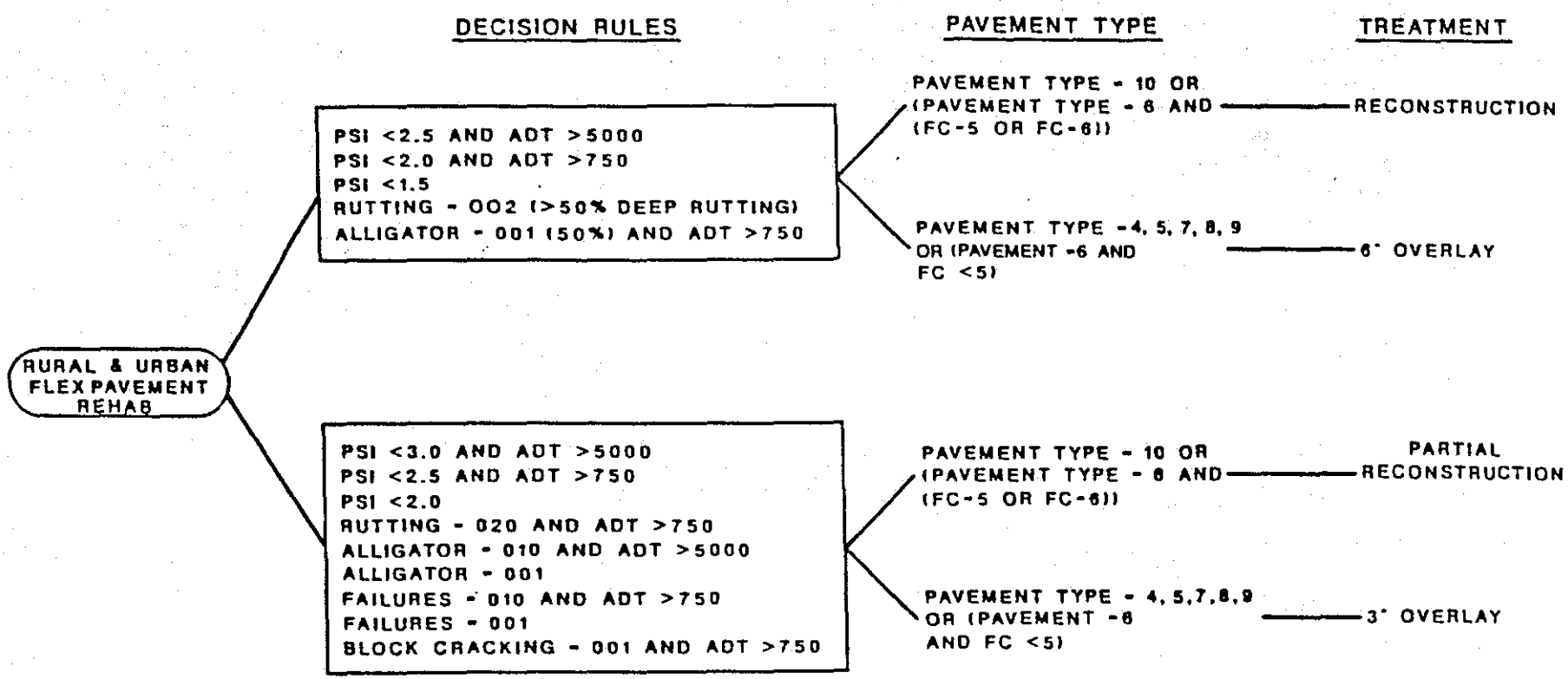
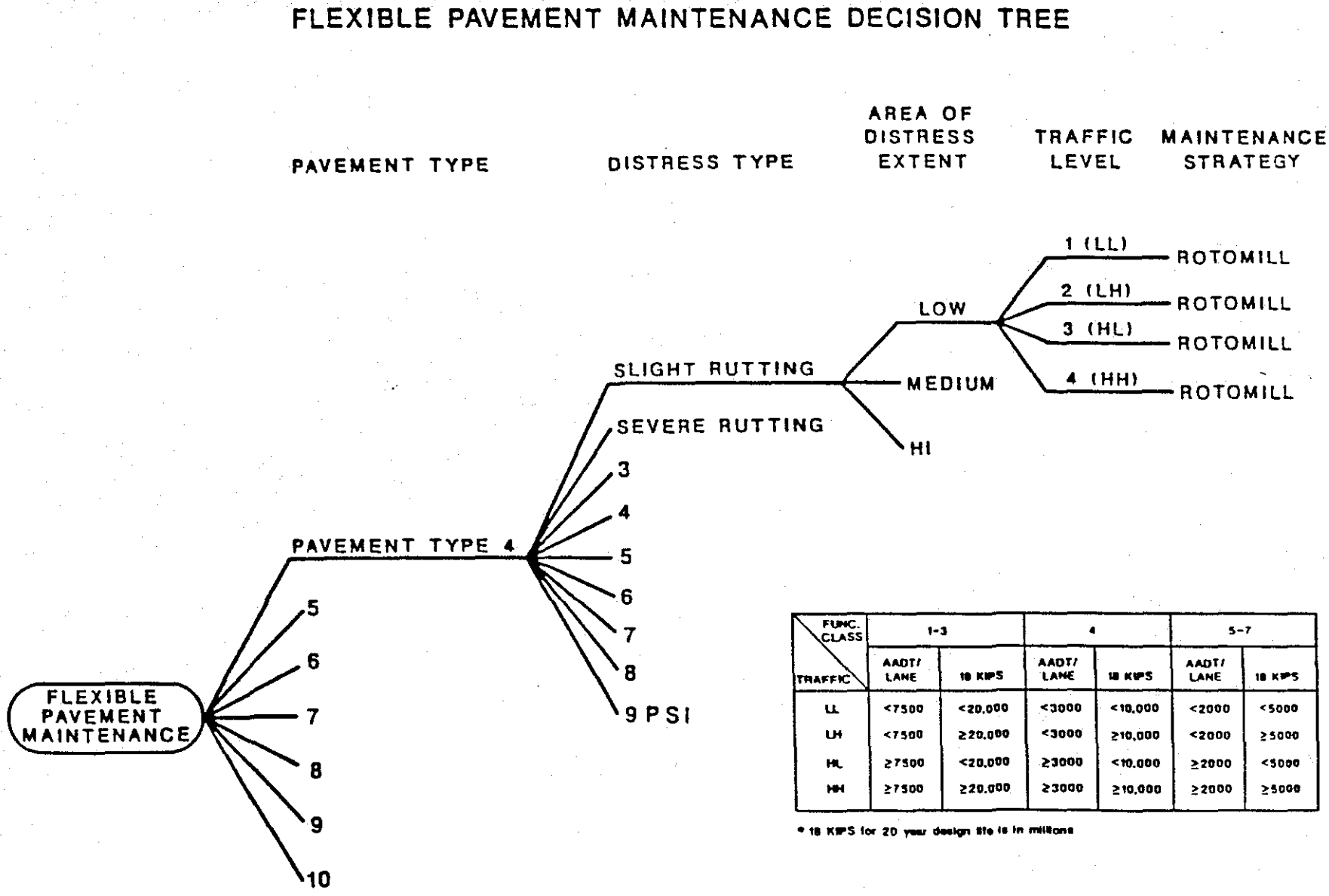


Figure C-6. Rural and Urban Flexible Pavement Rehabilitation Decision Tree.



FUNC. CLASS / TRAFFIC	1-3		4		5-7	
	AADT/ LANE	18 KIPS	AADT/ LANE	18 KIPS	AADT/ LANE	18 KIPS
LL	<7500	<20,000	<3000	<10,000	<2000	<5000
LH	<7500	≥20,000	<3000	≥10,000	<2000	≥5000
HL	≥7500	<20,000	≥3000	<10,000	≥2000	<5000
HH	≥7500	≥20,000	≥3000	≥10,000	≥2000	≥5000

* 18 KIPS for 20 year design life is in millions

Figure C-7. One branch of the Flexible Pavement Maintenance Decision Tree.

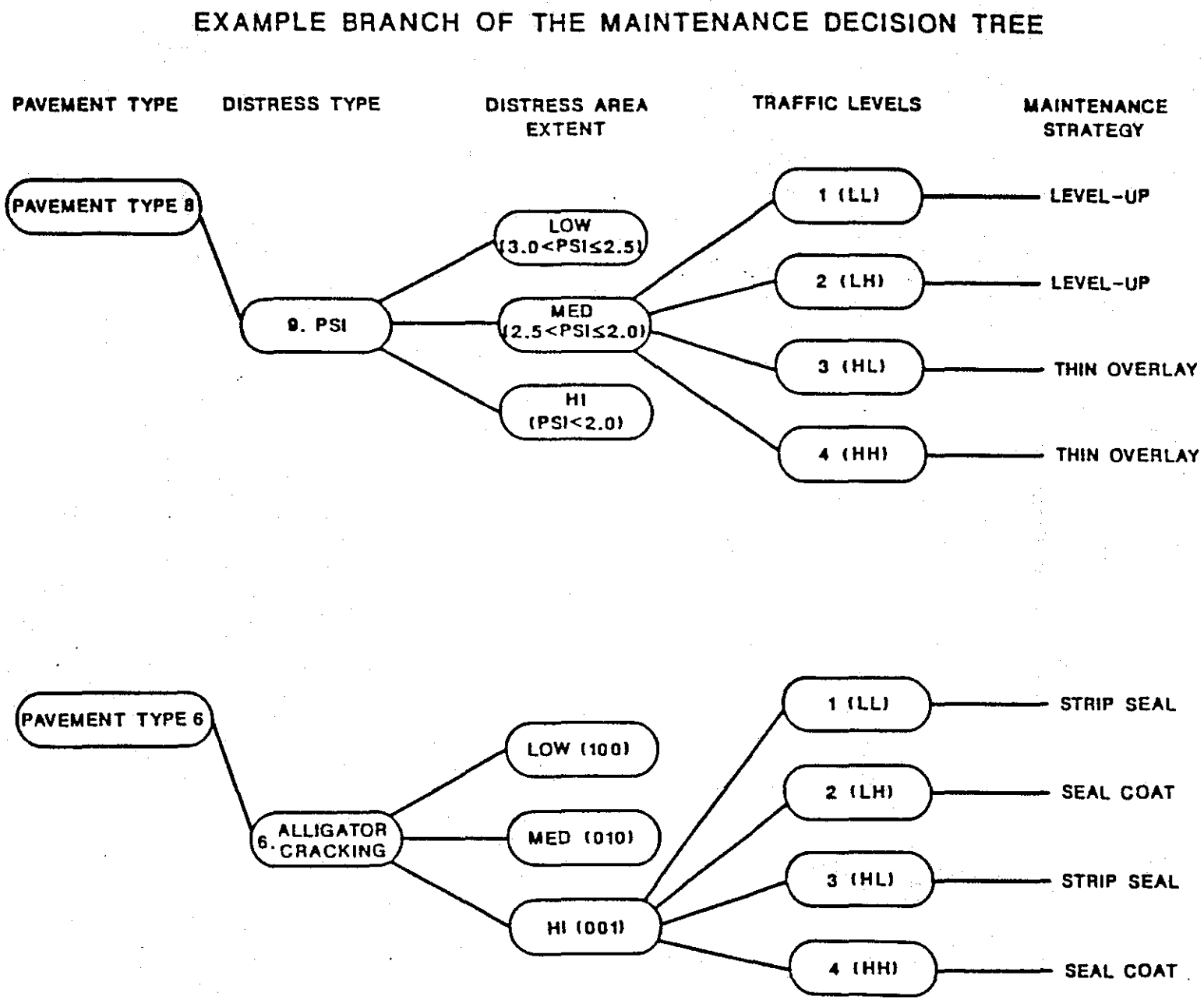


Figure C-8. Other Example of Branches From the Maintenance Decision Trees.

Listing of Maintenance Stragegies

0	Do Nothing		
1	Seal Cracks	8	Slurry Seal
2	Partial Patch	9	Level-up
3	Full Depth Patch	10	Thin Overlay
4	Fog Seal	11	Rotomill
5	Strip Seal	12	Spot Seal
6	Seal Coat	13	Rotomill + Seal Coat
7	Asphalt-Rubber Seal	14	Rotomill + Thin Overlay

Figure C-9. Maintenance Strategies Included in the System.

Thick ACP - 5 1/2" Performance Equation: Black Base

	Distress	Traffic	Area 100	Area 010	Area 001
1	Slight Rutting	LL	11	11	11
		LH	11	11	11
		HL	11	11	11
		HH	11	11	11
2	Severe Rutting	LL	9	14	14
		LH	13	14	14
		HL	13	14	14
		HH	13	14	11
3	Block Cracking	LL	1	6	6
		LH	1	7	7
		HL	1	6	7
		HH	1	7	7
4	Patching	LL	0	0	0
		LH	0	0	0
		HL	0	0	0
		HH	0	0	0
5	Failures	LL	3	3	3
		LH	3	3	3
		HL	3	3	3
		HH	3	3	3
6	Alligator Cracking	LL	12	6	7
		LH	7	7	7
		HL	12	6	10
		HH	7	7	10
7	Longitudinal Cracking	LL	1	1	6
		LH	1	1	7
		HL	1	1	7
		HH	1	1	1
8	Transversal Cracking	LL	1	1	6
		LH	1	1	7
		HL	1	1	7
		HH	1	1	7
			3.0-2.5	2.5-2.0	<2.0
9	PSI	LL	9	9	10
		LH	9	10	10
		HL	9	9	10
		HH	9	10	10

Figure C-10. Selection Maintenance Strategy, Pavement Type 4.

Medium ACP-2 1/2 - 5 1/2" Performance Equation: Hot Mix

	Distress	Traffic	Area 100	Area 010	Area 001
1	Slight Rutting	LL	9	9	9
		LH	9	9	11
		HL	9	9	9
		HH	9	9	11
2	Severe Rutting	LL	9	11	14
		LH	9	14	14
		HL	11	11	14
		HH	11	14	14
3	Block Cracking	LL	0	6	6
		LH	1	6	6
		HL	1	6	6
		HH	1	6	6
4	Patching	LL	0	0	0
		LH	0	0	0
		HL	0	0	0
		HH	0	0	0
5	Failures	LL	3	3	3
		LH	3	3	3
		HL	3	3	3
		HH	3	3	3
6	Alligator Cracking	LL	12	12	6
		LH	12	6	7
		HL	12	6	7
		HH	12	7	7
7	Longitudinal Cracking	LL	0	1	6
		LH	1	1	6
		HL	1	1	6
		HH	1	1	6
8	Transversal Cracking	LL	0	1	6
		LH	1	1	6
		HL	1	1	6
		HH	1	1	6
			3.0-2.5	2.5-2.0	<2.0
9	PSI	LL	9	9	9
		LH	9	9	10
		HL	9	9	10
		HH	9	10	10

Figure C-11. Selection Maintenance Strategy, Pavement Type 5.

Thick ACP - 5 1/2" Performance Equation: Black Base

	Distress	Traffic	Area 100	Area 010	Area 001
1	Slight Rutting	LL	11	11	11
		LH	11	11	11
		HL	11	11	11
		HH	11	11	11
2	Severe Rutting	LL	9	14	14
		LH	13	14	14
		HL	13	14	14
		HH	13	14	11
3	Block Cracking	LL	1	6	6
		LH	1	7	7
		HL	1	6	7
		HH	1	7	7
4	Patching	LL	0	0	0
		LH	0	0	0
		HL	0	0	0
		HH	0	0	0
5	Failures	LL	3	3	3
		LH	3	3	3
		HL	3	3	3
		HH	3	3	3
6	Alligator Cracking	LL	12	6	7
		LH	7	7	7
		HL	12	6	10
		HH	7	7	10
7	Longitudinal Cracking	LL	1	1	6
		LH	1	1	7
		HL	1	1	7
		HH	1	1	1
8	Transversal Cracking	LL	1	1	6
		LH	1	1	7
		HL	1	1	7
		HH	1	1	7
			3.0-2.5	2.5-2.0	<2.0
9	PSI	LL	9	9	10
		LH	9	10	10
		HL	9	9	10
		HH	9	10	10

Figure C-10. Selection Maintenance Strategy, Pavement Type 4.

Composite		Peformance Equation: Overlay		
Distress	Traffic	Area 100	Area 010	Area 001
1 Slight Rutting	LL	11	9	9
	LH	11	9	9
	HL	11	9	9
	HH	11	9	10
2 Severe Rutting	LL	9	9	10
	LH	13	13	14
	HL	9	9	14
	HH	9	13	14
3 Block Cracking	LL	0	6	6
	LH	1	6	6
	HL	1	6	6
	HH	1	6	6
4 Patching	LL	0	0	0
	LH	0	0	0
	HL	0	0	0
	HH	0	0	0
5 Failures	LL	3	3	3
	LH	3	3	3
	HL	3	3	3
	HH	3	3	3
6 Alligator Cracking	LL	12	12	5
	LH	12	12	6
	HL	12	5	5
	HH	12	5	6
7 Longitudinal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
8 Transversal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
		3.0-2.5	2.5-2.0	<2.0
9 PSI	LL	0	9	9
	LH	9	9	9
	HL	9	9	10
	HH	9	10	10

Figure C-13. Selection Maintenance Strategy, Pavement Type 7.

Overlay (concrete)		Peformance Equation: Overlay		
Distress	Traffic	Area 100	Area 010	Area 001
1 Slight Rutting	LL	9	9	9
	LH	9	9	10
	HL	9	9	9
	HH	9	9	10
2 Severe Rutting	LL	9	9	10
	LH	13	13	14
	HL	9	9	14
	HH	13	14	14
3 Block Cracking	LL	0	6	6
	LH	1	6	6
	HL	1	6	6
	HH	1	6	6
4 Patching	LL	0	0	0
	LH	0	0	0
	HL	0	0	0
	HH	0	0	0
5 Failures	LL	3	3	3
	LH	3	3	3
	HL	3	3	3
	HH	3	3	3
6 Alligator Cracking	LL	12	12	5
	LH	12	12	6
	HL	12	5	5
	HH	12	5	6
7 Longitudinal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
8 Transversal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
		3.0-2.5	2.5-2.0	<2.0
9 PSI	LL	0	9	9
	LH	9	9	10
	HL	9	10	10
	HH	9	10	10

Figure C-14. Selection Maintenance Strategy, Pavement Type 8.

Overlay (flexible)		Peformance Equation: Overlay		
Distress	Traffic	Area 100	Area 010	Area 001
1 Slight Rutting	L	9	9	9
	LH	9	9	9
	HL	9	9	10
	HH	9	9	10
2 Severe Rutting	LL	9	9	10
	LH	9	10	10
	HL	9	9	10
	HH	9	10	10
3 Block Cracking	LL	0	6	6
	LH	1	6	6
	HL	1	6	6
	HH	1	6	6
4 Patching	LL	0	0	0
	LH	0	0	0
	HL	0	0	0
	HH	0	0	0
5 Failures	LL	3	3	3
	LH	3	3	3
	HL	3	3	3
	HH	3	3	3
6 Alligator Cracking	LL	12	12	5
	LH	12	12	6
	HL	12	5	5
	HH	12	5	6
7 Longitudinal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
8 Transversal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
		3.0-2.5	2.5-2.0	<2.0
9 PSI	LL	0	9	9
	LH	9	9	9
	HL	9	10	10
	HH	9	10	10

Figure C-15. Selection Maintenance Strategy, Pavement Type 9.

Surface Treatment — Peformance Equation: Surf. Treat.

	Distress	Traffic	Area 100	Area 010	Area 001
1	Slight Rutting	LL	0	0	9
		LH	0	0	9
		HL	0	9	9
		HH	0	9	10
2	Severe Rutting	LL	9	9	9
		LH	9	9	10
		HL	9	9	9
		HH	9	10	10
3	Block Cracking	LL	0	6	6
		LH	1	6	6
		HL	1	6	6
		HH	1	6	6
4	Patching	LL	0	0	0
		LH	0	0	0
		HL	0	0	0
		HH	0	0	0
5	Failures	LL	3	3	3
		LH	3	3	3
		HL	3	3	3
		HH	3	3	3
6	Alligator Cracking	LL	12	12	5
		LH	12	12	6
		HL	12	5	5
		HH	12	5	6
7	Longitudinal Cracking	LL	0	1	6
		LH	1	1	6
		HL	1	1	6
		HH	1	1	6
8	Transversal Cracking	LL	0	1	6
		LH	1	1	6
		HL	1	1	6
		HH	1	1	6
			3.0-2.5	2.5-2.0	<2.0
9	PSI	LL	0	0	0
		LH	0	0	9
		HL	9	9	9
		HH	9	10	10

Figure C-16. Selection Maintenance Strategy, Pavement Type 10.