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16. Abstract
In the early 1980's the Texas State Department of Highways and Public Transportation implemented its Pavement Evaluation System. This system was designed to (a) document trends in network condition and (b) generate a one year estimate of rehabilitation funding. The information generated by this system has been used for many purposes including funding request, project prioritization and documenting the consequences of changes in funding levels.

However, a limitation of this system was its inability to project future conditions and make multi-year needs estimates. This is the subject of this research report. Regression equations were built for each major distress type from a pavement data base containing a 10 year history of condition trends from over 350 random sections in Texas. These equations were used to age individual sections which did not qualify for maintenance or rehabilitation in a particular year. A simple decision tree was developed to estimate the maintenance requirements if rehabilitation is not warranted. This decision tree represents the opinions of experienced maintenance engineers. A case study and sensitivity analysis are presented.

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Estimating Flexible Pavement Maintenance and Rehabilitation Fund Requirements for a Transportation Network

by

A. Stein

T. Scullion

Research Report 409-1
PES Improvements
Research Study Number 2-18-85-409

Sponsored by

State Department of Highways & Public Transportation in cooperation with the Federal Highway Administration

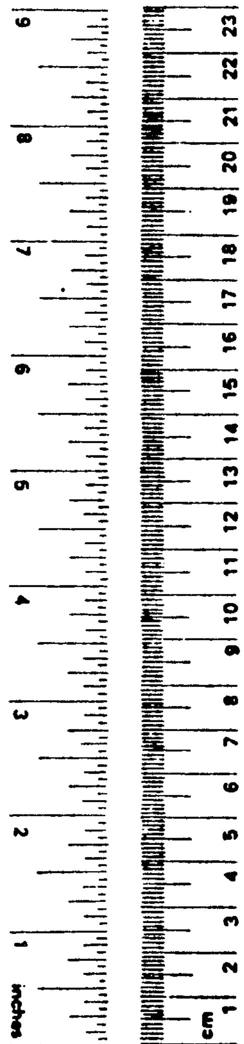
February 1988

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

METRIC CONVERSION FACTORS

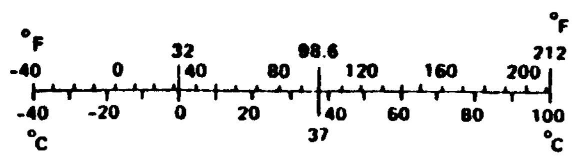
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

ABSTRACT

In the early 1980's the Texas State Department of Highways and Public Transportation implemented its Pavement Evaluation System. This system was designed to (a) document trends in network condition and (b) generate a one year estimate of rehabilitation funding. The information generated by this system has been used for many purposes including funding request, project prioritation and documenting the consequences of changes in funding levels.

However a limitation of this system was its inability to project future conditions and make multi-year needs estimates. This is the subject of this research report. Regression equations were built for each major distress type from a pavement data base containing a 10 year history of condition trends from over 350 random sections in Texas. These equations were used to age individual sections which did not qualify for maintenance or rehabilitation in a particular year. A simple decision tree was developed to estimate the maintenance requirements if rehabilitation is not warranted. This decision tree represents the opinions of experienced maintenance engineers. A case study and sensitivity analysis are presented.

DISCLAIMER

This report is not intended to constitute a standard, specification or regulation, and does not necessarily represent the views or policy of the FHWA or Texas State Department of Highways and Public Transportation.

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CHAPTER ONE

INTRODUCTION

To assist with the management of its 70,000 mile pavement network, the Texas State Department of Highways and Public Transportation (SDHPT) has been active in the development of pavement management systems since the early 1970's. The major constraint encountered during the evaluation process was the limited availability of funding for construction and maintenance which created the necessity to develop procedures capable of distributing the available funds in the most optimal way.

The state of Texas is divided into twenty-four districts for the purpose of maintenance and rehabilitation of the highway network (Figure 1). A list of the counties and their districts is given in Table 1. Pavement inspection procedures and systems were developed for individual districts at the operational level(1). Very little analysis or summarization was performed. Although the initial results of this work appeared promising, in the late 1970's the SDHPT focused its attention on the need for information at the district and state network levels.

Subsequently the initial work was incorporated into a set of decision-making tools known as the Rehabilitation and Maintenance System (RAMS). This system was designed by the Texas Transportation Institute (TTI) at Texas A&M University for the purpose of providing the SDHPT's central office and individual districts the allocation models to ensure an efficient distribution of funds(2,3,4,5,6).

Implementation of these models through the various state districts has proceeded since they were completed in 1980. The first program within the RAMS series, the State Cost Estimating Program, was implemented within the Department's Flexible Pavement Evaluation System (PES) in 1981 and was intended to:

a) calculate current pavement scores,

b) calculate an appropriate rehabilitation funding strategy for those sections below a minimum score, and

c) calculate a reinspection date for those sections above a minimum score.

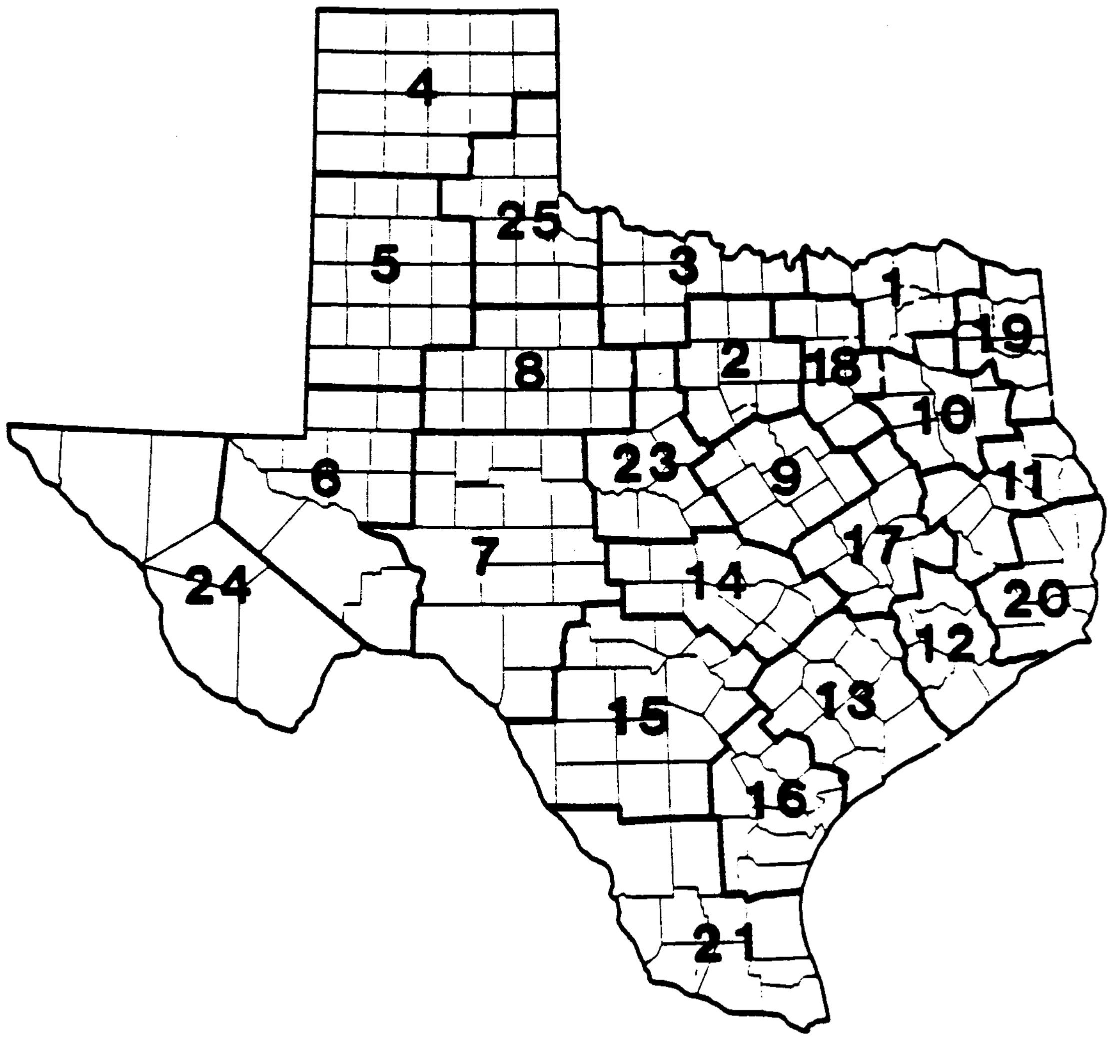

Figure 1. SDHPT District Outline

TABLE 1. County Numbering System

TEXAS COUNTIES

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CO. NO.	COUNTY NAME	DIST. NO.	CO. NO.	COUNTY NAME	DIST NO.	CO. NO.	COUNTY NAME	DIST. NO.	CO. NO.	COUNTY NAME	DIST NO.
1	ANDERSON	10	65	DONLEY	25	129	KARNES	16	192	REAGAN	7
2	ANDREWS	6	66	KENEDY	21	130	KAUFMAN	18	193	REAL	7
3	ANGELINA	11	67	DUVAL	21	131	KENDALL	15	194	RED RIVER	1
4	ARANSAS	16	68	EASTLAND	23	66	KENEDY	21	195	REEVES	6
5	ARCHER	3	69	ECTOR	6	132	KENT	8	196	REFUGIO	16
6	ARMSTRONG	4	70	EDWARDS	7	133	KERR	15	197	ROBERTS	4
7	ATASCOSA	15	71	ELLIS	18	134	KIMBLE	7	198	ROBERTSON	17
8	AUSTIN	13	72	EL PASO	24	135	KING	25	199	ROCKWALL	18
9	BAILEY	5	73	ERATH	2	136	KINNEY	7	200	RUNNELS	7
10	BANDERA	15	74	FALLS	9	137	KLEBERG	16	201	RUSK	10
11	BASTROP	14	75	FANNIN	1	138	KNOX	25	202	SABINE	11
12	BAYLOR	3	76	FAYETTE	13	139	LAMAR	1	203	SAN AUGUSTINE	11
13	BEE	16	77	FISHER	8	140	LAMB	5	204	SAN JACINTO	11
14	BELL	9	78	FLOYD	5	141	LAMPASAS	23	205	SAN PATRICIO	16
15	BEXAR	15	79	FOARD	25	142	LA SALLE	15	206	SAN SABA	23
16	BLANCO	14	80	FORT BEND	12	143	LAVACA	13	207	SCHLEICHER	7
17	BORDEN	8	81	FRANKLIN	1	144	LEE	14	208	SCURRY	8
18	BOSQUE	9	82	FREESTONE	17	145	LEON	17	209	SHACKELFORD	8
19	BOWIE	19	83	FRIO	15	146	LIBERTY	20	210	SHELBY	11
20	BRAZORIA	12	84	GAINES	5	147	LIMESTONE	9	211	SHERMAN	4
21	BRAZOS	17	85	GALVESTON	12	148	LIPSCOMB	4	212	SMITH	10
22	BREWSTER	24	86	GARZA	5	149	LIVE OAK	16	213	SOMERVELL	2
23	BRISCOE	25	87	GILLESPIE	14	150	LLANO	14	214	STARR	21
24	BROOKS	21	88	GLASSCOCK	7	151	LOVING	6	215	STEPHENS	23
25	BROWN	23	89	GOLIAD	16	152	LUBBOCK	5	216	STERLING	7
26	BURLESON	17	90	GONZALES	13	153	LYNN	5	217	STONEWALL	8
27	BURNET	14	91	GRAY	4	154	MADISON	17	218	SUTTON	7
28	CALDWELL	14	92	GRAYSON	1	155	MARION	19	219	SWISHER	5
29	CALHOUN	13	93	GREGG	10	156	MARTIN	6	220	TARRANT	2
30	CALLAHAN	8	94	GRIMES	17	157	MASON	14	221	TAYLOR	8
31	CAMERON	21	95	GUADALUPE	15	158	MATAGORDA	13	222	TERRELL	6
32	CAMP	19	96	HALE	5	159	MAVERICK	15	223	TERRY	5
33	CARSON	4	97	HALL	25	160	MC CULLOCH	23	224	THROCKMORTON	3
34	CASS	19	98	HAMILTON	9	161	MC LENNAN	9	225	TITUS	19
35	CASTRO	5	99	HANSFORD	4	162	MC MULLEN	15	226	TOM GREEN	7
36	CHAMBERS	20	100	HARDEMAN	25	163	MEDINA	15	227	TRAVIS	14
37	CHEROKEE	10	101	HARDIN	20	164	MENARD	7	228	TRINITY	11
38	CHILDRESS	25	102	HARRIS	12	165	MIDLAND	6	229	TYLER	20
39	CLAY	3	103	HARRISON	19	166	MILAM	17	230	UPSHUR	19
40	COCHRAN	5	104	HARTLEY	4	167	MILLS	23	231	UPTON	6
41	COKE	7	105	HASKELL	8	168	MITCHELL	8	232	UVALDE	15
42	COLEMAN	23	106	HAYS	14	169	MONTAGUE	3	233	VAL VERDE	7
43	COLLIN	18	107	HEMPHILL	4	170	MONTGOMERY	12	234	VAN ZANDT	10
44	COLLINGSWORTH	25	108	HENDERSON	10	171	MOORE	4	235	VICTORIA	13
45	COLORADO	13	109	HIDALGO	21	172	MORRIS	19	236	WALKER	17
46	COMAL	15	110	HILL	9	173	MOTLEY	25	237	WALLER	12
47	COMANCHE	23	111	HOCKLEY	5	174	NACOGDOCHES	11	238	WARD	6
48	CONCHO	7	112	HOOD	2	175	NAVARRO	18	239	WASHINGTON	17
49	COOKE	3	113	HOPKINS	1	176	NEWTON	20	240	WEBB	21
50	CORYELL	9	114	HOUSTON	11	177	NOLAN	8	241	WHARTON	13
51	COTTLE	25	115	HOWARD	8	178	NUECES	16	242	WHEELER	25
52	CRANE	6	116	HUDSPETH	24	179	OCHILTREE	4	243	WICHITA	3
53	CROCKETT	7	117	HUNT	1	180	OLDHAM	4	244	WILBARGER	3
54	CROSBY	5	118	HUTCHINSON	4	181	ORANGE	20	245	WILLACY	21
55	CULBERSON	24	119	IRION	7	182	PALO PINTO	2	246	WILLIAMSON	14
56	DALLAM	4	120	JACK	2	183	PANOLA	19	247	WILSON	15
57	DALLAS	18	121	JACKSON	13	184	PARKER	2	248	WINKLER	6
58	DAWSON	5	122	JASPER	20	185	PARMER	5	249	WISE	2
59	DEAF SMITH	4	123	JEFF DAVIS	24	186	PECOS	6	250	WOOD	10
60	DELTA	1	124	JEFFERSON	20	187	POLK	11	251	YOAKUM	5
61	DENTON	18	125	JIM HOGG	21	188	POTTER	4	252	YOUNG	3
62	DE WITT	13	126	JIM WELLS	16	189	PRESIDIO	24	253	ZAPATA	21
63	DICKENS	25	127	JOHNSON	2	190	RAINS	1	254	ZAVALA	15
64	DIMMIT	15	128	JONES	8	191	RANDALL	4			

A sound analytical program is needed for the future that will assist in predicting preventive maintenance strategies, using planning models for identifying network maintenance and rehabilitation costs over a planning horizon taking into consideration the current condition of pavement, user safety, and user comfort. It is the purpose of this research effort to design, test and validate a computerized model to provide decision makers with sufficient quantitative information to recommend appropriate courses of action regarding state highway maintenance and rehabilitation strategies.

Specifically, the objectives of this research are:

1. Develop a Fortran-based mainframe computer program to calculate accurate state-wide cost estimates, visual condition schedules, and routine maintenance costs using the annual statewide survey.

2. Use a systematic sampling method whereby sufficient data are collected on a random sampling basis to provide accurate information for funding justification purposes.

3. Develop an input format and examine typical problems using actual data from a state-wide survey from a selected district.

4. Run a case study for a complete district to show whether the results found in the typical sections of road still hold for a full district.

5. Perform limited sensitivity analyses to observe how the minimum acceptable utility, traffic levels, and climatic variations affect the estimated funding requirements.

Chapter Two reviews the Pavement Evaluation System currently used by the State of Texas. It also contains an explanation of the data gathering techniques used by the SDHPT. Chapter Three describes the technique utilized to predict pavement conditions. The fourth chapter explains the proposed system to predict pavement maintenance and rehabilitation needs and describes its different parts. Chapter Five examines typical problems worked with the computer program using actual data from a state-wide survey. Chapter Six contains the results of the case study for a full district (District 11-Lufkin), and the results of the limited sensitivity analysis. The last chapter contains the conclusions and recommendations found in this research.

In Appendix A the regression equations developed for distress types and PSI on each of 4 pavement types are presented. These equations are used to generate deterioration rates for each individual section. In Appendix B the decision rules for applying maintenance treatments are given. In Appendix C the computer code used to make cost estimates is given.

CHAPTER TWO

RELATED BACKGROUND

Condition Rating in Texas

An efficient use of highway funding makes it necessary to develop a complete and efficient method for condition rating. The purpose of a condition rating is to give current information concerning the roughness, structural capacity, safety, and visual distress of a section of road, to be used in a number of activities that can be summarized as follows:

1. Development of a structural rating,

2. Aid in projections of budget requirement,

3. Aid in maintenance and rehabilitation decisions, and

4. Input the relevant pavement performance history.

The roughness of a road can be expressed in terms of what is known as "Serviceability Index" (SI) obtained with the Mays Ride Meter, and it is based on a scale which ranges from 0 to 5. A score of 5 represents a smooth road, and a score of 0 represents a road that is impossible to use. The Mays Ride Meter is a car-mounted device that measures the relative movement between the rear axle and the mass of the car when the car is traveling at 50 miles per hour. This raw value is transformed to the 0 to 5 scale by using a relationship between roughness and Serviceability Index. The structural capacity evaluation is obtained through the use of the Dynaflect (8) or Falling Weight Deflectometer (FWD). The Dynaflect is the most commonly used non-destructive test device in the United States. This machine is mounted on a two-wheel trailer and produces a dynamic force of 1000 lbs at a frequency of 8 cycles per second. The resulting deflections are measured by 5 sensors, each 1 foot apart, with the first one directly between the wheels. The FWD is a new non-destructive testing device capable of applying loads similar to those applied by truck traffic.

Safety on pavements is mainly analyzed in terms of skid resistance. Most skid related accidents occur under wet or icy conditions. For that reason, most skid-resistance tests are conducted on wet pavements. The skid number is the standard factor for measuring skid resistance. Skid data were collected in the initial implementation efforts of the Pavement Evaluation System (PES) of 1978 to 1980. However, it has not been collected for PES in recent years because:

1) It was costly to collect at the network level.

2) The skid values were having an overriding effect on the pavement score calculation.

3) Skid numbers are related to pavement safety, whereas distress and Mays ride are related to pavement's structural condition. A separated system for safety would be more appropriate.

4) Skid number itself is not a good predictor of accident potential. Work in Texas is currently underway to improve the Wet Weather Safety Index (9), which has been shown to be a much better indicator of accident potential.

The techniques and instruments described before do not, in general, supply all of the necessary information about the section of road under analysis. Thus, a visual survey of the pavement surface is necessary to determine its level of distress (10). The types of distress rated prior to 1984 were: rutting, raveling, flushing, failures, alligator cracking, longitudinal cracking, and transverse cracking. After 1984 raveling and flushing were dropped and replaced with block cracking and patching. The information is recorded in rating forms (Figure 2) and then transferred into a central data bank where it can be used for different purposes. A brief description of each distress type is given below;

Rutting: a surface depression in the wheel paths. It is caused by consolidation or lateral movement of the materials due to traffic loads.

Raveling: wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder. (Prior to 1984)

Flushing: loss of surface texture due to an excess of asphalt in the pavement surface. (Prior to 1984)

Failures: surface eroded or badly cracked or depressed.

Alligator Cracking: interconnected cracks forming a series of small blocks resembling an alligator's skin or chicken wire.

Longitudinal Cracking: cracks parallel to the pavement centerline.

Transverse Cracking: cracks at right angles to the centerline.

Block Cracking: interconnecting cracks forming blocks ranging in size from 1' x 1' upto 10' x 10'. (after 1984)

Patching: repairs made to pavement distresses. (after 1984)

State Department of Highways
and Public Transportation
FORM 1624 (Replaces Form 1505)

FLEXIBLE PAVEMENT EVALUATION

6-84

SYSTEM - ID & CARD - ID: M M S (1 2 3) E I (4 5)

DISTRICT NO. (6 7)

RATERS: (8 – 29) (30 – 51)

DATE: MONTH (52 53) DAY (54 55) YEAR (56 57)

COMMENTS / NOTES

NOTE:
Zero should be inserted in appropriate pavement condition column if no visual defect is noted.

LOCATION										PAVEMENT CONDITIONS										
SYSTEM ID	CARD - ID	COUNTY NO.	FOREMAN NO.	HIGHWAY NO. (PRE / NO / SUF)	FROM: MILEPOST	FROM: DISPLACEMENT (+/−)	TO: MILEPOST	TO: DISPLACEMENT (+/−)	LANE	RUTTING (1/2"-1" = 1, >1" = 2, % Area: 1 - 25, 26 - 50, > 50)	PATCHING (% Area: 1 - 10, 11 - 50, > 50)	FAILURES (NO. PER LN/MI.: 1 - 5, 6 - 10, > 10)	BLOCK CRACKING (% Area: 1 - 10, 11 - 50, > 50)	ALLIGATOR CRACKING (% Area: 1 - 10, 11 - 50, > 50)	LONGITUDINAL CRACKING (LIN. FT PER STA/LN: 10 - 99, 100 - 200, > 200)	TRANSVERSE CRACKING (NO. PER STA: 1 - 4, 5 - 10, > 10)	COMMENT CODE	SPEED LIMIT	PAVEMENT TYPE	COMMENTS / NOTES
M M S	E 2																			
M M S	E 2																			
M M S	E 2																			
M M S	E 2																			
M M S	E 2																			
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Card columns: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Figure 2. Maintenance Rating Form for Flexible Pavements

Pavement scores are calculated by converting the pavement distress data into Utility Values.

Utility values are obtained using the formula

$$U = 1 - a \exp(-b/x) \quad (1)$$

a and b = least square estimates of the regression coefficients
x = % distress from rating
U = the visual score given x (range 0 to 1.0)

After U is found, an overall visual utility score (AVUC) is calculated with the formula

$$AVUC = (U_1^{b_1})\ (U_2^{b_2}) \ldots (U_n^{b_n}) \quad (2)$$

where,

b_i = Climatic weighting factors, i = 1 to 7.

The original pavement score was defined as a combination of Serviceability Index (riding quality), safety, Maintenance Cost and Visual Utility are combined into a single utility score, between 0-100, that is used as an indicator of the overall condition of the pavement section.

$$\text{Pavement Current Score} = [(\text{Visual Utility})^{a_1} \times (\text{Riding Quality})]^{a_2} \times [\text{Maintenance Cost}]^{a_3} [\text{Safety Index}]^{a_4} \quad (3)$$

where,

a_1, a_2, a_3, a_4 = Weighting factors.

On the basis of that overall score and the individual visual distresses, a maintenance strategy or a rehabilitation strategy is selected. Chapter Four gives a more extensive description of the pavement score determination.

Annual Statewide Survey

The necessary information for each section of road analyzed was obtained from the Texas Annual Statewide Survey. In 1982, all roads in every District in Texas were divided into segments of approximately two miles in length. A segment was considered as all pavement areas between two predetermined mileposts. In three of the 25 Districts (8, Abilene; 11, Lufkin; and 15, San Antonio), a 100 percent sample in each roadway system (Interstate, State, U.S., and Farm-to-Market) was taken. In the remaining 21 Districts, five percent of the total number of segments were randomly selected for sampling. Figure 3 shows the location of each District and its percent surveyed. For each section, the visual distresses and Serviceability Index were measured and the visual and riding quality utilities were computed. A value of 1 was given to the safety index and the Maintenance Cost as these items were not available in the initial implementation. Thus, the overall pavement evaluation score could be determined.

In 1983, the SDHPT conducted a more extensive survey of the roads in Texas. One hundred (100) percent of the Interstate roadway system, fifty (50) percent of the U.S. and State roadway systems, and twenty (20) percent of the Farm-to- Market roadway system were surveyed, giving an average of thirty seven (37) percent of the total roadway network. Utility scores, Serviceability Index, and overall pavement evaluation scores were calculated for each section. In recent years the PES has been expanded to include rigid as well as flexible pavements. For the last 3 years the following sampling scheme has been used: evaluate 100% Interstate, 50% US and SH highway and a random 20% sample of all other highways.

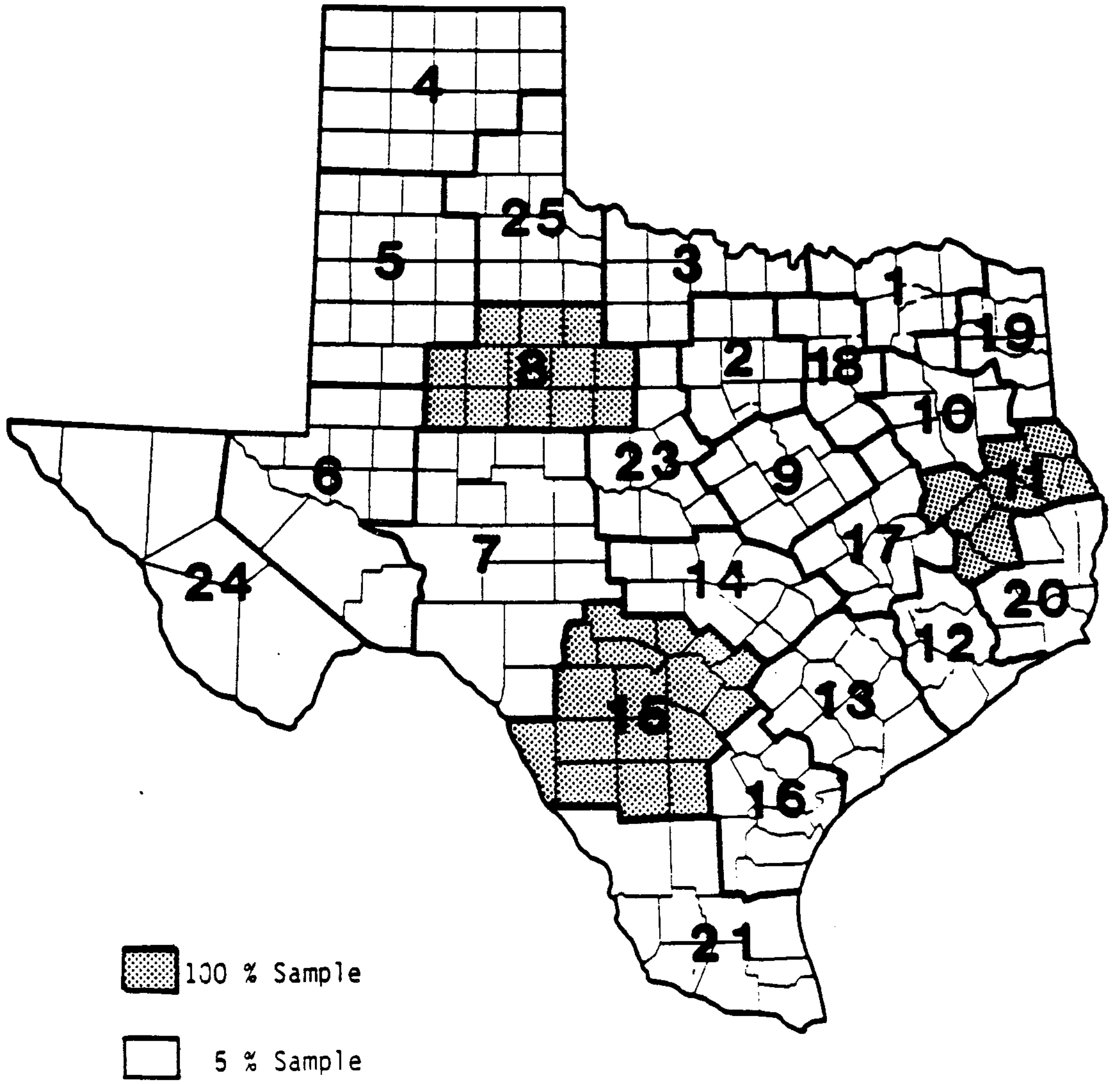

Figure 3. 1983 Statewide Survey

CHAPTER THREE

PERFORMANCE EQUATIONS FOR PREDICTING PAVEMENT CONDITION

In order to be able to predict the pavement performance in terms of Serviceability Index and distress, equations that reflect the functional performance curve of the pavement were selected.

In the American Association of State Highway and Transportation Officials (AASHTO) Road Test, which was conducted in 1958-1960, the performance function was assumed to be of the form

$$g = \left(\frac{W}{\rho}\right)^{\beta}$$

where

g = the damage function (normalized variable that ranges from 0 to 1)

W = time, 18 kip-ESAL, or climatic cycles(depending on the type of distress-e.g. alligator cracking-load; transversal cracking-climatic cycles) necessary to reach a level of g. At the AASHTO Road Test 18-kip ESAL were used primarily

ρ = quantity of normalized 18-kip ESAL, time, or climatic cycles until g reaches a value of 1. It is assumed to be a function of structural variables.

β = power that dictates the level of curvature of the curve.

The damage function was expressed in terms of Serviceability Index ratio,

$$g = \frac{P_o - P}{P_o - P_t} \qquad (5)$$

where,

P_o = initial Serviceability Index

P_t = terminal Serviceability Index

P = actual Serviceability Index

Combining equations (4) and (5) the AASHTO Road Test performance equation can be rewritten as

$$P = P_o - (P_o - P_t)(W/\rho)^{\beta} \tag{6}$$

Figure 4 gives a graphical representation of the AASHTO performance curve.

This form of equation assumes that the serviceability index - versus - traffic curve never reverses its curvature. By way of contrast, Garcia-Diaz, Riggins and Liu, demonstrated that a number of Serviceability Index - versus - traffic relations show a reversal of curvature as illustrated in Figure 5 (11).

The equation for the S-shaped curve is of the form

$$g = e^{-\left(\frac{\rho}{W}\right)^{\beta}} \tag{7}$$

Combining equations (4) and (6) the S-shaped curve equation can be rewritten as

$$P = P_o - (P_o - P_f)\ e^{-\left(\frac{\rho}{W}\right)^{\beta}} \tag{8}$$

The same relationship that was used with the Serviceability Index can be applied to the distress area index (A), and the distress severity index (S).

$$A = A_o - (A_o - A_f)\ e^{-\left(\frac{\rho}{W}\right)^{\beta}} \tag{9}$$

$$S = S_o - (S_o - S_f)\ e^{-\left(\frac{\rho}{W}\right)^{\beta}} \tag{10}$$

Arithmetic and logarithmic models for asphaltic pavements with granular base, and black base, and overlaid pavements were developed by Garcia-Diaz, Riggins, and Liu using a stepwise regression. These equations were utilized in the development of the deterioration schedules for each pavement section. Appendix A shows Asphalt Concrete(AC) over Black Base, AC over Granular Base, and Overlay regression equations for rutting, alligator cracking, longitudinal cracking, transversal cracking, and Serviceability Index. It also shows Surface Treated pavement regression equations for all seven distresses and PSI.

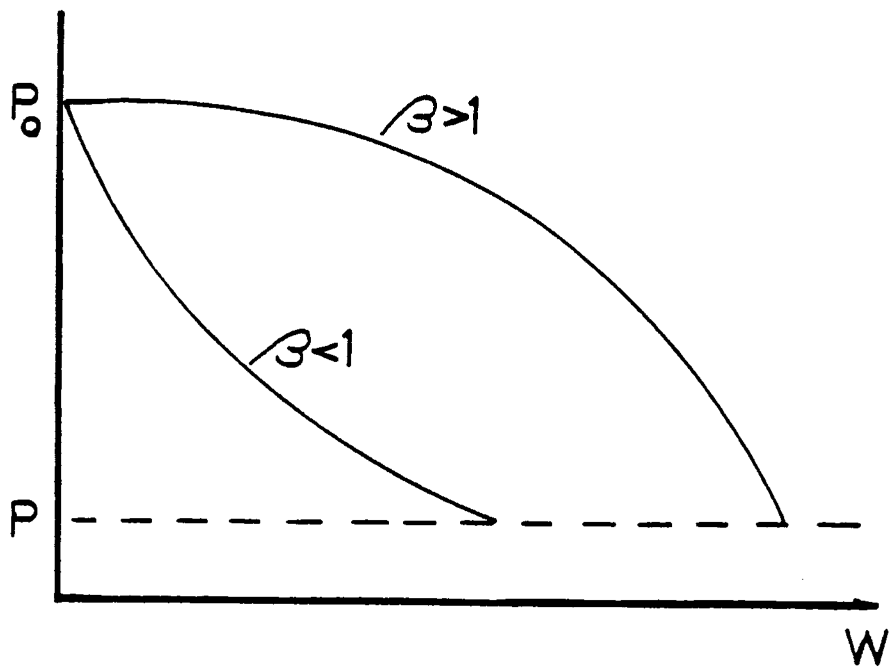

Figure 4. AASHTO Road Test Performance Equation

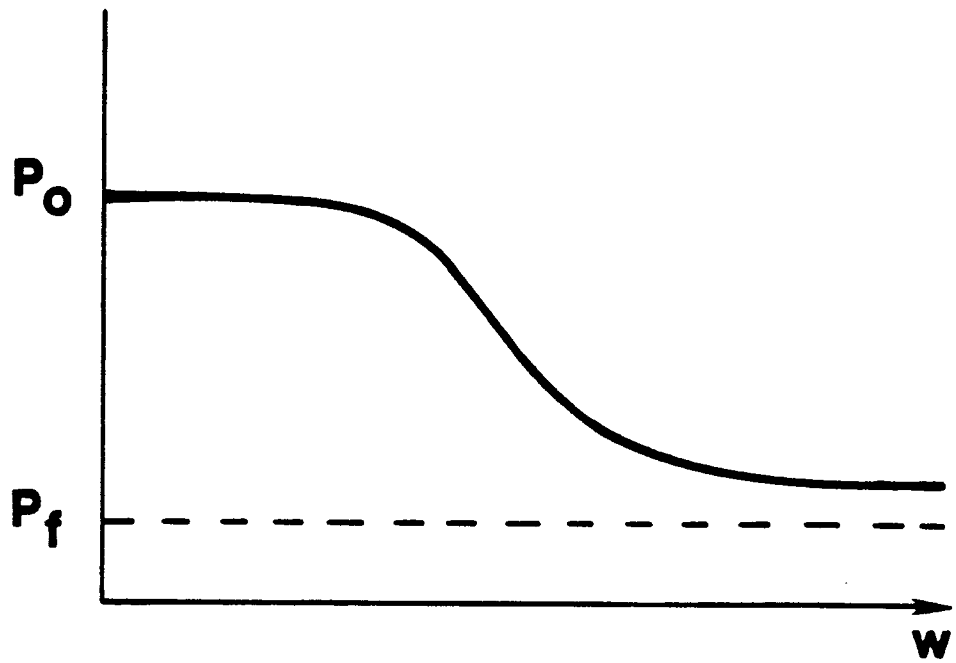

Figure 5. S-Shaped Performance Equation

CHAPTER FOUR

PREDICTIONS OF MAINTENANCE AND REHABILITATION NEEDS FOR THE STATE OF TEXAS

In 1982, the Texas State Department of Highways and Public Transportation implemented its Pavement Evaluation System. This system was designed to a) determine statewide pavement condition and b) estimate one-year statweide rehabilitation needs. Following the successful implementation of the system, the necessity was felt to create a program that could predict the rehabilitation and maintenance needs as well as the budget requirements over any planning horizon. This chapter describes the development of such a system. Appendix C gives the input needs of the program, as well as a listing of the source codes.

The Pavement Evaluation System can be divided into two major areas (Figure 6):

1. Maintenance

2. Rehabilitation and Reconstruction

Within the system the required maintenance is determined by reference to a set of decision trees. Maintenance is only considered when rehabilitation is not warranted. Rehabilitation is defined as any strategy more costly than a 2 1/2 inch overlay.

Overview of the Model Logic

It is important to understand how the overall system works before the individual components are discussed in detail.

The program inputs the percent area for each of 7 distresses (rutting, raveling, flushing, failures, alligator cracking, longitudinal cracking, and transverse cracking), the pavement Serviceability Index, and the current Pavement Score. [**NOTE**: The procedure described in this report uses the data collected using the rating schemes in existence prior to 1984. It is a simple matter to update this system to the existing rating scheme. Versions of the program are available for both rating scheme]. Then it follows the decision criteria according to Table 2. These decisions criteria were developed by the SDHPT . One observation from the initial implementation efforts was the pavements whose score had fallen below the minimum score of 35 were failed pavements, usually in need of structural rehabilitation. However, much of the work proposed by the Districts was on pavements with relatively high scores (i.e. 55-75), these treatments being generally preventive maintenance activities, such as seal coats and thin overlays.

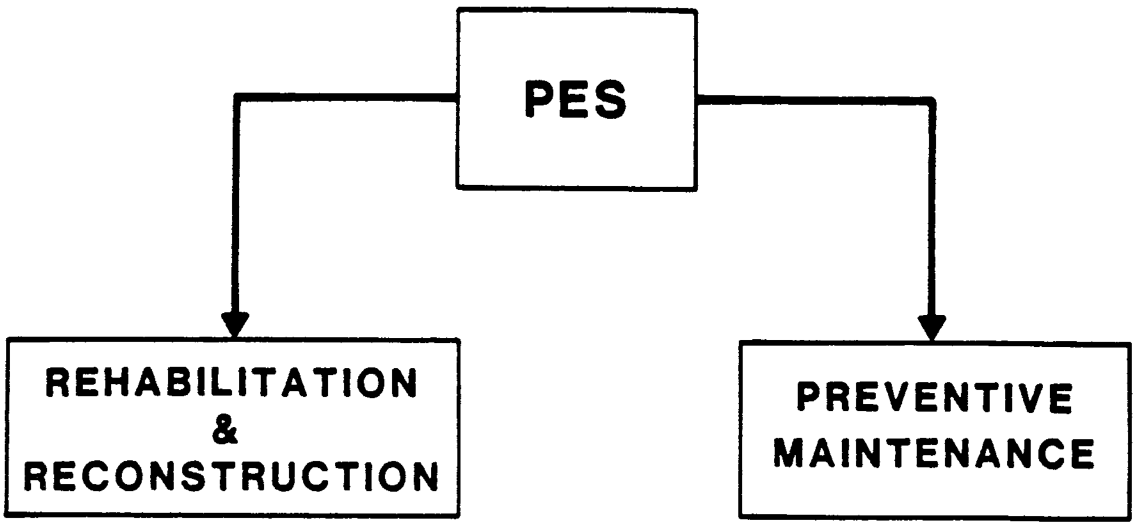

Figure 6. Major Divisions of the Pavement Evaluation System

The set of decision criteria in Table 2 generally describe the kinds of decisions that are made. The model is arranged to follow these criteria. If criterion 1 is selected, the program ages the section for 1 year according to a "deterioration matrix." The program calculates a unique deterioration matrix for each pavement section, based on traffic level, pavement thickness, and climate. The matrices are generated using the performance equations developed with the S-shaped curves discussed in the previous chapter.

Table 2. The Decision Criteria for the Pavement Evaluation System

1. If the pavement utility score is greater than the maintenance level (75) - Do nothing

2. If the pavement utility score is less than the maintenance level but greater than the minimum score - Do maintenance

3. If the pavement utility score is less than minimum but a seal coat or a thin overlay is recommended - Do maintenance

4. If maintenance is recommended but the economic analysis of that alternative against a rehabilitation strategy is negative - Do rehabilitation

5. If pavement score is less than minimum and the minimum strategy is medium overlay - Do rehabilitation

After aging the section 1 year, the program then calculates the score for that year. If the score falls into decision criterion 2 or 3, the program selects a preventive maintenance set that can have up to 5 preventive maintenance strategies depending on the pavement type, distress type, percent area, and traffic level. The selection of preventive maintenance strategies is discussed in the next section of this report. The program then resets the existing distress levels for the chosen strategies. It then calculates a new score and starts aging the highway as described above.

If the score is less than minimum, the program selects the best rehabilitation strategy. Each of the rehabilitation strategies are run through deterioration calculations to determine their life expectancy. This life expectancy is compared to a minimum allowable expected life to determine which of the strategies has the smallest positive difference between life expectancy and minimum life, and that one is chosen as the strategy to be implemented. It then calculates the new score and starts aging the highway again. The program has the capability of aging (and rehabilitating) the pavement up to 20 years. Figure 7 gives a flowchart of the major areas of the program.

Description and Input Variables

Pavement types. A listing of the pavement types is shown in Table 3. The list includes ten pavement types and ranges from continuously reinforced concrete (EP-1) to thin surfaced flexible base (EP-10) (6). These descriptions are intended to cover a range of existing pavement types which compose the existing state maintained highway network. These descriptions are based on the current cross section of a pavement structure - not the original construction alone. The Pavement Evaluation System, which calculates score and funding strategy, was initially implemented only for pavement types EP-4 through EP-10. Rigid pavement evaluations were started in 1984.

Maintenance and Rehabilitation Management. Pavement maintenance and rehabilitation can extend the life and improve the performance level of a road.

Maintenance strategies can keep the pavement at an acceptable performance level until rehabilitation is required. Rehabilitation strategies can strengthen the pavement to a level sufficient to extend its life many years. Maintenance and rehabilitation decisions are based on the type of pavement and the type of distresses affecting a section of road.

Once the distresses affecting a section of road have been identified, a decision can be reached on whether to apply maintenance or rehabilitation, and, in either case, what type of strategy will be best to correct the problem.

Preventive Maintenance

Preventive maintenance is any work required to maintain a section of road at a desired level of condition. Maintenance of existing roads is important in pavement management systems because, even though many maintenance strategies do not strengthen the pavement, they help to keep the pavement in usable condition until a rehabilitation can be scheduled.

In Texas, the State Department of Highways and Public Transportation (SDHPT) recommended basically 14 different preventive maintenance strategies for flexible pavements. Table 4 gives typical average cost for each type of maintenance strategy. These numbers are input variables and hence can be changed to meet an agency's requirements. These strategies are applied depending upon variables such as type of distress, area and severity of distress, type of pavement, location, and cost.

Descriptions of the strategies and their presently defined cost estimation functions are given below:

Seal Crack. The process of filling cracks with bituminous materials to prevent further cracking and wetting of the subgrade.

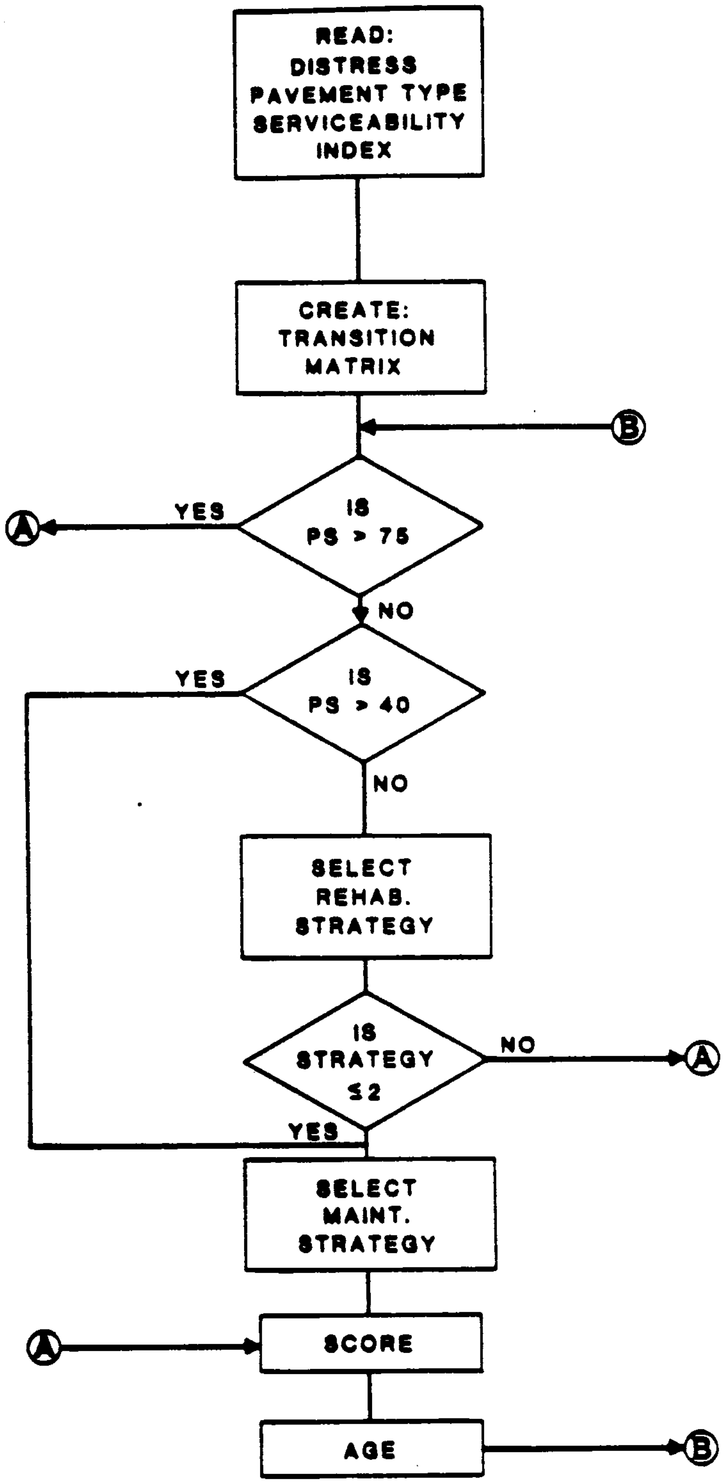

Figure 7. Flowchart of Major Areas of the Program

TABLE 3. Listing of Pavement Types

Pavement Type	Description
EP-1	Continuously reinforced concrete pavement
EP-2	Jointed reinforced concrete pavement
EP-3	Jointed plain concrete pavement
EP-4	Thick asphaltic concrete pavement (greater than 5 1/2" of hot-mixed asphaltic layers)
EP-5	Intermediate thickness asphaltic concrete pavement (2 1/2" to 5 1/2" of hot-mixed asphaltic layers)
EP-6	Thin surfaced flexible base pavement (hot-mixed asphaltic layers less than 2 1/2" thick)
EP-7	Composite pavement (concrete pavement which has received an asphalt overlay)
EP-8	Overlaid and/or widened old concrete pavement
EP-9	Overlaid and/or widened old flexible pavement
EP-10	Thin surfaced flexible base pavement (surface treatment - seal coat combinations)

Cost: length of crack (ft) x unit cost ($/ft)

Surface Patching. The process of replacing and compacting bituminous material in the pavement surface.

Cost: Area of patch(yd) * depth(in) * unit cost($/yd * in)

Full Depth Patching. A full depth asphalt concrete patch that is designed to ensure strength equal to that of the surrounding asphalt. Could involve reworking the base and subgrade.

Cost: Area(yd^2) * depth(in) * unit cost($/$yd^2$ * in)

Fog Seal. Cold mixture of asphaltic emulsion and water that seals the pavement surface against the entrance of air and water, reduces raveling and oxidation (8).

Cost: Width of section(yds) * length(yds)* unit cost($/$yd^2$)

Strip Seal. Asphalt concrete layer that is applied to a partial section of road to improve skid resistance and bleeding of pavements. Its cost is based on the percent of the pavement area affected by the existing distresses.

Small area - Cost: 250 yd^2 * unit cost($/$yd^2$)

Medium area - Cost: 500 yd^2 * unit cost($/$yd^2$)

Large area - Cost: 1000 yd^2 * unit cost($/$yd^2$)

Seal Coat. Application of asphalt layer with an aggregate coat to seal the surface against the entrance of air and water, reduce raveling, and improve skid resistance.

Cost: Length of section(yds) * width of section(yds)
* unit cost($/$yd^2$)

Asphalt-Rubber Seal Coat. A mixture of asphalt and at least 15 percent recycled ground rubber used to prevent reflection cracks, to seal the surface against the entrance of air and water, and to correct raveling.

Cost: Width(yds) * length(yds) * unit cost($/yd)

Slurry Seal. A mix of asphaltic emulsions, water, and fine aggregate that is applied to seal the surface against air and water and to increase durability for the freeze-thaw cycles.

Cost: Width(yds) * length(yds) * unit cost($/$yd^2$)

Level-Up. A thin layer of asphaltic concrete cement that will even the pavement surface.

TABLE 4. Mean Costs for Preventive Maintenance

Strategy	Cost
1 - Seal Crack	0.23 ft.
2 - Patching	4.20 yd^2/inch
3 - Full Depth Repair	4.45 yd^2/inch
4 - Fog Seal	0.25 yd^2
5 - Strip Seal	0.70 yd^2
6 - Seal Coat	0.60 yd^2
7 - Asphalt-Rubber Seal Coat	1.25 yd^2
8 - Slurry Seal	0.35 yd^2
9 - Level-Up	1.65 yd^2
10 - Thin Overlay	2.40 yd^2
11 - Rotomill	0.85 yd^2
12 - Spot Seal	0.60 yd^2
13 - Rotomill + Seal Coat	2.50 yd^2
14 - Rotomill + Thin Overlay	3.25 yd^2

Cost: Width(yds) * 1000 yds * unit cost($/yd^2)

Thin Overlay. A 1 to 1 1/2 inch lift of asphaltic concrete that will not increase the strength of the pavement.

Cost: Length(yds) * width(yds) * unit cost($/yd^2)

Rotomill. It is a machine designed with the purpose of planning off variable thicknesses of asphalt.

This machine can be used together with an overlay, or a seal coat application creating two new strategies:

Rotomill + Seal coat

Rotomill + Overlay

Spot Seal. Application of asphalt to spots in the surface to prevent cracks, and to seal the surface of the pavement.

The most important factors that affect the selection of a preventive maintenance strategy are: type of pavement, type of distress, extent of distress, traffic level, and the 18-kip equivalent single axle load level. Appendix B gives the tabulation of the different preventive maintenance strategies that can be applied in each of the 672 combinations of pavement type (7), distress type (8), distress extent (3), traffic levels (2), and 18-kip equivalents (2) that can occur. In order to facilitate the selection of preventive maintenance strategies, a decision tree has been created from which the program can select up to five strategies depending on the distresses affecting the section of road. Figure 8 presents an overview of the decision tree related to preventive maintenance feasible strategies. The decision trees used in this project were developed by Highway Department maintenance personnel in the Central Office and Districts. The basic inputs to each tree are:

- extent of each pavement distress

- pavement type

- traffic level

For each individual distress/pavement type/traffic level combination, an appropriate maintenance strategy is defined. The possible strategies are shown in Table 5.

Once individual maintenance strategies have been defined for each distress type (and level of PSI) then a procedure to calculate a dominant strategy is used.

The dominant strategy selection procedure ranks the various selected strategies in order of their ability to repair several

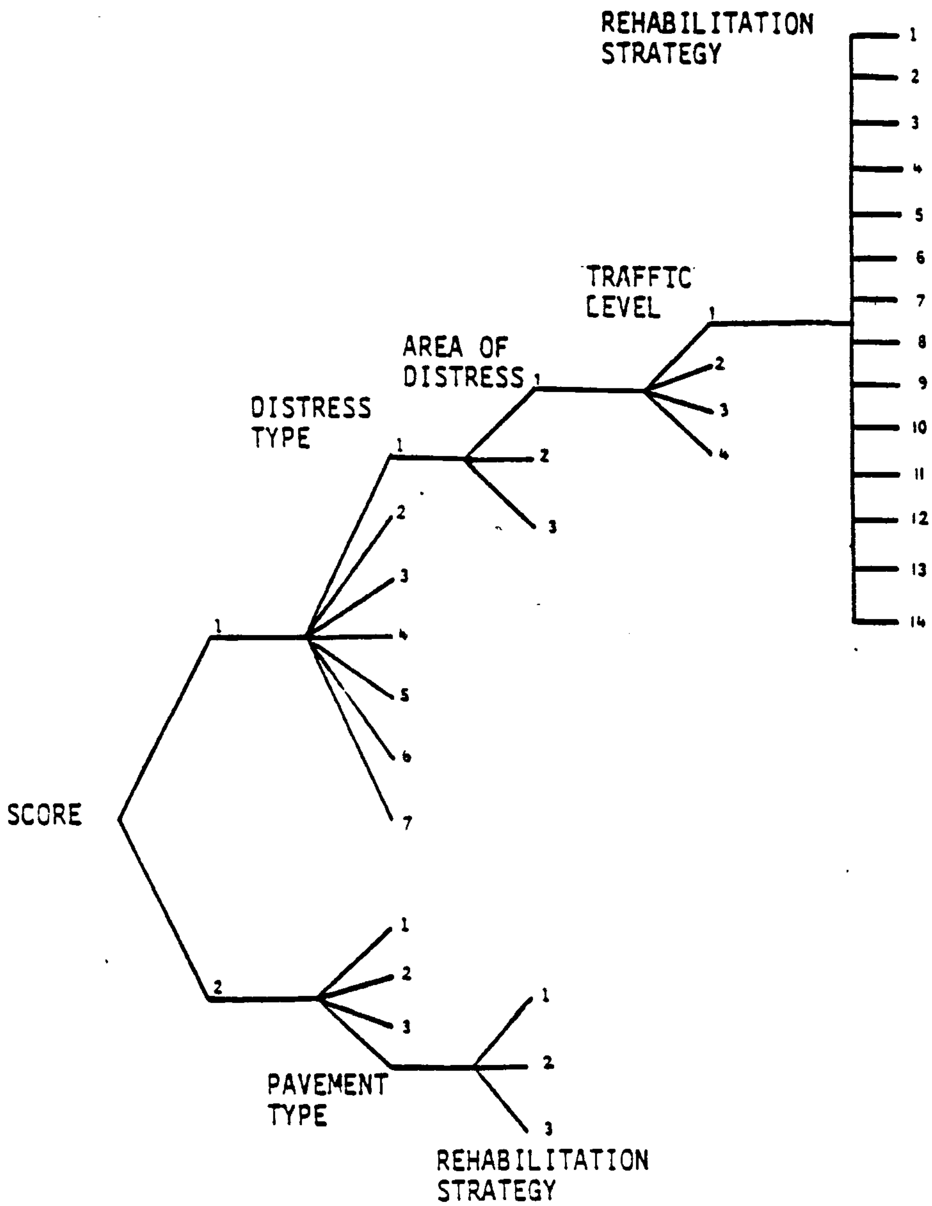

Figure 8. Rehabilitation and Maintenance Decision Tree.

TABLE 5. Listing of Maintenance Strategies.

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

distresses. Rotomill plus thin overlay (Strategy 14) is ranked first followed by Strategies 13, 10, 9, 7, 6,... The selection procedure selects the highest ranked strategy that has been chosen to repair an individual distress and then makes additional checks for routine maintenance requirements (i.e. crack seals). For instance if Strategy 14 has been selected, it only remains to check if any full depth repairs are required. Similarly for thin overlays and level-ups, additional checks are made for full depth repairs, surface patching, and crack seals.

An example of one branch of the decision tree is shown in Figure 9. Similar branches exist for the 7 pavement types and 9 distress types considered in the model

Rehabilitation

The primary purpose of any rehabilitation activity is to improve the structural performance and riding characteristics of a pavement. No pavement is designed to last forever; therefore, it is safe to assume that during the life cycle of a pavement, it will deteriorate to an unacceptable level. It will then require some kind of rehabilitation to an acceptable level in order to continue to serve (12).

The three major rehabilitation activities are: overlays, reconstruction, and recycling.

Overlay. Overlaying is a rehabilitation strategy that consists of placing layers of asphalt concrete (AC) pavement to improve or extend the service life of a section of road. Overlays can be of different thicknesses with a maximum of 7 1/2 inches. An overlay with a thickness of less than 1 1/2 inches does not add structural strength to the pavement. This technique is used to correct rutting, cracking, and raveling and to improve the Serviceability Index.

Reconstruction. Many times just one lane of a section of road has structural damage while the other lane has retained its strength. When such a case occurs, a partial reconstruction of one lane can be more cost effective than an overlay that must be applied to the whole section.

Recycling. Recycling is the technique of removing the existing pavement, processing it, mixing it with new aggregate and a recycling agent, and placing it back onto the roadway.

Table 6 illustrates some specific techniques used in each of the major rehabilitation activities along with the condition they are intended to correct

Five rehabilitation funding strategies are considered within the current PES ranging from the equivalent of seal coat maintenance (R-1) to a 7 1/2 in. thick asphalt concrete overlay.

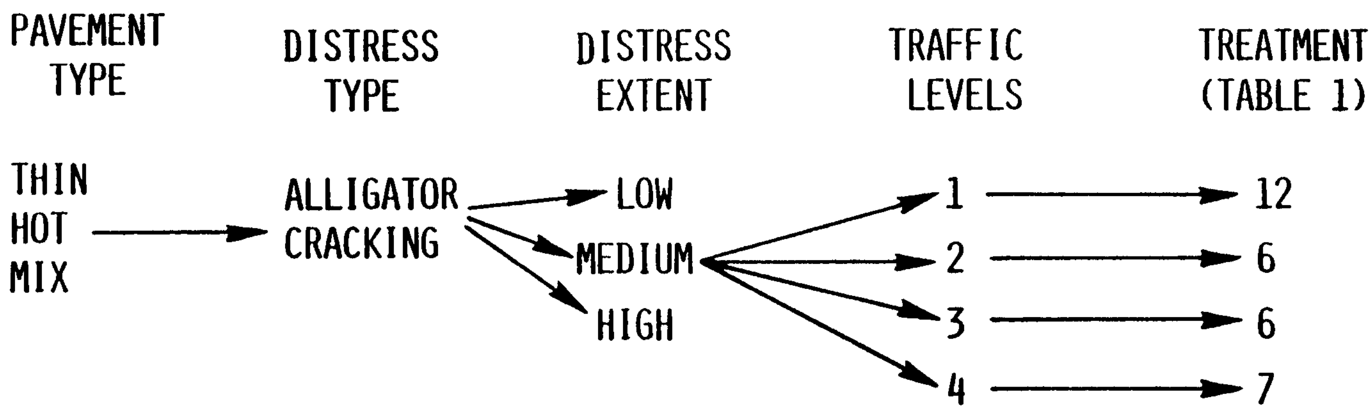

Figure 9. Example Branch of the Decision Tree

These rehabilitation funding strategies were selected from a listing originally prepared by J. L. Brown (13). A description of the rehabilitation strategies is shown in Table 7. Table 8 is a listing of the five separate funding strategies and their associated costs(statewide average) in terms of dollars per lane foot per mile (one foot wide strip a mile long).

Both maintenance and rehabilitation costs should vary somewhat from district to district. Thus, these costs must be developed for each of the twenty-four districts within the state.

The Current Pavement Score (PSC)

The Current Pavement Score was designed to be a combination of Visual Utility, Serviceability Index, Safety, and Maintenance cost, that is used as an indicator of the overall condition of the pavement section at the moment of inspection. However early in the implementation effort it was determined that skid data was too costly to collect on a network and that reliable maintenance cost data was not available. Therefore both of these were dropped from the pavement score calculation procedure. The next sections of this report describe in detail how the pavement score is calculated within the State of Texas Pavement Evaluation System.

Visual Defect Evaluation Form for Flexible Pavements. The form shown in Figure 2 was jointly developed by the SDHPT and TTI for the 1983 data collection effort. The pavement rating procedure is described in detail in the Department's Raters Manual (17). This form is a composite of the original visual condition survey procedure developed by Epps (10) and the new utility concepts. The data collected with this form are used to calculate the visual defect utility which is a component of the current pavement score (PSC). This score will be further discussed in the next subsection.

Additional inputs required for calculating the current PS (PSC)

Table 9 shows the additional inputs necessary to calculate the current PS (PSC) for each highway segment. The inputs which are included in this table fall into the categories used in Tables 10, 11, 12, and 13.

To calculate the PSC for a highway segment these inputs and the appropriate utility curves are required. The proposed overall pavement score equation is as follows:

$$PSC = [(AVU)^{a_1} \ (SIU)^{a_2} \ (SKU)^{a_3} \ (SCU)^{a_4}]^{1/FC} \qquad (11)$$

where,

PSC = Pavement Evaluation System score which represents a highway segment's relative priority for rehabilitation

TABLE 6. Rehabilitation Strategy Information

1.	PCC Overlay	- restore structural strength
2.	AC Overlay	- restore structural strength - correct cracking - correct raveling - improve ride quality
3.	Inverted Overlay	- restore structural strength - correct cracking - correct raveling - improve ride quality
4.	Rubber Asphalt plus Overlay	- restore structural strength - correct cracking - correct raveling - water resistant - improve ride quality
5.	Hot Recycling	- restore structural strength - conserve material - correct cracking - correct raveling
6.	Heater Remix	- restore structural strength - correct cracking - correct raveling
7.	Lane Reconstruction	- restore structural strength

TABLE 7. Listing of Rehabilitation Funding Strategies

Funding Strategy	Description of Equivalent Maintenance or Rehabilitation	
	Hot Mix Pavement	Surface Treated Pavement
R-1	Seal coat, or fog seal, or extensive patching plus seal	Seal Coat
R-2	1" ACP overlay, or seal plus level-up	Partial reconstruction
R-3	2 1/2" ACP overlay	Full reconstruction, reworking and adding additional base and surfacing
R-4	4" ACP overlay or rotomill plus thin overlay	Not applicable
R-5	7 1/2" ACP overlay or reconstruction	Not applicable

TABLE 8. The Equivalent Statewide Average Cost for Each PES Funding Strategy

Funding Strategy	Equivalent Cost ($/foot-mile)
R-1	214
R-2	925
R-3	2000
R-4	3550
R-5	7000

TABLE 9. Additional Inputs Required to Calculate Pavement Score

1. Highway Functional Class
2. ADT/Lane
3. 18-kip Equivalent Single Axles in Design Lane
4. Rainfall (in./year)
5. Freeze-Thaw Factors (cycles/year)

Inputs 4 and 5 are available on a county basis. For each pavement section, a county number is input. These environmental factors are obtained via a table look-up.

TABLE 10. Average Daily Traffic Factors (ADTF)

ADT/Lane	Average Daily Traffic Factors
300 or less	1.00
301 - 750	0.96
751 - 2000	0.92
2001 - 7500	0.88
7501 - 25,000	0.84
greater than 25,000	0.80

TABLE 11. 18-kip Equivalent Axle Load Factors (KEF)

18-kip EAL	18-kip EAL Factors
less than 6×10^6	1.00
6×10^6 - 12×10^6	0.95
greater than 12×10^6	0.90

TABLE 12. Rainfall Factors

Rainfall (in./yr.)	Rainfall Factor (RF)
20 or less	1.00
21 - 40	0.97
greater than 40	0.94

TABLE 13. Freeze-Thaw Factors

Freeze Cycles (cycles/year)	Freeze-Thaw Factors (FF)
10 or less	1.000
11 - 30	0.973
31 - 50	0.967
greater than 50	0.960

AVU = Adjusted visual defect utility.

SIU = Serviceability index utility.

SKU = Skid number utility

SCU = Structural Capacity utility.

a_1, a_2, a_3, a_4 = Weighting factors.

$a_1 = \frac{1}{(ADTF)(KEF)}$ and $a_2 = a_3 = a_4 = 1$

ADTF = Average daily traffic factor, as given in Table 10.

KEF = 18-kip equivalent axle loading factor (Table 11).

FC = Functional Class weighting factor.

Functional Class	Factor
1	0.80
2	0.80
3	0.80
4	0.90
5	0.95
6	1.00
7	1.00

$$AVU = (U_{rutting})^{b_1} (U_{raveling})^{b_2} (U_{flushing})^{b_3} (U_{Fail})^{b_4} (U_{allig.})^{b_5} (U_{long.})^{b_6} (U_{trans.})^{b_7} \quad (12)$$

The utility inputs developed for the original PES, required to compute the AVU can be obtained from utility curves developed by SDHPT personnel. Equations which approximate these curves are as follows:

Rutting.

1/2" - 1" "Slight Rutting"

$$U_{rutting} = 1 - 0.323\, e^{-12.365(1/x)} \quad (13)$$

$\geq$ 1" "Severe Rutting"

$$U_{rutting} = 1 - 0.694\ e^{-10.132(1/x)} \tag{14}$$

where x = percent of area (wheelpath)

Raveling.

$$U_{raveling} = 1 - 0.570\ e^{-24.911(1/x)} \tag{15}$$

where x = percent of area (total surface)

Flushing.

$$U_{flushing} = 1 - 0.647\ e^{-34.99(1/x)} \tag{16}$$

where x = percent of area (total surface)

Failures.

$$U_{failures} = 1 - 1.351\ e^{-5.778(1/x)} \tag{17}$$

where x = number of failures per mile

Alligator Cracking.

$$U_{alligator\ cracking} = 1 - 0.559\ e^{-4.962(1/x)} \tag{18}$$

where x = percent of area (wheelpath)

Longitudinal Cracking.

$$U_{longitudinal\ cracking} = 1 - 0.774\ e^{-161.98(1/x)} \tag{19}$$

where x = lin. ft. per lane per station

Transverse Cracking.

$$U_{transverse\ cracking} = 1 - 0.545\ e^{-6.798(1/x)} \tag{20}$$

where x = number per station

For all equations listed above, the utility is 1.0 when x is zero. The b coefficients are determined by the following relationships with Rainfall Factor (RF) and Freeze-Thaw Factor (FF):

b_1 = 1/RF, rutting

b_2 = 1/(RF)(FF), patching

b_3 = 1/(RF)(FF), failures

b_4 = 1/(RF)(FF), block cracking

b_5 = 1/(RF)(FF), alligator cracking

b_6 = 1/(RF)(FF), longitudinal cracking

$b_7 = 1/(RF)(FF)$, transverse cracking

The Rainfall Factor and Freeze-Thaw Factor can be obtained from Tables 12 and 13.

Serviceability Index

There are three curves available for use and these curves are a function of a factor defined by multiplying the ADT/Lane by the SPEED for each highway segment. The ADT/Lane is the Average Daily Traffic for the highway segment and SPEED is the posted speed limit for the highway segment.

Curve A: (ADT)(SPEED) < 27,500

$SIU = 1.0$	if $2.5 \le SI \le 5.0$
$SIU = 1.0 - 0.10 \left(\frac{2.5 - SI}{0.5}\right)$	if $2.0 \le SI < 2.5$
$SIU = -0.2666 + 0.58333\ (SI)$	if $0.8 \le SI < 2.0$
$SIU = 0.20 \left(\frac{SI}{0.8}\right)^2$	if $0 \le SI < 0.8$
$SUY = 0$	if $SI < 0$

where

SIU = Serviceability Index Utility

SI = Serviceability Index (obtained by use of the Mays Ride Meter)

Curve B: 27,500 < (ADT)(SPEED) < 165,000

$SIU = 1.0$	if $3.0 \le SI \le 5.0$
$SIU = 1.0 - 0.10 \left(\frac{3.0 - SI}{0.5}\right)$	if $2.5 \le SI < 3.0$
$SIU = -0.5583 + 0.58333\ (SI)$	if $1.3 \le SI < 2.5$
$SIU = 0.20 \left(\frac{SI}{1.3}\right)^2$	if $0 \le SI < 1.3$
$SIU = 0$	if $SI < 0$

Curve C: (ADT)(SPEED) > 165,000

$SIU = 1.0$	if $3.5 \leq SI \leq 5.0$
$SIU = 1.0 - 0.10 \left(\frac{3.5 - SI}{0.5}\right)$	if $3.0 \leq SI < 3.5$
$SIU = -0.85 + 0.58333 (SI)$	if $1.8 \leq SI < 3.0$
$SIU = 0.20 \left(\frac{SI}{1.8}\right)^2$	if $0 \leq SI < 1.8$
$SIU = 0$	if $SI < 0$

Determination of Final Attributes as a Function of Current Attributes.

An important component of this system is the ability to estimate what the Final Pavement Score (FPS) will be for a given highway segment after some type of maintenance or rehabilitation is applied. To aid in this task, Tables 14, 15, and 16 were developed.

Table 14 provides a method of determining the final utility value for each distress after the rehabilitation of a highway segment given the initial utility values before rehabilitation. For example, an R-3 strategy (2 1/2" ACP overlay) will have a large effect on deep rutting, and hence the after-treatment utility value will be at its maximum level. The values given in this table indicate how effective a particular strategy is at remedying a particular distress type. Table 14 also provides a method of determining the final serviceability index following each of the maintenance strategies.

Table 15 provides a method of determining the final serviceability index following each of the rehabilitation strategies. The data used to generate this table were obtained from actual condition and performance information available in District 21 and the Texas Flexible Pavement Data Base.

Table 16 provides a method of determining the final utility value of each distress after the maintenance of a highway segment given the initial utility values before maintenance. For example, an M-01 treatment (seal coat) will have no effect on deep rutting, and hence the after-treatment utility value will be the same as the before treatment value.

Selection of strategies R-1 or R-2 (seal coat or thin overlay) indicates that even though the pavement score for a section of road is below the minimum required score, the section of road can be repaired satisfactorily using one or more maintenance treatments. If the PES system recommends either R-1 or R-2 then that section is reprocessed by the maintenance decision tree routine.

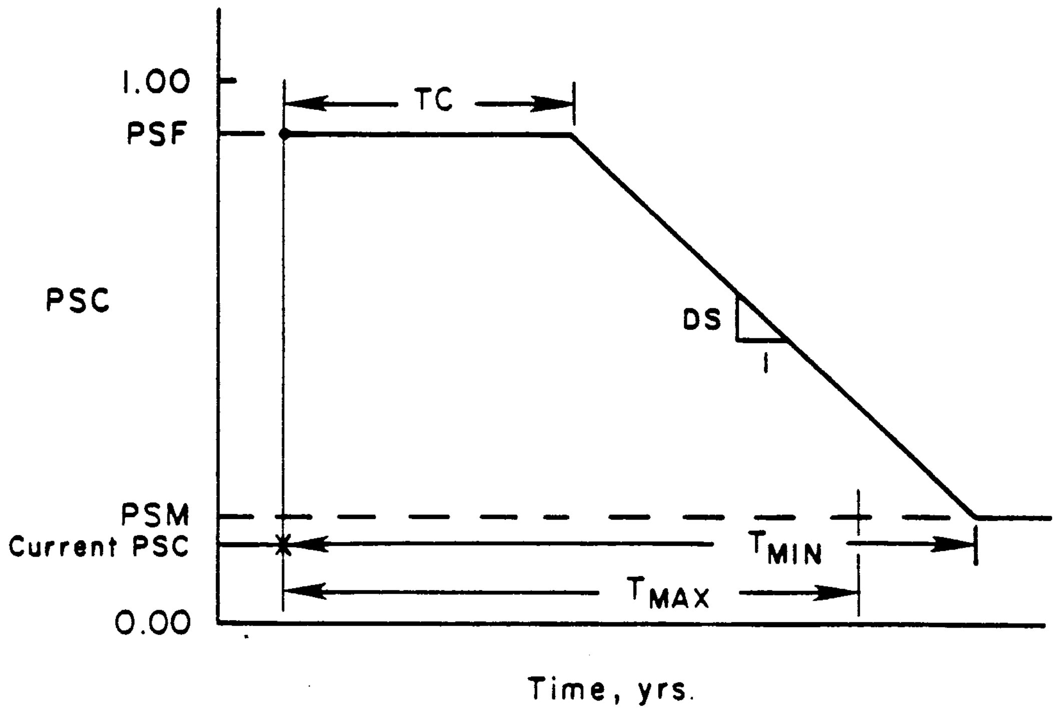

Figure 10. Selection of a Rehabilitation Funding Level

TABLE 14. Gain in PES Components for the Various Rehablitation Funding Strategies

Distress	Maximum % Recovery of Utility Score Following Various Funding Strategies				
	R-1	R-2	R-3	R-4	R-5
"Slight" Rutting < 1"	33	100	100	100	100
"Severe" Rutting > 1"	0	70	100	100	100
Raveling	100	100	100	100	100
Flushing	100	100	100	100	100
Failures	25	62	75	87	100
Alligator Cracking	60	80	100	100	100
Longitudinal Cracking	60	80	100	100	100
Transverse Cracking	75	100	100	100	100

TABLE 15. Determination of the Final Serviceability Index as a Function of Current Serviceability Index

Attribute	Current Attribute Measure (before Rehabilitation)	Final Values Following Funding Strategy				
		R-1	R-2	R-3	R-4	R-5
Serviceability	0.0 - 1.0	SI Current + 0.2	4.3	4.5	4.5	4.5
	1.0 - 2.0	SI Current + 0.2	4.3	4.5	4.5	4.5
	2.1 - 3.0	SI Current + 0.1	4.3	4.5	4.5	4.5
	3.1 - 4.0	SI Current	4.3	4.5	4.5	4.5
	4.1 - 5.0	SI Current	4.3	4.5	4.5	4.5

TABLE 16. Gain in PES components for the Various Maintenance Strategies

For distress 0 = strategy has no effect on distress
100 = strategy fully repairs distress
For serviceability Index 100 indicate an increase of PSI by 1.00 units.

Strategy	Rutting < 1"	Rutting > 1"	Raveling	Flushing	Failures	Alligator	Longitudinal	Transverse	Serviceability Index
M-01	0	0	0	0	0	0	100	100	0
M-02	0	0	0	0	100	30	0	0	50
M-03	100	100	0	0	100	50	0	0	100
M-04	0	0	100	0	0	10	10	10	0
M-05	0	0	50	50	0	70	0	0	0
M-06	0	0	100	100	0	100	100	100	0
M-07	0	0	100	100	0	100	100	100	0
M-08	0	0	100	100	0	100	100	100	0
M-09	100	100	100	100	100	100	100	100	150
M-10	100	100	100	100	100	100	100	100	200
M-11	100	100	100	100	0	0	0	0	50
M-12	0	0	50	50	0	50	15	15	0
M-13	0	0	100	100	0	100	0	0	50
M-14	100	100	100	100	100	100	100	100	200

Selection of a Rehabilitation Funding Level

The selection of a Rehabilitation Funding level is made by using the concepts illustrated in Figure 10. The graph shows that the current pavement score (PSC) is below the minimum acceptable score (PSM). After a rehabilitation strategy has been applied, the score rises to PSF, remains relatively constant for a period of time, TC, and then begins to deteriorate along a slope, DS. It again reaches a minimum score at a time, TMAX. If TMAX is greater than the minimum acceptable time, TMIN, the rehabilitaion strategy is accepted. The rehabilitation strategy that is selected is the one with the least cost which lasts longer than TMIN. Details of how each of these variables is determined are given in the following sections.

Minimum Acceptable PS (PSM). The values for PSM shown in Table 17 are listed for six highway functional classifications. The definitions for these highway functional classification types were as follows (6):

1. Principal Arterial:

   (a) Interstate System

   (b) Other principal arterials

   These facilities provide continuous and connected routes to all large urban areas and corridor movements with trip length and travel characteristics which are of statewide or interstate interest.

2. Minor Arterial:

   This system connects cities and other traffic generators and provides for relatively high speeds over long distances. It is spaced to provide arterials to all developed areas.

3. Major Collector:

   Provide service to intercounty travel corridors and connect county traffic generators with cities, towns, or higher classified routes.

4. Minor Collector:

   Collect traffic from local roads and provide service to smaller communities.

Minimum Allowable Time to Next Rehabilitation. Table 18 shows how the minimum allowable times to next rehabilitation are organized. These times are a function of highway functional classification and traffic factor. The table considers only the first factor and a simple equation incorporates the traffic factor. The initial allowable time from the table and the traffic factor are related as follows:

$$TMIN = (TMINI)(TF) \quad (21)$$

where

TMIN = the minimum allowable time (years) to the next application of a rehabilitation funding strategy following the application of the rehabilitation strategy currently being considered.

TMINI = same as TMIN except unadjusted for traffic (Table 19).

TF = traffic factor for the highway segment being considered (Table 19), as explained in the next section.

Traffic Factors Required for Calculating TMIN and DS. Table 19 shows the traffic factors which are used to determine the final values of TMIN (Minimum Allowable time between treatments) and DS (Deterioration Slope) for each highway segment. These factors should be a function of highway functional classification, percent trucks, and AADT. Currently, the traffic factors have been developed with available data for only two AADT levels and the four functional classifications because presently available data precluded use of percent trucks at this time. These factors were developed from pavement survival data available from District 21 and the Texas Flexible Pavement Data Base.

Rehabilitation Strategy Deterioration Slopes. Table 20 shows the initial deterioration slopes (PSI) for five funding strategies and seven pavement types. A simple equation is used to determine the final deterioration slope (DS) as a function of traffic, climatic, and subgrade soil factors. This equation is as follows:

$$DS = (DSI)(TF)(CF)(SF) \quad (22)$$

where

DS = deterioration slope of a funding strategy for a given pavement type after adjustment for traffic and climate conditions

DSI = initial deterioration slope obtained from Table 20

TF = traffic factor for the highway segment being considered (Table 19)

CF = climate factor (Table 21)

SF = soil factor (Table 22)

The deterioration slopes and appropriate traffic factors were presented by Lytton and Scullion in the report 239-6F of the Texas Transportation Institute(6).

Climate Factors. The climate factors shown in Table 21 have all been set to unity. As additional research is accomplished in subsequent studies, the climatic effects on pavement deterioration rates will be further examined and developed. Currently, it is expected that these factors can be made a function of freeze-thaw cycles and rainfall.

Soil Factors. The soil factors shown in Table 22 range between 1.00 for non-expansive soil to 1.15 for a highly expansive soil in a climate with moderate rainfall. The soil factor increases the slope of the PES deterioration curve to account for the effect of expansive clays. These clays are known to be most active in the central Texas area where annual wetting and drying cycles are common.

Calculation of final PS (PSF). For a given highway type and funding strategy the PSF is a function of the final (after maintenance) AVU, SI, and SN. The final AVU (AVUF) is calculated from the values given in Table 14, the SI values are selected from Table 15, and the SN is given a value of 1. Then the appropriate utility equation for SI and SN is used to convert these two attributes to utilities. A simple multiplication of the final AVU, SI utility, and SN utility results in the PSF as follows:

$$PSF = \left[(AVUF)^{a_1} (SIUF)^{a_2} (SKUF)^{a_3} (SCUF)^{a_4}\right]^{1/FC} \qquad (23)$$

where

AVUF = final AVU after maintenance or rehabilitation

SIUF = final serviceability index utility after maintenance or rehabilitation

SKUF = final skid number utility after maintenance or rehabilitation

SCUF = final structural capacity utility after maintenance or rehabilitation

a_1, a_2, a_3, a_4, and FC are as defined in Equation 11.

Currently, the routine maintenance cost utility and skid number utility are set at 1.0 and, as such, do not affect the calculated value of PSF.

TABLE 17. Minimum Acceptable PS (PSM)

Highway Functional Classification	F.C. No.	Minimum Acceptable PS
Principal Arterial (IH and Urban Freeway)	1, 2	0.50
Minor Arterial (US and SH)	3, 4	0.45
Major Collector (FM)	5	0.40
Minor Collector (FM)	6	0.30

TABLE 18. Recommended Minimum Allowable Time (TMINI) Until Next Application of Rehabilitation

Functional Class	TMINI (years)
1	9
2	7
3	7
4	5
5	3
6	3

TABLE 19. Traffic Factors Required for Calculating TMIN and DS (TF)

AADT	% Trucks	Highway Functional Classification			
		Principal Arterial, (1, 2)	Minor Arterial, (3, 4)	Major Collector, (5)	Minor Collector, (6)
HIGH Arterial: AADT 10,000 Collector: AADT 2,000	High	1.40	1.40	1.40	1.40
	Low	1.10	1.10	1.00	1.00
LOW Arterial: AADT 10,000 Collector: AADT 2,000	High	1.20	1.20	1.20	1.20
	Low	1.00	1.00	1.00	1.00

TABLE 20. Initial Deterioration Slopes (DSI) for Five Funding Strategies and Seven Pavement Type Combinations (Units: Pes units/year)

Funding Strategies	Pavement Type (refer to Table 3)						
	EP-4	EP-5	EP-6	EP-7	EP-8	EP-9	EP-10
R-1	0.10	0.10	0.10	0.10	0.10	0.10	0.10
R-2	0.083	0.110	0.110	0.110	0.110	0.110	0.110
R-3	0.083	0.10	0.10	0.10	0.10	0.10	0.10
R-4	0.083	0.083	0.083	0.083	0.083	0.083	0.083
R-5	0.059	0.059	0.059	0.059	0.058	0.059	0.059

TABLE 21. Climate Factors (CF)

Freeze-thaw cycles (cycles/yr)	Rainfall (in./yr)		
	> 20	21-40	< 40
> 10	1.0	1.0	1.0
11 - 30	1.0	1.0	1.0
31 - 50	1.0	1.0	1.0
< 20	1.0	1.0	1.0

TABLE 22. Soil Factors

Plasticity Index	Rainfall (in./yr)		
	< 20	21-40	> 40
< 20	1.00	1.00	1.00
20 - 40	1.02	1.07	1.05
> 40	1.05	1.15	1.10

Calculation of TMAX. To calculate the time a given rehabilitation funding strategy will last after it is applied to a highway segment, the PSF, PSM, TC, and DS must be known. They are related by the following equation:

$$TMAX = TC + \frac{PSF - PSM}{DS} \quad (24)$$

where

TMAX = the time a given maintenance or rehabilitation funding strategy will last to a minimum PS (PSM)

TC = time of constant service for a given maintenance or rehabilitation funding strategy obtained from Table 20

PSF = the final PS after a maintenance or rehabilitation funding strategy is applied

PSM = the minimum PS obtained from Table 17

DS = deterioration slope obtained from Table 20 and adjusted for traffic, climate, and soil factors (Tables 19, 21, and 22, respectively).

Calculation of Low-High Traffic-Load Factors. A component of the preventive maintenance decision tree is the Low-High factor for the traffic-load combination of the section of road. Table 23 gives the break-over points for average daily traffic per lane and 18-kip respectively depending on the functional class of the road. Above the break-over point, the factor is considered high and below it the factor is considered low. Table 24, gives the possible low-high combinations and the code assigned to each one.

Deterioration Matrix. If a section does not require maintenance in the current year it is aged using deterioration matrices. Equations are available for Asphaltic Concrete (AC) over Black Base, AC over Granular Base, Overlays, and Surface Treated Pavements. The program selects appropriate performance equations for a given highway based on the input pavement type as shown in Table 25.

The deterioration matrix is developed in an iterative process in which the basic S-shape performance equation is used to find W given g. Using this approach the current value of damage g is known, using S-shape curve performance equations, as estimate is made as to the value of damage one year from current. The regression equations used are shown in Appendix A, note using these curves the deterioration rate will be a function of the variable shown in Table A-1.

TABLE 23. Break-Over Points for Average Daily Traffic and 18-kip by Functional Class.

Functional Class	Average Daily Traffic	18-kip x 10^6
1	12,000	8.0
2	12,000	8.0
3	8,000	6.0
4	8,000	6.0
5	2,000	2.5
6	2,000	2.5
7	2,000	2.5

TABLE 24. Low-High Codes for Maintenance Decision Tree

Low-High	Code
LL	1
LH	2
HL	3
HH	4

The applicable relationship, equation (7)

$$g = e^{-\left(\frac{\rho}{W}\right)^{\beta}}$$

where

g	=	percent area of distress normalized to a scale 0 to 1
W	=	accumulated 18-kip loads, time, or weather cycles
ρ and β	=	regression equations for each specific distress and pavement type as shown in Appendix A.

Solving for W yields

$$W = \frac{\rho}{(-\ln g)^{1/\beta}} \qquad (25)$$

With this equation, the levels of load, time, or cycles can be determined at which the specified percentage of distress (g) is reached.

The steps of the construction of the deterioration matrix are as follows:

1. Given the current damage level g from pavement inspection data, of calculate W, (the term W represents either the theoretical number of 18 kip ESAL or Months (depending on distress type) to reach the level of damage g.)

$$W = \frac{\rho}{(-\ln g)^{1/\beta}}$$

2. Increment the value of W by 1 year. This involves adding either 1 years worth of 18 kip Equivalents to W or adding 12 month to W. The number of 18 kips ESAL per month is known for each section within the Texas PES system.

3. Find g (the damage) for the next year by using the incremented W value in the signoidal equation.

An illustration of the matrices is shown on Table 26. This illustrates the predicted growth rate between year N and N+1 for longitudinal cracking in thin asphalt pavements for three different enviromental zones. In this case, the freeze-thaw cycles factor chiefly accounts for the varying growth-rate predictions.

The predictions from these deterioration matrices can be also illustrated in graphical form as shown in Figure 11, where the predicted growth in rutting an a hot mix pavement is given for three different traffic loading conditions.

By using the deterioration matrices, the maintenance and rehabilitation prediction routines, the decision trees, and the decision criteria, it is possible to make predictions of the timing and type of maintenance and rehabilitation activities for each section in the state's network. Typical cases of such predictions are shown in the following chapter.

TABLE 25. Performance Equation Used by Pavement Type.

Pavement Type	Performance Equations Used
4	Hot Mix on Black Base (BB)
5	Hot Mix (HM) on Granular Base
6	Hot Mix (HM) on Granular Base
7	Overlay (OV)
8	Overlay (OV)
9	Overlay (OV)
10	Surface Treatment (ST)

TABLE 26. Predicted Growth of Longitudinal Cracking in Differing Climatic Zones

% Extent of Distress in Year N	% Extent of Distress (Year N+1)		
	Zone 1	Zone 2	Zone 3
10	14	22	13
15	19	28	19
20	24	34	24
25	29	42	29
Thornthwaite Index	12	-21	-47
Air Freeze-Thaw Cycles	26	80	30
Avg. Max. Montnly Temp. °F	67	59	62
Average Soil PI	20	20	5

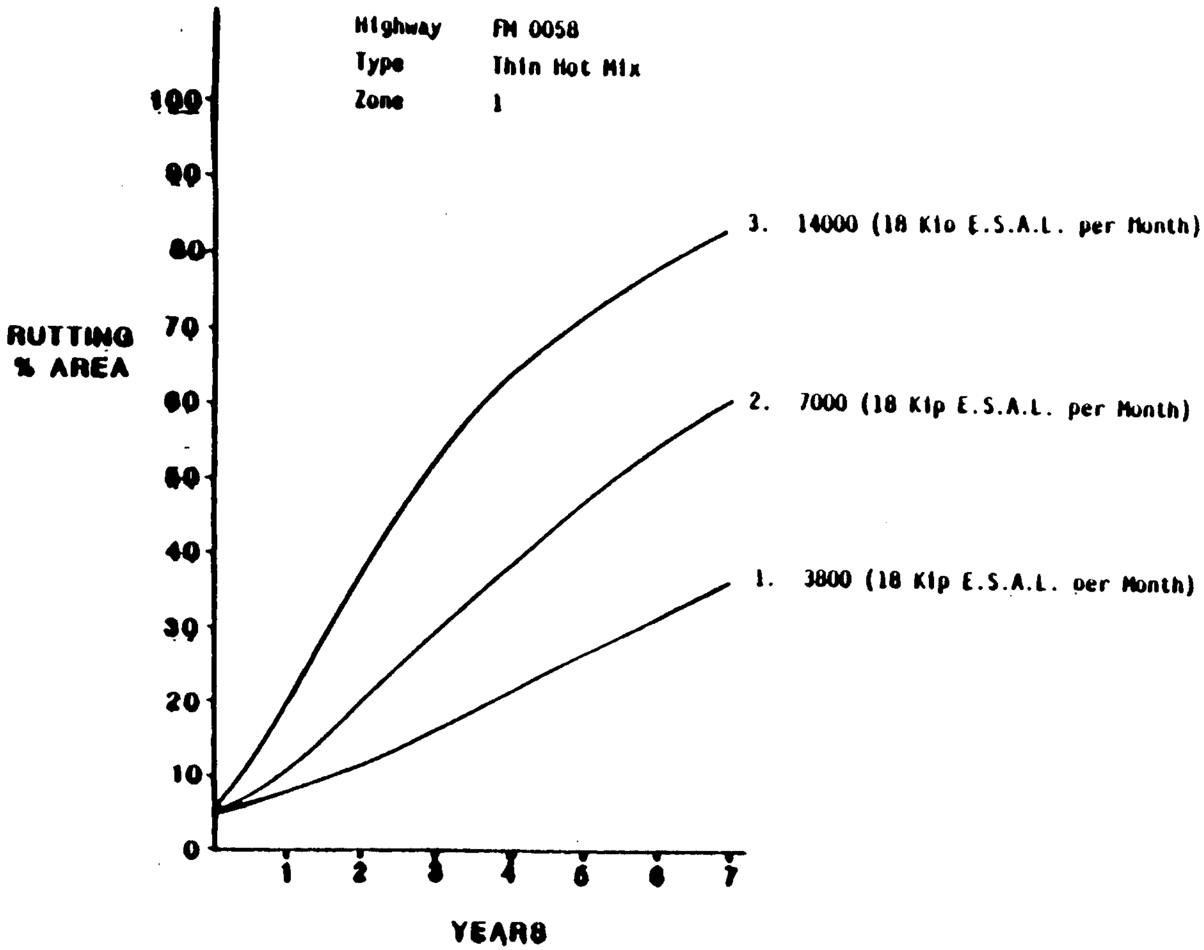

Figure 11. Predicted Growth in Rutting Area for Different Traffic Loadings

CHAPTER FIVE

EXAMPLE PROBLEM

To illustrate the calculation procedure, the data from a single 2-mile highway section will be processed. The information for the example is shown below.

Planning Horizon:	10 years
Maintenance Level:	65 (PES score when maintenance applied)
Rehabilitation Level:	40 (PES score when rehabilitation applied)
Highway:	FM 324
Milepost:	MP 0-2
District:	11
County:	3 (Angelina)
Functional Class:	4 (Collector)
Pavement Type:	8 (Overlaid Concrete Pavement)
ADT/Lane:	1850
18-kip ESAL(20 yrs):	2.65 million

The pavement was evaluated, and the distresses found in the section are shown in Table 27.

The mean Mays Ride value on this section was measured to be 1.6.

Pavement Score Calculation Procedure

Within the Pavement Evaluation System, the following scores are calculated.

1. Unweighted Visual Utility Score (UVU)

   where

$$UVU = (U_{rutting}) \times (U_{raveling}) \times (U_{flushing}) \times (U_{failures}) \times (U_{alligator\ cracking}) \times (U_{longitudinal\ cracking}) \times (U_{transverse\ cracking})$$

2. Adjusted Visual Utility Score (AVU)

   where

$$AVU = (U_{rut})^{b_1} \times (U_{rav})^{b_2} \times (U_{flu})^{b_3} \times (U_{fail})^{b_4} (U_{allig})^{b_5} \times (U_{long})^{b_6} \times (U_{trans})^{b_7}$$

TABLE 27. Visually Observed Distresses for FM-342

Distress	Area Covered	As coded on Inspection Form
Slight Rutting	0	000
Severe Rutting	0	000
Raveling	0	000
Flushing	0	000
Failures	0	000
Alligator Cracking	6-25%	010
Longitudinal Cracking	100-199 lin. ft.	010
Transverse Cracking	4 per 100 ft	100

where the b values are environmental weighting factors dependent upon rainfall and freeze-thaw cycles. The values of b are defined in the main body of the report and the environmental factors are obtained from Tables 9 and 10.

3. Weighted Visual Utility Score (WVU)

where

$$WVU = AVU^{a_1}$$

where a_1 is a traffic associated weighting factor, as defined in the main body of the report.

4. Pavement Score (PSC)

where

$$PSC = [(AVU)^{a_1} \times (SIU)^{a_2} \times (SKU)^{a_3} \times (SCU)^{a_4}]^{1/FC}$$

where SKU (Skid Utility) and SCU (Structural Capacity Utility) are both set to 1.0. a_2, a_3, and a_4 are set to 1.0 and FC is a factor based on functional class.

For the data presented above for FM324 the following scores are calculated.

$$UVU = (1.00) \times (1.00) \times (1.00) \times (1.00) \times (0.53) \times (0.99) \times (0.71) = 0.40$$

the individual utility values being obtained from formulas (13) to (20).The rainfall and freeze-thaw values for this county are 30 in./yr and 26 cycles/yr, respectively, therefore from Table 10, RF = 0.97 and Table 11, FF = 0.973.

therefore

$$AVU = (1.00)^{1.06} \times (1.00)^{1.06} \times (1.00)^{1.06} \times (1.00)^{1.06} \times (0.53)^{1.06} \times (0.99)^{1.06} \times (0.71)^{1.06} = 0.35$$

From Tables 12 and 13

$$a_1 = \frac{1}{ADTF \times EALT} = \frac{1}{0.92 \times 1.0} = 1.087$$

$$WVU = (0.35)^{1.087} = 0.321$$

From the SIUC equation for an ADT x Speed = 101,750

$$SIU = -0.5583 + 0.58333\ (1.6)$$

$$= 0.375$$

$$PSC = (0.321 \times 0.375 \times 1.00 \times 1.00)^{1/0.95}$$

$$= 0.108$$

When these value are presented in the PES outputs, the scores are rounded and multiplied by 100. For this section of FM 324, the following scores would be reported.

UVU = 40

AVU = 35

WVU = 32

PSC = 11

Calculating the Appropriate Funding Level

The current pavement score for this section is 0.11. This is below the minimum acceptable of 0.40 (Table 17), therefore a rehabilitation funding level would be calculated.

The first step in calculating the funding level is to determine the final pavement score after each funding strategy (R-1, R-2, or R-3 for surface treated pavements).

Calculating final AVU for Strategy R-1. For each distress utility value the final utility value is determined using the following equation.

$$U_{final} = U_{initial} + (1-U_{initial}) \times G$$

where G is the % gain factor obtained from Table 14 where U_{final} has a maximum value of 1.0.

The calculation of the final AVU for strategy R-1 on FM 324 is shown below.

Distress	$U_{initial}$	G from Table 14	U_{final} after R-1
Rutting < 1"	1.000	33	1.000
Raveling	1.000	100	1.000
Flushing	1.000	100	1.000
Failures	1.000	25	1.000
Alligator Cracking	0.530	60	0.824
Longitudinal Cracking	0.990	60	0.996
Transverse Cracking	0.710	75	0.928

$$AVU_{final} = (1.000)^{1.06} \times (1.000)^{1.06} \times (1.000)^{1.06} \times (1.000)^{1.06}$$

$$(0.824)^{1.06} \times (0.996)^{1.06} \times (0.928)^{1.06}$$

$$= .745$$

Final PSI = 1.8 from Table 15

$$SIU_{final} = 1.00$$

$$PSF = ((.745)^{1.087} \times 0.783 \times 1.00 \times 1.00)^{1/0.95}$$

$$= 0.338$$

for strategy R-2

$$PSF = ((.899)^{1.087} \times 1.00 \times 1.00 \times 1.00)^{1/0.95}$$

$$= 0.885$$

for strategy R-3

$$PSF = ((1.00)^{1.087} \times 1.00 \times 1.00 \times 1.00)^{1/0.95}$$

$$= 1.000$$

Calculation of Tmax (Time Until Next Rehabilitation).

$$T_{max} = Tc + \frac{PSF - PSM}{DS}$$

PSM = 0.40 from Table 17

DS = (DSI)(TF)(CF)(SF)

DSI is obtained from Table 20

TF is obtained from Table 19

CF is obtained from Table 21

SF is obtained from Table 22

DS = 0.100 x 1.00 x 1.00 x 1.00 x 1.00 = 0.100

R-1 $T_{max} = 0 + \frac{0.338 - 0.40}{0.100} = -0.2$ years

R-2 $T_{max} = 0 + \frac{0.885 - 0.40}{0.100} = 4.85$ years

R-3 $T_{max} = 0 + \frac{1.000 - 0.40}{0.100} = 6.00$ years

<u>Calculation of Tmin (Minimum Allowable Time)</u>.

$T_{min} = T_{mini} \times TF$

T_{mini} (from Table 18) = 5.0

TF (from Table 19) = 1.0

$T_{min} = 3.0 \times 1.0 = 5.0$ years

<u>Funding Strategy Selection</u>. Select first strategy such that

$T_{max} > T_{min}$

R-1 $T_{max} = -0.2$ $T_{min} = 5.0$

R-2 $T_{max} = 4.52$ $T_{min} = 5.0$

R-3 $T_{max} = 6.00$ $T_{min} = 5.0$

Therefore, R-3 would be selected for this highway. This is a 2 1/2-inch thick ACP overlay.

Aging the Pavement.

To age the pavement through time, the iterative process developed in the last part of Chapter Four is used.

1.- Calculate ρ'sand β's . The constants ρ and β are calculated for each distress that affects the section of road. These distresses will in turn be used to construct the deterioration matrix that will enable the deterioration of the pavement.

Appendix A gives ρ and β formulas for Alligator Cracking on an Overlay pavement as follows:

ρ and β for Alligator Cracking:

$$\rho = -0.0159 * FTC + 0.0082 * AVT - 0.0121 * PI + 0.0162 * OVTH + 0.145 * HPR2 - 0.0135 * HPR3$$

where,

FTC = Freeze-Thaw Cycles/yr

AVT = Average Temperature

PI = Plasticity Index

HPR2 = Equivalent Tnickness X Elastic Modulus of the Subgrade

The Equivalent Thickness is assumed based on pavement type and the Elastic modulus is assigned based on climatic region. Once the FWD is incorporated into PES (planned for 1987) then project specific estimates can be made.

$$HPR3 = 10^{10}/HPR2$$

$$\rho = -0.0159 * 26 + 0.0082 * 67 - 0.0121 * 20 + 0.0162 * 3 + 0.145 * 30 - 0.0135 * 2$$

$$\rho = 4.2631$$

$$= 0.0185 * XTI + 0.171 * HPR3$$

where,

XTI = Thornthwaite Index + 50.0

$$\beta = 0.0185 * 62 + 0.171 * 2$$

$$\beta = 1.4834$$

ρ and β for Longitudinal Cracking:

ρ = 135.08

β = 2.3006

ρ and β for Transverse Cracking:

ρ = 154.60

β = 0.99673

2.- Construct the Deterioration Matrix for the Pavement Section. The deterioration matrix is developed in an iterative process in which the basic S-shape performance equation is used to find W given g.

The applicable relationship, equation (7)

$$g = e^{-\left(\frac{\rho}{W}\right)^{\beta}}$$

where

g = percent area of distress

W = accumulated 18-kip loads, time, or weather cycles

ρ and β =regression equations for each specific distress and pavement type

a. Given g(% area), find W.

$$W = \frac{\rho}{(-\ln g)^{1/\beta}}$$

$$W = \frac{4.2631}{[-Ln(0.01)^{1/1.4834}}$$

$$W = 1.5227$$

b. Increase W by 1 year.

W is a load expressed in N18 kips/month therefore compute

N(months) = W * 1000 * 240/EALT
EALT = 20 year 18 kip ESAL (in thousands)

= 1.5227 * 1000 * 240 / 2652

= 137.8 months

$$N = N + 12$$
$$= 137.8 + 12$$
$$= 149.8$$
$$W = \frac{N * EALT}{240 * 1000}$$
$$= \frac{149.8 * 2652}{240 * 1000}$$
$$= 1.6553$$

c. Find g for next year given W.

$$g = e^{-\left(\frac{\rho}{W}\right)^{\beta}}$$

$$g = e^{-\left(\frac{4.2631}{1.6553}\right)^{1.4834}}$$

$$g = 0.0171 = 1.71 \text{ (Alligator Cracking at t+1)}$$

For this reason the alligator cracking is calculated to increase from 1.0% to 1.7% in one year.

d. Generate Deterioration Matrix. The previous calculation procedure is followed year-by-year, distress-by-distress until a table, such as Table 28, is complete.

Predicting Long Term Funding Requirements

After the deterioration matrix has been built, the analysis over the planning horizon begins. It is assumed that after a major rehabilitation the time for constant level of service (i.e. time that the section will be in top condition) is 3 years. Thus, during the first three years after rehabilitation nothing happens to the section of road but loss of serviceability due to traffic. This change is minimal and does not affect the overall score of the section. Typically, at year five after rehabilitation, the distresses begin to appear and the score changes in the following way.

1989 $\quad UVUC = (1.00)(1.00)(1.00)(1.00)(.972)(1.00)(1.00)$
$\quad = .972$

$$AVUC = (1.00)^{1.06}(1.00)^{1.06}(1.00)^{1.06}(1.00)^{1.06}(.972)^{1.06}(1.00)^{1.06}(1.00)^{1.06}$$

TABLE 28. Deterioration Matrix for FM 324, MP 0-2

% Area Now	% Area Next Year		
	Alligator Cracking	Longitudinal Cracking	Transverse Cracking
1.00	1.71	3.90	3.27
2.00	2.94	5.93	4.88
3.00	4.17	7.85	6.07
4.00	5.35	9.44	7.34
5.00	6.52	10.57	8.66
6.00	7.63	12.34	9.67
7.00	8.65	13.57	10.70
8.00	9.71	14.83	12.90
9.00	10.80	16.12	13.14
10.00	11.76	17.43	13.84
.	.	.	.
.	.	.	.
.	.	.	.
100.00	100.00	100.00	100.00

= .966

SIU = 1.00

PESC = .966

1990 The increase of the distresses is shown below (from Table 28).

Distress	t = 1989	t = 1990
Alligator Cracking	1.71 = 2%	2.94%
Longitudinal Cracking	3.90 = 4%	9.44%
Transverse Cracking	3.27 = 4%	7.34%
SI	3.5	3.3

UVUC = (1.00)(1.00)(1.00)(1.00)(.896)(.975)(.989)

= .864

AVUC = (.890)(.963)(.988)

= .847

SIU = 1.00

PESC = .850

1991 PESC = 64

Maintenance Decision Tree In 1991 the score falls into the area where preventive maintenance is needed. Thus, a maintenance schedule has to be recommended. This is done by using the decision tree for composite pavements (Table 29). It can be seen that for the distresses that are affecting the pavement, maintenance strategy 12 (spot seal) is recommended. For the maintenance strategy the final utility value is determined using the following equation.

$$U_{final} = 1 - [U_{initial} - U_{initial}]*[Max\ gain]$$

where maximum gain is the % gain factor for the maintenance strategy obtained from Table 16 where U_{final} has a maximum value of 1.00.

Table 29: Selection Maintenance Strategy, Pavement Type 8

Overlay (concrete) Peformance Equation: Overlay
PES RATING

Distress	Traffic	PES Rating		
		100	010	001
Slight Rutting	LL	9	9	9
	LH	9	9	10
	HL	9	9	9
	HH	9	9	10
Severe Rutting	LL	9	9	10
	LH	13	13	14
	HL	9	9	14
	HH	13	14	14
Raveling	LL	4	4	5
	LH	4	4	5
	HL	4	6	6
	HH	4	6	6
Flushing	LL	0	5	5
	LH	0	5	5
	HL	5	6	6
	HH	6	6	6
Failures	LL	3	3	3
	LH	3	3	3
	HL	3	3	3
	HH	3	3	3
Alligator Cracking	LL	12	12	5
	LH	12	12	6
	HL	12	5	5
	HH	12	5	6
Longitudinal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
Transverse Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6

Distress	initial	Max Gain from Table 16	U_{final} after M-12
Rutting	0	0	
Raveling	0	.5	
Flushing	0	.5	
Failures	0	0	
Alligator Cracking	0.91	.5	.95
Longitudinal Cracking	0.84	.15	.86
Transverse Cracking	0.88	.15	.90
SI	3.3	0	3.3

$$AVU = (1.00)^{1.06}(1.00)^{1.06}(1.00)^{1.06}(1.00)^{1.06}(.95)^{1.06}(.88)^{1.06}(.90)^{1.06}$$

$$= .75$$

$$SIUC = 1$$

$$PESC = 75$$

The final schedule for FM324 for the 10 year period is shown in Table 30. Although the computation process is long and involved the results obtained, shown in Table 30, appear to be reasonable. The pavement under analysis was a composite (asphalt over concrete). It was predicted to require an immediate 2 1/2 inch overlay, followed by a crack seal in year 8 and crack seal and seal coat in year 10.

TABLE 30. Rehabilitation and Maintenance Schedule for FM 324

Year	PESM	PES	Strategy	
1984	40	19	R-03	Medium Overlay
1985	40	100		
1986	40	100		
1987	40	100		
1988	40	100		
1989	40	96		
1990	40	84		
1991	40	64	M-12	Seal Coat
1992	40	75		
1993	40	57	M-1, M-12	Seal Cracks, Seal Coats
1994	40	98		

CHAPTER SIX

SENSITIVITY ANALYSIS AND CASE STUDIES

Sensitivity Analysis

A limited sensitivity analysis has been performed using data obtained from the 1983 State survey. The analysis was directed to assess the response of the program to changes in a) maintenance level, b) traffic load, and c) climate.

Seven sections of road from District 11 (Lufkin) were selected for the analysis. These sections of road were selected according to pavement type, functional class, traffic, and load. Specific information about the sections of road are given in Table 31.

Maintenance Levels Sensitivity Analysis. To examine the effect of the minimum allowable pavement score, before maintenance has to be applied, upon the selection of funding requirements, five levels (60, 65, 70, 75, 80) of minimum score were analyzed. Table 32 shows the results of maintenance and rehabilitation costs for all the sections at different minimum allowable score levels for a planning horizon of twenty years.

As can be observed, the maintenance cost appears to be inversely proportional to the minimum score, and the rehabilitation cost directly proportional to the minimum score. This relationsnip is due to the fact that when the minimum allowable score is high, maintenance would have to be done so frequently that it is more cost effective to do a rehabilitation which will last longer at a high score. On the other hand, when the minimum score is low, the percent of distress of a section increases to a higher level, causing a need for a more extensive and correspondingly more expensive maintenance strategy. However, such maintenance will be required less frequently and thus is more cost effective than a rehabilitation strategy. A level between 70 and 75 minimum allowable score was found to be the most economical for this small data set. This cost was compared to the cost incurred by not having preventive maintenance strategies when the pavement falls below an acceptable score of 45. It was found that the cost of maintaining the road at a level between 70 and 75 will be less expensive than to let the road fall to an unacceptable level of less than 45 and then rehabilitate (Table 32).

Sensitivity to Traffic Loading. To examine the effect of traffic loading, sections of road corresponding to each of the four performance equations (Black Base, Hot Mix, Overlay, Surface Treated) were analyzed with their actual traffic loadings. They were then re-analyzed with one half and double the actual loadings. Figures 11 to 22 show the rehabilitation and maintenance cycles for each of the twelve cases. Also, Table 33 shows the maintenance and renabilitation

TABLE 31. Information on Selected Pavement Sections

Highway	Pavement Type	Functional Class	Pavement Score	Average Daily Traff	18 kip per day x 10^6
SH 63	4	4	54	4,200	3.8
SH 287	5	5	67	2,100	2.7
FM 58	6	5	44	1,800	1.6
FM 324	7	4	40	2,800	2.5
FM 324	8	4	28	3,100	2.9
SH 103	9	4	65	6,000	5.4
FM 324	10	5	62	2,200	2.1

TABLE 32. Maintenance, Rehabilitation, and Total Cost at Different Minimum Allowable Utility Scores

Minimum PES Score	Maintenance Cost	Rehabilitation Cost	Total Cost
80	321,214	1,180,000	1,501,214
75	326,319	1,066,600	1,392,919
70	334,761	1,032,600	1,367,361
65	375,240	1,032,600	1,407,840
60	395,107	1,032,600	1,427,707

costs for the sections at the different traffic levels. As the traffic loading is increased, the predicted total cost also increases.

Sensitivity to Climatic Conditions. To examine the effect of climatic conditions on pavement life, sections of road corresponding to each of the four performance equations (Black Base, Hot Mix, Overlay, Surface Treated) were analyzed with their actual traffic loadings for three different climatic zones, Districts 21 (Dry, No Freeze), 19 (Wet, Freeze), and 4 (Dry, Freeze-Thaw cycling). Table 34 shows the maintenance and rehabilitation costs for the sections at the different climatic conditions. Higher total costs were observed for the wet and freeze climatic zone (District 19) than for the other two zones. This difference is due to the fact that the regression equations that predict pavement deterioration rates are sensitive to district rainfall. The problem is further increased by the thermal cracking which is a function of freeze-thaw cycles.

Case Studies

Predicting Funding Needs for a Single County. The program has been used to predict the funding requirements for several counties. Typical results for Angelina County in East Texas are shown in Table 35. The rehabilitation costs are for medium and thick overlays and reconstruction. Note that in this county there is a large backlog of roads in very poor condition and hence the high first year rehabilitation costs. The decision criteria used to generate these results are those given in Table 2. However, varying the criteria in Table 2, the consequences of delaying preventive maintenance can be observed. With the existing criteria, preventive maintenance is initiated with a pavement score of 75 (low distress). Table 36 illustrates the consequences of delaying preventive maintenance.

In this table, Criteria A are as shown in Table 2, Criteria B involves delaying preventive maintenance until moderate levels of distress exist (pavement score less than 50), and Criteria C involves delaying maintenance and rehabilitation until extensive distress exists (pavement score less than minimum allowable score for rehabilitation).

As would be anticipated, the predicted rehabilitation costs increase as the preventive maintenance work is delayed. However, the predicted total cost increases from $1.78 million per year to $2.35 million per year as the maintenance work is delayed.

A further analysis performed with the Angelina County data was to study the effects of traffic loadings on predicted maintenance and rehabilitation cost estimates. Results of this analysis are shown in Table 37. As the traffic loading on the pavement is increased, the predicted total cost also increases. The true results are even more dramatic since the Rehabilitation cost figure for each traffic level

TABLE 33. Maintenance and Rehabilitation Costs at Different Traffic Load Levels

Traffic Level	Maintenance Cost	Rehabilitation Cost	Total Cost
Half Traffic	345,895	608,000	953,895
Normal Traffic	326,319	1,104,600	1,430,919
Double Traffic	302,110	1,182,600	1,484,710

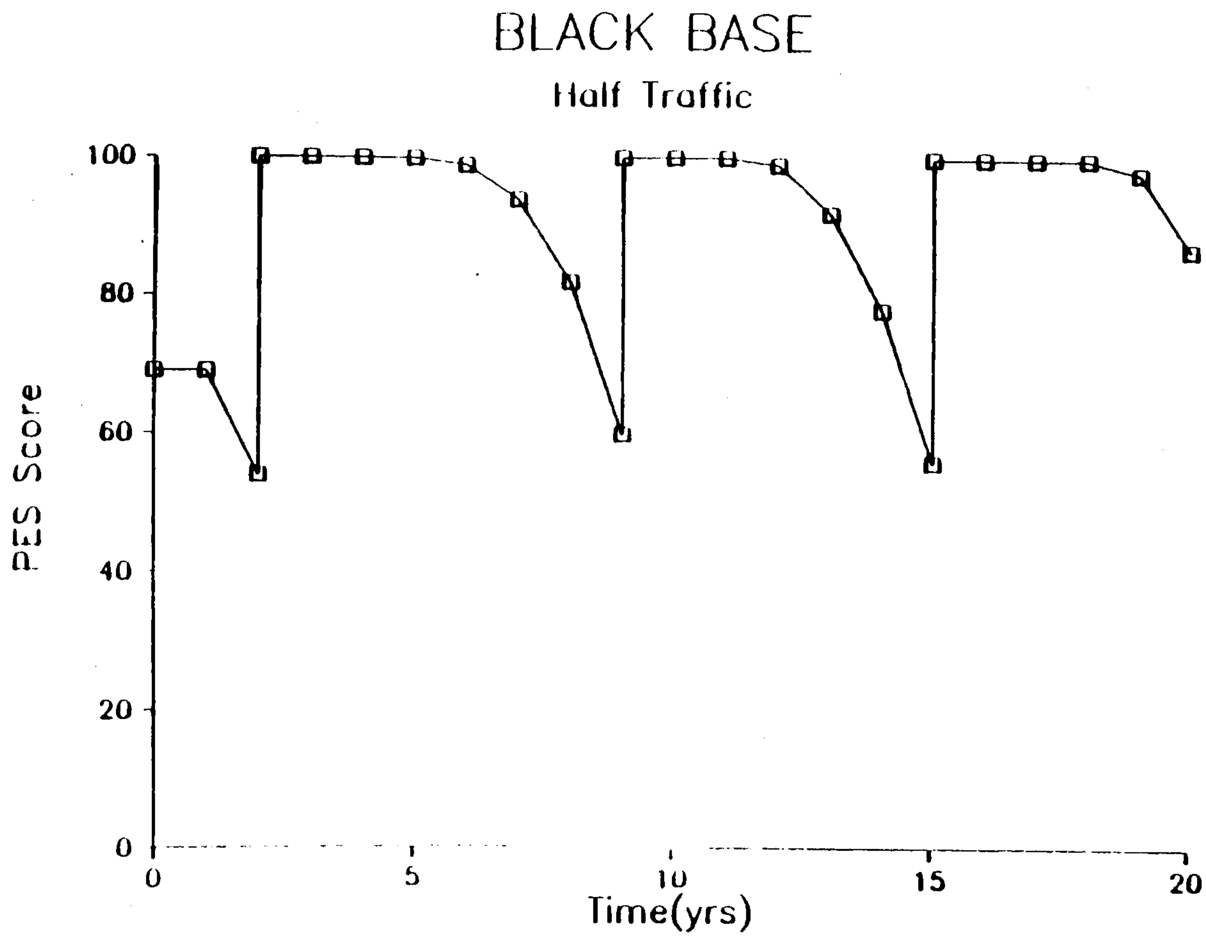

Figure 12. Rehabilitation Cycle for Black Base Pavement, Half Traffic Load.

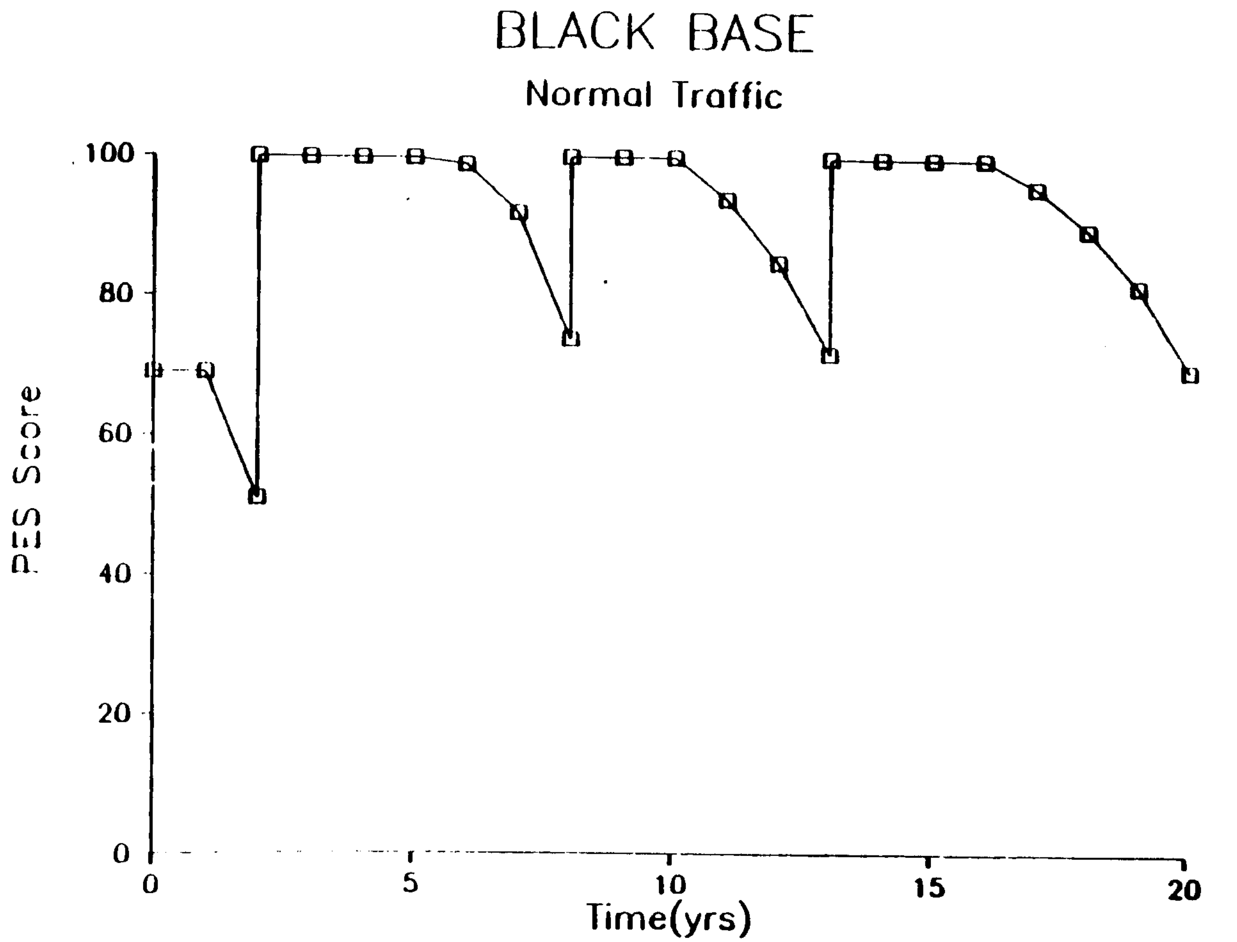

Figure 13. Rehabilitation Cycle for Black Base Pavement, Normal Traffic Load.

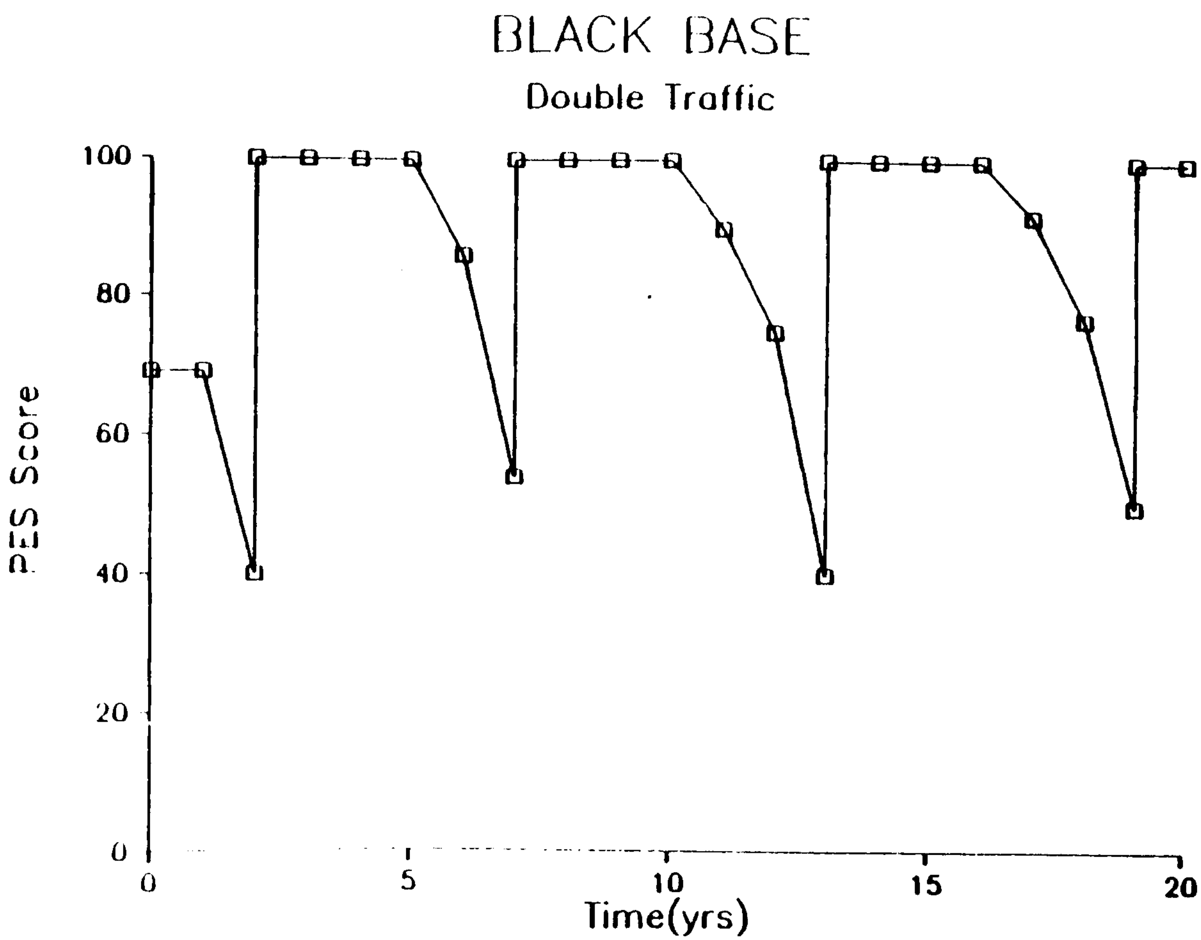

Figure 14. Rehabilitation Cycle for Black Base Pavement, Double Traffic Load.

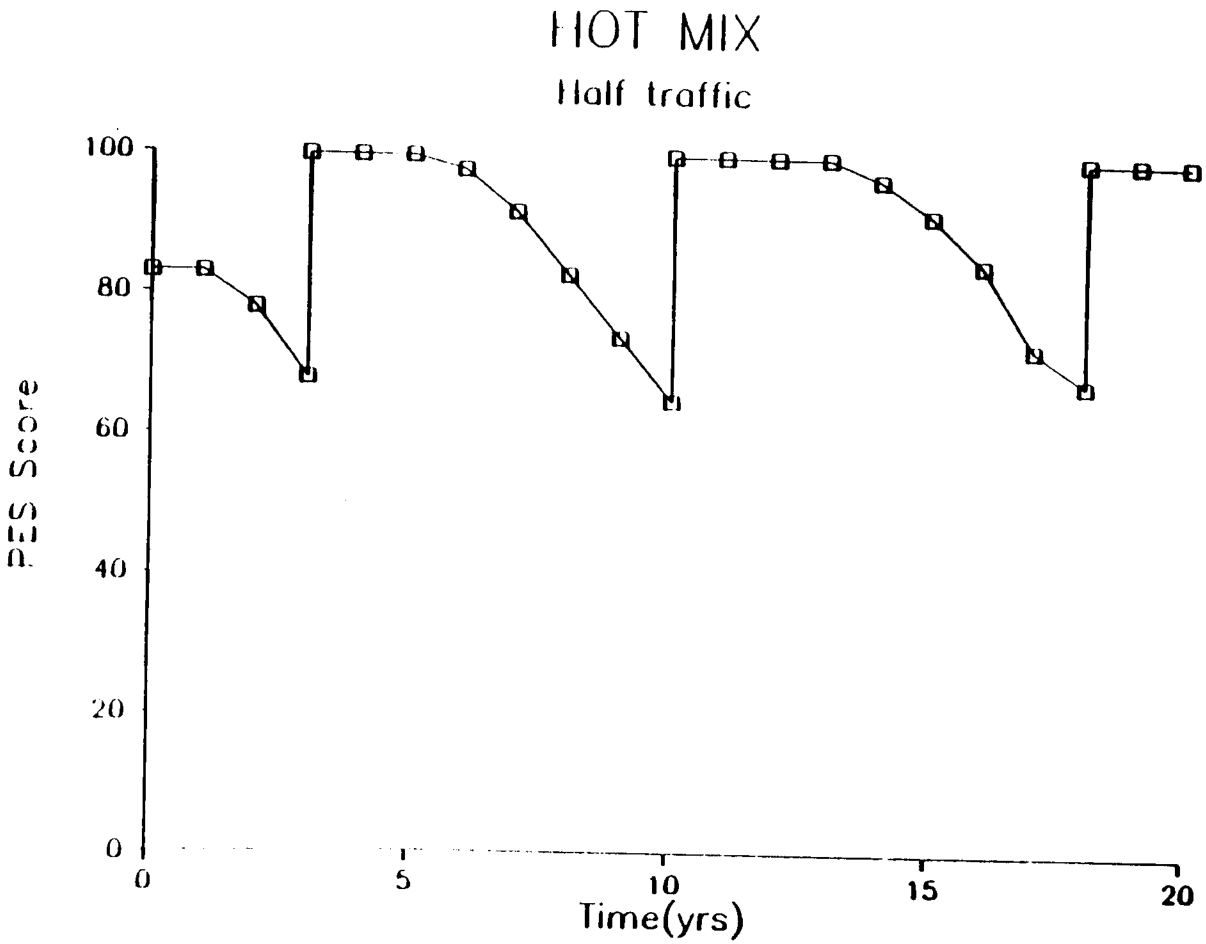

Figure 15. Rehabilitation Cycle for Hot Mix Pavement, Half Traffic Load

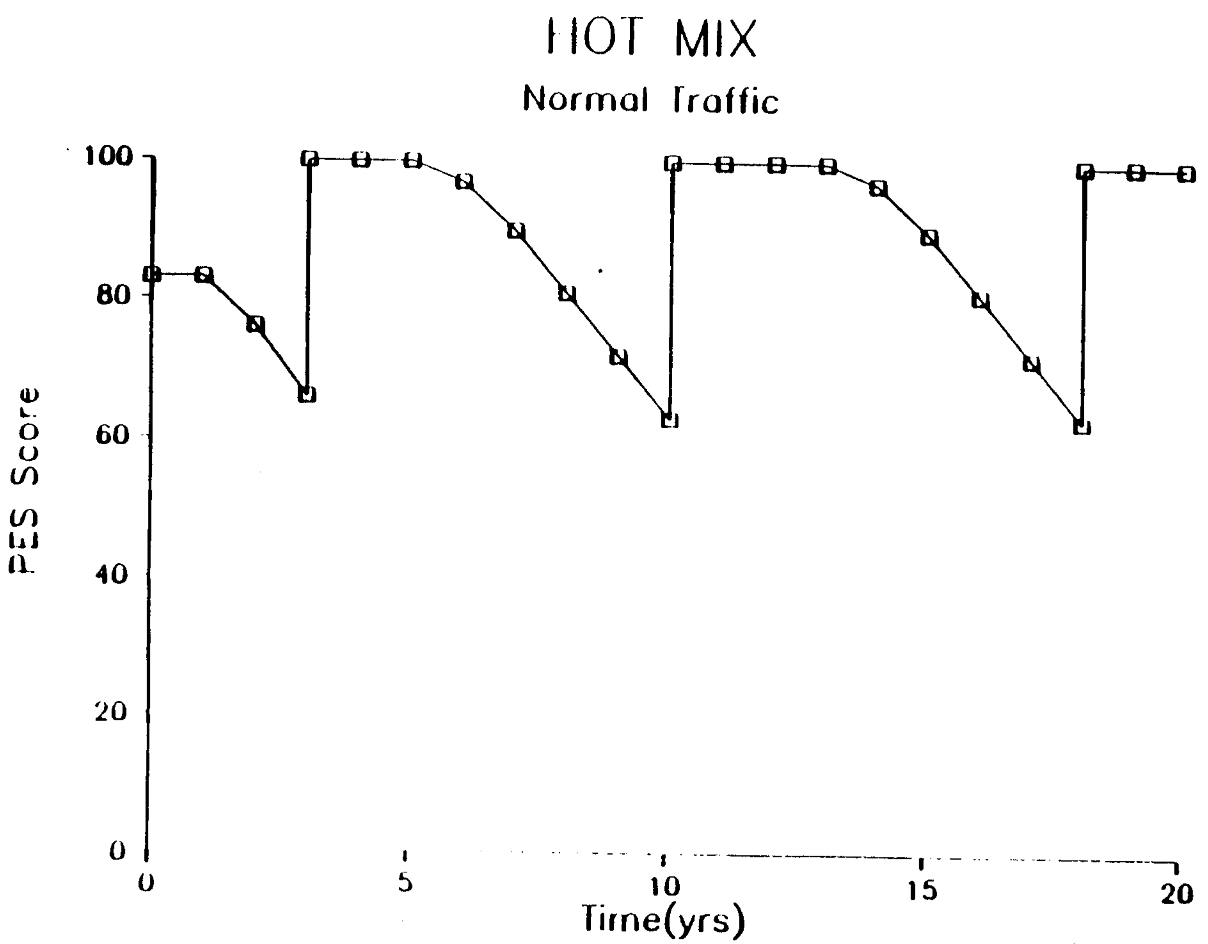

Figure 16. Rehabilitation Cycle for Hot Mix Pavement, Normal Traffic Load

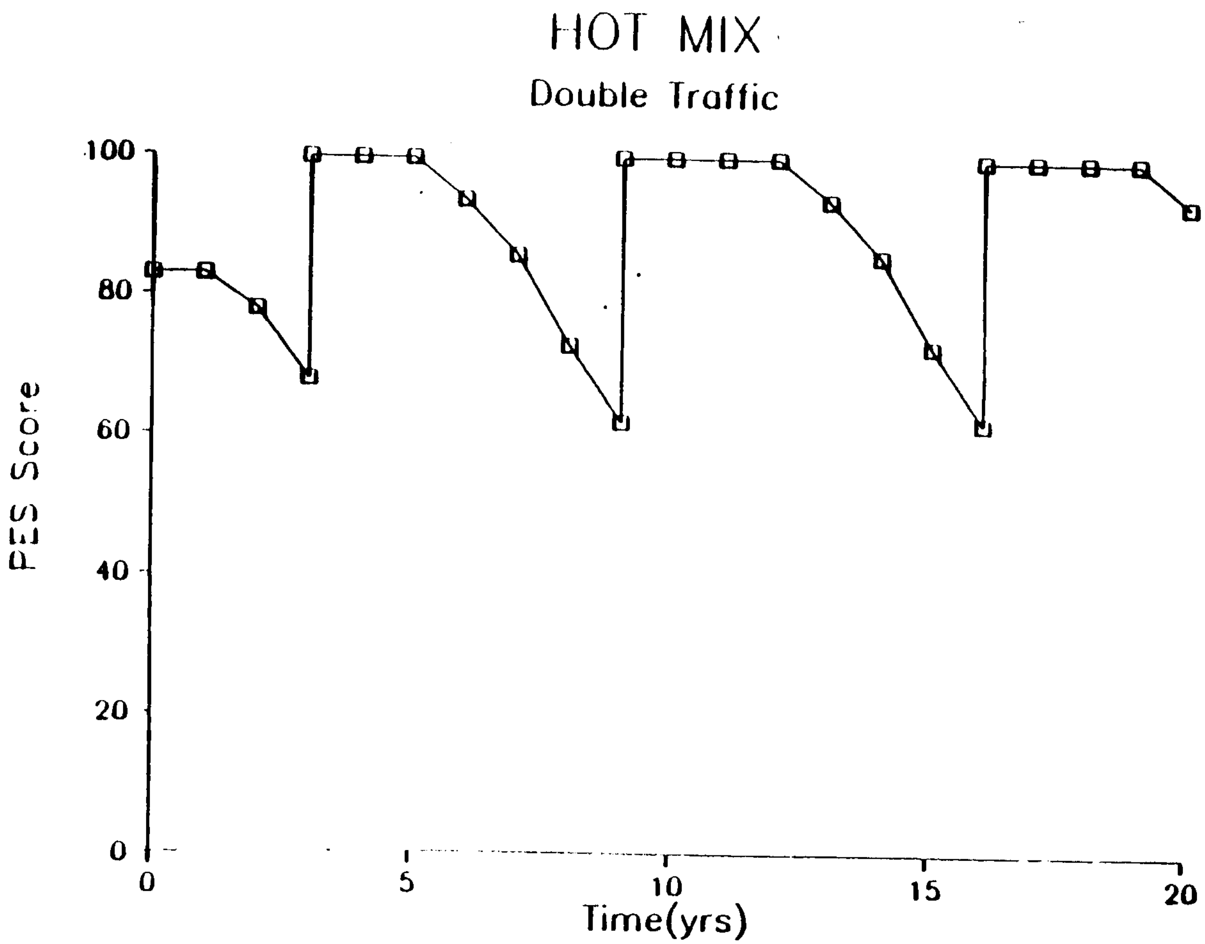

Figure 17. Rehabilitation Cycle for Hot Mix Pavement, Double Traffic Load

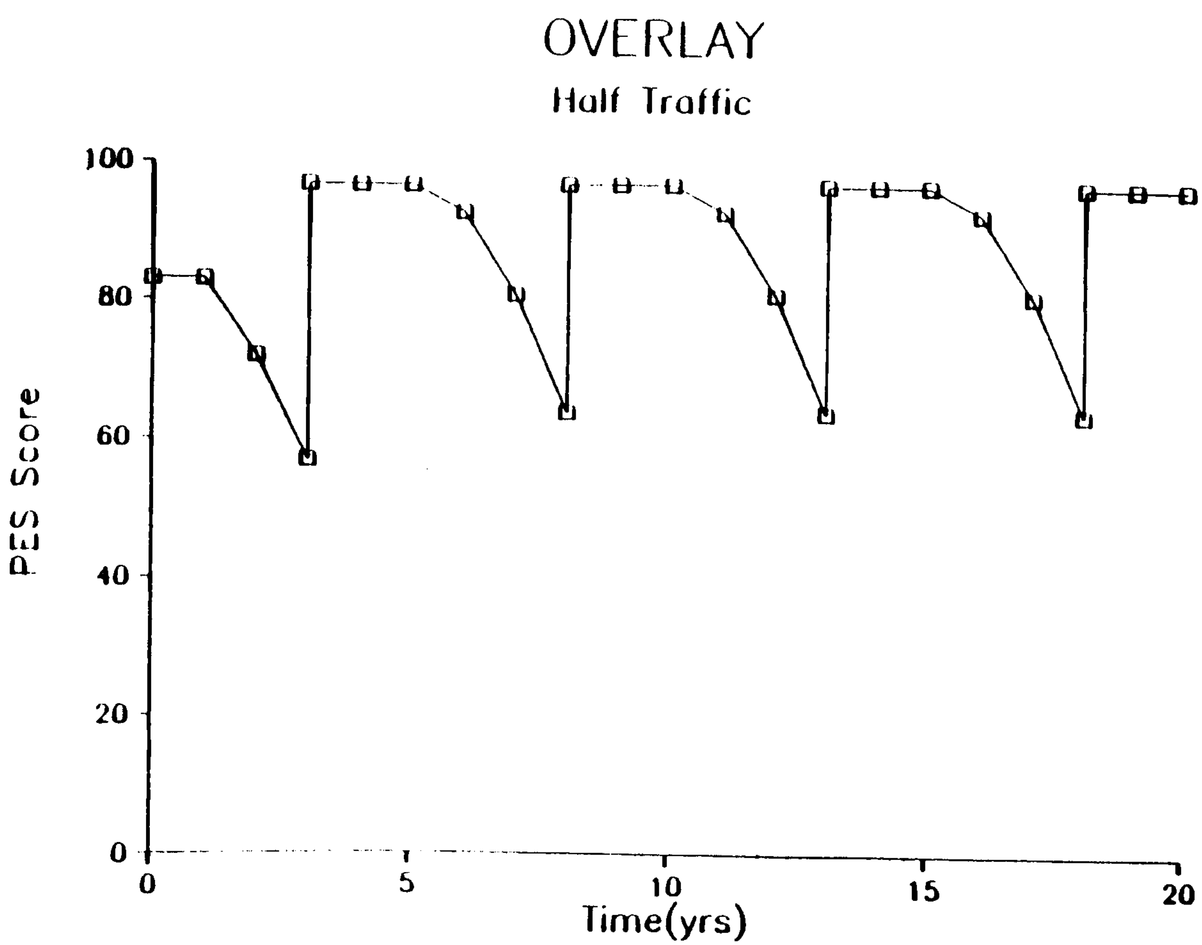

Figure 18. Rehabilitation Cycle for Overlays, Half Traffic Load

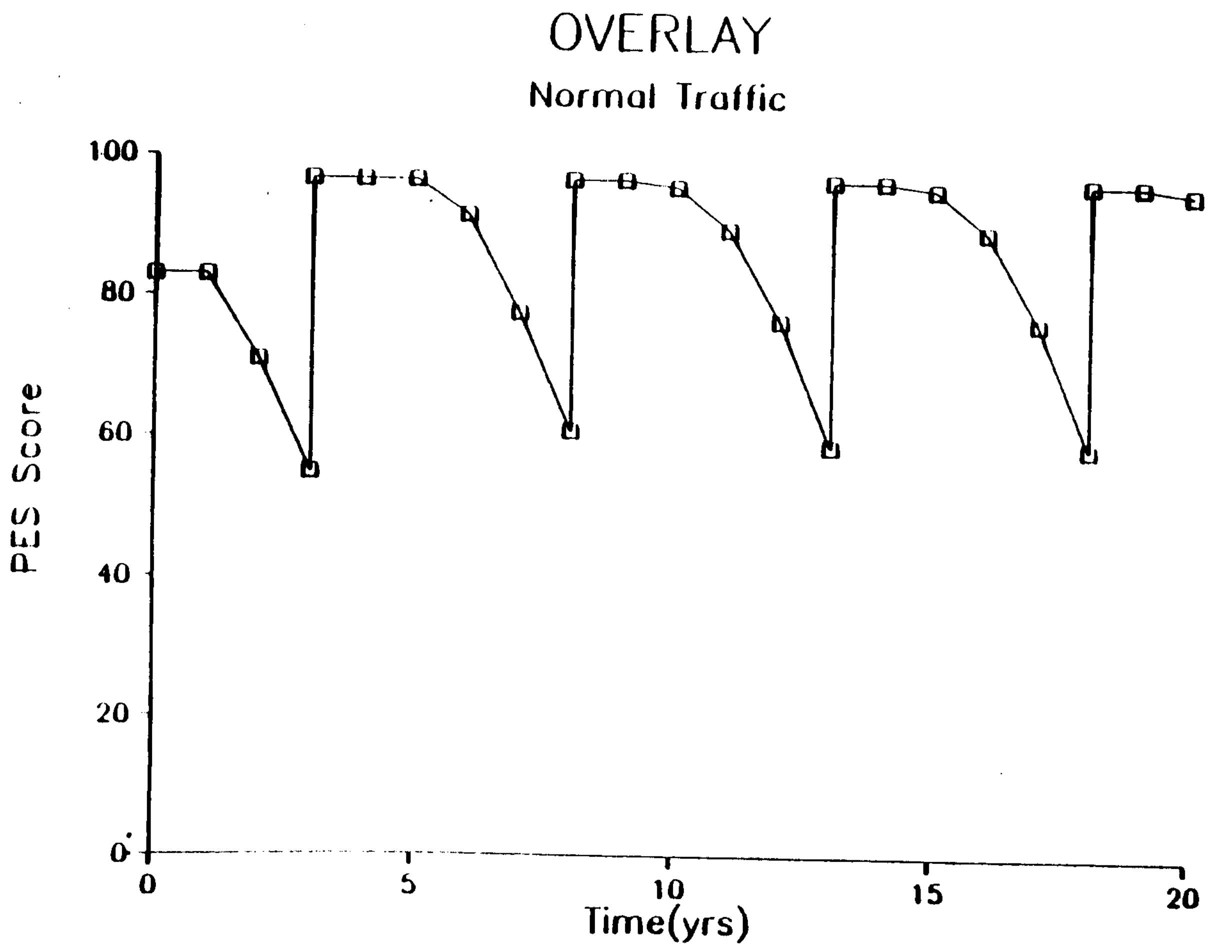

Figure 19. Rehabilitation Cycle for Overlays, Normal Traffic Load

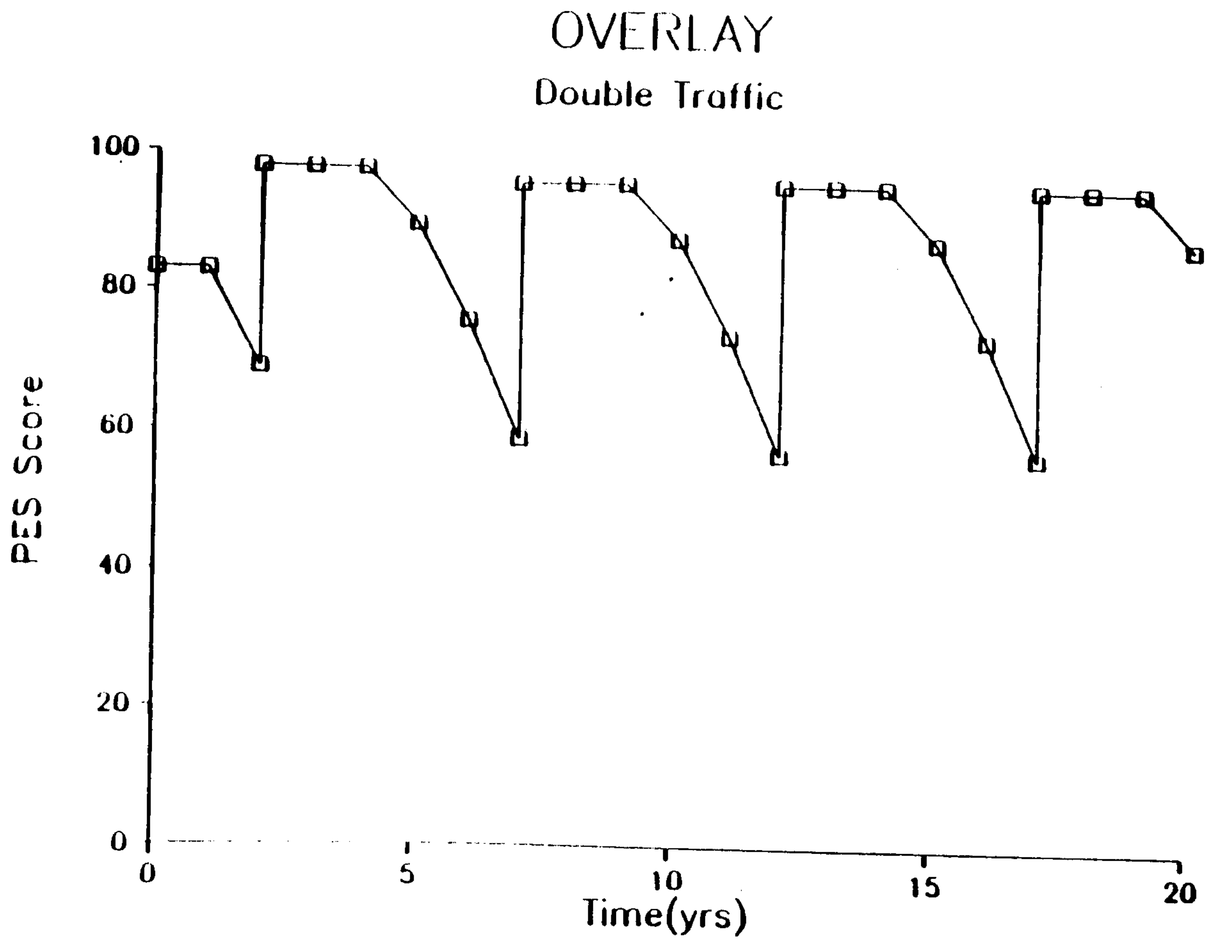

Figure 20. Rehabilitation Cycle for Overlays, Double Traffic Load

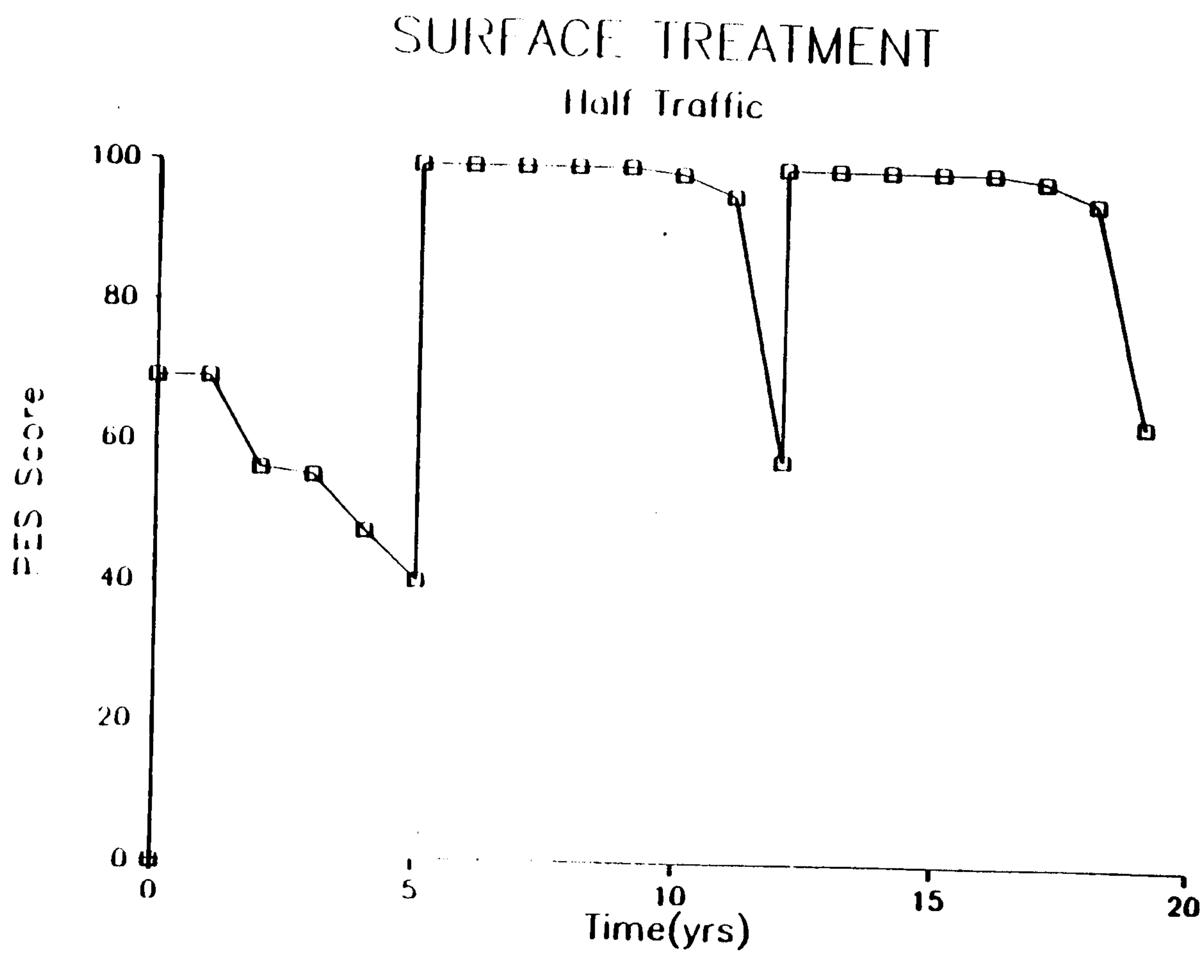

Figure 21. Rehabilitation Cycle for Surface Treated Pavements, Half Traffic Load

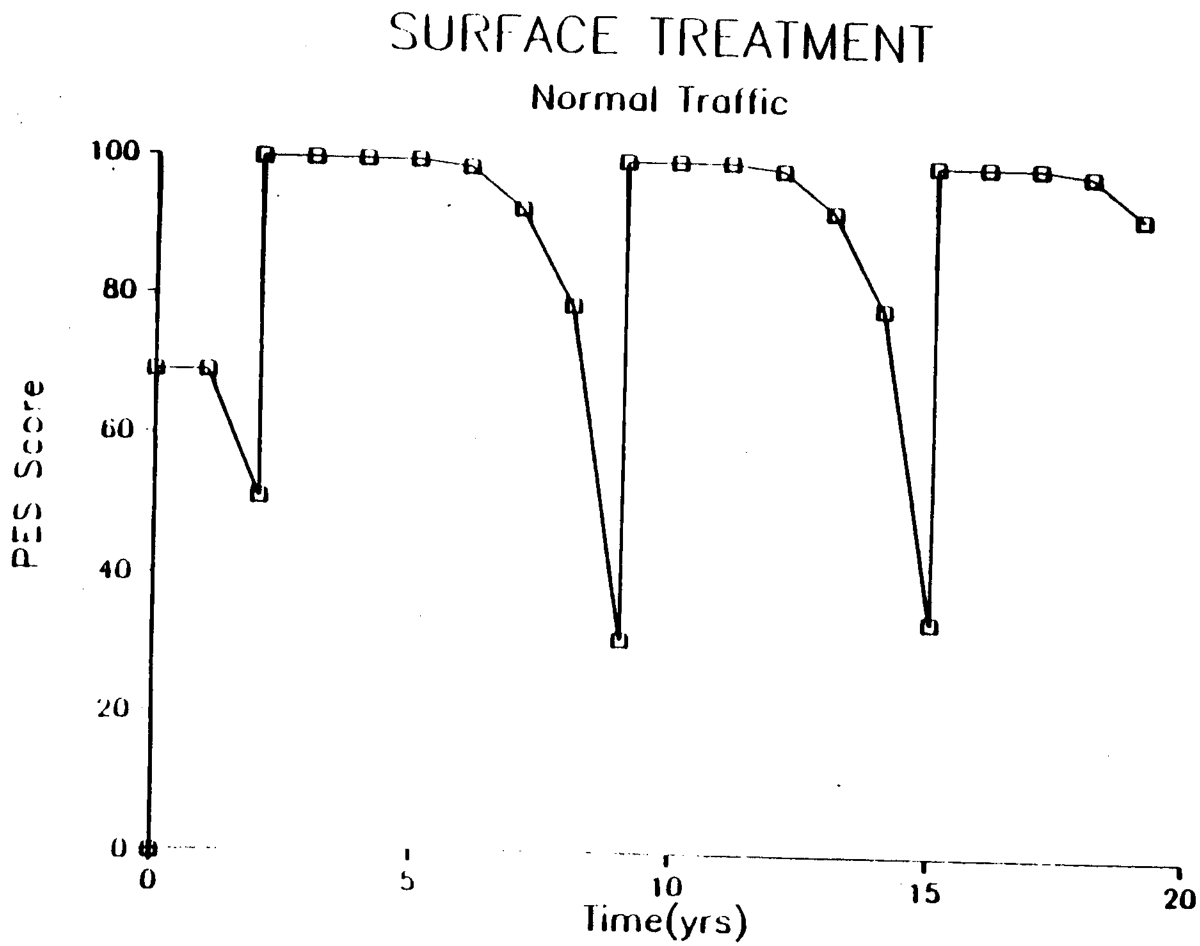

Figure 22. Rehabilitation Cycle for Surface Treated Pavements, Normal Traffic Load

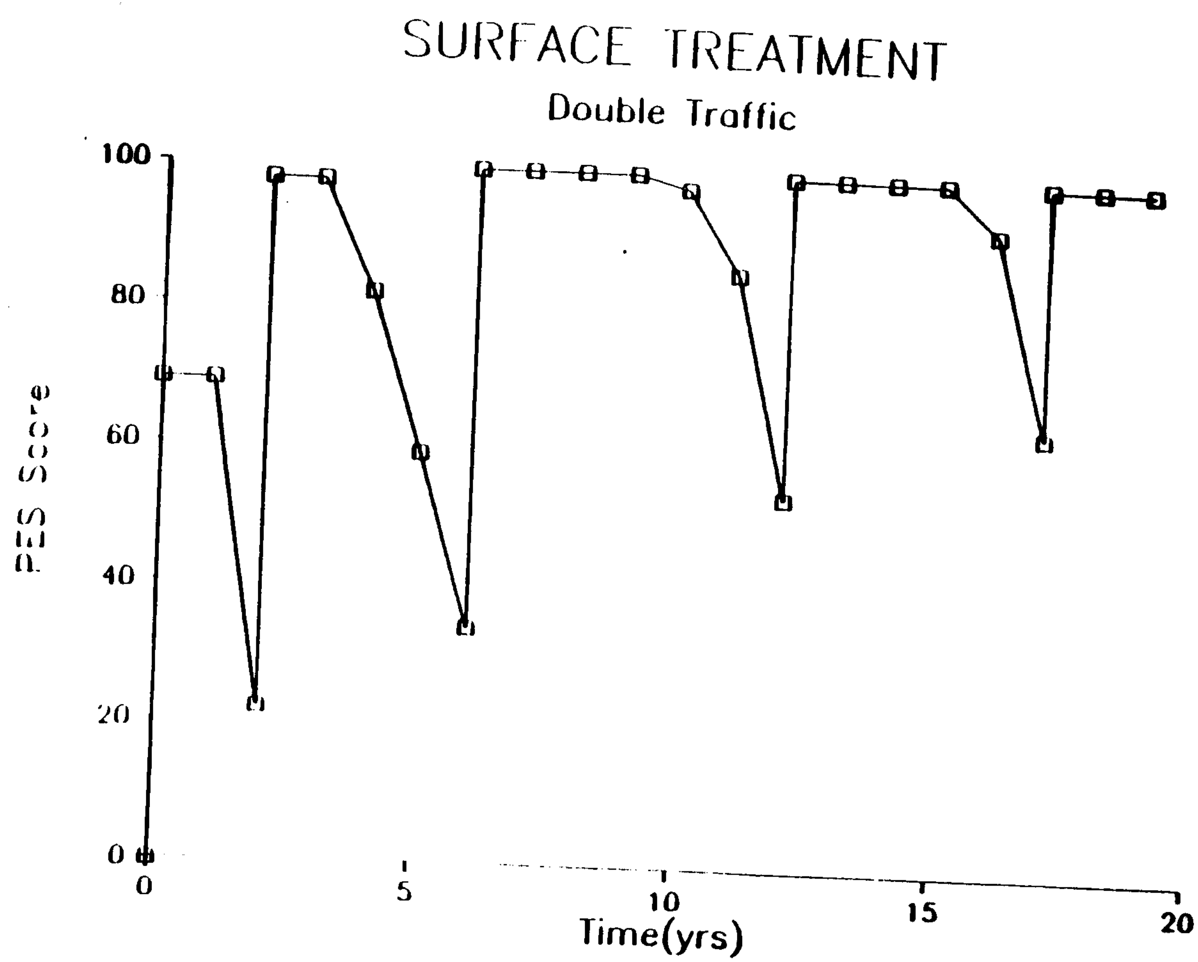

Figure 23. Rehabilitation Cycle for Surface Treated Pavements, Double Traffic Load

includes the large first year figure required to eliminate the backlog of poor pavements.

Predicting Funding Needs for a Single District. The program was used to predict the funding requirements for the low volume Farm to Market roads in District 11. The Farm to Market network in District 11 consists of 875 sections, each approximately two miles long.

Five runs were made with the program using different decision criteria. The runs were made with the following scenarios:

1.- No maintenance, and minimum pavement score level of 40.

2.- No maintenance, and minimum pavement score level of 60.

3.- Maintenance and rehabilitation levels of 40.

4.- Maintenance and rehabilitation levels of 60.

5.- Maintenance level of 75, and rehabilitation level of 40.

Table 38 gives the results of the runs for a five year analysis period.

As can be anticipated, the total cost is higher for the scenarios where no preventive maintenance is allowed (Runs 1 and 2). Furthermore, the difference in costs is more obvious when different levels of maintenance and rehabilitation are selected (Run 5). The difference in total cost between Runs 2 and 5 is of 55.75 million dollars in five years which can be translated to up to 49% savings in the same period of time using the proposed rehabilitation and maintenance levels of Run 5.

Figures 24 to 27 show the summary tables for Run 5. Figure 24 shows the miles of roadway breakdown by score and functional classification. It can be observed that:

a.- The mean scores for the FM network in District 11 are between 59 and 76 (average condition with low to moderate levels of distress).

b.- Fourteen percent of the FM network is below a score of 45 (extensive distress).

c.- Forty percent of the FM network is between a score of 45 and 75 (low to moderate distress).

d.- Forty six percent of the FM network is above a score of 75.

Figures 25 to 27 give the maintenance and rehabilitation costs per year, and per functional classification.

TABLE 34. Maintenance and Rehabilitation Costs at Different Climatic Zones

District	Maintenance Cost	Rehabilitation Cost	Total Cost
21 (Dry)	363,138	463,000	826,138
4 (Dry, Cold)	366,370	531,000	897,370
19 (Wet, Cold)	343,049	761,000	1,114,049

TABLE 35. Typical Results for Angelina County

YEAR	1984	1985	1986	1987
Rehabilitation Costs ($)	3,975,000	396,000	302,000	276,000
Maintenance Costs	1,072,000	687,000	722,000	816,000

TABLE 36. Consequence of Delaying Preventive Maintenance

Criteria	5 year Average Cost per Year (in million $)		
	Rehabilitation	Maintenance	Total
A	1.01	0.77	1.78
B	1.73	0.29	2.02
C	2.30	0.05	2.35

TABLE 37. Effect of Traffic on Predicted M&R Requirements

Traffic (18-kip ESAL)	5 Year Average Cost per Year (in millions) Rehabilitation	Maintenance	Total
1/2 Current Level	0.76	0.63	1.39
Current Level	1.01	0.77	1.78
Twice Current Level	1.70	1.07	2.77

TABLE 38. Maintenance and Rehabilitation Costs for Farm to Market Roads in District 11

Run	Rehab. Level	Maint. Level	Rehab. Cost($$10^3$)	Maint. Cost($$10^3$)	Total Cost($$10^3$)
1	40	None	102,468		102,468
2	60	None	112,668		112,668
3	40	40	101,113	228	101,341
4	60	60	105,802	590	106,392
5	40	75	54,322	2,600	56,922

*************MILES OF ROADWAY BREAKDOWN BY PAVEMENT SCORE AND FUNCTIONAL CLASSIFICATION*************

DISTRICT 11

MILES IN EACH FUNCTIONAL CLASS

PAVEMENT SCORE	1 INTERST	2 URBANFW	3 PRINCAR	4 MINORAR	5 MAJORCL	6 MINORCL	7 PARK
0 THRU 9	0.0	0.0	0.0	2.0	4.3	6.0	0.0
10 THRU 19	0.0	0.0	0.0	0.0	17.3	12.3	0.0
20 THRU 29	0.0	0.0	0.0	2.6	40.1	10.5	0.0
30 THRU 39	0.0	0.0	0.0	6.0	59.7	18.2	0.3
40 THRU 49	0.0	0.0	0.0	11.3	62.1	32.3	0.0
50 THRU 59	0.0	0.0	0.0	0.0	124.8	47.5	0.0
60 THRU 69	0.0	0.0	0.0	7.1	114.9	90.3	0.0
70 THRU 79	0.0	0.0	0.0	5.8	145.6	80.2	0.0
80 THRU 89	0.0	0.0	0.0	8.1	152.8	105.7	0.0
90 THRU 99	0.0	0.0	0.0	7.6	171.5	130.2	1.7
100	0.0	0.0	0.0	6.2	83.8	87.0	1.8
MEAN SCORE	0	0	0	59	70	76	74
SAMPLE SIZE	0	0	0	32	493	321	3

Figure 24. Miles of Roadway Breakdown by Pavement Score and Functional Classification

REHABILITATION AND MAINTENANCE COST PER YEAR

YEAR	REHABILITATION COST	MAINTENANCE COST
1984	38307488 0	789647 06
1985	22410000 0	639332 81
1986	7352500 00	279881 19
1987	3106000 00	258581 56
1988	19503488 0	436364 87
CUMULATIVE COST	90679500 00	2403817.91

Figure 25. Rehabilitation and Maintenance Cost per Year

MAINTENANCE COST BREAKDOWN BY YEAR AND FUNCTIONAL CLASSIFICATION

DISTRICT 11

YEAR	1 INTERST	2 URBANFW	3 PRINCAR	4 MINORAR	5 MAJORCL	6 MINORCL	7 PARK
1984	0 0	0 0	0 0	126141 06	614095.19	49411.62	0.0
1985	0 0	0 0	0 0	90.00	355498.12	283745.50	0.0
1986	0 0	0 0	0 0	17999 75	129324.00	132467.69	80.00
1987	0 0	0 0	0 0	2503 20	190312.62	65766.37	0.0
1988	0 0	0 0	0 0	106664 06	170398 06	159303 56	0.0

Figure 26. Maintenance Cost Breakdown by Year and Functional Classification

REHABILITATION COST BREAKDOWN BY YEAR AND FUNCTIONAL CLASSIFICATION

DISTRICT 11

YEAR	1 INTERST	2 URBANFW	3 PRINCAR	4 MINORAR	5 MAJORCL	6 MINORCL	7 PARK
1984	0.0	0.0	0.0	1949000.00	24564496.0	11734000.0	60000.00
1985	0.0	0.0	0.0	200000.00	15434000.0	6776000.00	0.0
1986	0.0	0.0	0.0	412500.00	5240000.00	1700000.00	0.0
1987	0.0	0.0	0.0	0.0	2526000.00	580000.00	0.0
1988	0.0	0.0	0.0	1076000.00	13797500.0	4630000.00	0.0

Figure 27. Rehabilitation Cost Breakdown by Year and Functional Classification

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

This research developed a program that computes the rehabilitation and maintenance funding needs for sections of road taking into consideration visual utility scores, structural conditions, traffic factors, and climatic factors. To evaluate the program, data from the 1983 Texas Annual Statewide Survey was utilized. The methodology used to accomplish the objective of this research was:

a) Develop a mathematical relationship to predict the increase of distress and decrease of serviceability index.

b) Generate deterioration matrices that will predict the yearly growth in each distress type using the relationships developed in (a).

c) Create a decision tree so that the appropriate maintenance procedure is selected.

d) Run the program with typical sections of road.

e) Perform a limited sensitivity analysis to see how the minimum acceptable utility score affects the estimated funding requirements. Also, determine how traffic levels and climatic variations will affect needed funds.

Conclusions

Through the application of the limited sensitivity analysis and case studies, the following observations were concluded:

1. The maintenance cost appears to be inversely proportional to the minimum score, and the rehabilitation cost directly proportional to the minimum score. This relationship is due to the fact that when the minimum allowable score is high, maintenance would have to be done so frequently that it is more cost effective to do a rehabilitation which will last longer at a high score. On the other hand, when the minimum score is low, the percent of distress of a section increases to a higher level, causing a need for a more extensive and correspondingly more expensive maintenance strategy. However, such maintenance will be required less frequently and thus is more cost effective than a rehabilitation strategy.

2. A level between 70 and 75 minimum allowable score was found to be the most economical. This cost was compared to the cost incurred by not having preventive maintenance strategies when the pavement

falls below an acceptable score of 45. It was found that the cost of maintaining the road at a level between 70 and 75 will be less expensive than to let the road fall to an unacceptable level of less than 45 and then rehabilitate.

3. As the traffic loading is increased, the life of the pavement decreases, and the predicted total cost increases.

4. Higher total costs were observed for the wet and freeze climatic zone (District 19) than for other climatic zones. This difference is due to the fact that the subgrade soil moisture content increases and it results in pavement breakup. The problem is further increased by the thermal cracking that causes a loss of strength in the pavement.

5. High first year rehabilitation costs were observed for many counties. This condition is due to the large backlog of roads in very poor condition.

Recomendations

The current system has been designed to assist the Texas State Department of Highways and Public Transportation in identifying rehabilitation and maintenance projects and associated costs through time for flexible pavements at a network level.

These goals have been achieved through the use of maintenance decision trees developed by the highway department maintenance personnel and deterioration matrices developed from the Texas performance equations. This current system is viewed as a first-level pavement management system. Efforts are underway to improve and extend this system to meet more of the Department's pavement management requirements.

Below are a list of recommendations as to how the system could be improved and expanded.

1. Evaluation of Preventive Maintenance and Rehabilitation Costs.

   The current system contains costs for the 14 maintenance strategies and the 5 rehabilitation strategies. There is a need to evaluate whether the costs are correctly represented within PES. This can be best done by surveying via a fill-in-the-blank questionnaire, the actual maintenance and rehabilitation costs district by district.

2. Evaluation of the Effect of Maintenance Strategies on the Life of a Pavement. Currently the maximum gain table for preventive maintenance strategies has been developed using the field experience of various highway engineers. However, there is a need for a more sound set of decisions in this area. This can be best achieved by monitoring for a period not less than 3 years

typical sections of road that have been treated with one or more of the maintenance strategies. It would be desirable to monitor sections in different areas of the State so the effect of climatic factors on the maintenance strategies can also be measured.

3. Need for Structural Evaluation. Pavements which are structurally very weak but have recently received maintenance such as thin overlay or seal coat could be rated very high within the existing PES, because its true structural condition has been masked. This makes it necessary to develop a methodology to include a structural condition utility in the pavement score calculation.

4. Budget and Time Optimization. An optimization scheme should be developed to deal with the limited availability of funds for the selected projects. A number of methods can be used to obtain a selection of desirable projects. These methods vary from ranking methods to optimization methods. Some of the suggested methods are listed below:

   a) Benefit/cost ranking
   b) Linear programming
   c) Integer programming, and
   d) Dynamic programming.

5. Link to Project Level Pavement Management System. The department has network level (PES) and a project level (FPS and RPS) pavement management systems. However, there is an urgent need to tie these systems together so that more cost-effective pavement rehabilitation programs can be developed. Specific areas of interest are:

   a. Interpretation of PES outputs. The Department does a good job in training raters on how to input information into the system. However, more attention should be given to instructing the Districts on how to interpret and use the outputs. This training could take the form of a report or regional schools for the District personnel responsible for using pavement evaluation data in preparing pavement improvement programs.

   b. Pavement Failure Analysis. PES identifies pavements in poor condition, it does not indicate the cause of the poor condition. Identification of this cause is fundamental to developing a pavement rehabilitation strategy.

      Many techniques are available for identifying the causes of pavement deterioration and several TTI reports (15) have given guidelines. It is recommended that schools be developed to train District personnel in pavement failure analysis. The PES data would be used as a starting point;

the need for detailed visual inspection, non-destructive and laboratory testing would be described by analysis of actual sections of highway. The goal of these schools would be to provide a badly needed link between the departments network and project level pavement management activities.

6. <u>Evaluation of Weighting Factors</u>. The current system contains several weighting factors for variables such as area of distress, traffic level, and climatic conditions. There is a need to evaluate whether these weights are correctly represented within PES. This can best be done by comparing the list of candidate rehabilitation projects as prepared by the Districts with their corresponding PES score, traffic level, etc. Statistical techniques such as discriminant analysis can be used to determine if adequate weighting is being given to each variable.

7. <u>Adaptation of Program for Use on Microcomputer</u>. The current system is based on mainframe, efforts are currently underway to transfer it to microcomputer.

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APPENDICES

TABLE A-1. Variables Used in the Regression Models

Environmental	Structural	Pavement History
Thornthwaite Index (TI)	Plasticity Index (PI)	
Freeze/Thaw (F/T)	Equivalent Thickness (H')[1]	N-18/month (N-18)
Average Temperature (T_{AVG})	Percent Asphalt Binder (Binder)[2]	
Plasticity Index (PI)	Overlay Thickness (OVTH)[3]	
Liquid Limit (LL)	Total Asphalt Thickness (ASPH)[4]	
	Surfacing Thickness (HMAC)[5]	
	Dynaflect Mean Deflection (DMD)	

1. Equivalent thickness is the transformed pavement thickness based on the following expression:

$$H' = \sum_{i=1}^{m} (E_i/E_s)^n \, t_i$$

where

m = number of pavement layers under consideration

E_i = elastic modulus for the i-th layer

t_i = thickness of the i-th layer

E_s = elastic modulus of the subgrade as determined from Dynaflect measurements.

n = Odemark's constant (0.33) or can be obtained from field data.

Appendix A

ρ and β Equations for Sigmoidal

$$g = \exp\left(-\frac{\rho}{N}\right)^{\beta}$$

for longitudinal and transverse cracking N is in terms of Number of Months in service. For all other distress types N is in terms of 18 kip ESAL.

TABLE A-1. Variables Used in the Regression Models (Cont'd)

In the regression models this variable is transformed as follows:

$$HPR2 = H'*E_s/10^5$$

The HPR3 term appearing in the regression equations is defined as follows:

$$HPR3 = \frac{10^{10}}{E_s * (H')^3}$$

FOOTNOTES TO TABLE A-1

2. This term is for black base and hot mix asphalt concrete pavements.
3. This term is for overlay pavements.
4. This term is for black base pavements. It is the total asphalt thickness of black base + surfacing course.
5. This term is for Hot Mix pavements.
6. The N-18/month value represents the observed value during the first performance period.

TABLE A-2. Arithmetic Regression Models for the Design Parameters (PSI)

Black Base

$$\rho = -0.02182(F/T) - 0.00831(PI) + 0.04499(Binder) + 0.15019(HPR2)$$

$$\beta = 0.01201(TI) + 0.03166(F/T) + 0.13775(T_{AVG}) + 0.00114(PI) - 0.31331(Binder) - 0.03234(HPR2)$$

$$P_f = -0.00637(F/T) - 0.01550(T_{AVG}) - 0.00658(PI) + 0.27714(Binder) + 0.05097(HPR2)$$

Hot Mix

$$\rho = -0.02000(TI) - 0.02481(F/T) - 0.03078(PI) + 0.60781(Binder) + 0.06424(HPR2)$$

$$\beta = 0.04045(F/T) + 0.22931(T_{AVG}) - 0.53013(Binder)$$

$$P_f = -0.00665(F/T) - 0.07017(T_{AVG}) - 0.02473(PI) + 0.57235(Binder) + 0.00722(HPR2)$$

Overlays

$$\rho = 0.26503(OVTH) + 0.07180(HPR2)$$

$$\beta = 0.00413(TI) + 0.01036(F/T) + 0.04759(T_{AVG}) + 0.01707(N\text{-}18) - 0.09144(OVTH) - 0.01066(HPR2)$$

$$P_f = 0.33037(OVTH) + 0.07627(HPR2)$$

TABLE A-3. Logarithmic Regression Models for the Design Parameters (PSI)

Black Base

$$\rho = (F/T)^{-0.46679} * (T_{AVG})^{-0.86233} * (PI)^{-0.26711} * (HPR2)^{1.65694}$$

$$\beta = (F/T)^{-0.60949} * (T_{AVG})^{0.93499} * (Binder)^{-1.37608} * (HPR2)^{-0.72725}$$

$$P_f = (F/T)^{-1.50634} * (T_{AVG})^{-2.69460} * (Binder)^{4.17755} * (HPR2)^{1.60919}$$

Hot Mix

$$\rho = (TI)^{-0.31419} * (F/T)^{-0.69942} * (T_{AVG})^{-0.96204} * (Binder)^{0.44492} * (HPR2)^{1.85110}$$

$$\beta = (F/T)^{0.40391} * (T_{AVG})^{0.44517} * (N\text{-}18)^{0.04576} * (Binder)^{-1.50340}$$

$$P_f = (F/T)^{-0.89516} * (T_{AVG})^{-3.14575} * (Binder)^{5.31210} * (HPR2)^{0.44486}$$

Overlays

$$\rho = (F/T)^{-0.24351} * (Binder)^{0.71372} * (HPR2)^{0.185059}$$

$$\beta = (F/T)^{0.09767} * (N\text{-}18)^{0.17402} * (Binder)^{-0.30623} * (HPR2)^{-0.22623}$$

$$P_f = (F/T)^{-0.14525} * (T_{AVG})^{-0.25053} * (N\text{-}18)^{-0.24283} * (Binder)^{0.32304} * (HPR2)^{0.62508}$$

TABLE A-4. Regression Equations for Black Base Pavements

Rutting

Area

ρ = 0.00175 F/T - 0.0141 T_{AVG} + 0.257 ASPH

β = -0.00493 F/T + 0.0262 T_{AVG} + 0.0387 PI - 0.0433 ASPH

Severity

ρ = 0.00263 - 0.0137 T_{AVG} + 0.253 ASPH

β = 0.00337 TI - 0.00928 F/T + 0.0341 T_{AVG} + 0.0242 PI - 0.071 ASPH

Alligator

Area

ρ = 0.134 HPR2 - 0.067 HPR3

β = 0.856 HPR3

Severity

ρ = -0.00986 PI + 0.0422 ASPH + 0.0554 HPR2

β = 1.37 HPR3

Longitudinal

Area

ρ = 5.33 ASPH + 29.44 BINDER - 6.38 HPR3

β = 0.0181 T_{AVG} + 0.421 HPR3

Severity

ρ = -0.425 F/T - 0.0943 PI - 2.915 ASPH + 22.16 BINDER - 11.59 HPR3

β = 0.118 TI + 0.0389 F/T - 0.731 BINDER + 0.553 HPR3

Transverse

Area

ρ = -1.739 PI + 0.428 ASPH + 48.38 BINDER - 46.7 HPR3

β = 0.0153 F/T + 0.625 HPR3

Severity

ρ = -0.502 PI + 26.75 BINDER - 29.96 HPR3

β = 0.165 TI + 0.0362 F/T - 1.047 BINDER + 1.1488 HPR3

TABLE A-5. Regression Equations for Hot Mix Pavements

Rutting

Area

$$\rho = 0.2776\ HMAC + 0.0151\ HPR2$$

$$\beta = 0.0128\ TI + 0.0326\ T_{AVG} - 0.0331\ HMAC - 0.00382\ HPR2$$

Severity

$$\rho = -0.00770\ PI + 0.386\ HMAC$$

$$\beta = -0.000720\ F/T + 0.0273\ T_{AVG} - 0.00267\ HMAC - 0.000418\ HPR2$$

Alligator

Area

$$\rho = 0.372\ HMAC$$

$$\beta = 2.198\ HPR3$$

Severity

$$\rho = -0.0000749\ PI + 0.291\ HMAC$$

$$\beta = 3.145\ HPR3$$

Longitudinal

Area

$$\rho = -0.988\ F/T + 4.38\ T_{AVG} - 2.99\ PI + 7.21\ HMAC$$

$$\beta = 0.0422\ F/T + 0.359\ HPR3$$

Severity

$$\rho = -0.144\ TI + 3.018\ T_{AVG} - 3.155\ PI + 8.331\ HMAC$$

$$\beta = 0.0343\ TI + 0.0502\ F/T$$

Transverse

Area

$$\rho = -1.97\ TI - 0.326\ F/T + 5.193\ T_{AVG} - 1.768\ PI - 26.3\ HPR3$$

$$\beta = 0.017\ TI - 0.0433\ F/T - 0.115\ HMAC - 0.0159\ HPR2 + 0.259\ HPR3$$

Severity

$$\rho = -0.196\ TI + 2.90\ T_{AVG} - 2.690\ PI + 5.475\ HMAC$$

$$\beta = 0.0519\ F/T + 0.537\ HPR3$$

TABLE A-6. Regression Equations for Overlaid Pavements

Rutting

Area

$$\rho = -0.00119\ PI + 0.369\ OVTH + 0.0485\ HPR2$$

$$\beta = 0.0059\ TI - 0.00217\ F/T + 0.0206\ T_{AVG} - 0.122\ OVTH + 0.0789\ HPR3$$

Severity

$$\rho = -0.00507\ PI + 0.233\ OVTH + 0.0705\ HPR2 - 0.000779\ HPR3$$

$$\beta = 0.00900\ TI + 0.0146\ T_{AVG} + 0.0024\ PI - 0.0789\ OVTH + 0.0840\ HPR3$$

Alligator

Area

$$\rho = -0.0159\ F/T + 0.00820\ T_{AVG} - 0.0121\ PI + 0.0162\ OVTH + 0.145\ HPR2 - 0.0135\ HPR3$$

$$\beta = 0.0185\ TI + 0.171\ HPR3$$

Severity

$$\rho = -0.00975\ F/T + 0.0152\ T_{AVG} - 0.0106\ PI + 0.0568\ HPR2 - 0.0315\ HPR3$$

$$\beta = 0.0301\ TI + 0.2267\ HPR3$$

Longitudinal

Area

$$\rho = -0.0168\ TI - 0.0870\ F/T + 1.63\ T_{AVG} - 0.179\ PI + 2.68\ OVTH + 0.840\ HPR2$$

$$\beta = 0.0331\ TI + 0.00433\ F/T - 0.00713\ T_{AVG} - 0.0589\ OVTH + 0.399\ HPR3$$

Severity

$$\rho = -0.214\ F/T + 1.55\ T_{AVG}$$

$$\beta = 0.0218\ TI + 0.0134\ F/T - 0.0156\ HPR2 - 0.073\ HPR3$$

Transverse

Area

$$\rho = -0.794\ F/T + 1.922\ T_{AVG} + 22.81\ OVTH$$

$$\beta = -0.0097\ TI + 0.0149\ F/T - 0.0229\ T_{AVG} + 0.0441\ PI - 0.129\ OVTH + 0.480\ HPR3$$

TABLE A-6. Regression Equations for Overlaid Pavements (cont'd)

Transverse (cont'd)

Severity $\rho = -0.0627\ F/T + 1.23\ T_{AVG} + 5.273\ OVTH$

$\beta = 0.0187\ TI + 0.0117\ F/T + 0.0109\ PI - 0.0305\ HPR2 + 0.108\ HPR3$

TABLE A-7. Regression Equations for Surface Treated Pavements

PSI

$$\rho = -0.173 + 0.00687 * T_{AVG} - 0.000632 * TI + 0.0133 * FLEXL + 0.00075 * LL + 0.00153 * F/T - 0.0214 * DMD$$

$$\beta = 1.0$$

$$P_f = 0.83$$

Rutting

Area

$$\rho = -0.1035 + 0.00544 * T_{AVG} + 0.0067 * FLEXL - 0.0015 * LL + 0.00162 * PI + 0.00077 * F/T$$

$$\beta = 1.540 + 0.0169 * TI - 0.072 * FLEXL$$

Severity

$$\rho = -0.0678 + 0.00320 * T_{AVG} + 0.00566 * FLEXL - 0.00031 * LL + 0.00048 * F/T$$

$$\beta = 1.78$$

Ravelling

Area

$$\rho = 1.03 + 0.0146 * TI + 0.0064 * F/T - 0.609 * DMD$$

$$\beta = 1.28$$

Severity

$$\rho = 0.62 + 0.0129 * TI + 0.0066 * F/T - 0.449 * DMD$$

$$\beta = 1.40$$

Flushing

Area

$$\rho = 0.488 + 0.013 * TI + 0.00345 * F/T - 0.213 * DMD$$

$$\beta = 1.27$$

Severity

$$\rho = -0.14 + 0.031 * T_{AVG} + 0.0103 * \text{[illegible]} - \text{[illegible]} - 0.201 * DMD$$

$$\beta = 1.50$$

Alligator

Area

$$\rho = -0.179 + 0.0121 * T_{AVG} + 0.004 * FLEXL - 0.0011 * LL + 0.00153 * F/T$$

TABLE A-7. Regression Equations for Surface Treated Pavements (Cont'd)

Alligator (cont'd)

Area (cont'd) $\beta = 1.867 - 0.009 * TI + 0.144 * FLEXL - 0.577 * DMD$

Severity $\rho = -0.22 + 0.012 * T_{AVG} + 0.00033 * TI + 0.0027 * FLEXL - 0.00058 * LL + 0.0017 * F/T$

$\beta = 2.91 - 0.099 * T_{AVG} + 0.013 * FLEXL - 1.567 * DMD$

Longitudinal

Area $\rho = -63.1 + 4.52 * T_{AVG} + 0.541 * TI + 7.41 * FLEXL + 1.11 F/T$

$\beta = 1.15$

Severity $\rho = -120 + 6.77 * T_{AVG} + 1.14 * TI + 4.78 * FLEXL + 1.32 * F/T$

$\beta = 1.20$

Transverse

Area $\rho = -66.4 + 2.156 * TI + 10.1 * FLEXL + 0.718 * F/T$

$\beta = 2.06 + 0.0734 * FLEXL - 0.06 * LL + 0.061 * PI - 0.0037 * F/T$

Severity $\rho = 96.3 - 1.04 * T_{AVG} + 1.07 * TI - 0.318 * F/T$

$\beta = 1.10 + 0.16 * LL - 0.24 * PI - 0.015 * F/T$

Patching

Area $\rho = 0.008 + 0.0025 * T_{AVG} + 0.00022 * TI + 0.0017 * FLEXL - 0.0012 * PI$

$\beta = 1.75$

Severity $\rho = -0.04 + 0.0035 * T_{AVG} + 0.003 * FLEXL - 0.0004 * LL + 0.00039 * F/T$

$\beta = -0.16 + 0.050 * T_{AVG} + 0.090 * FLEXL - 0.069 * LL + 0.082 * PI - 0.027 * F/T$

Appendix B

Decision Rules proposed to generate maintenance alternatives for flexible pavments.

Codes

1 Seal Cracks
2 Partial (Skin) Patch
3 Full Depth Patch
4 Fog Seal
5 Strip Seal
6 Seal Coat
7 Asphalt-Rubber Seal
8 Slurry Seal
9 Level-up
10 Thin Overlay
11 Rotomill
12 Spot Seal
13 Rotomill + Seal Coat
14 Rotomill + Thin Overlay

Table B-1. Selection Maintenance Strategy, Serviceability Index

Performance Equation: PSI

Pavement Type	Traffic	PSI 3.0-3.5	PSI 2.5-3.0	PSI 1.5-2.0	PSI 1.5
4	LL	0	9	9	10
	LH	0	9	10	10
	HL	0	9	9	10
	HH	0	9	10	10
5	LL	0	9	9	9
	LH	0	9	9	10
	HL	0	9	9	10
	HH	0	9	10	10
6	LL	0	9	9	9
	LH	0	9	9	10
	HL	0	9	9	9
	HH	0	9	10	10
7	LL	0	0	9	9
	LH	0	9	9	9
	HL	0	9	9	10
	HH	0	9	10	10
8	LL	0	0	9	9
	LH	0	9	9	10
	HL	0	9	10	10
	HH	0	9	10	10
9	LL	0	0	9	9
	LH	0	9	9	9
	HL	0	9	10	10
	HH	0	9	10	10
10	LL	0	0	0	0
	LH	0	0	0	9
	HL	0	9	9	9
	HH	0	9	10	10

Table B-2. Selection Maintenance Strategy, Pavement Type 4

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

Distress	Traffic	Area 100	Area 010	Area 001
Slight Rutting	LL	11	11	11
	LH	11	11	11
	HL	11	11	11
	HH	11	11	11
Severe Rutting	LL	9	14	14
	LH	13	14	14
	HL	13	14	14
	HH	13	14	11
Raveling	LL	4	6	6
	LH	4	6	6
	HL	4	10	10
	HH	4	10	10
Flushing	LL	11	11	11
	LH	11	11	11
	HL	11	10	10
	HH	11	10	10
Failures	LL	3	3	3
	LH	3	3	3
	HL	3	3	3
	HH	3	3	3
Lontigudinal Cracking	LL	1	1	6
	LH	1	1	7
	HL	1	1	7
	HH	1	1	7
Transverse Cracking	LL	1	1	6
	LH	1	1	7
	HL	1	1	7
	HH	1	1	7
Alligator Cracking	LL	12	6	7
	LH	7	7	7
	HL	12	6	10
	HH	7	7	10

Table B-3. Selection Maintenance Strategy, Pavement Type 5

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

Distress	Traffic	Area 100	Area 010	Area 001
Slight Rutting	LL	9	9	9
	LH	9	9	11
	HL	9	9	9
	HH	9	9	11
Severe Rutting	LL	9	11	14
	LH	9	14	14
	HL	11	11	14
	HH	11	14	14
Raveling	LL	4	6	5
	LH	4	6	5
	HL	4	10	10
	HH	4	10	10
Flushing	LL	5	6	6
	LH	5	6	6
	HL	5	6	6
	HH	5	6	6
Failures	LL	3	3	3
	LH	3	3	3
	HL	3	3	3
	HH	3	3	3
Alligator Cracking	LL	12	12	6
	LH	12	6	7
	HL	12	6	7
	HH	12	7	7
Longitudinal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
Transverse Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6

Table B-4. Selection Maintenance Strategy, Pavement Type 6

Thin ACP - 2 1/2" Peformance Equation: Hot Mix

Distress	Traffic	Area 100	Area 010	Area 001
Slight Rutting	LL	9	9	9
	LH	9	9	9
	HL	9	9	9
	HH	9	9	10
Severe Rutting	LL	9	9	9
	LH	9	10	10
	HL	9	9	9
	HH	9	10	10
Raveling	LL	4	4	5
	LH	4	4	5
	HL	4	6	6
	HH	4	6	6
Flushing	LL	0	5	6
	LH	0	5	6
	HL	5	6	6
	HH	6	6	6
Failures	LL	3	3	3
	LH	3	3	3
	HL	3	3	3
	HH	3	3	3
Alligator Cracking	LL	12	12	5
	LH	12	12	6
	HL	12	5	5
	HH	12	5	6
Longitudinal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
Transverse Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6

Table B-5. Selection Maintenance Strategy, Pavement Type 7

Composite Peformance Equation: Overlay

Distress	Traffic	Area 100	Area 010	Area 001
Slight Rutting	LL	11	9	9
	LH	11	9	9
	HL	11	9	9
	HH	11	9	10
Severe Rutting	LL	9	9	10
	LH	13	13	14
	HL	9	9	14
	HH	9	13	14
Raveling	LL	4	4	5
	LH	4	4	5
	HL	4	6	6
	HH	4	6	6
Flushing	LL	0	5	6
	LH	0	5	6
	HL	5	6	6
	HH	6	6	6
Failures	LL	3	3	3
	LH	3	3	3
	HL	3	3	3
	HH	3	3	3
Alligator Cracking	LL	12	12	5
	LH	12	12	6
	HL	12	5	5
	HH	12	5	6
Longitudinal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
Transversal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6

Table B-6. Selection Maintenance Strategy, Pavement Type 8

Overlay (concrete) Peformance Equation: Overlay

Distress	Traffic	Area 100	Area 010	Area 001
Slight Rutting	LL	9	9	9
	LH	9	9	10
	HL	9	9	9
	HH	9	9	10
Severe Rutting	LL	9	9	10
	LH	13	13	14
	HL	9	9	14
	HH	13	14	14
Raveling	LL	4	4	5
	LH	4	4	5
	HL	4	6	6
	HH	4	6	6
Flushing	LL	0	5	5
	LH	0	5	5
	HL	5	6	6
	HH	6	6	6
Failures	LL	3	3	3
	LH	3	3	3
	HL	3	3	3
	HH	3	3	3
Alligator Cracking	LL	12	12	5
	LH	12	12	6
	HL	12	5	5
	HH	12	5	6
Longitudinal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
Transverse Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6

Table B-7. Selection Maintenance Strategy, Pavement Type 9

Overlay (flexible) Peformance Equation: Overlay

Distress	Traffic	Area 100	Area 010	Area 001
Slight Rutting	LL	9	9	9
	LH	9	9	9
	HL	9	9	10
	HH	9	9	10
Severe Rutting	LL	9	9	10
	LH	9	10	10
	HL	9	9	10
	HH	9	10	10
Raveling	LL	4	4	5
	LH	4	4	5
	HL	4	6	6
	HH	4	6	6
Flushing	LL	0	5	6
	LH	0	5	6
	HL	5	6	6
	HH	6	6	6
Failures	LL	3	3	3
	LH	3	3	3
	HL	3	3	3
	HH	3	3	3
Alligator Cracking	LL	12	12	5
	LH	12	12	6
	HL	12	5	5
	HH	12	5	6
Longitudinal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
Transverse Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6

Table B-8. Selection Maintenance Strategy, Pavement Type 10

Surface Treatment Peformance Equation: Surf. Treat.

Distress	Traffic	Area 100	Area 010	Area 001
Slight Rutting	LL	0	0	9
	LH	0	0	9
	HL	0	9	9
	HH	0	9	10
Severe Rutting	LL	9	9	9
	LH	9	9	10
	HL	9	9	9
	HH	9	10	10
Raveling	LL	4	4	5
	LH	4	4	5
	HL	4	6	6
	HH	4	6	6
Flushing	LL	0	5	5
	LH	0	5	5
	HL	0	6	6
	HH	5	6	6
Failures	LL	2	3	3
	LH	3	3	3
	HL	3	3	3
	HH	3	3	3
Alligator Cracking	LL	12	12	5
	LH	12	12	6
	HL	23	5	5
	HH	12	5	6
Longitudinal Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6
Transverse Cracking	LL	0	1	6
	LH	1	1	6
	HL	1	1	6
	HH	1	1	6

APPENDIX C

PAVEMENT EVALUATION SYSTEM DATA

Four different sets of data are used throughout the program. The first two are related to information for every county such as rainfall or average temperature. The third data set is the information for the decision tree, and the last one is the survey information for every pavement section analyzed.

<u>Data Set #1 (PESTAC)</u>

This data set consists of 27 Tac Tables that can be read in any order. The information stored in the tables is:

No.	Name	Description
1.	MMSADTBN	ADT boundaries by highway functional classification
2.	MMSATRAF	Traffic factors by adjusted adt ranges
3.	MMSCFREZ	County average annual freeze-thaw cycles
4.	MMSCOMPE	Composite pavement distress type and severity
5.	MMSCRAIN	County average annual inches of rainfall
6.	MMSFLEXL	Flexible pavement distress type and severity
7.	MMSFREEZ	Average annual freeze-thaw cycle boundaries
8.	MMSFUNCL	Functional classification pavement score factors
9.	MMSKIPBN	18-KIP boundaries by highway functional class.
10.	MMSMAXDS	Pavement remaining life maximum deterioration slope
11.	MMSMCCLC	Roadway maintenance cost calculation boundaries
12	MMSMINPS	Functional classification minimum allowable pavement score
13.	MMSRAINS	Average annual inches of rainfall boundaries
14.	MMSREAVU	Rehabilitated pavement estimated adjusted visual utility

No.	Name	Description
15.	MMSREHDS	Rehabilitated pavement deterioration slope
16.	MMSREHEF	Rehabilitated pavement enviromental factors
17.	MMSREHFS	Rehabilitated pavement foot-mile cost per strategy
18.	MMSREHSF	Rehabilitated pavement soil factors
19.	MMSREHSI	Rehabilitated pavement serviceability index
20.	MMSREHSN	Rehabilitated pavement skid number
21.	MMSREHTC	Rehabilitated pavement life time constant
22.	MMSSICLC	Serviceability Index utility calculation boundaries
23.	MMSSOILS	County average soil plasticity indices
24.	MMSTMING	Pavement life calculation variables
25.	MMSTMINC	Rehabilitated pavement minimum life increase
26.	MMS18KIP	Traffic factors by 18-KIP ranges
27.	MMSSNCLC	Skid number utility calculation boundaries

A complete description of these tables is given in the Pavement Evaluation System Technical Reference Manual of the SDHPT (16).

Data Set #2 (SUBOVDAT)

This data set consists of a two-dimensional array of 2 by 254. The purpose of the data set is to provide information of the average weather and Thornthwaite Index and the average temperature for every one of the 254 counties in Texas. The input format is:

C1 - C7 County identification
C8 - C16 Thornthwaite Index
C27 - C37 Average temperature

Data Set #3 (DT DATA)

DT DATA stands for decision tree data. In this file maintenance strategies are assigned to every combination of factors that might come up in the maintenance analysis. The file consists of a three-dimensional array of 7 by 28 by 4, which corresponds to seven pavement types, eight distresses with three levels of distress each, plus Serviceability Index with four levels, and four possible combinations of traffic and 18-kips.

Input form:

C1 - C11	Four strategies for possible traffic and 18-kip combinations
Lines 1 - 28	Distresses and PSI for Pavement Type 04
29 - 56	Distresses and PSI for Pavement Type 05
57 - 84	Distresses and PSI for Pavement Type 06
85 - 112	Distresses and PSI for Pavement Type 07
113 - 140	Distresses and PSI for Pavement Type 08
141 - 168	Distresses and PSI for Pavement Type 09
169 - 196	Distresses and PSI for Pavement Type 10

Data Set #4

This data set is the Texas Annual Statewide Survey data that will be analyzed by the program. The input format is as follows.

Card 1

CC	Format	Name	
1 - 4	I4	INYEAR	Year of the Survey
5 - 12	A8	RUNDAT	Date of the Run
13 - 15	I3	IHOR	Planning Horizon
16 - 18	I3	IPMNT	Maintenance Level

Card 2

CC	Format	Name	
1 - 2	I2	DIST	District Number
3 - 5	I3	CNTY	County Number
6 - 12	A7	HWAY	Highway ID Number

13 - 15	I3	BMIL	Beginning Milepost of section in analysis
16	A1	BSIGN	+ or - miles
17 - 18	F2.1	BDISP	Portion of road over or under milepost sign
19 - 21	I3	EMIL	Ending milepost
22	A1	ESIGN	+ or - miles
23 - 24	F2.1	EDISP	Portion over or under milepost
25	A1	LANE	Right or left lane
26	I1	LCOUNT	0
CC	Format	Name	
27 - 47	7I3	IVIS(I), I=1,7	Distress: rutting, raveling, flushing, failures, transversal cracking, alligator cracking, longitudinal cracking
48 - 49	F2.1	SRVC	Serviceability Index
50 - 51	F2.0	SKID	Skid resistance
52 - 53	I2	SLMT	Maximum velocity
54 - 55	I2	TYPE	Pavement type
56	I1	HWFC	Highway functional classification
57 - 58	I2	NLANES	Number of lanes
59 - 61	F3.0	WDTH	Width of the section
62 - 67	I6	ADTL	Average daily traffic for the next 20 years

68 - 72	I5	EALT	Average equivalent load for the next 20 years
73 - 74	F2.1	LGTH	Length of section
75 - 77	3X		
78 - 80	F3.2	AVUC	Adjusted visual utility score
81 - 83	I3	WVUC	Weighted visual utility score
84 - 86	F3.2	PESC	Pavement evaluation score
87 - 89	3X		
90 - 92	I3	SIUC	Serviceability Index utility score
93 - 95	I3	SKUC	Skid number utility score
CC	Format	Name	
96 - 98	I3	RMUC	Road maintenance utility score
99 -101	A3	RWAY	Roadway
102-112	11X		
113	I1	DESIGN	Design factor

Last Card: 99

COMPUTER CODE

```
C ******** CURRENT VESION AS OF MARCH 1, 1985 ************
C
C      ************************************************************
C
C      THIS PROGRAM PREDICTS PAVEMENT PERFORMANCE IN TERMS OF DISTRESS
C      AND PRESENT SERVICEABILITY INDEX FOR A TWENTY YEAR PERIOD.
C      THIS IS ACHIEVED THROUGH THE USE OF "S-SHAPED" CURVES OF THE
C      FORM:
C                                            BETA
C             DIST  =   EXP-(RHO/W)
C
C      THE STRUCTURAL PERFORMANCE OF THE PAVEMENT IS EVALUATED IN
C      TERMS OF THE FOLLOWING DISTERSS TYPES:
C
C                DISTRESS                      PRIMARY VARIABLE
C           1) RUTTING                              N-18
C           2) RAVELLING                            ADT
C           3) FLUSHING                             ADT
C           4) FAILURES                             N-18
C           5) ALLIGATOR CRACKING                   N-18
C           6) LONGITUDINAL CRACKING                TIME
C           7) TRANSVERSAL CRACKING                 TIME
C
C      ************************************************************
C
C
C
      DIMENSION     FRLANE(6), STGY(5), T(5), FUNC(7), PESM(7)
      DIMENSION     PRTY(5), UCOST(5), SCOST(5,5), HMILES(11,7)
      DIMENSION     AUPL(6), ADTF(6), EUPL(3), EALF(3)
      DIMENSION     COMPSC(8,3), FLEXSC(8,3), TCLS(5,10)
      DIMENSION     FRTH(254), RAIN(254), SOILPI(254)
      DIMENSION     RUPL(3), RFFR(3), FUPL(4), FTFR(4)
      DIMENSION     FAVU(10,5), FSDS(5,10), ECFS(25,5)
      DIMENSION     FSIU(5,5), FSKU(6,5), IVIS(7), V(8)
      DIMENSION     IORDER(8), MMCODE(27), ITOTAL(2,7)
      DIMENSION     SIBNRY(3,3), SNBNRY(3,3), CMBNRY(3,3)
      DIMENSION     TRAF(7,4), TRAFC(7), TRAFD(7)
      DIMENSION     ATNR(7,10), DSMAX(10), CLIF(3,4), SOLF(3,3)
      DIMENSION     A(20), B(20), ENDVIS(8), VI(7), RVIS(8), RVISO(8)
      DIMENSION     DISL(8,100), PSIL(50), V1(8), TIN(254), AVTP(254)
      DIMENSION     OV2(4,4), OV3(4,4), BB2(4,2), BB3(4,2), RYCOST(20)
      DIMENSION     MYCOST(20), RFCOST(20,7), IEXT(6), MFCOST(20,7)
      DIMENSION     MSTRAT(14),  UNITS(8), UNIT2(9), MTREE(7, 28, 4)
      DIMENSION     IST(9), MAREA(9), DST(6), DAREA(6), DCOST(6)
      INTEGER       BMIL,EMIL,WVUC,SIUC,SKUC,RMUC
      INTEGER       STGY, TYPE, HWFC, DESIGN, LHI
      INTEGER       DIST, CNTY, SLMT, ADTL, EALT, MNTH
      INTEGER       RUT, RAVEL, FLUSH, FAIL, ALGCRK, TRNCRK
      REAL*8        OLDHW, HWAY, RUNDAT, MMCODE, MMSIN, CMANT, CTOT
      REAL*8        TMPSIV, TMPSNV, TMPAVU, JCOST, CSUM, SCOST, UCOST
      REAL*8        CREHAB, CYMANT
      REAL          LANE, LGTH , MYCOST, MFCOST
      LOGICAL       FLAG, FRNTAG
      DATA LINENO /00/
      DATA MSTRAT / 'M-01', 'M-02', 'M-03', 'M-04', 'M-05', 'M-06',
     1              'M-07', 'M-08', 'M-09', 'M-10', 'M-11', 'M-12',
     2              'M-13', 'M-14'/
      DATA IORDER / 6, 5, 4, 7, 3, 1, 2, 8/
      DATA OV2 /10.0,14.0,18.0,22.0,
     1          18.0,22.0,26.0,30.0,
     2          18.0,22.0,26.0,30.0,
     3          14.0,18.0,22.0,26.0/
C
      DATA OV3 /14.0,12.0,10.0,8.0,
     1           8.0, 6.0, 4.0,2.0,
     2           8.0, 6.0, 4.0,2.0,
     3          10.0, 8.0, 6.0,4.0/
C
      DATA BB2 /18.0,22.0,26.0,30.0,
     1          14.0,18.0,22.0,26.0/
C
C
C
```

```
      DATA BB3 / 1.8, 1.4, 1.0, 0.6,
     1          2.0, 1.6, 1.2, 0.8/
      DATA MMCODE / 'MMSATRAF', 'MMSCFREZ', 'MMSCOMPE', 'MMSCRAIN',
     1              'MMSFLEXF', 'MMSFREEZ', 'MMSFUNCL', 'MMSRAINS',
     2              'MMSREAVU', 'MMSREHDS', 'MMSREHFS', 'MMSREHSI',
     3              'MMSREHSN', 'MMSREHTC', 'MMS18KIP', 'MMSSOILS',
     4              'MMSSICLC', 'MMSSNCLC', 'MMSMCCLC', 'MMSTMINC',
     5              'MMSADTBN', 'MMSKIPBN', 'MMSTMINI', 'MMSMAXDS',
     6              'MMSREHEF', 'MMSREHSF', 'MMSMINPS' /
      DATA OLDHW  /'        '/
      DATA FRLANE  /'A','B','C','X','Y','Z'/
      DATA PRTY   /'*    ','**   ','***  ','****','****'/
      DATA STGY   /'R-01','R-02','R-03','R-04','R-05'/
  110 FORMAT ( I3, 7X, A8)
  114 FORMAT ( 10X, F5.0, 7X, F3.2)
  118 FORMAT ( 22X, F2.0)
  124 FORMAT ( 29X, F4.3)
  125 FORMAT ( 22X, F4.3)
  134 FORMAT ( 10X, F2.0, 10X, F4.3)
  138 FORMAT ( 22X, F3.2)
  142 FORMAT ( 10X, F2.0, 10X, F3.2)
  156 FORMAT ( 22X, F5.0)
  168 FORMAT ( 22X, F2.1)
  184 FORMAT ( 22X, F3.1)
  190 FORMAT ( 22X, F5.0)
  206 FORMAT ( 22X, F2.2)
  515 FORMAT ( I4, A8, I3, I3 )
  560 FORMAT (I2,I3,A7,2(I3,A1,F2.1),A1,I1,7I3,F2.1,F2.0,2I2,I1,I2,
     1        F3.0,I6,I5,F2.1,3X,F3.2,I3,F3.2,3X,3I3,A3,11X,I1)
  600 FORMAT(1H1,
     1  'STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION',
     2  27X,'RUN DATE ',A8,27X,'PAGE',I3,/,
     3  ' PAVEMENT EVALUATION SYSTEM (PES) - PROGRAM NO. 413551',/,
     4  ' REHABILITATION STRATEGY AND COST ESTIMATES - REPORT R06',/,
     5  ' DISTRICT ',I3,/)
  605 FORMAT(' COUNTY',I4,/)
  610 FORMAT ('          +-- MILEPOST --+            +-- PV',
     1         'T. -+---------------- DISTRESS ------------------+',
     2         '------------- STRATEGY ----------------+',/,
     3         '         +    & DISP.   + F RD/ PVT. +  SCO',
     4         'RE  +                                           +',
     5         'YEAR                       MAINT    REHAB. +',/,
     6         ' HIGHWAY   BEGIN   END     C WAY TYPE  MIN. ',
     7         'CALC  RUT1 RUT2 RAVL FLUS FAIL ALIG LONG TRNS PSI',
     8         '                           COST      COST')
  611 FORMAT(/,20X,'MAINTENANCE STRATEGIES',40X,'REHAB. STRATEGIES',//,
     1        15X,'CODE',16X,'STRATEGY',37X,'CODE',16X,'STRATEGY',/,
     2        15X,'M-01',14X,'SEAL CRACKS',36X,'R-01',14X,'SEAL COAT',/,
     3        15X,'M-02',14X,'PATCH',42X,'R-02',14X,'THIN OVERLAY',/,
     4        15X,'M-03',14X,'FULL DEPTH RPAIR',31X,'R-03',14X,'MEDIUM',
     5        'OVERLAY',/,
     6        15X,'M-04',14X,'FOG SEAL',39X,'R-04',14X,'THICK OVERLAY',
     7        /,15X,'M-05',14X,'STRIP SEAL',37X,'R-05',14X,'RECONSTRUC',
     8        'TION',/,15X,'M-06',14X,'SEAL COAT',38X,/,
     9        15X,'M-07',14X,'ASPHALT-RUBBER SEAL',/,
     1        15X,'M-08',14X,'SLURRY SEAL',/,
     2        15X,'M-09',14X,'LEVEL UP',/,
     3        15X,'M-10',14X,'THIN OVERLAY',/,
     4        15X,'M-11',14X,'ROTOMILL',/,
     5        15X,'M-12',14X,'SPOT SEAL',/,
     6        15X,'M-13',14X,'ROTOMILL + SEAL',/,
     7        15X,'M-14',14X,'ROTOMILL + OVERLAY',///)
  621 FORMAT (' ')
  622 FORMAT (1X,A7)
  623 FORMAT (1H+, 7X,2(1X,I3,A1,F3.1),2X,I1)
  624 FORMAT (1H+,27X,A3,2X,I2,3X,I3,2X,I3,3X)
  625 FORMAT(1H+, 92X, I4, 2X, A4,12X, F9.2,/)
  626 FORMAT(1H+, 92X, I4, 2X, A4, 1X, A4, 7X, F9.2,/)
  627 FORMAT(1H+, 92X, I4, 2X, A4, 1X, A4, 1X, A4,2X, F9.2,/)
  628 FORMAT(1H+, 92X, I4, 2X, 3(A4,1X),/, 99X, A4,12X, F9.2,/)
  629 FORMAT(1H+, 92X, I4, 2X, 3(A4,1X),/,99X,2(A4,1X),6X,F9.2,/)
  630 FORMAT(1H+,92X,I4, 2X, 3(A4,1X),/,99X,3(A4,1X),1X,F9.2,/)
  632 FORMAT ( 1H+, 47X,8(1X,F4.1),1X,F3.1)
  634 FORMAT ( 1H+,81X,/)
```

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635 FORMAT ( 1H+,119X, F8.2,/)
636 FORMAT ( 41X, 'TOTALS:',5X,'MAINT.',
     1        2X,F11.2,3X,'REHAB.',2X, F11.2,2X,/)
640 FORMAT ( 1H+, 92X,I4,2X, A4,21X,  F9.2,/)
641 FORMAT ( 1H+,  91X,I4,2X, '*', A4, '*',20X, F9.2,/)
650 FORMAT (  21X, '******CUMULATIVE COSTS:',5X,'MAINTENANCE',
     1         2X,F12.2,3X,'REHABILITATION',2X, F12.2,2X,
     2         '************',/)
652 FORMAT( 14X, 12(1H*),
     1        40H*MILES OF ROADWAY BREAKDOWN BY PAVEMENT ,
     1        36HSCORE AND FUNCTIONAL CLASSIFICATION*, 12(1H*), /,
     2        14X, 1H*, 98X, 1H*, /,
     3        14X, 1H*, 42X, 10HDISTRICT  , I2, 44X, 1H*, /,
     4        14X, 1H*, 42X, 12H------------, 44X, 1H*, /,
     5        14X, 1H*, 98X, 1H*, /,
     6        14X, 1H*, 36X, 30HMILES IN EACH FUNCTIONAL CLASS, 32X,
     6        1H*, /, 14X, 1H*, 32X, 1H1, 9X, 1H2, 9X, 1H3, 9X, 1H4,
     7        9X, 1H5, 9X, 1H6, 9X, 1H7, 5X, 1H*, /,
     8        14X, 1H*, 29X, 7HINTERST, 3X, 7HURBANFW, 3X, 7HPRINCAR,
     9        3X, 7HMINORAR, 3X, 7HMAJORCL, 3X, 7HMINORCL,
     1        4X, 4HPARK, 4X, 1H*, /,
     1        14X, 1H*, 11X, 14HPAVEMENT SCORE, 73X, 1H*, /,
     1        14X, 1H*, 98X, 1H* )
654 FORMAT(14X, 1H*, 13X, I2, ' THRU ', I2, 5X, 7(F6.1, 4X),
     1        1H*, /, 14X, 1H*, 98X, 1H*)
656 FORMAT(14X, 1H*, 17X, '100', 8X, 7(F6.1, 4X), 1H*, /,
     2        14X, 1H*, 98X, 1H*, /,
     2        14X, 1H*, 98X, 1H*, /,
     2        14X, 100(1H*))
657 FORMAT(14X, 1H*, 98X, 1H*, /,
     1        14X, 1H*, 98X, 1H*, /,
     1        14X, 1H*, 12X, 'MEAN SCORE', 6X, 7(I6,4X), 1H*, /,
     1        14X, 1H*, 98X, 1H*, /,
     1        14X, 1H*, 12X, 'SAMPLE SIZE', 5X, 7(I6,4X), 1H*, /,
     1        14X, 1H*, 98X, 1H*, /,
     1        14X, 1H*, 98X, 1H*, /,
     1        14X, 100(1H*))
658 FORMAT(//,14X,'NOTE - FRONTAGE ROADS (ROADWAYS A-C AND X-Z) ',
     1       'ARE CONSIDERED AS FUNCTIONAL CLASS 5 (MAJORCL).', /,
     1       14X, 'NOTE - SAMPLE SIZE INDICATES NO. OF ROADWAYS',
     1       ' INSPECTED * CARE NEEDED WHEN INTERPRETING RESULTS' )
660 FORMAT( 12X, 47(1H*), 15HCOST  BREAKDOWN, 47(1H*),/,
     1          12X, 1H*, 107X, 1H*, /,
     2          12X, 1H*, 45X, 9HDISTRICT ,I3, 50X, 1H*,/,
     3          12X, 1H*, 45X, 12H------------,50X, 1H*,/,
     4          12X, 1H*, 107X, 1H*, /,
     4          12X, 1H*, 107X, 1H*,/,
     5          12X, 1H*, 4X, 7HURGENCY,14X,
     5          35HCOSTS FOR EACH RECOMMENDED STRATEGY,
     6          20X,24HSUM OF         % OF TOTAL, 3X, 1H*, /,
     7          12X,1H*,4X, 6HRATING,7X,4HR-01,7X,4HR-02,7X,4HR-03,
     7      7X,4HR-04,7X,4HR-05,16X,5HCOSTS,10X,5HCOSTS,6X,1H*)
665 FORMAT( 14X,27(1H*), 35HREHABILITATION AND MAINTENANCE COST,
     1        9H PER YEAR,29(1H*),/,
     2        14X,1H*,98X,1H*,/,14X,1H*,98X,1H*,/,
     3        14X,1H*, 20X, 4HYEAR, 15X,14HREHABILITATION, 15X,
     4        11HMAINTENANCE,19X,1H*,/, 14X, 1H*,44X,4HCOST,23X,
     5        4HCOST,23X,1H*,/,14X, 1H*, 98X, 1H*)
666 FORMAT ( 14X, 1H*, 9X, 15HCUMULATIVE COST, 13X, F12.2, 16X
     1          F12.2, 21X, 1H*)
667 FORMAT(14X, 1H*, 20X, I4, 13X, F12.2, 16X, F12.2,21X,1H*,/,
     1        14X,1H*,98X,1H*)
668 FORMAT ( 14X, 100(1H*))
669 FORMAT (14X,1H*, 98X, 1H*,/, 14X, 1H*, 98X, 1H*)
670 FORMAT( 12X, 1H*, 107X, 1H*,/,
     1    12X, 1H*, 5X, A4, 2X,5(F11.2), 12X, F11.2, 8X, F5.1, 5X, 1H*)
671 FORMAT( 12X, 19(1H*),
     1        38HREHABILITATION COST BREAKDOWN BY YEAR ,
     1        29HAND FUNCTIONAL CLASSIFICATION,18(1H*),/,
     2        12X, 1H*,102X, 1H*, /,
     3        12X, 1H*, 44X, 10HDISTRICT  , I2, 46X, 1H*, /,
     4        12X, 1H*, 44X, 12H------------, 46X, 1H*, /,
     5        12X, 1H*,102X, 1H*, /,
     6        12X, 1H*,102X, 1H*,/,
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     6         12X, 1H*, 16X, 1H1,12X, 1H2,12X, 1H3,12X, 1H4,
     7         12X,1H5,12X, 1H6,14X, 1H7, 5X, 1H*, /,
     8         12X, 1H*, 13X, 7HINTERST, 6X, 7HURBANFW, 6X, 7HPRINCAR,
     9         6X, 7HMINORAR, 6X, 7HMAJORCL, 6X, 7HMINORCL,
     1         10X, 4HPARK, 3X, 1H*, /,
     1         12X, 1H*,  5X, 4HYEAR, 93X, 1H*, /,
     1         12X, 1H*,102X, 1H* )
  672 FORMAT(12X, 1H*, 5X, I4, 1X, 7(F11.2,2X), 1X, 1H*,/,
     1         12X, 1H*,102X, 1H*)
  673 FORMAT(12X,104(1H*))
  674 FORMAT(12X,7(F10.2,4X))
  675 FORMAT( 12X, 20(1H*),
     1         35HMAINTENANCE COST BREAKDOWN BY YEAR ,
     1         29HAND FUNCTIONAL CLASSIFICATION,20(1H*),/,
     2         12X, 1H*,102X, 1H*, /,
     3         12X, 1H*, 44X, 10HDISTRICT  , I2, 46X, 1H*, /,
     4         12X, 1H*, 44X, 12H------------, 46X, 1H*, /,
     5         12X, 1H*,102X, 1H*, /,
     6         12X, 1H*,102X, 1H*,/,
     6         12X, 1H*, 16X, 1H1,12X, 1H2,12X, 1H3,12X, 1H4,
     7         12X,1H5,12X, 1H6,14X, 1H7, 5X, 1H*, /,
     8         12X, 1H*, 13X, 7HINTERST, 6X, 7HURBANFW, 6X, 7HPRINCAR,
     9         6X, 7HMINORAR, 6X, 7HMAJORCL, 6X, 7HMINORCL,
     1         10X, 4HPARK, 3X, 1H*, /,
     1         12X, 1H*,  5X, 4HYEAR, 93X, 1H*, /,
     1         12X, 1H*,102X, 1H* )
  680 FORMAT( 12X, 1H*, 107X, 1H*,/,
     1          12X,109(1H*),//,
     2          12X,'NOTE - DUE TO ROUNDING, PERCENTAGES MAY NOT SUM ',
     3          'TO EXACTLY 100.0.')
  681 FORMAT(//,12X,'***  END REPORT R06  ***')
  690 FORMAT( ////////////,
     1     38X, 37(1H*), /,
     2     38X, 1H*, 35X, 1H*, /,
     3     38X, 1H*, 2X, 31HNO RECORDS SELECTED FOR REQUEST,2X,1H*, /,
     4     38X, 1H*, 35X, 1H*, /,
     5     38X, 37(1H*))
  691 FORMAT(//,' *****   END PROGRAM NO. 413551    *****')
C
C
C        ********************************************
C        READ DATA FROM 27 TACTABLES / ANY ORDER
C        ********************************************
C
C
C         INVALID TACS TABLE NAME CAUSES RUN TO ABORT WITH MESSAGE
C             INDICATING PROBLEM TABLE NAME.
C         AT END OF TABLING, THIS FILE IS REWOUND BECAUSE CALLED
C             SUBROUTINE BIGSUB (PGM. NO. 413550) ALSO NEEDS TO
C             READ IN THESE TACS TABLES.
C
C
  999 READ ( 25, 110, END=240 ) ICODE, MMSIN
      IF ( MMSIN .NE. MMCODE(ICODE)) GOTO 99
      GOTO ( 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17,
     1        18, 19, 20, 21, 22, 23, 24, 25, 26, 27), ICODE
C
    1 DO 112 I = 1, 6
      READ ( 25, 114, END=99 ) AUPL(I), ADTF(I)
  112 CONTINUE
      GOTO 999
C
    2 DO 116 I = 1, 254
      READ ( 25, 118, END=99 ) FRTH(I)
  116 CONTINUE
      GOTO 999
C
C        NOTE - ORDER STORED IS NOT ORDER READ IN.
C
    3 DO 120 I = 1, 8
      DO 122 J = 1, 3
      READ ( 25, 124, END=99 ) COMPSC(IORDER(I),J)
  122 CONTINUE
  120 CONTINUE
      GOTO 999
```

```
C
    4 DO 126 I = 1, 254
      READ ( 25, 118, END=99 ) RAIN(I)
  126 CONTINUE
      GOTO 999
C
C         NOTE - ORDER STORED IS NOT ORDER READ IN.
C
    5 DO 128 I = 1, 8
      DO 130 J = 1, 3
      READ ( 25, 124, END=99 ) FLEXSC(IORDER(I),J)
  130 CONTINUE
  128 CONTINUE
      GOTO 999
C
    6 DO 132 I = 1, 4
      READ ( 25, 134, END=99 ) FUPL(I), FTFR(I)
  132 CONTINUE
      GOTO 999
C
    7 DO 136 I = 1, 7
      READ ( 25, 138, END=99 ) FUNC(I)
  136 CONTINUE
      GOTO 999
C
    8 DO 140 I = 1, 3
      READ ( 25, 142, END=99 ) RUPL(I), RFFR(I)
  140 CONTINUE
      GOTO 999
C
    9 DO 144 I = 1, 10
      DO 146 J = 1, 5
      READ ( 25, 138, END=99 ) FAVU(I,J)
  146 CONTINUE
  144 CONTINUE
      GOTO 999
C
   10 DO 148 I = 1, 5
      DO 150 J = 1, 10
      READ ( 25, 125, END=99 ) FSDS(I,J)
  150 CONTINUE
  148 CONTINUE
      GOTO 999
C
   11 DO 152 I = 1, 25
      DO 154 J = 1, 5
      READ ( 25, 156, END=99 ) ECFS(I,J)
  154 CONTINUE
  152 CONTINUE
      GOTO 999
C
   12 DO 157 I = 1, 5
      DO 158 J = 1, 5
      READ ( 25, 168, END=99 ) FSIU(I,J)
  158 CONTINUE
  157 CONTINUE
      GOTO 999
C
   13 DO 160 I = 1, 6
      DO 162 J = 1, 5
      READ ( 25, 118, END=99 ) FSKU(I,J)
  162 CONTINUE
  160 CONTINUE
      GOTO 999
C
   14 DO 164 I = 1, 5
      DO 166 J = 1, 10
      READ ( 25, 168, END=99 ) TCLS(I,J)
  166 CONTINUE
  164 CONTINUE
      GOTO 999
C
   15 DO 170 I = 1, 3
      READ ( 25, 142, END=99 ) EUPL(I), EALF(I)
```

```
  170 CONTINUE
      GOTO 999
C
   16 DO 174 I = 1, 254
      READ ( 25, 118, END=99 ) SOILPI(I)
  174 CONTINUE
      GOTO 999
C
   17 DO 176 I = 1, 3
      DO 178 J = 1, 3
      READ ( 25, 168, END=99 ) SIBNRY(I,J)
  178 CONTINUE
  176 CONTINUE
      GOTO 999
C
   18 DO 180 I = 1, 3
      DO 182 J = 1, 3
      READ ( 25, 184, END=99 ) SNBNRY(I,J)
  182 CONTINUE
  180 CONTINUE
      GOTO 999
C
   19 DO 186 I = 1, 3
      DO 188 J = 1, 3
      READ ( 25, 190, END=99 ) CMBNRY(I,J)
  188 CONTINUE
  186 CONTINUE
      GOTO 999
C
   20 DO 192 I = 1, 7
      DO 194 J = 1, 4
      READ ( 25, 138, END=99 ) TRAF(I,J)
  194 CONTINUE
  192 CONTINUE
      GOTO 999
C
   21 DO 196 I = 1, 7
      READ ( 25, 190, END=99 ) TRAFC(I)
  196 CONTINUE
      GOTO 999
C
   22 DO 198 I = 1, 7
      READ ( 25, 168, END=99 ) TRAFD(I)
  198 CONTINUE
      GOTO 999
C
   23 DO 200 I = 1, 7
      DO 202 J = 1, 10
      READ ( 25, 168, END=99 ) ATNR(I,J)
  202 CONTINUE
  200 CONTINUE
      GOTO 999
C
   24 DO 204 I = 1, 10
      READ ( 25, 206, END=99 ) DSMAX(I)
  204 CONTINUE
      GOTO 999
C
   25 DO 208 I = 1, 3
      DO 210 J = 1, 4
      READ ( 25, 168, END=99 ) CLIF(I,J)
  210 CONTINUE
  208 CONTINUE
      GOTO 999
C
   26 DO 212 I = 1, 3
      DO 214 J = 1, 3
      READ ( 25, 138, END=99 ) SOLF(I,J)
  214 CONTINUE
  212 CONTINUE
      GOTO 999
C
   27 DO 216 I = 1, 7
      READ ( 25, 206, END=99 ) PESM(I)
```

```
  216 CONTINUE
      GOTO 999
C
C        INVALID TACS TABLE NAME CAUSES RUN ABORT.
C
   99 WRITE ( 6, 98) MMSIN, MMCODE(ICODE)
   98 FORMAT ( 10X, 21HERROR IN READING TACS, //,
     1           14HMMSCODE READ   ,A8, 12HINSTEAD OF   , A8)
      GOTO 6000
C
C        REWIND SEQUENTIAL TACS TABLE FILE FOR SUBROUTINE BIGSUB,
C        PGM. NO. 413550, USE.
C
  240 REWIND 25
C
C
C
C     ***********************************************************
C     READ  YEAR OF INSPECTION AND PGM. RUN DATE.
C     ***********************************************************
C
C
C
      READ  (2,515) INYEAR, RUNDAT, IHOR, IPMNT
      DO 50 I = 1,254
   50 READ(1,55)TIN(I),AVTP(I)
   55 FORMAT( 7X,G9.3,20X, 20X, G10.3)
      INP98 = 0
      IREAD = 0
      IALV  =  0
C
C
C
C     ***********************************************************
C     READ FIRST NON-98 AND NON-99 (DISTRICT) RECORD AND BEGIN WORK.
C     ***********************************************************
C
C
C
      WRITE (6,611)
  770 READ   ( 2, 560) DIST, CNTY, HWAY, BMIL, BSIGN, BDISP,
     1             EMIL, ESIGN, EDISP, LANE, LCOUNT, (IVIS(I),I=1,7),
     2             SRVC, SKID, SLMT, TYPE, HWFC, NLANES, WDTH, ADTL,
     1             EALT, LGTH, AVUC, WVUC, PESC,
     3             SIUC, SKUC, RMUC, ROADWY, DESIGN
C
C
C
C     ***********************************************************
C
C     THIS SUBROUTINE CHANGES THE FIELD RATING, E.G. 100, 010, 001,
C     TO A PERCENTAGE OF THE AREA.  RANGE FROM 0 TO 100.
C
C     ***********************************************************
C
      CALL DECODE(IVIS,RVIS,RVISO)
        IDIST  =  DIST
C
C       DISTRICT = 99   --   END OF RUN.
C       DISTRICT = 98   --   NO RECORDS SELECTED FOR REPORTING FOR
C                            THE USER-SUBMITTED REPORT REQUEST.
C
      IF(DIST.EQ.99) GO TO 6000
      IF(DIST.NE.98) GO TO 780
      DIST=1000
      IPAGE=1
      LINENO=0
      WRITE (6,600) RUNDAT, IPAGE, INDIST
      WRITE (6,690)
      WRITE (6,681)
      INDIST=0
      IPAGE=0
      GOTO  770
  780 CONTINUE
```

```
C
C
C
C     ************************************************************
C     INITIALISE COST ARRAYS PREPARATORY TO BEGINNING NEW SEGMENT.
C     ************************************************************
C
C     THESE ARRAYS ARE USED IN DETERMINING COST FIGURES FOR OUTPUT
C     AT THE END OF A REPORT REQUEST OR END OF A DISTRICT WHICHEVER
C     COMES FIRST.
C
C
  840 DO 850      IZ1= 1,5
      UCOST(IZ1)       = 0.0
  850 CONTINUE
      DO 841      IZ1 = 1,20
      RYCOST(IZ1) = 0.0
      MYCOST(IZ1) = 0.0
  841 CONTINUE
      DO 842      IZ1 = 1,20
      DO 843      IZ2 = 1,7
      RFCOST(IZ1,IZ2) = 0.0
  843 CONTINUE
  842 CONTINUE
      DO 844      IZ1 = 1,20
      DO 845      IZ2 = 1,7
      MFCOST(IZ1,IZ2) = 0.0
  845 CONTINUE
  844 CONTINUE
      DO 860      IZ1= 1, 5
      DO 870      IZ2=1, 5
      SCOST (IZ1,IZ2) = 0.0
  870 CONTINUE
  860 CONTINUE
      DO 880    IZ1 = 1 ,11
      DO 890    IZ2 = 1, 7
      HMILES(IZ1,IZ2) = 0.0
  890 CONTINUE
  880 CONTINUE
      DO 892  IZ1 = 1, 2
      DO 894  IZ2 = 1, 7
      ITOTAL(IZ1,IZ2) = 0
  894 CONTINUE
  892 CONTINUE
      CSUM        = 0.0
      CMANT       = 0.0
      CTOT        = 0.0
      MNTH        = 0
      IPAGE       = 0
      CREHAB      = 0.0
C
C
C
C     ************************************************************
C     ASSIGN BASIC PROGRAM VARIABLES AND CALCULATE ITEMS SUCH AS
C     ADT, 18-KIP, AND SURFACE WIDTH FOR THE ROADWAY.
C     ************************************************************
C
C
C     ADT IS INPUT TO THIS ROUTINE AS ALL LANES BOTH DIRECTIONS.
C     18-KIP IS INPUT AS ALL LANES IN ONE DIRECTION ONLY.
C     SURFACE WIDTH (FOR COST COMPUTATIONS) IS JUDGED TO BE
C         ALL LANES FOR HWY. DESIGN 1 AND 2,
C         0.5 OF TOTAL FOR ALL OTHER HWY. DESIGNS, OR
C         EXACTLY 24.0 FEET FOR ANY FRONTAGE LANE ROADWAY NO
C              MATTER WHAT HWY. DESIGN.
C
C
C
  895 IT          = TYPE
      IFIST = 0
      CYMANT = 0.0
      ISWITH = 0
      FLAG        = .FALSE.
```

```
      IC          = HWFC
      INX = 0
      JX = 0
      IENT = 0
C
C       DETERMINE IF FRONTAGE ROAD OR NOT.  IF SO, SET FLAG FOR
C       FURTHER CALCULATIONS BELOW.
C
      FRNTAG = .FALSE.
      DO 902 ILNO = 1, 6
      IF ( LANE.EQ.FRLANE(ILNO)) GOTO 905
  902 CONTINUE
      GOTO 910
  905 IC = 5
      FRNTAG = .TRUE.
  910 CONTINUE
      IF (DESIGN .GT. 2) WDTH = WDTH / 2.0
      IF (FRNTAG) WDTH = 24.0
      RFAL        = RAIN(CNTY)
      FTCC        = FRTH(CNTY)
      PLSX        = SOILPI(CNTY)
      AADT        = FLOAT(ADTL)/2.0
      AKIP        = FLOAT(EALT)/1000.0
      IF (NLANES .LE. 3) GOTO 930
      IF (NLANES .GT. 4) GOTO 920
      AADT        = AADT * .60
      AKIP        = AKIP * .70
      GOTO 930
  920 AADT        = AADT * .40
      AKIP        = AKIP * .50
  930 CONTINUE
C    4 LANE 60/40 SPLIT        MORE THAN 4 LANES 40/60 SPLIT IN AADT
      IF ( .NOT. FRNTAG ) GOTO 950
      AADT        = 0.05 * AADT
      AKIP        = 0.05 * AKIP
  950 PSMN        = PESM(IC)
      ADTS = AADT * SLMT
C
C     ***********************************************************
C
C     SELECT/GENERATE TRANSITION MATRICES BASED ON PAVEMENT
C     TYPE.
C           DISL --- DISTRESS TRANSITION MATRIX
C                      (100 X 7)   R R F F A L T
C             T(I,J) --- FINAL STATE GIVEN CURRENT STATE I
C                        AND DISTRESS TYPE J
C             PSIL (50 X 1)   T(I) FINAL PSI GIVEN INITIAL PSI
C                               VALUE = I/10
C
C     ***********************************************************
C
C     SELECT FROM 4 SUBROUTINES DEPENDING ON PAVEMENT TYPE:
C
C           PAV. TYPE                        SUBROUTINE
C
C               4                       BLACK BASE    (BB)
C               5                       HOT MIX       (HM)
C               6                       HOT MIX       (HM)
C               7                       OVERLAY       (OV)
C               8                       OVERLAY       (OV)
C               9                       OVERLAY       (OV)
C              10                       SURF. TREAT.  (ST)
C
C     ***********************************************************
C
C  ******************SURFACE TREATMENT***********************
C
      IF (TYPE.NE.10) GO TO 970
      N18MTH = (EALT * 1000.0)/240.0
      IF (N18MTH.LT.3000.0) GO TO 659
      ID = 2
      GO TO 989
  659 CONTINUE
C
```

```
      KPESC = INT((PESC + 0.001) * 100.0)
      IF (KPESC.LT.80) GO TO 960
      DMD = 1.06
      GO TO 964
  960 IF (KPESC.LT.60) GO TO 961
      DMD = 1.30
      GO TO 964
  961 IF (KPESC.LT.40) GO TO 962
      DMD = 1.55
      GO TO 964
  962 IF (KPESC.LT.20) GO TO 963
      DMD = 1.80
      GO TO 964
  963 DMD = 2.04
  964 CONTINUE
      FLEXL =  6.0
      IF (AADT .GT. 400) FLEXL = 8.0
      IF (AADT .GT. 750) FLEXL = 10.0
      CALL ST(CNTY,IT,PESC,TIN,FRTH,AVTP,DMD,PLSX,FLEXL,DISL,PSIL,
     1        EALT,AADT, AKIP)
      GO TO 995
C
C    ********************BLACK BASE*****************************
C
  970 IF (TYPE.NE.4) GO TO 980
      ASPH    = 7.50
      KPESC = INT((PESC + 0.001) * 100.0)
      ID = IT - 3.0
      IF (KPESC.LT.25) GO TO 971
      IF (KPESC.LT.51) GO TO 972
      IF (KPESC.LT.76) GO TO 973
      HPR2 = BB2(4,ID)
      HPR3 = BB3(4,ID)
      GO TO 974
  971 HPR2 = BB2(1,ID)
      HPR3 = BB3(1,ID)
      GO TO 974
  972 HPR2 = BB2(2,ID)
      HPR3 = BB3(2,ID)
      GO TO 974
  973 HPR2 = BB2(3,ID)
      HPR3 = BB3(3,ID)
  974 CONTINUE
C
      CALL BB (CNTY,IT,PESC,TIN,FRTH,AVTP,ASPH,HPR2,HPR3,PLSX,
     1         DISL,PSIL,EALT)
      GO TO 995
C
C    ***********************HOT MIX**************************
C
  980 IF (IT.NE.5. AND . IT.NE.6) GO TO 988
      IF ( IT.EQ.6 ) GO TO 981
      HMAC = 4.0
      GO TO 983
  981 HMAC = 2.0
  983 CONTINUE
      KPESC = INT((PESC+0.001) * 100)
      ID = IT - 4.0
      IF (KPESC.LT.25) GO TO 984
      IF (KPESC.LT.51) GO TO 985
      IF (KPESC.LT.76) GO TO 986
      HPR2 = OV2(4,ID)
      HPR3 = OV3(4,ID)
      GO TO 987
  984 HPR2 = OV2(1,ID)
      HPR3 = OV3(1,ID)
      GO TO 987
  985 HPR2 = OV2(2,ID)
      HPR3 = OV3(2,ID)
      GO TO 987
  986 HPR2 = OV2(3,ID)
      HPR3 = OV3(3,ID)
  987 CONTINUE
      CALL HM(CNTY,IT,PESC,TIN,FRTH,AVTP,HMAC,HPR2,HPR3,PLSX,
```

```
     1                DISL,PSIL,EALT)
      GO TO 995
C
C    ***********************OVERLAY***********************
C
  988 CONTINUE
      ID = IT - 5.0
  989 KPESC = INT((PESC+0.001) * 100.0)
      OVTH = 2.0
      IF (KPESC.LT.25) GO TO 990
      IF (KPESC.LT.51) GO TO 991
      IF (KPESC.LT.76) GO TO 992
      HPR2 = OV2(4,ID)
      HPR3 = OV3(4,ID)
      GO TO 993
  990 HPR2 = OV2(1,ID)
      HPR3 = OV3(1,ID)
      GO TO 993
  991 HPR2 = OV2(2,ID)
      HPR3 = OV3(2,ID)
      GO TO 993
  992 HPR2 = OV2(3,ID)
      HPR3 = OV3(3,ID)
  993 CONTINUE
      CALL OV (CNTY,IT,PESC,TIN,FRTH,AVTP,HPR2,HPR3,OVTH,PLSX,
     1         DISL,PSIL,EALT)
  995 CONTINUE
C
C
C                   *************************
C                   DETAIL LINE PRINT CONTROL
C                   *************************
C
C
C        PAGE EJECT - NEW COUNTY (NEW DIST.), NEW R06 REQUEST,
C             50 OR MORE DETAIL LINES PRINTED (48 OR MORE IF
C             STARTING NEW HIGHWAY IN SAME CO. OF SAME REQ.).
C        BLANK LINE - STARTING NEW HIGHWAY IN SAME CO. OF SAME REQ.
C        NO CO. OR HWY. - ON SAME HIGHWAY IN SAME CO. OF SAME REQ.
C             BUT STARTING NEW PES SEGMENT.
C        NO CO., HWY., SEGMENT POST INFO., OR FUNC. CLASS. - OTHER
C             THAN 1ST RECORD ASSOCIATED WITH ONE PES SEGMENT ON
C             SAME HIGHWAY IN SAME CO. OF SAME REQ.
C
C
      IF (INP98.NE.0) GO TO 1000
      IF (CNTY.NE.ICNTY) GO TO 1000
      IF (LINENO.GE.40) GO TO 1000
      IF (HWAY.NE.OLDHW) GO TO 1100
      GO TO 1200
 1000 IPAGE = IPAGE + 1
      LINENO = 0
      WRITE(6,600) RUNDAT, IPAGE, DIST
      WRITE (6,605) CNTY
      WRITE(6,610)
 1100 IF (LINENO.GE.38) GO TO 1000
      LINENO = LINENO + 2
      WRITE(6,621)
      WRITE(6,622) HWAY
      GO TO 1300
 1200 LINENO = LINENO + 1
      WRITE(6,621)
      IF (LCOUNT.GT.1) GO TO 1400
 1300 WRITE(6,623) BMIL, BSIGN, BDISP, EMIL, ESIGN, EDISP, HWFC
      MNTH = 0
      ISTEP = 0
 1400 CONTINUE
      KPESC  = INT(PESC * 10.)
      KPESC  = KPESC + 1
      HMILES(KPESC,IC) = HMILES(KPESC,IC) + LGTH
      LPESC = INT(PESC * 100.)
      ITOTAL( 1, IC) = ITOTAL( 1, IC) + LPESC
      ITOTAL( 2, IC) = ITOTAL( 2, IC) + 1
      RFAL       = RAIN(CNTY)
```

```
      FTCC       = FRTH(CNTY)
C
C         ***************************************
C         CALCULATE CLIMATIC WEIGHTING FACTORS
C         ***************************************
C
      CALL FINDRF ( RFAL, RUPL, RFFR, FTCC, FUPL, FTFR, V)
C
C     ************************************************************
C
C     DO LOOP FOR THE TWENTY YEAR PERIOD
C
C     ************************************************************
C
      IYR = INYEAR
      DO 7000 IY=1,IHOR
      ISKAP = 0
      ISKIP = 0
C
C
C    IYR = INYEAR + IY
      TPESM = (PESM(IC) + 0.001) * 100.0
      KPESM = TPESM
      TPESC = (PESC + 0.001) * 100.0
      KPESC = TPESC
      WRITE(6,624) ROADWY, IT, KPESM, KPESC
      ICNTY = CNTY
      OLDHW = HWAY
      WRITE ( 6,632) (RVIS(I),I = 1,8), SRVC
C
C
C
C       ************************************************************
C       DETERMINE TRAFFIC FACTOR (TF) FOR USE ALONG A DETERIORATION
C       SLOPE IN THE CALCULATION OF A PAVEMENT'S LIFE.
C
C       THEN, BRANCH DEPENDING UPON COMPARISON OF PRESENT PAVEMENT
C       SCORE TO MINIMUM ALLOWABLE FOR THAT FUNCTIONAL CLASSIFICATION.
C       ************************************************************
C
C
C
      CALL FINDTF ( IC, AADT, AKIP, TRAF, TRAFC, TRAFD, TF, LHI)
      IF (ISTEP.NE.0) GO TO 1401
 1401 ISTEP = 1
      IF ( PESC .LT. PESM(IC) ) GO TO 2001
C
C
      IF ( KPESC .LT. IPMNT ) GO TO 1600
C
      MNTH = MNTH + 12
      IFIST = 0
      GO TO 4000
C
C
C
C       ********************************************************
C       WHEN PRESENT PAVEMENT SCORE G.T. 75, CALCULATE THE
C       SCORE FOR THE FOLLOWING YEAR USING THE AGED DISTRESSES.
C       ********************************************************
C
C       WHEN ROADWAY'S PAVEMENT SCORE EXCEEDS THE MINIMUM REQUIRED,
C       THE PROGRAM CALCULATES THE SCORE FOR THE FOLLOWING YEAR,
C       AND THE ROUTINE MAINTENANCE COST FOR THAT YEAR USING THE
C       FOLLOWING SEQUENCE OF SUBROUTINES:
C            SUBROUTINE                    PURPOSE
C
C            ROUTINE                  ROUTINE MAINTENANCE COST
C            AGING                    INCREASE % OF DISTRESS
C            SCORE                    OBTAIN PES FOR NEXT YEAR
C
C
C
```

```
C ****************************************************************
C
C       WHEN THE PAVEMENT SCORE IS LESS THAN 75 BUT GREATER THAN
C       THE MINIMUM ALLOWABLE SCORE, THE PROGRAM WILL SELECT A
C       PREVENTIVE MAINTENANCE STRATEGY. THE ONLY EXEPTION TO
C       THE RULE IS WHEN IT IS MORE COST EFFECTIVE TO HAVE A MAJO
C       BILITATION THAT WILL LAST X NUMBER OF YEARS, THAN TO HAVE
C       MANY MAINTENANCE STRATEGYES THAT WILL LAS Y NUMBER OF YEARS
C       WHERE  X = NY
C
C ****************************************************************
C
C
C            SUBROUTINE                         PURPOSE
C
C            MAITRE                         SUBROUTINE THAT WILL SET UP
C                                           THE INPUT TO SUBROUTINE TRE
C            TRE                            SELECT BEST PREVENTIVE MAINT.
C                                           STRATEGY(OR UP TO 5 STRAT.)
C            IMPROV                         RESET DISTRESSES ACCORDING TO
C                                           MAINT. STRAT. SELECTED.
C            TEST                           ECONOMIC ANALYSIS.
C            SORT                           ARRANGE IN NUMERICAL ORDER
C                                           THE MAINTENANCE STRATEGIES
C                                           SELECTED.
C            SCORE                          CALCULATE THE NEW SCORE.
C
 1600 CONTINUE
      CALL MAITRE (DIST,CNTY,HWAY,BMIL,BSIGN,BDISP,EMIL,ESIGN,EDISP,
     1       LANE,IVIS,SRVC,IT,IC,NLANES,WDTH,ADTL,EALT,
     2       KPESC, LHI, JX, RCOST,RVIS,RVISO,IEXT,ISTE,IALV,
     3       IST, MAREA, DST, DAREA, DCOST, JS, TOT)
      IF (IT.EQ.10) GO TO 1601
      IF (KPESC.GT.KPESM) GO TO 1603
 1601 IF (KPESC.GE.KPESM + 7) GO TO 1603
      IENT  =  1
      IMY = 0
      GO TO 1610
 1603  IENT = 0
      IF (IEXT(1).EQ.0) GO TO 4000
      CALL SORT(IEXT,ISTE)
      ISWITH = 1
 1602 CALL IMPROV(IEXT,ISTE,RVIS,SRVC)
      CALL SCORE(RVIS,SRVC,V,FLEXSC,ADTS,SIBNRY,FUNC,IC,IAVUC,
     1           ISIUC,PESC,IT)
      RMPT = IPMNT/100.0
      IF(PESC.GT.RMPT) GO TO 1604
      ISTE = 1
      IEXT(1) = 10
      TOT = 2.55 * LGTH * WDTH * 586.7
      GO TO 1602
 1604 CONTINUE
      IMY = 0
      IF (IEXT(1).EQ.10) GO TO 1607
      IF (ISTE.GT.3) GO TO 1607
      JX = 1
      GO TO 1610
 1607 JX = 2
 1610 CONTINUE
C
      INX = 0
      CALL TEST (DIST,IT,J,AVUC,SRVC,SKID,FAVU,FSIU,FSKU,LGTH,
     1              AVU,SIV,SNV,RVIS,ENDVIS,V,FLEXSC,ADTS,WDTH,
     2              SIBNRY,FUNC,IC,JX,RVISO,TCLS,ISWITH,ECFS,TOT,
     3              DISL,PSIL,IAVUC,ISIUC,PESC,PESM,INX,V1,SIV1,
     4          CNTY,IT,TIN,FRTH,AVTP,PLSX,
     1           OV2,OV3,BB2,BB3,OVTH,ASPH,DMD,
     2           FLEXL,EALT,HPR2,HPR3,AADT,AKIP,HMAC,IENT)
C
      INX = 0
      JX = J
      IF (J.EQ.3) IMY = 0
      IF (J.EQ.3) GO TO 3200
 1675 IF (ISTE.GT.5) GO TO 1760
```

```
      IF (ISTE.EQ.5) GO TO 1755
      IF ( ISTE.GE.4 ) GO TO 1750
      IF ( ISTE.EQ.3 ) GO TO 1725
      IF ( ISTE.EQ.2 ) GO TO 1700
      WRITE(6,625) IYR, MSTRAT(IEXT(1)), TOT
      GO TO 1775
 1700 WRITE(6,626) IYR, (MSTRAT(IEXT(I)),I=1,2), TOT
      GO TO 1775
 1725 WRITE(6,627) IYR, (MSTRAT(IEXT(I)), I=1,3), TOT
      GO TO 1775
 1750 WRITE(6,628) IYR, (MSTRAT(IEXT(I)), I=1,4), TOT
      GO TO 1775
 1755 WRITE(6,629) IYR, (MSTRAT(IEXT(I)), I=1,5), TOT
      GO TO 1775
 1760 WRITE(6,630) IYR, (MSTRAT(IEXT(I)), I=1,6), TOT
 1775 CONTINUE
      IFIST = 1
      CYMANT = CYMANT + TOT
      CMANT  = CMANT + TOT
      MFCOST(IY,IC) = MFCOST(IY,IC) + TOT
      MYCOST(IY) = MYCOST(IY) + TOT
      IF(IMY.EQ.1) GO TO 3030
      GO TO 4000
C
C        **************************************************
C        WHEN PRESENT PAVEMENT SCORE L.T. MINIMUM, CALCULATE
C        REHABILITATION NEEDS.
C        **************************************************
C
C        WHEN THE ROADWAY'S PAVEMENT SCORE IS UNDER THE MINIMUM
C        ALLOWED FOR THAT PAVEMENT TYPE USED IN THE GIVEN FUNCTIONAL
C        CLASS, REHAB. IS REQUIRED AND A SERIES OF COMPUTATIONS ARE
C        MADE.  THE MINIMUM ACCEPTABLE LIFE OF A REHABILITATED
C        PAVEMENT GIVEN THE SAME PAVEMENT TYPE AS IN PLACE AND THE
C        SAME FUNCTIONAL CLASS AS PRESENT IS GAINED.  FOR EACH OF
C        5 POSSIBLE REHAB. STRATEGIES (PROGRESSIVELY MORE ALL-
C        ENCOMPASSING), THE ESTIMATED REHABILITATED PAVEMENT SCORE
C        IS COMPUTED AND RUN THRU DETERIORATION CALCULATIONS TO
C        GAIN THE LIFE EXPECTANCY.  THIS EXPECTED LIFE IS COMPARED
C        TO THE MINIMUM ALLOWABLE TO DETERMINE WHICH OF THE 5
C        STRATEGIES HAS THE NEAREST ABOVE-MINIMUM LIFE AND THAT ONE
C        IS CHOSEN AS THE STRATEGY TO USE.  GIVEN THE CHOSEN STRATEGY,
C        COST OF REHABILITATION IS COMPUTED AND RUNNING TOTAL FOR THE
C        DISTRICT OR REPORT-REQUEST DISTRICT PORTION (WHICHEVER IS
C        LESS) ARE KEPT.  AN URGENCY-OF-REHAB-NEED IS THEN CREATED
C        BY DETERMINING JUST HOW FAR BELOW THE MINIMUM ALLOWABLE THE
C        PRESENT PAVEMENT SCORE IS.  THE 5 STRATEGY LIVES, CHOSEN
C        STRATEGY AND ITS COST, AND THE URGENCY DETERMINATION ARE
C        THEN PRINTED.
C        NEW TRANSITION MATRICES ARE CREATED FOR THE REHABILITATED
C        SECTION AND THEN THE SECTION IS AGED BASED ON THE NEW
C        MATRIX. IF STRATEGIES 1 OR 2 ARE SELECTED, THE PROGRAM WILL
C        TRY TO SELECT A MAINTENANCE STRATEGY INSTEAD.
C
C     THE SEQUENCE OF SUBROUTINES IS AS FOLLOWS:
C
C              SUBROUTINE                 PURPOSE
C
C               FINDTI              ASSIGN MINIMUM LIFE FOR
C                                   MAINTENANCE STRATEGY
C               FINAVU              CALCULATE ESTIMATED ADJUSTED
C                                   VISUAL UTILITY(AVU), ESTIMATED
C                                   SKID NUMBER(SN), AND ESTIMATED
C                                   SERVICEABILITY INDEX(SI) FOR EACH
C                                   OF 5 MAINTENANCE STRATEGIES.
C               SCORE               CALCULATE THE NEW SCORE FOR EACH
C                                   MAINTENANCE STRATEGY.
C               FITMAX              CALCULATE EXPECTED LIFE FOR EACH
C                                   MAINTENANCE STRATEGY.
C               LIMIT               PLACE ALIMIT UPON STRAT. SELECTION
C               SURVTA              ASSIGN NEW VALUES FOR GENERATION
C                                   OF TRANSITION MATRIX AFTER REHAB.
C               AGING               AGE DISTERSSES
C               SCORE               CALCULATE PES.
```

```
C
C
C
 2001 CALL FINDTI ( IC, IT, ATNR, TMNI )
       ISWITH = 1
       INX = 0
       MNTH = 0
       TMIN       = TMNI * TF
C
C
C         LOOP THRU ONCE FOR EACH OF 5 REHAB. STRATEGIES.
C
C
       DO 3000 J = 1, 5
       IF ((IT.EQ.7) .OR. (IT.EQ.8)) GOTO 3010
       CALL FINAVU ( IT, J, AVUC, SRVC, SKID, FAVU, FSIU, FSKU,
     1              AVU, SIV, SNV, RVIS,ENDVIS)
       GOTO 3020
3010  CALL FINAVU ( IT, J, AVUC,SRVC, SKID, FAVU, FSIU, FSKU,
     1              AVU, SIV, SNV, RVIS,ENDVIS)
 3020 CONTINUE
C
       ISKUC = 1000
       IRMUC = 1000
       CALL SCORE (ENDVIS,SIV,V,FLEXSC,ADTS,SIBNRY,FUNC,IC,IAVUC,ISIUC,
     1           PESF,IT)
       CALL FITMAX ( J, IT, RFAL, RUPL, FTCC, FUPL, PLSX, TF,
     1              PESF, PSMN, TCLS, FSDS, CLIF, SOLF, TMAX)
       T(J)       = TMAX
       IF ( FLAG ) GO TO 3000
       IRMS       = STGY(J)
       JX         = J
       PESC = PESF
       WVUC  =  IAVUC
       SIUC  =  ISIUC
       SKUC  =  ISKUC / 10
       RMUC  =  IRMUC / 10
       DO 2555 I=1,8
       V1(I) = ENDVIS(I)
 2555 CONTINUE
       SIV1 = SIV
       IF ( TMAX .GE. TMIN ) FLAG = .TRUE.
 3000 CONTINUE
       FLAG = .FALSE.
C
C     USE SUBROUTINE LIMIT TO CHECK FOR HIGH VOL ROADS WITH NO LOAD
C     ASSOCIATED DISTRESS OR LOW VOLUME ROADS
C     FOR EITHER SET JMAX AS MAXIMUM STRATEGY LEVEL
C
       JSET = 0
       CALL LIMIT ( IVIS, SRVC, IC, AADT, JMAX)
       IF ( JMAX .EQ. 0) GOTO 3100
       IF ( JX .LE. JMAX) GOTO 3100
       JX = JMAX
       IRMS = STGY(JMAX)
       JSET = 1
3100  AREA       = LGTH*WDTH
       IRMS = STGY(JX)
       ISTEP = 0
       IF (JX.GT.2) GO TO 3200
       GO TO 1600
C
C      ***************************************************************
C
C
C      CREATE A NEW TRANSITION MATRIX FOR THE REHABILITATED SECTION
C      USING THE END DISTRESSES AND END PAVEMENT SCORE.
C
C      INPUTS TO THIS SUBROUTINE ARE ALL THE NECESSARY VARIABLES FOR
C      FOR THE SECTION, PLUS, THE REHAB. STRATEGY TO BE USED.
C      OUTPUT FOR THIS SUBROUTINE IS THE NEW TRANSITION MATRIX.
C
C      ***************************************************************
C
 3200 CONTINUE
```

```
      IFIST = 1
      AREA = LGTH*WDTH
      IRMS = STGY(JX)
C
 3030 CALL SURVTA (CNTY,JX,IT,PESC,TIN,FRTH,AVTP,PLSX,
     1               OV2,OV3,BB2,BB3,OVTH,ASPH,DMD,DISL,
     2               FLEXL,PSIL,EALT,HPR2,HPR3,AADT,AKIP,HMAC)
      JCOST        = AREA * ECFS(DIST,JX)
      IF(IMY.EQ.1) GO TO 4000
C
C        ROUND JCOST TO NEAREST 100.00.  ENTIRE REPORT WILL THEN SHOW
C        COST FIGURES IN HUNDREDS.
C
      JCOST = (JCOST + 50.00) / 100.00
      KOST  = JCOST
      KOST  = KOST * 100
      IF(KOST.LT.100) KOST=100
      JCOST = KOST
      PDIF       = (PESM(IC) - PESC)*10.
      IPDIF      = INT(PDIF) + 1
      IF ( IPDIF .GT. 5 ) IPDIF = 5
      URGECY     = PRTY(IPDIF)
C
C        COMPUTE SUMS FOR TABLES AT END OF DISTRICT OR REQUEST
C        WHICHEVER COMES FIRST.
C
      CREHAB = CREHAB + JCOST
      CSUM       = CSUM + JCOST
      SCOST (IPDIF,JX) = SCOST (IPDIF,JX) + JCOST
      UCOST (IPDIF)   = UCOST (IPDIF) + JCOST
      IF ( JSET .EQ. 1) GOTO 3040
      WRITE (6,640) IYR, IRMS, JCOST
      GOTO 3050
 3040 WRITE (6,641) IYR, IRMS, JCOST
 3050 CONTINUE
      INDIST = DIST
      INP98 = 0
      DO 95 I = 1,8
   95 RVIS(I) = V1(I)
      SRVC = SIV1
      RFCOST(IY,IC) = RFCOST(IY,IC) + JCOST
      RYCOST(IY) = RYCOST(IY) + JCOST
      GO TO 6998
 4000 CONTINUE
      INDIST = DIST
      INP98 = 0
C
C
C     ************************************************************
C
C     CALCULATE DISTRESSES FOR NEXT YEAR, AND SCORE FOR NEXT YEAR.
C
C     INPUT IS: ACTUAL DISTRESSES, PAVEMENT TYPE, STRATEGY, AND
C               TRANSITION MATRIX.
C     OUTPUT IS: NEW DISTRESSES, AND PAVEMENT SCORE.
C
C
C     ************************************************************
C
C
      IF (IFIST.EQ.1) GO TO 6990
      WRITE(6,634)
C
      CALL AGING (JX,IT,RVISO,TCLS,INX,ISWITH, RVIS,SRVC,DISL,PSIL)
 6990 CONTINUE
      CALL SCORE (RVIS,SRVC,V,FLEXSC,ADTS,SIBNRY,FUNC,IC,IAVUC,ISIUC,
     1            PESC,IT)
      IFIST = 0
      LINENO = LINENO + 1
      IF (LINENO.GE.37) GO TO 6999
      GO TO 6998
 6999 IPAGE = IPAGE + 1
      LINENO = 0
      WRITE (6,600) RUNDAT, IPAGE, DIST
```

```
      WRITE (6,605) CNTY
      WRITE (6,610)
      WRITE (6,621)
      WRITE(6,622) HWAY
      WRITE(6,623) BMIL, BSIGN, BDISP, EMIL, ESIGN, EDISP, HWFC
C
C     ***************************************************************
C
C                       END OF THE 20 YEAR LOOP
C
C     ***************************************************************
C
 6998 CONTINUE
      IYR = INYEAR + IY
 7000 CONTINUE
      IF (IHOR.EQ.1) GO TO 1199
      WRITE(6,636) CYMANT, CREHAB
      CREHAB = 0.0
      CYMANT = 0.0
      LINENO = LINENO + 2
C
 1199 CONTINUE
C
C
C       *************************************************************
C       ALL READS OTHER THAN 1ST READ OF NON-98 AND NON-99 DISTRICT
C       INPUT RECORDS ARE DONE BELOW.
C       *************************************************************
C
C
C
 4010 READ  ( 2, 560) DIST, CNTY, HWAY, BMIL, BSIGN, BDISP,
     1              EMIL, ESIGN, EDISP, LANE, LCOUNT, (IVIS(I),I=1,7),
     2              SRVC, SKID, SLMT, TYPE, HWFC, NLANES, WDTH, ADTL,
     1              EALT, LGTH, AVUC, WVUC, PESC,
     3              SIUC, SKUC, RMUC, ROADWY, DESIGN
      IF ( DIST .EQ. 99 ) GOTO 6000
C
C     ***************************************************************
C
C     THIS SUBROUTINE CHANGES THE FIELD RATING, E.G. 100, 010, 001,
C     TO A PERCENTAGE OF THE AREA.  RANGE FROM 0 TO 100.
C
C     ***************************************************************
C
      CALL DECODE(IVIS,RVIS,RVISO)
      IF ( DIST .NE. 98 ) GOTO 4020
      INP98 = INP98 + 1
      IF (INP98.GT.1) GO TO 4025
      GO TO 4100
 4025 INDIST=1000
      IPAGE = 1
      LINENO = 0
      WRITE (6,600) RUNDAT, IPAGE, INDIST
      WRITE (6,690)
      WRITE (6,681)
      INDIST=98
      IPAGE=0
      GO TO 4010
 4020 IF (INDIST.EQ.98) GO TO 840
      IF ( SRVC .LT. 0.1 ) GOTO 4010
      IF (DIST.EQ.INDIST) GO TO 895
C
C
C
C       *************************************************************
C       OUTPUT MILEAGE AND COST SUMMARY TABLES (AT END OF DISTRICT OR
C       END OF REPORT REQUEST WHICHEVER COMES FIRST.
C       *************************************************************
C
C
C
 4100 WRITE (6,650) CMANT, CSUM
      CTOT = CMANT + CSUM
```

```
C     WRITE (6,651)  CTOT
      IPAGE = IPAGE + 1
      LINENO = 0
      WRITE (6,600) RUNDAT,IPAGE,IDIST
      WRITE (6 ,652) INDIST
      DO 4200  IZ1 = 1, 10
      IFROM = (IZ1 * 10) - 10
      IF(IZ1.EQ.1) IFROM=0
      ITO = (IZ1 * 10) - 1
      WRITE (6 ,654) IFROM, ITO, (HMILES(IZ1,IZ2), IZ2 = 1, 7)
 4200 CONTINUE
      WRITE (6 ,656) (HMILES(11,IZ2), IZ2 = 1, 7)
      DO 4490 IZ1 = 1, 7
      IF( ITOTAL(2,IZ1) .GE. 1) GOTO 4495
      ITOTAL( 1, IZ1) = 0
      GOTO 4490
 4495 ITOTAL( 1, IZ1)= ITOTAL( 1, IZ1) / ITOTAL( 2, IZ1)
 4490 CONTINUE
      WRITE ( 6, 657) ((ITOTAL(IZ1, IZ2), IZ2 = 1, 7), IZ1 = 1, 2)
      WRITE(6,600) RUNDAT, IPAGE, IDIST
      WRITE(6,665)
      IYERS = INYEAR
      DO 4220 IZ1 = 1,20
      WRITE(6,667)   IYERS,RYCOST(IZ1),MYCOST(IZ1)
      IYERS = INYEAR + IZ1
 4220 CONTINUE
      WRITE(6,668)
      WRITE(6,669)
      WRITE(6,666) CSUM, CMANT
      WRITE(6,669)
      WRITE(6,668)
      WRITE(6,600) RUNDAT, IPAGE, IDIST
      WRITE(6,671) IDIST
      IYRS = INYEAR
      DO 4240 IZ1 = 1,20
      WRITE(6,672) IYRS,(RFCOST(IZ1,IZ2),IZ2= 1,7)
      IYRS = INYEAR + IZ1
 4240 CONTINUE
      WRITE(6,673)
      WRITE(6,600) RUNDAT, IPAGE, IDIST
      WRITE(6,675) IDIST
      IYRS = INYEAR
      DO 4241 IZ1 = 1,20
      WRITE(6,672) IYRS,(MFCOST(IZ1,IZ2),IZ2= 1,7)
      IYRS = INYEAR + IZ1
 4241 CONTINUE
      WRITE(6,673)
      UCOST(4) = UCOST(4) + UCOST(5)
      DO 4500 IZ1= 1, 5
      SCOST (4,IZ1)=SCOST(4,IZ1)+SCOST(5,IZ1)
 4500 CONTINUE
      WRITE ( 6, 658)
      IPAGE = IPAGE + 1
      LINENO = 0
      WRITE (6,600) RUNDAT,IPAGE,INDIST
      WRITE (6,660) INDIST
      DO 5000    N2= 1, 4
      IF (CSUM.GT.0.00) GO TO 4998
      PERCEN=0.0
      GO TO 4999
 4998 PERCEN      = (UCOST(N2)/CSUM) * 100.0
 4999 WRITE(6,670) PRTY(N2),(SCOST(N2,IZ1), IZ1=1, 5),UCOST(N2),PERCEN
 5000 CONTINUE
      WRITE (6,680)
      IF (DIST.NE.98) GO TO 840
      INDIST=98
      WRITE(6,681)
      GO TO 4010
C
C
C        ************************************************************
C        WHEN DISTRICT = 99, END PROGRAM RUN.
C        ************************************************************
```

```
C
C
C
 6000 CONTINUE
      WRITE(6,691)
      STOP
      END
      SUBROUTINE FINDRF ( RFAL, RUPL, RFFR, FTCC, FUPL, FTFR, V )
C
C         ************************************
C         CALCULATE CLIMATIC WEIGHTING FACTORS
C         ************************************
C
C     RFAL - ANNUAL RAINFALL FOR COUNTY IN WHICH SEGMENT RESIDES.
C     RUPL - ARGUMENT VALUES FROM TACS TABLE MMSRAINS.  THESE ARE
C            INCHES-OF-RAINFALL-PER-YEAR BOUNDARIES.
C     RFFR - RESULT VALUES FROM TACS TABLE MMSRAINS.  THESE ARE FACTORS
C            ASSOCIATED WITH EACH BOUNDARY (SEE RUPL).
C     FTCC -ANNUAL FREEZE-THAW CYCLES FOR COUNTY IN WHICH SEG. RESIDES.
C     FUPL - ARGUMENT VALUES FROM TACS TABLE MMSFREEZ.  THESE ARE
C            FREEZE/THAW-CYCLES-PER-YEAR BOUNDARIES.
C     FTFR - RESULT VALUES FROM TACS TABLE MMSFREEZ.  THESE ARE FACTORS
C            ASSOCIATED WITH EACH BOUNDARY (SEE FUPL).
C     V    - 8-ELEMENT ARRAY WHICH HOLDS THE FACTORS TO BE APPLIED IN
C            COMPUTATION OF ADJUSTED VISUAL UTILITY (AVU) FROM
C            UNADJUSTED VISUAL UTILITY (UVU) IN LATER WORK.
C
C
       DIMENSION  V(8), RUPL(3), FUPL(4), RFFR(3), FTFR(4)
C     DATA RUPL   /20.0, 40.0, 99.0/
C     DATA RFFR   /1.00, 0.97, 0.94/
C     DATA FUPL   /10.0, 30.0, 50.0, 99.0/
C     DATA FTFR   /1.000, 0.973, 0.967, 0.960/
       RF         = RFFR(1)
       IF ( RFAL .LE. RUPL(1) ) GO TO 1200
       RF         = RFFR(3)
       IF ( RFAL .GT. RUPL(2) ) GO TO 1200
       RF         = RFFR(2)
 1200 CONTINUE
       FF         = FTFR(1)
       IF ( FTCC .LE. FUPL(1) ) GO TO 1500
       FF         = FTFR(4)
       IF ( FTCC .GT. FUPL(3) ) GO TO 1500
       FF         = FTFR(3)
       IF ( FTCC .GT. FUPL(2) ) GO TO 1500
       FF         = FTFR(2)
 1500 CONTINUE
C
C  NOTE - V(1) = RUTTING (1/2 IN. - 1 IN.)
C         V(2) = RUTTING (OVER 1 IN.)
C         V(3) = RAVELING
C         V(4) = FLUSHING
C         V(5) = FAILURES
C         V(6) = ALLIGATOR CRACKING
C         V(7) = LONGITUDINAL CRACKING
C         V(8) = TRANSVERSE CRACKING
C
      V(1)       = 1.00 / RF
      V(2)       = V(1)
      V(3)       = 1.0
      V(4)       = V(1)
      V(5)       = V(1) / FF
      V(6)       = V(5)
      V(7)       = V(5)
      V(8)       = V(5)
      RETURN
      END
      SUBROUTINE  FINDTI ( IC, IT, ATNR, TMNI )
C
C       *********************************************
C       ASSIGN MINIMUM LIFE FOR MAINTENANCE STRATEGY.
C       *********************************************
C
C       IC   - FUNCTIONAL CLASSIFICATION OF ROADWAY FOR REHAB.
```

```
C       IT   - PRESENT PAVEMENT TYPE OF ROADWAY FOR REHAB.
C       ATNR - TACS TABLE MMSTMINI.
C              ARG.    - 10 ENTRIES (1 FOR EACH PVT. TYPE) FOR EACH
C                        OF 7 FUNCT. CLASSES.
C              RESULT - MINIMUM ALLOWABLE LIFE FOR THE PARTICULAR
C                        PAVT. TYPE USED IN THE FUNCT. CLASS.
C       TMNI - RESULT FROM ATNR RETURNED TO CALLER.
C
      DIMENSION   ATNR(7,10)
      DATA ATNR   /70*3.00/
C
      TMNI        = ATNR(IC,IT)
      RETURN
      END
      SUBROUTINE AGING (JX,IT,RVISO,TCLS,INX,ISWITH,RVIS,SRVC,DISL,
     1                  PSIL)
C
C     ***********************************************************
C
C     DETERIORATE EACH DISTRESS USING THE TRANSITION MATRIX FOR THE
C     PAVEMENT TYPE.
C
C     ***********************************************************
C
C     JX     -      REHABILITATION STRATEGY
C     IT     -      PRESENT PAVEMENT TYPE OF ROADWAY FOR REHAB.
C     RVISO  -      8-ELEMENT ARRAY WHICH HOLDS THE DECODED ORIGINAL
C                   DISTRESSES FOR THE SECTION.
C     TCLS   -      TACS TABLE MMSRHTC.
C                   ARG. - COMBINATION OF PAVEMENT TYPE (PRESENTLY
C                          IN PLACE) AND STRATEGY UNDER INVESTIGATION
C                   RES. - TIME CONSTANT IN WHICH THE SECTION WILL
C                          NOT SUFFER ANY DISTRESS.
C     RVIS   -      8-ELEMENT ARRAY WHICH HOLDS THE ACTUAL DISTRESSES
C                    OF THE SECTION.
C     SRVC   -       ACTUAL PSI.
C     DISL   -      (8 X 100) ELEMENT ARRAY WHICH HOLDS THE TRANSITION
C                   MATRIX FOR THE DISTRESSES OF THE SECTION.
C     PSIL   -      50-ELEMENT ARRAY WHICH HOLDS THE TRANSITION MATRIX
C                   FOR THE PSI OF THE SECTION.
C
C
C
      DIMENSION DISL(8,100),PSIL(50),RVIS(8),A(8),TCLS(5,10),RVISO(8)
C
      IF (JX .NE. 0) GO TO 5
      TC = 0.0
      ITC =0
      GO TO 6
    5 TC = TCLS(JX,IT)
      ITC = INT(TC) + 1
    6 INX = INX + 1.0
      DO 10 I = 1,8
      IF (ISWITH.EQ.0.AND.INX.LT.5) GO TO 30
      IF (INX.LE.ITC) GO TO 10
      IF ( RVISO(2).LT.0.01) GO TO 11
      RVIS(1)=0.0
      GO TO 12
   11 RVIS(2) = 0.0
   12 CONTINUE
      IF (RVISO(I).GT.0.01) GO TO 20
      IF (INX.GE.TC+5) GO TO 20
   30 IF (RVIS(I).LT.0.01) GO TO 10
   20 IF (RVIS(I).LT.0.01) RVIS(I) = 1.0
      IJ = (INT(RVIS(I)))
      IF ( (RVIS(I) - IJ).GT. 0.1) IJ = IJ + 1.0
      RVIS(I) = DISL(I,IJ)
   10 CONTINUE
      IX = INT(SRVC * 10.0)
      SRVC = PSIL(IX)
      RETURN
      END
      SUBROUTINE FITMAX ( J, IT, RFAL, RUPL, FTCC, FUPL, PLSX, TF,
     1                    PESF, PSMN, TCLS, FSDS, CLIF, SOLF, TMAX)
C
C     ***********************************************************
```

```
C         CALCULATE EXPECTED LIFE FOR MAINTENANCE STRATEGY J.
C         **************************************************************
C
C         J      - 1 OF 5 STRATEGIES NOW UNDER CONSIDERATION.
C         IT     - PAVEMENT TYPE OF THE ROADWAY FOR REHAB.
C         RFAL   - AVG. ANNUAL INCHES OF RAINFALL FOR COUNTY IN WHICH
C                  ROADWAY RESIDES.
C         RUPL   - TACS TABLE MMSRAINS (ARGUMENT ONLY).
C                  ARG.    - BOUNDARIES (IN INCHES OF RAINFALL) WHICH
C                            SEPARATE LOW, MEDIUM, AND HIGH RAINFALL.
C                  RESULT - NOT USED.
C         FTCC   - AVG. ANNUAL FREEZE-THAW CYCLES FOR COUNTY IN WHICH
C                  ROADWAY RESIDES.
C         FUPL   - TACS TABLE MMSFREEZ (ARGUMENT ONLY).
C                  ARG.    - BOUNDARIES (IN FREEZE-THAW CYCLES) WHICH
C                            SEPARATE LOW, MEDIUM, AND HIGH CYCLES.
C         PLSX   - SOIL PLASTICITY INDEX FOR COUNTY IN WHICH
C                  ROADWAY RESIDES.
C         TF     - TRAFFIC FACTOR CALCULATED IN SUBROUTINE FINDTF.
C         PESF   - EXPECTED PAVEMENT SCORE OF ROADWAY GIVEN
C                  REHABILITATION USING THE STRATEGY NOW UNDER
C                  CONSIDERATION (COMPUTED IN BIGSUB, 413550).
C         PSMN   - MINIMUM ALLOWABLE PAVEMENT SCORE FOR THE ROADWAY.
C         TCLS   - TACS TABLE MMSREHTC.
C                  ARG.    - COMBINATION OF PAVEMENT TYPE (PRESENTLY IN
C                            PLACE) AND STRATEGY UNDER INVESTIGATION.
C                  RESULT - TIME (OR LIFE) CONSTANT USED IN COMPUTATION
C                            OF REHAB. STRATEGY PVT. LIFE.
C         FSDS   - TACS TABLE MMSREHDS.
C                  ARG.    - COMBINATION OF PAVEMENT TYPE (PRESENTLY IN
C                            PLACE) AND STRATEGY UNDER INVESTIGATION.
C                  RESULT - FACTOR USED IN COMPUTATION OF REHAB.
C                            STRATEGY PVT. LIFE.
C         CLIF   - TACS TABLE MMSREHEF.
C                  ARG.    - COMBINATION OF RAINFALL BOUNDARIES (RUPL)
C                            AND FREEZE-THAW CYCLE BOUNDARIES (FUPL).
C                  RESULT - CLIMATIC FACTOR FOR EACH RAIN/FREEZE-THAW
C                            COMBINATION.
C         SOLF   - TACS TABLE MMSREHSF.
C                  ARG.    - COMBINATION OF RAINFALL BOUNDARIES (RUPL)
C                            AND PLASTICITY INDEX BOUNDARIES.
C                  RESULT - SOIL FACTOR FOR EACH RAINFALL/PLASTICITY
C                            COMBINATION.
C         TMAX   - MAXIMUM PAVEMENT LIFE (IN YEARS) FOR THE STRATEGY
C                  UNDER INVESTIGATION RETURNED TO CALLER.
C
      DIMENSION  RUPL(3), FUPL(4)
      DIMENSION  TCLS(5,10), FSDS(5,10), CLIF(3,4), SOLF(3,3)
      TC         = TCLS(J,IT)
      DSI        = FSDS(J,IT)
      L = 1
      IF (RFAL.LE.RUPL(1)) GO TO 1100
      L = 3
      IF (RFAL.GT.RUPL(2)) GO TO 1100
      L = 2
 1100 CONTINUE
      K = 1
      IF (FTCC.LE.FUPL(1)) GO TO 1200
      K = 4
      IF (FTCC.GT.FUPL(3)) GO TO 1200
      K = 3
      IF (FTCC.GT.FUPL(2)) GO TO 1200
      K = 2
 1200 CONTINUE
      CF         = CLIF(L,K)
C
C       NO TACS TABLE FOR PLASTICITY INDEX BOUNDARIES.
C
      K          = 3
      IF ( PLSX .GT. 40.00 ) GO TO 1300
      K          = 2
      IF ( PLSX .GT. 20.00 ) GO TO 1300
      K          = 1
 1300 CONTINUE
```

```
      SF         = SOLF(L,K)
      DS         = DSI * TF * CF * SF
      TMAX       = TC + ( PESF - PSMN ) / DS
      RETURN
      END
      SUBROUTINE LIMIT ( IVIS, SRVC, IC, AADT, JMAX)
C
C    ***************************************************************
C
C    THIS SUBROUTINE PLACES A LIMIT UPON STRATEGY SELECTION.
C
C    ***************************************************************
C
C    JMAX IS THE MAXIMUM STRATEGY ( 1, 2 ,...) WHICH CAN BE APPLIED
C    THE RULES ARE ;
C
C    1)   AADT LT 50 THEN JMAX = 1
C
C    2)   NO SEVERE RUTTING IVIS(1), ALLIGATORING IVIS(5), OR
C         FAILURES IVIS(4), AND PSI ABOVE MINIMUM THEN JMAX = 2
C
C    3)   AS 2) WITH PSI BELOW MINIMUM JMAX = 3
C
C   JMAX IS RETURNED TO MAIN WHERE IT IS COMPARED WITH THE CHOSEN
C   STRATEGY JX
C
C   THIS ROUTINE HANDLES THE PROBLEMS OF HIGH VOLUME ROADS WHOSE
C   PAVEMENT SCORES ARE BELOW MINIMUM BUT HAVE NO LOAD ASSOCIATED
C   DISTRESS AND THOSE VERY LOW VOLUME FM'S FOR WHICH ONLY MINIMUM
C   STRATEGIES ARE APPROPRIATE
C
      DIMENSION IVIS(7), PSIMIN(7)
      DATA PSIMIN / 3.5, 3.5, 3.0, 3.0, 2.5, 2.5, 2.5 /
      JMAX = 0
      IF ( AADT .GT. 50 ) GOTO 10
      JMAX = 1
      GOTO 100
   10 SEVRUT = 0.0
      IF ( IVIS(1) .EQ. 002 .OR. IVIS(1) .EQ. 020 .OR. IVIS(1) .EQ. 200)
     1     SEVRUT = 1.0
      CRACKS = 0.0
      ICRK = IVIS(4) + IVIS(5)
      IF ( ICRK .GE. 1) CRACKS = 1.0
      IF ( SEVRUT .EQ. 1.0 .OR. CRACKS .EQ. 1.0 ) GOTO 100
      JMAX = 2.0
      IF (SRVC .GT. PSIMIN(IC)) GOTO 100
      JMAX = 3.0
  100 CONTINUE
      RETURN
      END
      SUBROUTINE DECODE(IVIS,RVIS,RVISO)
C
C     ***************************************************************
C
C     THIS SUBROUTINE TRANSFORMS THE CODED VISUAL READINGS
C
C     TO PERCENTAGES
C
C     ***************************************************************
C
C     IVIS  -     8-ELEMENT ARRAY WHICH HOLDS THE CODED VISUAL READINGS
C     RVISO -     8-ELEMENT ARRAY WHICH HOLDS THE TRANSFORMED VISUAL
C                 READINGS. RANGE 0 - 1
C
C
      REAL W(4),Z(4),F(4),L(4),T(4)
      INTEGER X(4),Y(4)
      DIMENSION RVIS(8),IVIS(7),RVISO(8)
C
      DATA F/0.0,10.71,24.99,50.0/
      DATA L/0.0,10.0,30.0,50.0/
      DATA T/0.0,8.33,29.17,50.0/
      DATA W/0.0,5.0,30.0,45.0/
      DATA X/000,100,010,001/
```

```
      DATA Y/000,200,020,002/
      DATA Z/0.0,12.0,30.0,50.0/
      DO 10 I = 1,8
   10 RVIS(I)= 0.0
C
      DO 100 I =1,4
C
C     RUTTING
C
      IF(IVIS(1).EQ.X(I)) GO TO 110
      IF(IVIS(1).EQ.Y(I)) RVIS(2) = Z(I)
      GO TO 120
  110 RVIS(1) = Z(I)
  120 CONTINUE
C
C     RAVELLING
C
      IF (IVIS(2).EQ.X(I)) RVIS(3) = Z(I)
C
C     FLUSHING
C
      IF (IVIS(3).EQ.X(I)) RVIS(4) = Z(I)
C
C     FAILURES
C
      IF (IVIS(4).EQ.X(I)) RVIS(5) = F(I)
C
C     ALLIGATOR CRACKING
C
      IF (IVIS(5).EQ.X(I)) RVIS(6) = W(I)
C
C     LONGITUDINAL CRACKING
C
      IF (IVIS(6).EQ.X(I)) RVIS(7) = L(I)
C
C     TRANSVERSAL CRACKING
C
      IF (IVIS(7).EQ.X(I)) RVIS(8) = T(I)
C
  100 CONTINUE
      DO 130 I = 1,8
  130 RVISO(I) = RVIS(I)
      RETURN
      END
      SUBROUTINE  FINAVU ( IT, J, AVUC, SRVC, SKID, FAVU, FSIU, FSKU,
     1                     AVU, SIV, SNV, RVIS, ENDVIS)
C
C        ************************************************************
C        CALCULATE ESTIMATED ADJUSTED VISUAL UTILITY (AVU), ESTIMATED
C        SKID NUMBER (SN), AND ESTIMATED SERVICABILITY INDEX (SI) FOR
C        EACH OF 5 MAINTENANCE STRATEGIES.
C        ************************************************************
C
C
C        J    - MAINTENANCE STRATEGY NO.
C        AVUC - PRESENT AVU OF THE PAVEMENT TO BE REHABILITATED.
C        SRVC - PRESENT AVG. SI VALUE OF THE PVT. TO BE REHABILITATED.
C        SKID - PRESENT AVG. SN VALUE OF THE PVT. TO BE REHABILITATED.
C        FAVU - TACS TABLE MMSREAVU.
C               ARG.   - 10 AVU BOUNDARIES FOR EACH OF 5 STRATEGIES.
C               RESULT - ESTIMATED AVU AFTER REHAB. FOR THAT STRATEGY.
C        FSIU - TACS TABLE MMSREHSI.
C               ARG.   - 5 SI BOUNDARIES FOR EACH OF 5 STRATEGIES.
C               RESULT - ESTIMATED SI OR, FOR STRATEGY 1 ONLY,
C                        INCREASE IN SI AFTER REHAB. FOR THAT STRATEGY.
C        FSKU - TACS TABLE MMSREHSN.
C               ARG.   - 6 SN BOUNDARIES FOR EACH OF 5 STRATEGIES.
C               RESULT - ESTIMATED SN AFTER REHAB. FOR THAT STRATEGY.
C        AVU  - SELECTED ENTRY FROM FAVU RETURNED TO CALLER.
C        SIV  - SELECTED ENTRY OR, FOR STRATEGY 1 ONLY, COMPUTED ITEM
C               FROM FSIU RETURNED TO CALLER.
C        SNV  - SELECTED ENTRY FROM FSKU RETURNED TO CALLER.
C
      DIMENSION   FAVU(10,5), FSIU(5,5), FSKU(6,5), MXGAIN(8,5)
      DIMENSION RVIS(8), ENDVIS(8)
```

```fortran
      REAL MXGAIN
      DATA MXGAIN /0.33, 0.0, 1.0, 1.0, 0.25, 0.6, 0.6, 0.75,
     1             1.00, 0.7, 1.0, 1.0, 0.62, 0.8, 0.8, 1.00,
     2             1.00, 1.0, 1.0, 1.0, 0.75, 1.0, 1.0, 1.00,
     3             1.00, 1.0, 1.0, 1.0, 0.87, 1.0, 1.0, 1.00,
     4             1.00, 1.0, 1.0, 1.0, 1.00, 1.0, 1.0, 1.00/
C     DATA FAVU   /0.79,0.81,0.82,0.84,0.86,0.88,0.89,0.91,0.93,0.94,
C    1             0.80,0.83,0.85,0.88,0.90,0.93,0.95,0.98,1.00,1.00,
C    2             40*1.00/
C     DATA FSIU   /0.2,0.2,0.1,0.0,0.0,5*4.3,20*4.5/
C     DATA FSKU   /36*45.0/
      DO 1200 K = 1, 9
      AL          = FLOAT(K-1) / 10.0
      AU          = FLOAT(K) /10.0
      IF ( AVUC .GE. AL .AND. AVUC .LE. AU ) GO TO 1300
 1200 CONTINUE
      K           = 10
 1300 AVU         = FAVU(K,J)
      SIV         = SRVC
      DO 1400 K = 1, 4
      AL          = FLOAT(K-1)
      AU          = FLOAT(K)
      IF ( SRVC .GE. AL .AND. SRVC .LE. AU ) GO TO 1500
 1400 CONTINUE
      K           = 5
 1500 IF ( J .GT. 1 ) GO TO 1600
      SIV         = SIV + FSIU(K,J)
      GO TO 1700
 1600 SIV         = FSIU(K,J)
 1700 DO 1800 K = 1, 5
      AL          = FLOAT(K-1) * 10.0
      AU          = FLOAT(K) * 10.0
      IF ( SKID .GE. AL .AND. SKID .LE. AU ) GO TO 1900
 1800 CONTINUE
      K           = 6
 1900 SNV         = FSKU(K,J)
      IJ = J
      IF ( IT .NE. 10) GOTO 1999
      IJ = IJ + 1
      IF ( IJ .GT. 5) IJ = 5
 1999 DO 2000 I = 1, 8
      ENDVIS(I) = RVIS(I) - (MXGAIN(I,IJ)*RVIS(I))
 2000 IF (ENDVIS(I) .LE. 0.0) ENDVIS(I) = 0.0
      RETURN
      END
      SUBROUTINE SCORE (RVIS,SRVC,V,FLEXSC,ADTS,SIBNRY,FUNC,IC,
     1                  IAVUC,ISIUC,PESC,IT)
C
C     ************************************************************
C
C     THIS SUBROUTINE CALCULATES THE PAVEMENT EVALUATION SCORE BASED
C     ON THE DISTRESSES AND THE PSI.
C
C     ************************************************************
C
C     THIS SUBROUTINE CALLS TWO OTHER SUBROUTINES:
C           UTLTY1 - CALCULATES VISUAL UTILITY VALUE
C           UTLTY2 - CALCULATES RIDE UTILITY VALUE
C
C
C     RVIS   -    8-ELEMENT ARRAY WHICH HOLDS THE ACTUAL VISUAL DIST.
C     SRVC   -    ACTUAL PSI.
C     ADTS   -    AVERAGE DAILY TRAFFIC.
C     SIBNRY-     FACTOR ASSOCIATED WITH EACH OF 3 SI BOUNDARIES FOR
C                 EACH OF 3 EQUATIONS USED IN THE DETERMINATION OF
C                SERVICEABILITY INDEX (SI) UTILITY.
C     FUNC   -    FACTOR ASSOCIATED WITH THE FUNCTIONAL CLASSIFICATION
C                 OF THE ROAD USED IN THE DETERMINATION OF THE PAVEMENT
C                 SCORE.
C     IC     -    FUNCTIONAL CLASSIFICATION OF ROADWAY FOR REHAB.
C     IAVUC  -    CALCULATED ADJUSTED VISUAL UTILITY
C     ISIUC  -    CALCULATED SERVICEABILITY INDEX.
C     PESC   -    CALCULATED PAVEMENT SCORE.
C
```

```
C
      DIMENSION  V(8),RVIS(8),FLEXSC(8,3),SIBNRY(3,3),FUNC(7)
      CALL UTLTY1(V,RVIS,UVUC,AVUC,IT)
      CALL UTLTY2(ADTS,SRVC,SIBNRY,SIUC)
      UPSC = SIUC *AVUC
      FNC = FUNC(IC)
      PESC = UPSC ** (1/FUNC(IC))
      PESC = (PESC + 0.00001)
      SIUCS = SIUC * 100.0
      ISIUC = INT(SIUCS)
      AVUCS = AVUC * 100.0
      IAVUC = INT(AVUCS)
      RETURN
      END
      SUBROUTINE UTLTY1 ( V, RVIS, UVUC, AVUC,IT)
C
C     RVIS - ACTUAL % OF EACH DISTRESS RANGE 0 TO 100%
C            RVIS 1 AND RVIS 2 ARE FOR RUTTING.
C
C   ***NOTE: THIS SUBROUTINE NOW USES EQUATIONS RATHER THAN
C            A TABLE LOOK-UP TO CALCULATE SCORES.
C
C
C
C      ********************************
C      CALCULATE VISUAL UTILITY VALUE
C      NOTE - V(1) AND V(2) ARE BOTH RUTTING, THEN THE REMAINING
C             6 VISUAL ITEMS FOLLOW AS V(3) THRU V(8).  THIS IS
C             DUE TO SPECIAL CODING ABILITIES FOR RUTTING.
C      ********************************
C
C     IVIS - 7-ELEMENT ARRAY CONTAINING THE VISUAL EVALUATION ITEMS
C            WHICH ARE RUTTING, RAVELING, FLUSHING, FAILURES,
C            ALLIGATOR, LONGITUDINAL, AND TRANSVERSE CRACKING.
C     V    - 8-ELEMENT ARRAY CONTAINING THE CLIMATIC WEIGHTING FACTORS
C            FOR EACH OF THE 7 VISUAL EVALUATION ITEMS.
C     SCORE - 3 FACTORS FOR EACH OF THE 7 VISUAL EVALUATION ITEMS
C            (8 TOTAL - REMEMBER, RUTTING TAKES UP 1 AND 2) FOR FLEXIBLE
C            OR COMPOSITE PAVEMENTS.
C     UVUC - UNADJUSTED VISUAL UTILITY CALCULATED HEREIN.
C     AVUC - ADJUSTED VISUAL UTILITY CALCULATED HEREIN.
C
      DIMENSION  V(8), RVIS(8),XVIS(8)
      DIMENSION  A(8),B(8),A1(8)
      DATA A/0.3229,0.6940,0.5703,0.6467,1.3507,0.5592,0.7738,0.5446/
      DATA A1/1.0,1.0,1.0,1.0,0.28,1.0,5.0,0.24/
      DATA B/12.365,10.13,24.91,34.99,5.7778,4.962,161.98,6.7973/
      DO 10 I= 1,8
      XVIS(I) = RVIS(I) * A1(I)
   10 CONTINUE
      UVUC = 1.00
      AVUC = 1.00
      IF(RVIS(1).GT.RVIS(2)) GO TO 20
      RVIS(1) = 0.0
      GO TO 30
   20 RVIS(2) = 0.0
   30 CONTINUE
      DO 100 I = 1,8
      IF(RVIS(I).LT.0.5) GO TO 100
      U = 1 - A(I)*(EXP(-B(I)/XVIS(I)))
      UVUC = UVUC * U
      IF(IT.NE.10) GO TO 40
      IF(I.GT.2) GO TO 40
      V(I) = V(I) * 0.5
   40 CONTINUE
      AVUC = AVUC * U ** V(I)
  100 CONTINUE
      RETURN
      END
      SUBROUTINE  UTLTY2 ( AADTS, AVGSI, SIBNRY, SIUC )
C
C      ******************************
C      CALCULATE RIDE UTILITY VALUE
C      ******************************
C
```

```
C     AADTS - ADJUSTED ADT FOR LANE * SPEED LIMIT FOR SEGMENT.
C     AVGSI - AVERAGE RIDE VALUE FOR LANE OR, IF UNAVAILABLE,
C             FOR ROADWAY.
C     SIBNRY - A FACTOR ASSOCIATED WITH EACH OF 3 SI BOUNDARIES FOR
C             EACH OF 3 EQUATIONS USED IN DETERMINATION OF
C             SERVICABILITY INDEX (SI) UTILITY.
C     SIUC  - SERVICABILITY INDEX UTILITY CALCULATED HEREIN.
C
C     CNSTNT - ONE CONSTANT FOR EACH SIBNRY EQUATION WHICH IS USED
C             IN PLACE OF AN ADDITIONAL SI BOUNDARY FACTOR.
C
      DIMENSION   SIBNRY(3,3), CNSTNT(3)
C     DATA     SIBNRY   /0.8, 1.3, 1.8, 2.0, 2.5, 3.0, 2.5, 3.0, 3.5/
      DATA     CNSTNT /-0.26666, -0.55833, -0.85000/
      SIUC       = 0.0
      IF ( AVGSI .LT. 0.0 ) GO TO 2000
      NC         = 3
      IF ( AADTS .GT. 165000 ) GO TO 1300
      NC         = 2
      IF ( AADTS .GT.  27500 ) GO TO 1300
      NC         = 1
 1300 SIUC       = 1.00
      IF ( AVGSI .GE. SIBNRY(NC,3) ) GO TO 2000
      IF ( AVGSI .LT. SIBNRY(NC,2) ) GO TO 1500
      SIUC       = 1.00 - ( 0.4 * ( ( SIBNRY(NC,3) - AVGSI ) ** 2) )
      GO TO 2000
 1500 IF ( AVGSI .LT. SIBNRY(NC,1) ) GO TO 1600
      SIUC       = CNSTNT(NC) + ( 0.58333 * AVGSI )
      GO TO 2000
 1600 SIUC       = 0.20 * ( ( AVGSI / SIBNRY(NC,1) ) ** 2 )
 2000 CONTINUE
      RETURN
      END
      SUBROUTINE OV(CNTY,IT,PESC,TIN,FRTH,AVTP,HPR2,HPR3,OVTH,PLSX,
     1               DISL,PSIL,EALT)
C
C     ************************************************************
C
C     THIS SUBROUTINE USES THE SURVIVAL CURVES TO GENERATE
C      TRANSITION MATRIX FOR OVERLAY PAVEMENTS.
C
C     ************************************************************
C
C
C     CNTY    -    COUNTY NUMBER
C     IT      -    PAVEMENT TYPE
C     PESC    -    PAVEMENT SCORE
C     TIN     -    THORNTHWAITE INDEX
C     FRTH    -    FREEZE/THAW CYCLES
C     AVTP    -    AVERAGE TEMPERATURE
C     HPR2    -    EQUIVALENT THICKNESS X ELASTIC MODULUS OF THE
C                  SUBGRADE AS DETERMINE FROM DINAFLECT MEASUREMENTS
C     HPR3    -     10 ** 10 / HPR2
C     OVTH    -    OVERLAY THICKNESS
C     PLSX    -    PLASTICITY INDEX
C     BINDER  -    PERCENT ASPHALT BINDER
C     DISL    -   (8 X 100)-ELEMENT ARRAY WHICH HOLDS THE TRANSITION
C                 MATRIX FOR THE DISTRESSES OF THE SECTION IN ANALYSIS
C     PSIL    -    TRANSITION MATRIX FOR THE PSI OF THE SECTION IN
C                  ANALYSIS
C
C
      INTEGER CNTY,EALT
      REAL W(100), N18, N18MTH, N, NX, NS, PS(50), N1, N2
      DIMENSION DISL(8,100), HEADER(10), RMIN(11), RMAX(11), X(11)
      DIMENSION TIN(254),FRTH(254),AVTP(254),RAIN(254),Y(8)
      DIMENSION PSIL(50),PIS(50)
C
C
C     WRITE(6,200)
C 200 FORMAT ( '1')
      ICTY = CNTY
      XTI  = TIN(ICTY) + 50.0
      AVT  = AVTP(ICTY)
      FTC  = FRTH(ICTY)
```

```
      BINDER = 6.0
      PI = PLSX
      KNT = 0
      PO = 4.2
C
C
      XAVT = AVT - 50.0
C
      N18MTH = (EALT * 1000.0)/240.0
C
C
C     OVERLAY PAVEMENTS PSI & DISTRESS
C
C
C     LINEAR RHO & BETA, PSI
C
      X(9) = 0.26503*OVTH + 0.07182*HPR2
      X(10) = 0.00413*XTI+0.01036*FTC+0.04769*XAVT+0.01707*
     & (N18MTH/1000.0)-0.009144*OVTH-0.01066*HPR2
      X(11) = 0.33037*OVTH + 0.07627*HPR2
      IF( X(9).LT. 0.0 .OR.X(10) .LT. 0.0 .OR.X(11).LT. 0.0 ) GO TO 312
      GO TO 313
C
C     LOG RHO & BETA, PSI
C
  312 X(9) = FTC**(-0.24351)*BINDER**(0.71372)*HPR2**(0.18059)
      X(10) = FTC**(0.09767)*(N18MTH/1000.0)**(0.17402)*BINDER**
     & (-0.30623)*HPR2**(-0.22623)
      X(11) = FTC**(-0.14525)*XAVT**(-0.25053)*(N18MTH/1000.0)**
     & (-0.24283)*BINDER**(0.32304)*HPR2**(0.62508)
C
C     LINEAR RHO & BETA, RUTTING AREA
C
  313 X(1) = -0.00119*PI+0.369*OVTH+0.0485*HPR2
      X(2) = 0.0059*XTI-0.00217*FTC+0.0206*AVT-0.122*OVTH+0.0789*HPR3
      IF( X(1).LT. 0.0 .OR. X(2) .LT. 0.0 ) GO TO 322
      GO TO 323
C
C     LOG RHO & BETA, RUTTING AREA
C
  322 X(1) = PI**(-0.1925)*OVTH**(0.6058)*HPR2**(0.1246)*HPR3**(-0.4419)
      X(2) = XTI**(0.1025)*FTC**(0.0163)*OVTH**(-0.2295)*HPR3**(0.1078)
C
C     LINEAR RHO & BETA, RUTTING SEVERITY
C
  323 Y(1) = -0.00507*PI+0.233*OVTH+0.0705*HPR2-0.000779*HPR3
      Y(2) = 0.009*XTI+0.0146*AVT+0.0024*PI-0.0789*OVTH+0.084*HPR3
      IF(Y(1) .LT. 0.0 .OR. Y(2) .LT. 0.0 ) GO TO 332
      GO TO 333
C
C     LOG RHO & BETA, RUTTING SEVERITY
C
  332 Y(1) = PI**(-0.2342)*OVTH**(0.578)*HPR2**(0.1396)*HPR3**(-0.4808)
      Y(2) = XTI**(0.0575)*OVTH**(-0.1112)*HPR3**(0.1201)
C
C     LINEAR RHO & BETA, ALLIGATOR CRACK AREA
C
  333 X(3) = -0.0159*FTC+0.0082*AVT-0.0121*PI+0.0162*OVTH+0.145*HPR2
     & -0.0135*HPR3
      X(4) = 0.0185*XTI+0.171*HPR3
      IF(X(3) .LT. 0.0 .OR. X(4) .LT. 0.0 ) GO TO 342
      GO TO 343
C
C     LOG RHO & BETA, ALLIGATOR CRACK AREA
C
  342 X(3) = FTC**(-0.2777)*AVT**(0.4)*PI**(-0.2165)*OVTH**(0.4861)
     & *HPR3**(-0.6399)
      X(4) = XTI**(0.2211)*AVT**(-0.1326)*OVTH**(-0.396)*HPR3**(0.1744)
C
C     LINEAR RHO & BETA, ALLIGATOR CRACK SEVERITY
C
  343 Y(3) = -0.00975*FTC+0.0152*AVT-0.0106*PI+0.0568*HPR2-0.0315*HPR3
      Y(4) = 0.0301*XTI+0.2267*HPR3
      IF(Y(3) .LT. 0.0 .OR. Y(4) .LT. 0.0 ) GO TO 352
```

```
      GO TO 353
C
C     LOG RHO & BETA, ALLIGATOR CRACK SEVERITY
C
  352 Y(3) = FTC**(-0.1235)*AVT**(0.3885)*PI**(-0.4525)*HPR3**(-0.6859)
      Y(4) = XTI**(0.3689)*FTC**(0.178)*AVT**(-0.3259)*OVTH**(-0.4326)
     & *HPR3**(0.1931)
C
C     LINEAR RHO & BETA, LONG. CRACK AREA
C
  353 X(5) = -0.0168*XTI-0.087*FTC+1.63*AVT-0.179*PI+2.68*OVTH+0.84*HPR2
      X(6) = 0.0331*XTI+0.00433*FTC-0.00713*AVT-0.0589*OVTH+0.399*HPR3
      IF(X(5) .LT. 0.0 .OR. X(6) .LT. 0.0 ) GO TO 362
      GO TO 363
C
C     LOG RHO & BETA, LONG. CRACK AREA
C
  362 X(5) = FTC**(-0.1447)*AVT**(1.2948)*PI**(-0.2014)*OVTH**(0.1864)
     & *HPR2**(0.1004)
      X(6) = XTI**(0.2914)*FTC**(0.1358)*AVT**(-0.2956)*OVTH**(-0.0808)
     & *HPR2**(-0.0324)*HPR3**(0.2972)
C
C     LINEAR RHO & BETA, LONG. CRACK SEVERITY
C
  363 Y(5) = -0.214*FTC+1.55*AVT
      Y(6) = 0.0218*XTI+0.0134*FTC-0.0156*HPR2+0.073*HPR3
      IF(Y(5) .LT. 0.0 .OR. Y(6) .LT. 0.0 ) GO TO 372
      GO TO 373
C
C     LOG RHO & BETA, LONG. CRACK SEVERITY
C
  372 Y(5) = XTI**(-0.0015)*FTC**(-0.0989)*AVT**(1.2089)*PI**(-0.0841)
      Y(6) = XTI**(0.2159)*FTC**(0.1175)*AVT**(-0.24)*HPR3**(0.1103)
C
C     LINEAR RHO & BETA, TRANS. CRACK AREA
C
  373 X(7) = -0.794*FTC+1.922*AVT+22.81*OVTH
      X(8) = -0.0097*XTI+0.0149*FTC-0.0229*AVT+0.0441*PI-0.129*OVTH
     & +0.43*HPR3
      IF(X(7) .LT. 0.0 .OR. X(8) .LT. 0.3 ) GO TO 382
      GO TO 383
C
C     LOG RHO & BETA, LONG. CRACK AREA
C
  382 X(7) = FTC**(-0.1509)*AVT**(1.1947)*OVTH**(0.4683)
      X(8) = XTI**(0.188)*FTC**(0.2676)*AVT**(-0.3966)*PI**(0.1576)
     & *OVTH**(-0.3127)*HPR2**(-0.0719)*HPR3**(0.1899)
C
C     LINEAR RHO & BETA, TRANS. CRACK SEVERITY
C
  383 Y(7) = -0.0627*FTC+1.23*AVT+5.273*OVTH
      Y(8) = 0.0187*XTI+0.0117*FTC+0.0109*PI-0.0305*HPR2+0.108*HPR3
      IF(Y(7) .LT. 0.0 .OR. Y(8) .LT. 0.0 ) GO TO 392
C
      GO TO 393
C     LOG RHO & BETA, TRANS. CRACK SEVERITY
C
  392 Y(7) = FTC**(-0.0805)*AVT**(1.1307)*PI**(-0.0506)*OVTH**(0.173)
      Y(8) = XTI**(0.1606)*FTC**(0.0922)*AVT**(-0.2142)*PI**(0.0618)
     & *HPR3**(0.1114)
C
  393 CONTINUE
C
      RHORA = X(1)
      BETRA = X(2)
      RHOAA = X(3)
      BETAA = X(4)
      RHOLA = X(5)
      BETLA = X(6)
      RHOTA = X(7)
      BETTA = X(8)
      RHOP  = X(9)
      BETAP = X(10)
      PF    = X(11)
```

```
C
C     WRITE (6,300) RHORA, BETRA, RHOAA, BETAA, RHOTA, BETTA, RHOLA,
C    1  BETLA, RHOP, BETAP, PF
C 300 FORMAT(// 1X,10G13.5/1X,1G13.5)
C
      DO 15 I = 1, 5
      DO 15 J = 1, 100
   15 DISL(I,J) = 0.0
C
C
C     CALCULATE DISTRESS
C
      DO 30 J = 1, 100
      IF (J.EQ.100) GO TO 507
C
      W(J)= J
      TO =W(J)/100.0
      GO TO 508
  507 TO = .9910
  508 CONTINUE
C
C     RUTTING AREA NOW
C
      SO = ALOG (TO)
      RO = ABS (SO)
      ANW = RO**(1/BETRA)
      N   = (1/ANW)*RHORA
      NX = N*1000000.0/N18MTH
C
C     RUTTING AREA NEXT YEAR
C
      IN = INT(NX)
      IN = IN + 12
      N18 = N18MTH*IN/1000000.0
      PWR = (RHORA/N18)**BETRA
      DISL(1,J) = EXP( -PWR) * 100.0
      DISL(2,J) = EXP( -PWR) * 100.0
C
C     RAVELLING
C
      DISL(3,J) = J + 1.0
C
C     FLUSHING
C
      DISL(4,J) = J + 1.0
C
C     FAILURES
C
      DISL(5,J) = J + 1.0
C
C
C     ALLIGATOR CRACKING NOW
C
      BA = 1/BETAA
      ANW = RO**BA
      N   = (1/ANW)*RHOAA
      NX = N*1000000.0/N18MTH
C
C     ALLIGATOR CRACKING NEXT YEAR
C
      IN = INT(NX)
      IN = IN + 12
      N18 = N18MTH*IN/1000000.0
      PWR = (RHOAA/N18)**BETAA
      DISL(6,J) = EXP( -PWR) * 100.0
C
C     LONGITUDINAL CRACKING NOW
C
      BD = 1/BETLA
      ANW = RO**BD
      N   = (1/ANW)*RHOLA
C
C     LONGITUDINAL CRACKING NEXT YEAR
C
```

```
         IN = INT(N)
         IN = IN + 12
         PWR = (RHOLA/IN)**BETLA
         DISL(7,J) = EXP( -PWR) * 100.0
C
C       TRANSVERSAL CRACKING NOW
C
         BL = 1/BETTA
         ANW = RO**BL
         N  = (1/ANW)*RHOTA
C
C       TRANSVERSAL CRACKING NEXT YEAR
C
         IN = INT(N)
         IN = IN + 12
         PWR = (RHOTA/IN)**BETTA
         DISL(8,J) = EXP( -PWR) * 100.0
   30 CONTINUE
C
C
C       PSI
C
C       WRITE(6,251)  XTI, FTC, AVT, PI, OVTH, BINDER, HPR2, HPR3, N18MTH
C  251 FORMAT(T10,'DATA INPUTS:'//T10,'TI+50  FTC    AVT     PI    OVTH'
C     &,'  BINDER  HPR2   HPR3  N18/MTH'/T7,4F7.0,2F7.1,F7.0,F7.2,F10.0)
C
        DO 40 J= 1,50
C       PSIL(J) = PSTE
         IF( RHOP .LE. 0.0 ) GO TO 40
         PS(J) = J/10.0
         PIS(J) = PS(J)
         IF(PS(J).GE.PO) PIS(J) = PO - 0.001
         B1 = (PO-PIS(J))/(PO-PF)
         B2 = ALOG(B1)
         B3 = B2 * (-1.0)
         IF (B3.LT.0.0) GO TO 99
         CALL MONTHS (B3, NS, RHOP, TI50, FTC, AVT50, OVTH, HPR2,
      & N18MTH)
          N1 = NS
        N2 = N1*1000000.0/N18MTH
        N2 = N2 + 12
        N18 = N2 * N18MTH/1000000.0
        BETAP = 0.00413*XTI+0.01036*FTC+0.04769*XAVT+0.01707*
      & (N18MTH/1000.0)-0.009144*OVTH-0.01066*HPR2
         IF( BETAP .LT. 0.0 ) GO TO 27
        GO TO 28
   27 BETAP = FTC**(0.09767)*(N18MTH/1000.0)**(0.17402)*BINDER**
     & (-0.30623)*HPR2**(-0.22623)
   28 CONTINUE
        PWR = (RHOP/N18)**BETAP
        IF(PWR.GT.80.0) PWR = 80.0
        PSIL(J) = PO - (PO - PF) * EXP( -PWR)
        IF (PSIL(J).GT.PS(J) ) PSIL(J) = PS(J)- 0.15
C      PSTE = PSIL(J)
        GO TO 29
   99 PSIL(J) = PIS(J)
   29 CONTINUE
   40 CONTINUE
C
C
C      WRITE(6,252)
C  252 FORMAT(/T26,'DISTRESS', T60, 'DISTRESS' /T12, 'N        RUTTING',
C     & '   RAVL FLUSH  FAIL  ALIG  LONG  TRNS ' / T11,
C     $'ACT      ONE   TWO    AREA  AREA  AREA  AREA  AREA  AREA')
C
C      DO 41 J = 1, 100
C
C      WRITE(6,255) W(J), (DISL(I,J), I = 1, 8)
C  255 FORMAT( F14.2, 2X, 8F6.2)
C   41 CONTINUE
C      DO 44 J = 1, 50
C      WRITE(6,257) PS(J), PSIL(J)
C  257 FORMAT(T8,F5.3,10X,F5.3)
C   44 CONTINUE
```

```
C
C
       KNT = KNT + 1
C     IF( KNT .EQ. 1 ) WRITE(6,200)
       IF( KNT .EQ. 1 ) KNT = 0
C
C
       RETURN
       END
       SUBROUTINE MONTHS (B3, NS, RHOP, TI50, FTC, AVT50, OVTH, HPR2,
     & N18MTH)
C
C      ****************************************************************
C
C      THIS SUBROUTINE IS USED BY THE SUBROUTINE OV TO CALCULATE THE
C      NUMBER OF MONTHS THAT HAVE PASSED FOR THE SECTION OF ROAD TO
C     HAVE THE PREDICTED PSI SCORE
C
C      ****************************************************************
C
       REAL NS, N18MTH
       NS = 0.0
       BQ = B3
       BW = 0.0
   15  BW = BW+12
       NS = N18MTH*BW/1000000.0
       BETAP = 0.00413*TI50 + 0.01036*FTC + 0.04769*AVT50 - 0.09144*
     & OVTH - 0.01066*HPR2
       BETOP = BETAP + (0.01707*NS)
       PWR = (RHOP/NS)**BETOP
       IF (PWR.LT.BQ) GO TO 10
       GO TO 15
   10  RETURN
       END
C
       SUBROUTINE BB(CNTY,IT,PESC,TIN,FRTH,AVTP,ASPH,HPR2,HPR3,PLSX,
     1               DISL,PSIL,EALT)
C
C     ****************************************************************
C
C     THIS SUBROUTINE USES THE SURVIVAL CURVES TO GENERATE
C      TRANSITION MATRIX FOR BLACK BASE PAVEMENTS.
C
C     ****************************************************************
C
C
C
C      CNTY    -    COUNTY NUMBER
C      IT      -    PAVEMENT TYPE
C      PESC    -    PAVEMENT SCORE
C      TIN     -    THORNTHWAITE INDEX
C      FRTH    -    FREEZE/THAW CYCLES
C      AVTP    -    AVERAGE TEMPERATURE
C      HPR2    -    EQUIVALENT THICKNESS X ELASTIC MODULUS OF THE
C                   SUBGRADE AS DETERMINE FROM DINAFLECT MEASUREMENTS
C      HPR3    -     10 ** 10 / HPR2
C      ASPH    -    ASPHALT THICKNESS
C      PLSX    -    PLASTICITY INDEX
C      BINDER  -    PERCENT ASPHALT BINDER
C      DISL    -   (8 X 100)-ELEMENT ARRAY WHICH HOLDS THE TRANSITION
C                  MATRIX FOR THE DISTRESSES OF THE SECTION IN ANALYSIS
C      PSIL    -    TRANSITION MATRIX FOR THE PSI OF THE SECTION IN
C                   ANALYSIS
C
C
      INTEGER CNTY,EALT
      REAL W(100), N18, N18MTH, N, NX, NS, PS(50), N1, N2
      DIMENSION DISL(8,100), HEADER(10), X(11)
      DIMENSION TIN(254),FRTH(254),AVTP(254),RAIN(254)
      DIMENSION PSIL(50),PIS(50)
C
C     WRITE (6,200)
C 200 FORMAT ( '1' )
C
      ICTY = CNTY
```

```
      XTI   = TIN(ICTY) + 50.0
      AVT   = AVTP(ICTY)
      FTC   = FRTH(ICTY)
      N18MTH = (EALT*1000.0)/240.0
      BINDER = 6.0
      PI = PLSX
      KNT = 0
      PO = 4.2
C
      XAVT = AVT - 50.0
C
C
C
C     LINEAR RHO & BETA, PSI
C
      X(9) = -0.02182*FTC-0.00831*PI+0.04499*BINDER+0.15013*HPR2
      X(10) = 0.01201*XTI+0.03166*FTC+0.13775*XAVT+0.00114*PI
     & -0.31331*BINDER-0.03234*HPR2
      X(11) = -0.00637*FTC-0.0155*XAVT-0.00658*PI+0.27714*BINDER
     & +0.05097*HPR2
C
      IF( X(9).LT. 0.0 .OR. X(10).LT. 0.0 .OR.X(11).LT. 0.0 ) GO TO 112
      GO TO 113
C
C
C     LOG RHO & BETA, PSI
C
  112 X(9)= FTC**(-0.46679)*XAVT**(-0.86233)*PI**(-0.26711)
     & *HPR2**(1.65694)
      X(10)= FTC**(0.60949)*XAVT**(0.93499)*BINDER**(-1.37608)
     & *HPR2**(-0.72725)
      X(11)= FTC**(-1.50634)*XAVT**(-2.6946)*BINDER**(4.17755)
     & *HPR2**(1.60919)
C
C
C     LINEAR RHO & BETA, RUTTING AREA
C
  113 X(1)= 0.00175*FTC-0.0141*AVT+0.257*ASPH
      X(2) = -0.00493*FTC+0.0262*AVT+0.0387*PI-0.0433*ASPH
      IF( X(1).LT. 0.0 .OR. X(2) .LT. 0.0 ) GO TO 122
      GO TO 123
C
C
C     LOG RHO & BETA, RUTTING AREA
C
  122 X(1)= AVT**(-0.6844)*PI**(-0.1021)*ASPH**(1.4756)*HPR3**(-0.0021)
      X(2) = FTC**(-0.1668)*AVT**(0.1231)*PI**(0.2238)*ASPH**(-0.0266)
C
C
C     LINEAR RHO & BETA, ALLIGATOR CRACK AREA
C
  123 X(3)= 0.134*HPR2 - 0.067*HPR3
      X(4) = 0.856*HPR3
      IF( X(3).LT. 0.0 .OR. X(4) .LT. 0.0 ) GO TO 142
      GO TO 143
C
C
C     LOG RHO & BETA, ALLIGATOR CRACK AREA
C
  142 X(3)= FTC**(-0.1961)*PI**(-0.2231)*HPR2**(0.644)*HPR3**(-0.31)
      X(4) = 1.4686
C
C
C
C     LINEAR RHO & BETA, LONG. CRACK AREA
C
  143 X(5)= 5.33*ASPH+29.44*BINDER-6.88*HPR3
      X(6) = 0.0181*AVT+0.421*HPR3
      IF( X(5).LT. 0.0 .OR. X(6) .LT. 0.0 ) GO TO 162
      GO TO 163
C
C
C     LOG RHO & BETA, LONG. CRACK AREA
C
```

```
  162 X(5)= ASPH**(0.6527)*BINDER**(2.2368)
      X(6) = 1.3178
C
C
C
C     LINEAR RHO & BETA, TRANS. CRACK AREA
C
  163 X(7)= -1.739*PI+0.428*ASPH+48.88*BINDER-46.7*HPR3
      X(8) = 0.0153*FTC+0.625*HPR3
      IF( X(7).LT. 0.0 .OR. X(8) .LT. 0.0 ) GO TO 182
      GO TO 183
C
C
C     LOG RHO & BETA, TRANS. CRACK AREA
C
  182 X(7)= PI**(-0.2152)*ASPH**(0.6152)*BINDER**(2.4561)*HPR2**(0.102)
      X(8) = FTC**(0.1664)*ASPH**(-0.1447)*BINDER**(-0.0495)
     & *HPR3**(0.204)
  183 CONTINUE
C
C
C
      RHORA = X(1)
      BETRA = X(2)
      RHOAA = X(3)
      BETAA = X(4)
      RHOLA = X(5)
      BETLA = X(6)
      RHOTA = X(7)
      BETTA = X(8)
      RHOP  = X(9)
      BETAP = X(10)
      PF    = X(11)
C
C     WRITE(6,300) RHORA, BETRA, RHOAA, BETAA,
C    & RHOTA, BETTA, RHOLA, BETLA,
C    $ RHOP, BETAP, PF
C 300 FORMAT( //  1X, 10G13.5 / 1X, 1G13.5/ )
C
      DO 15 I = 1, 5
      DO 15 J = 1, 100
   15 DISL(I,J) = 0.0
C
C
C     CALCULATE DISTRESS
C
      DO 30 J = 1, 100
      IF (J.EQ.100) GO TO 507
C
      W(J)= J
      TO =W(J)/100.0
      GO TO 508
  507 TO = .9910
  508 CONTINUE
C
C     RUTTING AREA NOW
C
      SO = ALOG (TO)
      RO = ABS (SO)
      ANW = RO**(1/BETRA)
      N   = (1/ANW)*RHORA
      NX = N*1000000.0/N18MTH
C
C     RUTTING AREA NEXT YEAR
C
      IN = INT(NX)
      IN = IN + 12
      N18 = N18MTH*IN/1000000.0
C    1         'IN',I8,'N18',F11.3,/)
      PWR = (RHORA/N18)**BETRA
      DISL(1,J) = EXP( -PWR) * 100.0
      DISL(2,J) = EXP( -PWR) * 100.0
C
C     RAVELLING
```

```
C
       DISL(3,J) = J + 1.0
C
C     FLUSHING
C
       DISL(4,J) = J + 1.0
C
C     FAILURES
C
       DISL(5,J) = J + 1.0
C
C
C     ALLIGATOR CRACKING NOW
C
       BA = 1/BETAA
       ANW = RO**BA
       N  = (1/ANW)*RHOAA
       NX = N*1000000.0/N18MTH
C
C     ALLIGATOR CRACKING NEXT YEAR
C
       IN = INT(NX)
       IN = IN + 12
       N18 = N18MTH*IN/1000000.0
       PWR = (RHOAA/N18)**BETAA
       DISL(6,J) = EXP( -PWR) * 100.0
C
C     LONGITUDINAL CRACKING NOW
C
       BD = 1/BETLA
       ANW = RO**BD
       N  = (1/ANW)*RHOLA
C
C     LONGITUDINAL CRACKING NEXT YEAR
C
       IN = INT(N)
       IN = IN + 12
       PWR = (RHOLA/IN)**BETLA
       DISL(7,J) = EXP( -PWR) * 100.0
C
C     TRANSVERSAL CRACKING NOW
C
       BL = 1/BETTA
       ANW = RO**BL
       N  = (1/ANW)*RHOTA
C
C     TRANSVERSAL CRACKING NEXT YEAR
C
       IN = INT(N)
       IN = IN + 12
       PWR = (RHOTA/IN)**BETTA
       DISL(8,J) = EXP( -PWR) * 100.0
   30 CONTINUE
C
C
C     PSI
C
       DO 40 J= 1,50
       PSIL(J) = PO
       IF( RHOP .LE. 0.0 ) GO TO 40
       IF(PF.GE.PO) GO TO 39
       PS(J) = J/10.0
       PIS(J) = PS(J)
       IF(PS(J).GE.PO) PIS(J) = PO - .001
       B1 = (PO-PIS(J))/(PO-PF)
       B2 = ALOG(B1)
       B3 = B2 * (-1.0)
       IF (B3.LT.0.0) GO TO 99
       ANW = B3**(1/BETAP)
       N1 = (1/ANW)*RHOP
       N2 = N1*1000000.0/N18MTH
       N2 = N2 + 12
       N18 = N2 * N18MTH/1000000.0
       PWR = (RHOP/N18)**BETAP
```

```
      PSIL(J) = PO - (PO - PF) * EXP( -PWR)
      IF (PSIL(J).GT.PS(J)) PSIL(J) = PS(J) - 0.15
C     PSTE = PSIL(J)
      GO TO 29
   39 PSIL(J) = 2.65
      GO TO 29
   99 PSIL(J) = PIS(J)
   29 CONTINUE
   40 CONTINUE
C
C     WRITE(6,251) XTI, FTC, AVT, PI, ASPH, BINDER, HPR2, HPR3, N18MTH
C 251 FORMAT(T10,'DATA INPUTS:'//T10,'TI+50  FTC    AVT      PI    ASPH'
C    &,'  BINDER  HPR2   HPR3  N18/MTH'/T7,4F7.0,2F7.1,F7.0,F7.2,F10.0)
C
C     WRITE(6,252)
C 252 FORMAT(/T26,'DISTRESS', T60, 'DISTRESS' /T12, 'N         RUTTING',
C    & '    RAVL FLUSH  FAIL  ALIG  LONG  TRNS ' / T11,
C    $'ACT      ONE     TWO    AREA  AREA  AREA  AREA  AREA  AREA')
C
C     DO 41 J = 1, 100
C
C     WRITE(6,255) W(J), (DISL(I,J), I = 1, 8)
C 255 FORMAT( F14.2, 2X, 8F6.2)
C  41 CONTINUE
C     DO 44 J = 1, 50
C     WRITE(6,257) PS(J), PSIL(J)
C 257 FORMAT(T8,F5.3,10X,F5.3)
C  44 CONTINUE
C
C
C
      KNT = KNT + 1
C     IF( KNT .EQ. 1 ) WRITE(6,200)
      IF( KNT .EQ. 1 ) KNT = 0
C
C
      RETURN
      END
C
C
      SUBROUTINE ST(CNTY,IT,PESC,TIN,FRTH,AVTP,DMD,PLSX,FLEXL,DISL,
     1              PSIL,EALT,AADT,AKIP)
C
C     ************************************************************
C
C
C     THIS SUBROUTINE USES THE SURVIVAL CURVES TO GENERATE
C     TRANSITION MATRIX FOR SURFACE TREATED PAVEMENTS.
C
C     ************************************************************
C
C
C     CNTY   -   COUNTY NUMBER
C     IT     -   PAVEMENT TYPE
C     PESC   -   PAVEMENT SCORE
C     TIN    -   THORNTHWAITE INDEX
C     FRTH   -   FREEZE/THAW CYCLES
C     AVTP   -   AVERAGE TEMPERATURE
C     FLEXL  -   THICKNESS OF FLEX BASE IN INCHES
C     DMD    -   DYNAFLECT MEAN DEFLECTION
C     LL     -   SUBGRADE LIQUID LIMIT
C     PLSX   -   PLASTICITY INDEX
C     DISL   -   (8 X 100)-ELEMENT ARRAY WHICH HOLDS THE TRANSITION
C                MATRIX FOR THE DISTRESSES OF THE SECTION IN ANALYSIS
C     PSIL   -   TRANSITION MATRIX FOR THE PSI OF THE SECTION IN
C                ANALYSIS
C
C
      INTEGER CNTY,EALT
      REAL W(100), N18, N18MTH, N, NX, NS, PS(50), N1, N2,ADT,NADT
      REAL LL
      DIMENSION DISL(8,100), HEADER(10), X(17), PIS(50)
      DIMENSION TIN(254),FRTH(254),AVTP(254),RAIN(254),PSIL(50)
C
C     WRITE (6,200)
```

```
C 200 FORMAT ( '1' )
      ICTY = CNTY
      TI50 = TIN(ICTY) + 50.0
      AVT  = AVTP(ICTY)
      FTC  = FRTH(ICTY)
      N18MTH = AKIP * 1000000./480.0
      PI = PLSX
      LL = 20.0 + (1.379 * PI)
      KNT = 0
      PO = 4.2
C
C
      AVT50 = AVT - 50.0
C
C
C
      X(17) = 0.83
C
C     PSI
      X(15)= -0.173 + 0.00687*AVT50 - 0.000632*TI50 + 0.0133*FLEXL
     1 + .00075*LL + .00153*FTC - 0.0214*DMD
C
      IF( X(15).GT. 0.511 )  X(15) = 0.511
      IF( X(15).LT. 0.0009 ) X(15) = 0.0009
C
      X(16) = 1.0
C
C     RUT AREA
      X(1)= -0.1035 + 0.00549*AVT50 + 0.0067*FLEXL - 0.0015*LL
     & + 0.00162*PI + 0.00077*FTC
      X(2) = 1.540 + 0.0169*TI50 - 0.072*FLEXL
C
      IF( X(1).GT. 0.117 ) X(1)= 0.117
      IF( X(1).LT. 0.0036 ) X(1)= 0.0036
C
      IF( X(2) .GT. 6.27 ) X(2) = 6.27
      IF( X(2) .LT. 0.615 ) X(2) = 0.615
C
C     RAV AREA
      X(3)= 1.030 + 0.0146*TI50 + 0.0064*FTC - 0.6089*DMD
      X(4) = 1.28
C
      IF( X(3).GT. 2.76 ) X(3)= 2.76
      IF( X(3).LT. 0.095 ) X(3)= 0.095
C
      IF( X(4) .GT. 6.1 ) X(4) = 6.1
      IF( X(4) .LT. 0.52 ) X(4) = 0.52
C
C
C     FLUSH AREA
      X(5)= 0.488 + 0.0127*TI50 + 0.00345*FTC - 0.213*DMD
      X(6) = 1.27
C
      IF( X(5).GT. 2.84 ) X(5)= 2.84
      IF( X(5).LT. 0.062 ) X(5)= 0.062
C
C     ALLIGATOR AREA
C
      X(7)= -0.179 + 0.0121*AVT50 + 0.0040*FLEXL - 0.0011*LL
     ! + 0.00153*FTC
      X(8) = 1.867 - 0.00908*TI50 + 0.144*FLEXL - 0.572*DMD
C
      IF( X(7).GT. 0.19 ) X(7)= 0.19
      IF( X(7).LT. 0.003 ) X(7)= 0.003
C
      IF( X(8) .GT. 7.29 ) X(8) = 7.29
      IF( X(8) .LT. 0.51 ) X(8) = 0.51
C
C
C
C     LONG AREA
C
      X(9)= -63.1 + 4.52*AVT50 + 0.541*TI50 + 7.41*FLEXL + 1.1145*FTC
      X(10)= 1.15
```

```
C
      IF( X(9).GT. 172.0 ) X(9)= 172.0
      IF( X(9).LT. 30.0 ) X(9)= 30.0
C
      IF( X(10).GT. 2.65 ) X(10)= 2.65
      IF( X(10).LT. 0.68 ) X(10)= 0.68
C
C
C
C
C     TRANS AREA
C
      X(11)= -66.4 + 2.156*TI50 + 10.12*FLEXL + 0.718*FTC
      X(12)= 2.059 + 0.0734*FLEXL - 0.06*LL + 0.0607*PI - 0.00375*FTC
      IF(X(11).GT. 176.0 ) X(11) = 176.0
      IF(X(11).LT. 41.0 ) X(11) = 41.0
C
      IF( X(12).GT. 2.65 ) X(12)= 2.65
      IF( X(12).LT. 0.61 ) X(12)= 0.61
C
C
C     PATCHING
C
      X(13)= 0.00799 + 0.00252*AVT50 + 0.000218*TI50 + 0.00166*FLEXL
     1       - 0.00125*PI
      X(14)= 1.75
C
      IF(X(13).GT. 0.104 ) X(13) = 0.104
      IF(X(13).LT. 0.0036 ) X(13) = 0.0036
C
      IF( X(14).GT. 5.36 ) X(14)= 5.36
      IF( X(14).LT. 0.63 ) X(14)= 0.63
C
C
C
C
C
      RHORA = X(1)
      BETRA = X(2)
      RHORV = X(3)
      BETRV = X(4)
      RHOFL = X(5)
      BETFL = X(6)
      RHOAA = X(7)
      BETAA = X(8)
      RHOLA = X(9)
      BETLA = X(10)
      RHOTA = X(11)
      BETTA = X(12)
      RHOPT = X(13)
      BETPT = X(14)
      RHOP  = X(15)
      BETAP = X(16)
      PF    = X(17)
C
C     WRITE(6,300) RHORA,BETRA,RHORV,BETRV,RHOFL,BETFL,RHOAA, BETAA,
C    & RHOTA, BETTA, RHOLA, BETLA,RHOPT,BETPT,
C    $ RHOP, BETAP, PF
C 300 FORMAT( //  1X, 10G13.5 / 1X, 7G13.5/ )
C
      DO 15 I = 1, 5
      DO 15 J = 1, 100
   15 DISL(I,J) = 0.0
C
C
C   CALCULATE DISTRESS
C
      DO 30 J = 1, 100
      IF (J.EQ.100) GO TO 507
C
      W(J)= J
      TO =W(J)/100.0
      GO TO 508
  507 TO = .9910
```

```
  508 CONTINUE
C
C     RUTTING AREA NOW
C
      SO = ALOG (TO)
      RO = ABS (SO)
      ANW = RO**(1/BETRA)
      N  = (1/ANW)*RHORA
C
C     RUTTING AREA NEXT YEAR
C
      N18 = N + (N18MTH * 12.0/1000000.0)
      PWR = (RHORA/N18)**BETRA
      DISL(1,J) = EXP( -PWR) * 100.0
      DISL(2,J) = EXP( -PWR) * 100.0
C
C     RAVELLING
C
      ANW = RO**(1/BETRV)
      ADT = (1/ANW)*RHORV
      NADT = ADT + (AADT * 365./1000000.)
      PWR = (RHORV/NADT)**BETRV
      DISL(3,J) = EXP(-PWR) * 100.0
C
C     FLUSHING
C
      ANW = RO**(1/BETFL)
      ADT = (1/ANW)*RHOFL
      NADT = ADT + (AADT * 365./1000000.)
      PWR = (RHOFL/NADT)**BETFL
      DISL(4,J) = EXP(-PWR) * 100.0
C
C     PATCHING
C     ANW = RO**(1/BETPT)
C     N  = (1/ANW)*RHOPT
C
C     PATCHING AREA NEXT YEAR
C
C     N18 = N + (N18MTH * 12.0/1000000.0)
C     PWR = (RHOPT/N18)**BETPT
C
      DISL(5,J) = J + 3.0
C
C
C     ALLIGATOR CRACKING NOW
C
      BA = 1/BETAA
      ANW = RO**BA
      N  = (1/ANW)*RHOAA
C
C     ALLIGATOR CRACKING NEXT YEAR
C
      N18 = N + (N18MTH * 12.0/1000000.0)
      PWR = (RHOAA/N18)**BETAA
      DISL(6,J) = EXP( -PWR) * 100.0
C
C     LONGITUDINAL CRACKING NOW
C
      BD = 1/BETLA
      ANW = RO**BD
      N  = (1/ANW)*RHOLA
C
C     LONGITUDINAL CRACKING NEXT YEAR
C
      IN = INT(N)
      IN = IN + 12
      PWR = (RHOLA/IN)**BETLA
      DISL(7,J) = EXP( -PWR) * 100.0
C
C     TRANSVERSAL CRACKING NOW
C
      BL = 1/BETTA
      ANW = RO**BL
      N  = (1/ANW)*RHOTA
```

```
C
C     TRANSVERSAL CRACKING NEXT YEAR
C
       IN = INT(W)
       IN = IN + 12
       PWR = (RHOTA/IN)**BETTA
       DISL(8,J) = EXP( -PWR) * 100.0
   30 CONTINUE
C
C
C     PSI
C
       DO 40 J= 1,50
       PSIL(J) = PO
       IF( RHOP .LE. 0.0 ) GO TO 40
       IF(PF.GE.PO) GO TO 39
       PS(J) = J/10.0
       PIS(J) = PS(J)
       IF(PS(J).GE.PO) PIS(J) = PO - .001
       B1 = (PO-PIS(J))/(PO-PF)
       B2 = ALOG(B1)
       B3 = B2 * (-1.0)
       IF (B3.LT.0.0) GO TO 99
       ANW = B3**(1/BETAP)
       N1 = (1/ANW)*RHOP
       N2 = N1*1000000.0/N18MTH
       N2 = N2 + 12
       N18 = N2 * N18MTH/1000000.0
       PWR = (RHOP/N18)**BETAP
       PSIL(J) = PO - (PO - PF) * EXP( -PWR)
       IF (PSIL(J).GT.PS(J)) PSIL(J) = PS(J) - 0.15
C     PSTE = PSIL(J)
       GO TO 29
   39 PSIL(J) = 2.65
       GO TO 29
   99 PSIL(J) = PIS(J)
   29 CONTINUE
   40 CONTINUE
C
C     WRITE(6,251) TI50, FTC, AVT, PI, FLEXL, DMD, LL, N18MTH
C 251 FORMAT(T10,'DATA INPUTS:'//T10,'TI+50  FTC    AVT     PI    FLEXL'
C    &,'   DMD    LL   N18/MTH'/T7,4F7.0,2F7.1,F7.0,F10.0)
C
C     WRITE(6,252)
C 252 FORMAT(/T26,'DISTRESS', T60, 'DISTRESS' /T12, 'N          RUTTING',
C    & '    RAVL FLUSH  PATCH ALIG  LONG  TRNS ' / T11,
C    $'ACT      ONE   TWO   AREA  AREA  AREA  AREA  AREA  AREA')
C
C     DO 41 J = 1, 100
C
C     WRITE(6,255) W(J), (DISL(I,J), I = 1, 8)
C 255 FORMAT( F14.2, 2X, 8F6.2)
C  41 CONTINUE
C     DO 44 J = 1, 50
C     WRITE(6,257) PS(J), PSIL(J)
C 257 FORMAT(T8,F5.3,10X,F5.3)
C  44 CONTINUE
C
      KNT = KNT + 1
C     IF( KNT .EQ. 1 ) WRITE(6,200)
      IF( KNT .EQ. 1 ) KNT = 0
C
C
C
C
      RETURN
      END
      SUBROUTINE SURVTA (CNTY,JX,IT,PESC,TIN,FRTH,AVTP,PLSX,
     1                   OV2,OV3,BB2,BB3,OVTH,ASPH,DMD,DISL,
     2                   FLEXL,PSIL,EALT,HPR2,HPR3,AADT,AKIP,HMAC)
C
C     *************************************************************
C
C       THIS SUBROUTINE CALCULATES THE SURVIVAL CURVES OF
```

```
C        SECTIONS OF ROAD THAT HAVE BEEN REHABILITATED
C
C      ***************************************************************
C
C      CNTY    -   COUNTY
C      JX      -   REHAB. STRATEGY USED
C      IT      -   PAVEMENT TYPE
C      PESC    -   FINAL PAVEMENT SCORE
C      TIN     -   THORNTHWAITE INDEX
C      FRTH    -   FREEZE/THAW CYCLES
C      AVTP    -   AVERAGE TEMPERATURE
C      HPR2    -   EQUIVALENT THICKNESS X ELASTIC MODULUS OF THE
C                  SUBGRADE AS DETERMINE FROM DINAFLECT MEASUREMENTS
C      HPR3    -    10 ** 10 / HPR2
C      OVTH    -   OVERLAY THICKNESS
C      PLSX    -   PLASTICITY INDEX
C      BINDER  -   PERCENT ASPHALT BINDER
C      DISL    -  (8 X 100)-ELEMENT ARRAY WHICH HOLDS THE TRANSITION
C                 MATRIX FOR THE DISTRESSES OF THE SECTION IN ANALYSIS
C      PSIL    -   TRANSITION MATRIX FOR THE PSI OF THE SECTION IN
C                  ANALYSIS
C
C      ASPH    -   ASPHALT THICKNESS
C      FLEXL   -   THICKNESS OF FLEX BASE IN INCHES
C      DMD     -   DYNAFLECT MEAN DEFLECTION
C      LL      -   SUBGRADE LIQUID LIMIT
C      PLSX    -   PLASTICITY INDEX
C      HMAC    -   HOT MIX  ASPHALT THICKNESS
C
       DIMENSION DISL(8,100), PSIL(50), PIS(50), TIN(254), FRTH(254)
       DIMENSION AVTP(254), RAIN(254), OV2(4,4), OV3(4,4), BB2(4,2)
       DIMENSION BB3(4,2)
C
       INTEGER CNTY, EALT
C
C
C      SURFACE TREATMENT
C
       IF (IT.NE.10) GO TO 20
C     GO TO 50
       IF (JX.NE.3) GO TO 10
       DMD = 1.06
       FLEXL = FLEXL + 3.0
       GO TO 11
   10 IF (JX.NE.2) GO TO 11
       DMD = DMD - 0.5
       IF (DMD.LT.1.06) DMD = 1.06
       FLEXL = FLEXL + 1.5
   11 IF (DMD.GT.1.5) DMD = 1.5
       CALL ST(CNTY,IT,PESC,TIN,FRTH,AVTP,DMD,PLSX,FLEXL,DISL,PSIL,
      1        EALT,AADT, AKIP)
       GO TO 50
C
C
C      BLACK BASE
C
   20 IF (IT.NE.4) GO TO 30
       IC = IT - 3
       IF (JX.NE.5) GO TO 21
       ASPH = ASPH + 6.0
       HPR2 = BB2(4,IC)
       HPR3 = BB3(4,IC)
C
       GO TO 25
   21 IF (JX.NE.4) GO TO 22
       ASPH = ASPH + 4.5
       HPR2 = BB2(4,IC)
       HPR3 = BB3(4,IC)
       GO TO 25
C
   22 IF (JX.NE.3) GO TO 23
        ASPH = ASPH + 3.0
       HPR2 = BB2(4,IC)
```

```
         HPR3 = BB3(4,IC)
         GO TO 25
C
   23 IF (JX.NE.2) GO TO 24
         ASPH = ASPH + 2.0
         HPR2 = HPR2 + 2.0
         IF ( HPR2.GT.BB2(4,IC)) HPR2 = BB2(4,IC)
         HPR3 = HPR3 - 0.4
         IF ( HPR3.LT.BB3(4,IC)) HPR3 = BB3(4,IC)
         GO TO 25
C
   24 ASPH = ASPH + 0.75

   25 CALL BB (CNTY,IT,PESC,TIN,FRTH,AVTP,ASPH,HPR2,HPR3,PLSX,
     1          DISL,PSIL,EALT)
         GO TO 50
C
C
C        HOT MIX
C
   30 IF (IT.NE.5.AND.IT.NE.6) GO TO 40
         IF ( JX.NE.1) GO TO 40
         HMAC = HMAC + 0.75
         CALL HM(CNTY,IT,PESC,TIN,FRTH,AVTP,HMAC,HPR2,HPR3,PLSX,
     1                 DISL,PSIL,EALT)
         GO TO 50
C
C
C        OVERLAY
C
   40 IF (IT.NE.5. AND .IT.NE.6) GO TO 41
         IC = 1
         GO TO 42
   41 IC = IT - 5
   42 CONTINUE
         IF (JX.NE.5) GO TO 43
         OVTH = 6.0
         HPR2 = OV2(4,IC)
         HPR3 = OV3(4,IC)
         GO TO 47
C
   43 IF ( JX.NE.4 ) GO TO 44
         OVTH = 4.5
         HPR2 = OV2(4,IC)
         HPR3 = OV3(4,IC)
         GO TO 47
C
   44 IF (JX.NE.3) GO TO 45
         OVTH = 3.0
         HPR2 = OV2(4,IC)
         HPR3 = OV3(4,IC)
         GO TO 47
C
   45 IF (JX.NE.2) GO TO 46
         OVTH = 2.0
         HPR2 = HPR2 + 2.0
         IF (HPR2.GT.OV2(4,IC)) HPR2 = OV2(4,IC)
         HPR3 = HPR3 - 0.4
         IF (HPR3.LT.OV3(4,IC)) HPR3 = OV3(4,IC)
         GO TO 47
C
   46 OVTH = 0.75
   47 CALL OV (CNTY,IT,PESC,TIN,FRTH,AVTP,HPR2,HPR3,OVTH,PLSX,DISL,
     1          PSIL,EALT)
C
   50 RETURN
      END
C
      SUBROUTINE HM(CNTY,IT,PESC,TIN,FRTH,AVTP,HMAC,HPR2,HPR3,PLSX,
     1                DISL,PSIL,EALT)
C
C     ***************************************************************
C
C     THIS SUBROUTINE USES THE SURVIVAL CURVES TO GENERATE
```

```
C      TRANSITION MATRIX FOR BLACK BASE PAVEMENTS.
C
C      ***********************************************************
C
C
C     CNTY   -   COUNTY NUMBER
C     IT     -   PAVEMENT TYPE
C     PESC   -   PAVEMENT SCORE
C     TIN    -   THORNTHWAITE INDEX
C     FRTH   -   FREEZE/THAW CYCLES
C     AVTP   -   AVERAGE TEMPERATURE
C     HPR2   -   EQUIVALENT THICKNESS X ELASTIC MODULUS OF THE
C                SUBGRADE AS DETERMINE FROM DINAFLECT MEASUREMENTS
C     HPR3   -    10 ** 10 / HPR2
C     HMAC   -   HOT MIX  ASPHALT THICKNESS
C     PLSX   -   PLASTICITY INDEX
C     BINDER -   PERCENT ASPHALT BINDER
C     DISL   -  (8 X 100)-ELEMENT ARRAY WHICH HOLDS THE TRANSITION
C               MATRIX FOR THE DISTRESSES OF THE SECTION IN ANALYSIS
C     PSIL   -   TRANSITION MATRIX FOR THE PSI OF THE SECTION IN
C                ANALYSIS
C
C
      INTEGER CNTY,EALT
      REAL W(100), N18, N18MTH, N, NX, NS, PS(50), N1, N2
      DIMENSION DISL(8,100), HEADER(10), X(11), Y(8)
      DIMENSION TIN(254),FRTH(254),AVTP(254),RAIN(254)
      DIMENSION PSIL(50),PIS(50)
C
C     WRITE (6,200)
C 200 FORMAT ( '1' )
C
      ICTY = CNTY
      XTI  = TIN(ICTY) + 50.0
      TI   =  TIN(ICTY)
      AVT  = AVTP(ICTY)
      FTC  = FRTH(ICTY)
      N18MTH = (EALT*1000.0)/240.0
      BINDER = 6.0
      PI = PLSX
      KNT = 0
      PO = 4.2
      ICK = 0
C
      XAVT = AVT - 50.0
C
C
C
C
C
C
C     LINEAR RHO & BETA , PSI
C
      X(9)= -0.02*XTI-0.02481*FTC-0.03078*PI+0.60781*BINDER*0.06424*HPR2
      X(10) = 0.04045*FTC+0.22931*XAVT-0.5301*BINDER
      X(11) = -0.00665*FTC-0.07017*XAVT-0.02472*PI+0.57235*BINDER
     & +0.00722*HPR2
      IF( X(9) .LT. 0.0 .OR. X(10) .LT. 0.0 .OR.X(11).LT.0.0) GO TO 212
      GO TO 213
C
C     LOG RHO & BETA, PSI
C
  212 X(9) = XTI**(-0.31419)*FTC**(-0.69942)*XAVT**(-0.96204)
     & *BINDER**(0.44492)*HPR2**(1.8511)
      X(10) = FTC**(0.40391)*XAVT**(0.44517)*N18MTH**(0.04576)
     & *BINDER**(-1.50304)
C     X(10) = 1.00
      X(11) = FTC**(-0.89516)*XAVT**(-3.14575)*BINDER**(5.3121)
     & *HPR2**(0.44486)
C
C     LINEAR RHO & BETA , RUTTING AREA
C
  213 X(1) = 0.2776*HMAC+0.0151*HPR2
      X(2) = 0.0128*XTI+0.0326*AVT-0.0331*HMAC-0.00382*HPR2
      IF( X(1) .LT. 0.0 .OR. X(2) .LT. 0.0 ) GO TO 222
```

```
      GO TO 223
C
C     LOG RHO & BETA , RUTTING AREA
C
  222 X(1) = PI**(-0.3303)*HMAC**(0.5756)
      X(2) = AVT**(0.2454)*HPR2**(-0.1132)
C
C     LINEAR RHO & BETA , RUTTING SEVERITY
C
  223 Y(1)  = -0.0077*PI+0.386*HMAC
      Y(2)  = -0.00072*FTC+0.0273*AVT-0.00267*HMAC-0.000418*HPR2
      IF( Y(1)  .LT. 0.0 .OR. Y(2)  .LT. 0.0 ) GO TO 232
      GO TO 233
C
C     LOG RHO & BETA , RUTTING SEVERITY
C
  232 Y(1)  = PI**(-0.4591)*HMAC**(0.826)
      Y(2)  = 2.6063
C
C     LINEAR RHO & BETA , ALLIGATOR CRACK AREA
C
  233 X(3) = 5.315 + 0.825*HMAC + 1.189*HPR3 - 0.0162*XTI - 0.114*AVT
      X(4) = 7.927 + 1.124*HMAC - 0.191*HPR2 - 0.198*PI
      IF( X(3) .LT. 0.0 .OR. X(4) .LT. 0.0 ) GO TO 242
      GO TO 243
C
C     LOG RHO & BETA, ALLIGATOR CRACK AREA
C
  242 X(3)  = PI**(-0.4155)*HMAC**(0.8605)
      X(4)  = 2.8661
C
C     LINEAR RHO & BETA , ALLIGATOR CRACK SEVERITY
C
  243 Y(3)  = -0.000075*PI+0.291*HMAC
      Y(4)  = 3.145*HPR3
      IF( Y(3) .LT. 0.0 .OR. Y(4) .LT. 0.0 ) GO TO 252
      GO TO 253
C
C     LOG RHO & BETA, ALLIGATOR CRACK SEVERITY
C
  252 Y(3) = PI**(-0.5858)*HMAC**(1.1462)
      Y(4) = 3.7293
C
C     LINEAR RHO & BETA LONG. CRACK AREA
C
  253 X(5) = -0.988*FTC+4.38*AVT-2.99*PI+7.21*HMAC
      X(6) = 0.0422*FTC + 0.359*HPR3
      IF( X(5) .LT. 0.0 .OR. X(6) .LT. 0.0 ) GO TO 262
      GO TO 263
C
C     LOG RHO & BETA, LONG. CRACK AREA
C
  262 X(5) = XTI**(-0.1089)*FTC**(-0.1605)*AVT**(1.6203)
     & *PI**(-0.2219)*HPR3**(-0.0088)
      X(6) =FTC**(0.241)*HMAC**(-0.0653)
C
C     LINEAR RHO & BETA, LONG. CRACK SEVERITY
C
  263 Y(5) = -0.144*XTI+3.018*AVT-3.155*PI+8.331*HMAC
      Y(6) = 0.0343*XTI + 0.0502*FTC
      IF( Y(5) .LT. 0.0 .OR. Y(6) .LT. 0.0 ) GO TO 272
      GO TO 273
C
C     LOG RHO & BETA, LONG. CRACK SEVERITY
C
  272 Y(5) = XTI**(-0.1232)*FTC**(-0.119)*AVT**(1.6797)
     & *PI**(-0.4653)*HMAC**(0.1199)
      Y(6) = FTC**(0.3494)
C
C     LINEAR RHO & BETA, TRANS. CRACK AREA
C
  273 X(7) = -1.97*TI -0.826*FTC+5.193*AVT-1.768*PI-26.3*HPR3
      X(8) = 0.017*TI +0.0433*FTC-0.115*HMAC-0.0159*HPR2
     & + 0.259*HPR3
```

```
      IF( X(7) .LT. 0.0 .OR. X(8) .LT. 0.0 ) GO TO 282
      GO TO 283
C
C     LOG RHO & BETA, TRANS. CRACK AREA
C
 282 X(7) = XTI**(-0.4432)*FTC**(-0.2055)*AVT**(1.8972)*PI**(-0.2218)
      X(8) = XTI**(0.0702)*FTC**(0.311)*HMAC**(-0.494)*HPR2**(-0.1237)
C
C     LINEAR RHO & BETA, TRANS. CRACK SEVERITY
C
 283 Y(7) = -0.196*XTI+2.9*AVT-2.69**PI+5.475*HMAC
      Y(8) = 0.0519*FTC + 0.537*HPR3
      IF( Y(7) .LT. 0.0 .OR. Y(8) .LT. 0.0 ) GO TO 292
      GO TO 293
C
C     LOG RHO & BETA, TRANS. CRACK SEVERITY
C
 292 Y(7) = XTI**(-0.1399)*FTC**(-0.157)*AVT**(1.7128)
     & *PI**(-0.5024)*HMAC**(0.0348)*HPR2**(0.0606)
      Y(8) = FTC**(0.2462) * HPR2**(-0.0049)
C
 293 CONTINUE
C
      RHORA = X(1)
      BETRA = X(2)
      RHOAA = X(3)
      BETAA = X(4)
      RHOLA = X(5)
      BETLA = X(6)
      RHOTA = X(7)
      BETTA = X(8)
C
C
      RHOP  = X(9)
      BETAP = X(10)
      PF    = X(11)
C
C
      RHORS = Y(1)
      BETRS = Y(2)
      RHOAS = Y(3)
      BETAS = Y(4)
      RHOLS = Y(5)
      BETLS = Y(6)
      RHOTS = Y(7)
      BETTS = Y(8)
C C
C
C     WRITE(6,300) RHORA, BETRA, RHOAA, BETAA,
C    & RHOTA, BETTA, RHOLA, BETLA,
C    $ RHOP, BETAP, PF
C 300 FORMAT( //  1X, 10G13.5 / 1X, 1G13.5/ )
C
      DO 15 I = 1, 5
      DO 15 J = 1, 100
  15 DISL(I,J) = 0.0
C
C
C    CALCULATE DISTRESS
C
      DO 30 J = 1, 100
      IF (J.EQ.100) GO TO 507
C
      W(J)= J
      TO =W(J)/100.0
      GO TO 508
 507 TO = .9910
 508 CONTINUE
C
C     RUTTING AREA NOW
C
      SO = ALOG (TO)
      RO = ABS (SO)
      ANW = RO**(1/BETRA)
```

```
      N  = (1/ANW)*RHORA
      NX = N*1000000.0/N18MTH
C
C     RUTTING AREA NEXT YEAR
C
      IN = INT(NX)
      IN = IN + 12
      N18 = N18MTH*IN/1000000.0
      PWR = (RHORA/N18)**BETRA
      DISL(1,J) = EXP( -PWR) * 100.0
      DISL(2,J) = EXP( -PWR) * 100.0
C
C     RAVELLING
C
      DISL(3,J) = J + 1.0
C
C     FLUSHING
C
      DISL(4,J) = J + 1.0
C
C     FAILURES
C
      DISL(5,J) = J + 1.0
C
C
C     ALLIGATOR CRACKING NOW
C
      BA = 1/BETAA
      ANW = RO**BA
    - N  = (1/ANW)*RHOAA
      NX = N*1000000.0/N18MTH
C
C     ALLIGATOR CRACKING NEXT YEAR
C
      IN = INT(NX)
      IN = IN + 12
      N18 = N18MTH*IN/1000000.0
      PWR = (RHOAA/N18)**BETAA
      DISL(6,J) = EXP( -PWR) * 100.0
C
C     LONGITUDINAL CRACKING NOW
C
      BD = 1/BETLA
      ANW = RO**BD
      N  = (1/ANW)*RHOLA
C
C     LONGITUDINAL CRACKING NEXT YEAR
C
      IN = INT(N)
      IN = IN + 12
      PWR = (RHOLA/IN)**BETLA
      DISL(7,J) = EXP( -PWR) * 100.0
C
C     TRANSVERSAL CRACKING NOW
C
      BL = 1/BETTA
      ANW = RO**BL
      N  = (1/ANW)*RHOTA
C
C     TRANSVERSAL CRACKING NEXT YEAR
C
      IN = INT(N)
      IN = IN + 12
      IF (ICK.EQ.1) GO TO 27
      PWR = (RHOTA/IN)**BETTA
      IF(PWR.LT.0.090) ICK = 1
      GO TO 28
   27 PWR = 0.073
   28 DISL(8,J) = EXP( -PWR) * 100.0
   30 CONTINUE
C
C
C     PSI
C
```

```
      DO 40 J= 1,50
      PSIL(J) = PO
      IF( RHOP .LE. 0.0 ) GO TO 40
      IF(PF.GE.PO) GO TO 39
      PS(J) = J/10.0
      PIS(J) = PS(J)
      IF(PS(J).GE.PO) PIS(J) = PO - .001
      B1 = (PO-PIS(J))/(PO-PF)
      B2 = ALOG(B1)
      B3 = B2 * (-1.0)
      IF (B3.LT.0.0) GO TO 99
      ANW = B3**(1/BETAP)
      N1 = (1/ANW)*RHOP
      N2 = N1*1000000.0/N18MTH
      N2 = N2 + 12
      N18 = N2 * N18MTH/1000000.0
      PWR = (RHOP/N18)**BETAP
      PSIL(J) = PO - (PO - PF) * EXP( -PWR)
      IF(PSIL(J).GT.PS(J)) PSIL(J) = PS(J) - 0.15
C     PSTE = PSIL(J)
      GO TO 29
   39 PSIL(J) = 2.65
      GO TO 29
   99 PSIL(J) = PIS(J)
   29 CONTINUE
   40 CONTINUE
C
C     WRITE(6,251) XTI, FTC, AVT, PI, HMAC, BINDER, HPR2, HPR3, N18MTH
C 251 FORMAT(T10,'DATA INPUTS:'//T10,'TI+50  FTC    AVT      PI    HMAC'
C    &,'  BINDER  HPR2    HPR3  N18/MTH'/T7,4F7.0,2F7.1,F7.0,F7.2,F10.0)
C
C     WRITE(6,253)
C 253 FORMAT(/T26,'DISTRESS', T60, 'DISTRESS' /T12, 'N         RUTTING',
C    & '   RAVL FLUSH  FAIL  ALIG  LONG  TRNS ' / T11,
C    $'ACT      ONE    TWO    AREA   AREA   AREA   AREA   AREA   AREA')
C
C     DO 41 J = 1, 100
C
C     WRITE(6,255) W(J), (DISL(I,J), I = 1, 8)
C 255 FORMAT( F14.2, 2X, 8F6.2)
C  41 CONTINUE
C     DO 44 J = 1, 50
C     WRITE(6,257) PS(J), PSIL(J)
C 257 FORMAT(T8,F5.3,10X,F5.3)
C  44 CONTINUE
C
C
C
      KNT = KNT + 1
C     IF( KNT .EQ. 1 ) WRITE(6,200)
      IF( KNT .EQ. 1 ) KNT = 0
C
C
      RETURN
      END
      SUBROUTINE TRE(DIST,CNTY,HWAY,BMIL,BSIGN,BDISP,EMIL,ESIGN,EDISP,
     1             LANE,IVIS,SRVC,IT,IC,NLANES,WDTH,ADTL,EALT,PESC,
     2             LOWHI,JX,RCOST,IEXT,ISTE,IALV,
     3             IST, AREA, DST, DAREA, DCOST, JS, TOT)
C
C ******************************************************************
C
C
C
C     THIS SUBROUTINE SELECTS THE MAINTENANCE STRATEGIES FOR
C     ANY SECTION OF ROAD.
C     INPUT: DISTRESS, PAVEMENT TYPE, SCORE, SERVICEABILITY
C
C     OUTPUT: MAINTENANCE STRATEGIES
C
C
C ******************************************************************
C
C     MAINTENANCE STRATEGIES:
C
```

```
C                    1.- SEAL CRACKS
C                    2.- PATCHING
C                    3.- FULL DEPTH REPAIR
C                    4.- FOG SEAL
C                    5.- STRIP SEAL
C                    6.- SEAL COAT
C                    7.- ASPHALT-RUBBER SEAL
C                    8.- SLURRY SEAL
C                    9.- LEVEL UP
C                   10.- THIN OVERLAY
C                   11.- ROTOMILL
C                   12.- SPOT SEAL
C                   13.- ROTOMILL + SEAL
C                   14.- ROTOMILL + OVERLAY
C
      DIMENSION IVIS(7)
      DIMENSION TOTALS(9,7), TOTLN(7) ,IEXT(6)
      DIMENSION MTREE(7, 28, 4), CSQYD(12,7), CCOST(12,7)
      DIMENSION IST(9), AREA(9), DST(6), DAREA(6), DCOST(6)
C
      INTEGER DIST, CNTY, ADTL, EALT, PESC
      INTEGER BMIL, EMIL, HWFC, DST
      REAL LNTH
C
      REAL*8  HWAY
C     REAL*8 UNIT2
C
C     DATA MSTRAT / 'SEAL CRA','CKS      ',
C    1              'PATCH   ','         ',
C    2              'FULL DEP','TH RPAIR',
C    3              'FOG SEAL','         ',
C    4              'STRIP SE','AL       ',
C    4              'SEAL COA','T        ',
C    5              'ASP-RUBB','ER SEAL ',
C    6              'SLURRY S','EAL      ',
C    7              'LEVEL UP','         ',
C    8              'THIN OVE','RLAY     ',
C    9              'ROTOMILL','         ',
C    1              'SPOT SEA','L        ',
C    2              'ROTOMILL','+ SEAL   ',
C    3              'ROTOMILL','+ OVERLY' /
C
C     DATA DSTRES / 'SLIGHT R','UTTING  ','        ',
C    1              'SEVERE R','UTTING  ','        ',
C    2              'RAVELLIN','G       ','        ',
C    3              'FLUSHING','        ','        ',
C    4              'FAILURES','        ','        ',
C    5              'ALLIGATO','R CRACKI','NG      ',
C    6              'LONGITUD','INAL CRA','CKING   ',
C    7              'TRANSVER','SE CRACK','ING     ',
C    8              'RIDING  ','QUALITY ','        '/
C
C     DATA UNITS  / 'SQ YDS  ', 'SQ YDS  ','SQ YDS  ','SQ YDS  ',
C    1              'PER LN/M', 'SQ YDS  ','LN FEET ','LN FEET '/
C     DATA UNIT2  / 'SQ YDS  ', 'SQ YDS  ','SQ YDS  ','SQ YDS  ',
C    1       'TOTAL   ', 'SQ YDS  ','LN FEET ','LN FEET ','MEAN PSI'/
C
C     DATA RSTRAT / 'SEAL COA','T       ',
C    1              'THIN OVE','RLAY    ',
C    2              'MEDIUM O','VERLAY  ',
C    3              'THICK OV','ERLAY   ',
C    4              'RECONSTR','UCTION  '/
C
C     DATA RST10  / 'SEAL COA','T       ','        ',
C    1              'SECTIONA','L RECONS','TRUCTION',
C    2              'FULL REC','ONSTRUCT','ION     '/
C
C     DATA PTYPE  / 'THICK HO','T MIX   ',' >5.5INS',
C    1              'INTERMED','IATE HOT',' MIX    ',
C    2              'THIN HOT',' MIX    ',' <2.5INS',
C    3              'COMPOSIT','E       ','        ',
C    4              'WIDENED ','OLD CONC','ETE     ',
C    5              'WIDENED ','OLD FLEX','IBLE    ',
```

```
C     6                 'SURFACE ','TREATED ','         '/
C
C     DATA IORDER / 7, 1, 1, 1, 1, 1, 1, 1,1,1,1,1/
C
C 510 FORMAT ( I2, I3, A7, 2(I3,A1,F2.1), A1, 7I3, F2.1, 3I2,
C      1          F4.0, I6, I5, I3, 2I1, F5.0)
C 600 FORMAT(1H1, /,
C      1  'STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION',
C      2  27X,'RUN DATE ',8X,27X,'PAGE',3X,/,
C      3  ' PAVEMENT EVALUATION SYSTEM (PES) - PROGRAM NO. AGGIE1',/,
C      4  ' MAINTENANCE STRATEGY AND COST ESTIMATES - REPORT R00',/,
C      5  ' DISTRICT ',I3)
C 610 FORMAT ( //, 45X,'MAINTENANCE AND REHABILITATION GUIDELINES',
C      1        //, 23X,'COUNTY ', I3, 12X, 'HIGHWAY  ', A7)
C 620 FORMAT ( /, 25X,' MILEPOST ', I3, A1, F3.1, ' - ', I3, A1,
C      1            F3.1, 9X, 'LANE ', A1, 8X, 'PAVEMENT SCORE ',I3)
C 635 FORMAT ( /, 29X,'MAJOR DISTRESS', 17X, 'EXTENT', 12X,'STRATEGY')
C 630 FORMAT ( /, 30X, 'PAVEMENT TYPE  ', 3A8, T80, 'ADT = ',
C      1            I6, 2X, '18KIPS = ', I5)
C 640 FORMAT ( /, 29X, '.', 3A8, T57, F7.0, 1X, A8, 5X, 2A8)
C 641 FORMAT ( /, 29X, '.', 3A8, T57, F7.0, 1X, A8)
C 650 FORMAT ( /, 29X, '.', 3A8, T60, F4.1, 14X, 2A8)
C 651 FORMAT ( /, 29X, '.', 3A8, T60, F4.1)
C 675 FORMAT ( /, 30X, 2A8, T96, F8.0)
C 680 FORMAT ( /, 30X, 3A8, T96, F8.0)
C 670 FORMAT ( //, 29X, 'RECOMMENDED REHABILITATION STRATEGY')
C 690 FORMAT ( /, 31X, 'NO REHAB APPLY MAINTENANCE ONLY ')
C 700 FORMAT ( //, 29X, 'RECOMMENDED MAINTENANCE', 5X,
C      1           'AREA  MATERIAL  LABOR   MATERIAL  EQUIP  TOTAL',/,T58,
C      2           ' SY    CODE      COST     COST      COST')
C 710 FORMAT ( /, 31X, 2A8, 7X, F7.0, T97, F7.0)
C 720 FORMAT ( //, T95, F9.0, //)
C 730 FORMAT ( //, 29X, 'NO MAINTENANCE REQUIRED' ,//)
C 732 FORMAT ( //, 27X, 'DISTRICT ', I3,'   TOTAL AREA OF DISTRESS' ,//,
C      1             8X, 'DISTRESS', 19X, 'UNITS', 13X,
C      2             'FUNCTIONAL CLASSES', //, 50X, '1',10X,'2',10X,'3',
C      3             10X,'4',10X,'5',10X,'6',10X,'7')
C 733 FORMAT ( 90X, 'SELECTION CRITERIA:  ALL PAVEMENTS WITH ',//,
C      1           95X, '1) PES SCORE < 80',/,
C      2           95X, '2) PES STRATEGY < 3 (MED. OVERLAY)')
C 734 FORMAT ( //, 8X, 3A8, 3X, A8, 7(3X,F8.0))
C 735 FORMAT ( //, 8X, 3A8, 3X, A8, 7(3X,F8.2))
C 740 FORMAT ( //, 27X, 'DISTRICT ', I3,
C      1             '    MAINTENANCE REQUIREMENTS    ( AREA )', //,
C      1             16X, 'STRATEGY', 11X, 'UNITS', 13X,
C      2             'FUNCTIONAL CLASSES', //, 50X, '1',10X,'2',10X,'3',
C      3             10X,'4',10X,'5',10X,'6',10X,'7')
C 750 FORMAT ( //, 16X, 2A8, 3X, A8, 7(3X,F8.0))
C 760 FORMAT ( //, 27X, 'DISTRICT ', I3,
C      1          '    MAINTENANCE REQUIREMENTS    ( COST IN DOLLARS )',//,
C      1          16X, 'STRATEGY', 29X, 'FUNCTIONAL CLASSES', //, 50X,
C      2          '1',10X,'2',10X,'3',10X,'4',10X,'5',10X,'6',10X,'7')
C 770 FORMAT ( //, 16X, 2A8, 11X, 7(3X,F8.0))
      IF (IALV.EQ.1) GO TO 8
      CALL SETUP(MTREE)
      IALV = 1
    8 CONTINUE
C
C
   10 DO 3 I1 = 1, 12
      DO 4 I2 = 1, 7
      CSQYD(I1,I2) = 0.0
      CCOST(I1,I2) = 0.0
    4 CONTINUE
    3 CONTINUE
C
      DO 5 I1 = 1,9
      DO 6 I2 = 1, 7
      TOTALS(I1,I2) = 0.0
    6 CONTINUE
    5 CONTINUE
C
      DO 7 I1 = 1, 7
    7 TOTLN(I1) = 0.0
```

```
   20  LNTH = 2.0
C      RCOST = RCOST * 100.0
C
        CALL STRAT ( IT, IVIS, LOWHI, SRVC, NLANES, WDTH, LNTH, MTREE,
      1               IST, AREA, DST, DAREA, DCOST, JS)
C
        IF ( JS .EQ. 0) GOTO 61
C      DO 60 I = 1, JS
C      CSQYD(DST(I),IC) = CSQYD(DST(I),IC) + DAREA(I)
C      CCOST(DST(I),IC) = CCOST(DST(I),IC) + DCOST(I)
C 60   CONTINUE
   61  CONTINUE
C
C      DO 62 I = 1, 8
C  62  TOTALS(I,IC) = TOTALS(I,IC) + AREA(I)
C      TOTALS(9,IC) = TOTALS(9,IC) + SRVC
C      TOTLN(IC) = TOTLN(IC) + 1.0
C      WRITE ( 6, 600) DIST
C      WRITE ( 6, 610) CNTY, HWAY
C      WRITE ( 6, 620) BMIL, BSIGN, BDISP, EMIL, ESIGN, EDISP,
C     1                LANE, PESC
        K = IT - 3
C      WRITE ( 6, 630)( PTYPE(J,K),J=1,3), ADTL, EALT
C
C      WRITE ( 6, 635)
C
C      DO 100 I = 1,8
C      IF ( AREA(I) .EQ. 0.0 ) GOTO 100
C      IF (IST(I) .EQ. 0) GOTO 95
C      WRITE ( 6, 640) (DSTRES(J,I),J=1,3), AREA(I), UNITS(I),
C     1                (MSTRAT(J,IST(I)),J=1,2)
C      GOTO 100
C 95   CONTINUE
C 95   WRITE ( 6, 641) (DSTRES(J,I),J=1,3), AREA(I), UNITS(I)
C 100  CONTINUE
C
C      IF (IST(9) .EQ. 0) GOTO 102
C      WRITE ( 6, 650)(DSTRES(J,9),J=1,3), SRVC,
C     1               (MSTRAT(J,9),J=1,2)
C      GOTO 103
C 102  CONTINUE
C 102  WRITE ( 6, 651)(DSTRES(J,9),J=1,3), SRVC
C 103  CONTINUE
C
C
C      WRITE ( 6, 670)
C
        IF ( JX .EQ. 0 ) GOTO 160
        IF ( .IT .EQ. 10) GOTO 140
C      WRITE ( 6, 675) (RSTRAT(J,JX),J=1,2), RCOST
C      GOTO 160
  140  CONTINUE
C 140  WRITE ( 6, 680) (RST10(J,JX),J=1,3), RCOST
        GOTO 160
C 150  CONTINUE
C 150  WRITE ( 6, 690)
  160  CONTINUE
C      WRITE ( 6, 700)
        TOT = 0.0
        IF ( JS .EQ. 0) GOTO 175
        ISTE = 0
        DO 170 I = 1, JS
C      WRITE ( 6, 710 )(MSTRAT(J,DST(I)),J=1,2), DAREA(I), DCOST(I)
        TOT = TOT + DCOST(I)
  170  CONTINUE
C      WRITE ( 6, 720 ) TOT
C
        DO 176 I = 1,JS
        IEXT(I) = DST(I)
        ISTE = ISTE + 1
  176  CONTINUE
        GOTO 180
  175  CONTINUE
C 175  WRITE ( 6, 730)
```

```
      IEXT(1) = 0
      ISTE =  1
C 177 CONTINUE
  180 CONTINUE
C
      INDIST = DIST
      INCNTY = CNTY
      DO 302 I = 1, 7
      IF (TOTLN(I) .EQ. 0.0) GOTO 302
      TOTALS(9,I) = TOTALS(9,I) / TOTLN(I)
  302 CONTINUE
C     DO 304 I = 1, 8
C     WRITE( 6, 734) (DSTRES(J,I), J=1,3), UNIT2(I),
C    1               (TOTALS(I,J), J=1,7)
C 304 CONTINUE
C     WRITE( 6, 735) (DSTRES(J,9), J=1,3), UNIT2(9),
C    1               (TOTALS(9,J), J=1,7)
C     WRITE ( 6, 600) INDIST
C     WRITE ( 6, 733)
C     WRITE ( 6, 740) INDIST
C     DO 310 I = 1, 12
C     WRITE ( 6, 750) (MSTRAT(J,I), J=1,2), UNITS(IORDER(I)),
C    1               (CSQYD(I,J), J=1,7)
C 310 CONTINUE
C
C     PRINT ESTIMATED COST DATA
C     ANY SMALL DOLLAR AMOUNTS LT 1000 SET EQUAL TO 0
C
      DO  315 I = 1, 12
      DO  316 J = 1,  7
      IF ( CCOST(I,J) .LT. 1000.0 ) CCOST(I,J) = 0.0
  316 CONTINUE
  315 CONTINUE
C     WRITE ( 6, 600) INDIST
C     WRITE ( 6, 733)
C     WRITE ( 6, 760) INDIST
C     DO 320 I = 1, 12
C     WRITE ( 6, 770) (MSTRAT(J,I), J=1,2), (CCOST(I,J),J=1,7)
C 320 CONTINUE
C     IF ( DIST .NE. 99) GOTO 10
C
      RETURN
      END
C
      SUBROUTINE SETUP(MTREE)
C
C
C ****************************************************************
C
C     THIS SUBROUTINE ASSIGN REHABILITATION STRATEGIES TO EVERY
C     BRANCH OF THE DECISION TREE.
C
C ****************************************************************
C
C
C
      DIMENSION MTREE( 7, 28, 4)
      READ ( 3, 100) (((MTREE(I,J,K),K=1,4),J=1,28),I=1,7)
  100 FORMAT (4(I2,1X))
      RETURN
      END
C
C
C
      SUBROUTINE STRAT(IT,IVIS,LOWHI,SRVC,NLANES,WDTH,LNTH,MTREE,
     1       IST, AREA, DST, DAREA, DCOST, JS)
C
C
C ****************************************************************
C
C     THIS SUBROUTINE IS USED BY SUBROUTINE TRE IN THE SELECTION
C     OF THE BEST MAINTENANCE STRATEGY.
C
C ****************************************************************
```

```
C
C
      DIMENSION RUT(7), DIS(4), DPATCH(7), SPATCH(7), JSEQ1(4)
      DIMENSION JSEQ2(3),PAREA(3,8), COST(12)
      DIMENSION MTREE(7,28,4), IVIS(7), JMS(14), RAREA(14)
      INTEGER DST, RUT, DIS
      REAL LNTH
C
      DIMENSION IST(9), AREA(9), DST(6), DAREA(6), DCOST(6)
C
      DATA RUT / 000, 100, 010, 001, 200, 020, 002 /
      DATA DIS / 000, 100, 010, 001 /
      DATA DPATCH / 12.0, 10.0, 8.0, 10.0, 10.0, 10.0, 4.0/
      DATA SPATCH / 6.0, 4.5, 2.5, 2.5, 2.5, 2.5, 1.5 /
      DATA JSEQ1 / 7, 6, 8, 4/
      DATA JSEQ2 /  5, 12, 1/
      DATA PAREA / 5.0, 30.0, 50.0,
     2             5.0, 30.0, 50.0,
     3             5.0, 30.0, 50.0,
     4             5.0, 30.0, 50.0,
     5             1.0,  3.0,  5.0,
     6             2.0, 10.0, 20.0,
     7            50.0,100.0, 200.0,
     8             2.0, 5.0, 10.0/
      DATA COST / 0.25, 1.5, 2.5, 0.5, 0.5, 0.95, 1.2, 0.6,
     1            1.5, 2.4, 1.7, 0.5/
C
C
C
      DO 10 N = 1, 9
      AREA(N) = 0.0
      IST(N) = 0
   10 CONTINUE
C
      DO 11 N = 1, 5
      DST(N) = 0
      DAREA(N) = 0.0
      DCOST(N) = 0.0
   11 CONTINUE
C
      K = LOWHI
C
C
C     HANDLE RUTTING SEPERATELY
C
      DO 20 NR = 1, 7
      IF ( IVIS(1) .EQ. RUT(NR) ) GOTO 30
   20 CONTINUE
   30 IF ( NR .EQ. 1) GOTO 50
      J = NR - 1
      IF ( J .LT. 4 ) GOTO 40
      IST(2) = MTREE(IT-3,J,K)
      AREA(2) = PAREA(J-3,2) * 0.01 * LNTH * 1760. * WDTH * 0.33
      GOTO 50
   40 CONTINUE
      IST(1) = MTREE(IT-3,J,K)
      AREA(1) = PAREA(J,1) * 0.01 * LNTH * 1760. * WDTH * 0.33
   50 CONTINUE
C
C     OTHER DISTESS TYPES
C
      DO 100 M = 2 , 7
      L = M + 1
      DO 110 N = 1, 4
      IF ( IVIS(M) .EQ. DIS(N)) GOTO 120
  110 CONTINUE
  120 IF ( N .EQ. 1 ) GOTO 100
      J = 6 + (M-2)*3 + N-1
      IST(L) = MTREE(IT-3,J,K)
      AREA(L) = PAREA(N-1,L) * 0.01 * LNTH * 1760. * WDTH * 0.33
      IF ( M.EQ.4 ) AREA(L) = PAREA(N-1,L) * NLANES
      IF ( M.EQ.6 ) AREA(L) = PAREA(N-1,L) * LNTH * 5280. * 0.01
      IF ( M.EQ.7 ) AREA(L) = PAREA(N-1,L) * WDTH * 5280. * 0.01 *LNTH
C
```

```
C     PUT IN CASE OF M = 6 AND 7
C
  100 CONTINUE
C
C
      J = 25
      IF ( SRVC .GT. 3.0) GOTO 200
      J = 26
      IF ( SRVC .GT. 2.5) GOTO 200
      J = 27
      IF ( SRVC .GT. 1.5) GOTO 200
      J = 28
  200 IST(9) = MTREE(IT-3,J,K)
      AREA(9) = LNTH * 1760. * WDTH * 0.33
C
C     WRITE(6,201) (IST(I),I=1,9)
C     WRITE(6,202) (AREA(I),I=1,8)
C201  FORMAT( 10X, 9I6)
C202  FORMAT(10X, 8F6.1)
C DOMINANT STRATEGY CALCCULATION
C
      DO 300 I = 1, 14
  300 JMS(I) = 0
      DO 310 I = 1,9
      IF ( IST(I) .EQ. 0) GOTO 310
      J = IST(I)
      JMS(J) = 1
      RAREA(J) = AREA(I)
  310 CONTINUE
C
      JS = 0
      IF ( JMS(3) .EQ. 0 ) GOTO 395
      JS = JS + 1
      DST(JS) = 3
      DAREA(JS) = RAREA(3) * 20.0
      DCOST(JS) = DAREA(JS) * DPATCH(IT-3) * COST(3)
C
  395 IF ( JMS(2) .EQ. 0 ) GOTO 400
      JS = JS + 1
      DST(JS) = 2
      DAREA(JS) = RAREA(2) * 20.0
      DCOST(JS) = DAREA(JS) * SPATCH(IT-3) * COST(2)
C
  400 IF ( JMS(13) .EQ. 0) GOTO 440
      JS = JS + 2
      DST(JS-1) = 11
      DST(JS) = 9
      DAREA(JS-1) = RAREA(11)
      DCOST(JS-1) = DAREA(JS-1) * COST(11)
      DAREA(JS) = RAREA(9)
      DCOST(JS) = DAREA(JS) * COST(9)
      GOTO 999
C
  440 IF ( JMS(14) .EQ. 0) GOTO 450
      JS = JS + 2
      DST(JS-1) = 11
      DST(JS) = 10
      DAREA(JS-1) = RAREA(11)
      DAREA(JS) = LNTH * 1760. * WDTH * 0.33
      DCOST(JS-1) = DAREA(JS-1) * COST(11)
      DCOST(JS) = DAREA(JS) * COST(10) * 1.5
      GOTO 999
C
  450 IF ( JMS(11) .EQ. 0) GOTO 460
      JS = JS + 1
      DST(JS) = 11
      DAREA(JS) = RAREA(11)
      DCOST(JS) = DAREA(JS) * COST(11)
C
  460 IF ( JMS(10) .EQ. 0) GOTO 470
      JS = JS + 1
      DST(JS) = 10
      DAREA(JS) = LNTH*1760. * WDTH*0.33
      DCOST(JS) = DAREA(JS) * COST(10)
```

```
      GOTO 999
C
  470 IF ( JMS(9) .EQ. 0) GOTO 480
      JS = JS + 1
      DST(JS) = 9
      DAREA(JS) = RAREA(9)
      DCOST(JS) = DAREA(JS) * COST(9)
      GOTO 999
C
C
  480 DO 490 I = 1 , 4
      IF ( JMS(JSEQ1(I)) .EQ. 0) GOTO 490
      JS = JS + 1
      DST(JS) = JSEQ1(I)
      DAREA(JS) = LNTH*1760. * WDTH*0.33
      DCOST(JS) = DAREA(JS) * COST(JSEQ1(I))
      GOTO 999
  490 CONTINUE
C
      DO 500 I = 1,3
      IF ( JMS(JSEQ2(I)) .EQ. 0) GOTO 500
      JS = JS + 1
      DST(JS) = JSEQ2(I)
      DAREA(JS) = RAREA(JSEQ2(I))
      DCOST(JS) = DAREA(JS) * COST(JSEQ2(I))
      GOTO 999
  500 CONTINUE
C
  999 CONTINUE
      IF ( IT .EQ. 10 ) GOTO 1010
      IF ( JS .EQ. 0 ) GOTO 1010
      DO 1000 IX = 1, JS
 1000 IF ( DST(IX) .EQ. 2) GOTO 1002
      IF ( IVIS(5) .EQ. 000 .OR. IVIS(5) .EQ. 100) GOTO 1002
      JS = JS + 1
      J = 2
      IF ( IVIS(5) .EQ. 001) J = 3
      DST(JS) = 2
      DAREA(JS) = PAREA(J,6)*0.01 * LNTH*1760. * WDTH*0.33
      DCOST(JS) = DAREA(JS) * COST(2) * SPATCH(IT-3)
 1002 CONTINUE
C
C
C     LOOK FOR LONGITUDINAL CRACKS
C
C
      DO 1004 IX = 1, JS
 1004 IF ( DST(IX) .EQ. 1) GOTO 1010
      IF ( IVIS(6) .EQ. 000 .OR. IVIS(6) .EQ. 100) GOTO 1006
      JS = JS + 1
      J = 2
      IF ( IVIS(6) .EQ. 001) J = 3
      DST(JS) = 1
      DAREA(JS) = PAREA(J,7)*LNTH*5280.*0.01
      DCOST(JS) = DAREA(JS) * COST(1)
 1006 CONTINUE
C
C
C     LOOK FOR TRANSVERSE CRACKING
C
C
      IF ( IVIS(7) .EQ. 000 .OR. IVIS(7) .EQ. 100) GOTO 1010
      JS = JS + 1
      J = 2
      IF ( IVIS(7) .EQ. 001) J = 3
      DST(JS) = 1
      DAREA(JS) = PAREA(J,8) * WDTH * LNTH * 5280. * 0.01
      DCOST(JS) = DAREA(JS) * COST(1)
 1010 CONTINUE
      RETURN
      END
C
      SUBROUTINE RECODE(RVIS,IVIS)
C
```

```
C     *****************************************************************
C
C     THIS SUBROUTINE TRANSFORMS THE PERCENT VISUAL READINGS
C
C     TO  THE FORM (000,100,010,001)
C
C     *****************************************************************
C
C     IVIS  -     8-ELEMENT ARRAY WHICH HOLDS THE CODED VISUAL READINGS
C     RVISO -     8-ELEMENT ARRAY WHICH HOLDS THE TRANSFORMED VISUAL
C                 READINGS. RANGE 0 - 1
C
C
      REAL W(4),Z(4),F(4),L(4),T(4)
      INTEGER X(4),Y(4)
      DIMENSION RVIS(8),IVIS(7),RVISO(8)
C
      DATA F/50.0,35.71,17.89,0.0/
      DATA L/50.0,40.0,20.0,0.0/
      DATA T/50.0,42.0,17.0,0.0/
      DATA W/35.0,25.0,3.0,0.0/
      DATA X/001,010,100,000/
      DATA Y/002,020,002,000/
      DATA Z/60.0,50.0,25.0,0.0/
C
C
      DO 5 I=1,7
    5 IVIS(I)  =  000
       DO 20 I = 1,4
C
C     RUTTING
C
      IF ( RVIS(2).LT.0.01 ) GO TO 10
      IF ( RVIS(2).LT.Z(I) ) IVIS(1) = Y(I)
      GO TO 15
   10 IF ( RVIS(1).LE.Z(I) ) IVIS(1) = X(I)
C
C     RAVELLING
C
   15 IF ( RVIS(3).LE.Z(I) ) IVIS(2) = X(I)
C
C     FLUSHING
C
      IF ( RVIS(4).LE.Z(I) ) IVIS(3) = X(I)
C
C      FAILURES
C
      IF ( RVIS(5).LE.F(I) ) IVIS(4) = X(I)
C
C
C
C     ALLIGATOR CRACKING
C
      IF ( RVIS(6).LE.W(I) ) IVIS(5) = X(I)
C
C     LONGITUDINAL CRACKING
C
      IF ( RVIS(7).LE.L(I) ) IVIS(6) = X(I)
C
C
C
      IF ( RVIS(8).LE.T(I) ) IVIS(7) = X(I)
   20 CONTINUE
      RETURN
      END
      SUBROUTINE  FINDTF ( IC, AADT, AKIP, TRAF, TRAFC, TRAFD, TF, LHI)
C
C        *******************************************
C        CALCULATE DETERIORATION FACTOR FOR TRAFFIC
C        *******************************************
C
C        IC    - FUNCTIONAL CLASS. OF ROADWAY FOR REHAB.
C        AADT  - ADJUSTED ADT OF ROADWAY FOR REHAB.
C        AKIP  - ADJUSTED 18-KIP EQUIV. OF ROADWAY FOR REHAB.
```

```
C         TRAF   - TACS TABLE MMSTMINC.
C                  ARG.    - 4 FACTORS FOR EACH OF 7 FUNCT. CLASSES.
C                  RESULT - TRAFFIC FACTOR.
C         TRAFC - TACS TABLE MMSADTBN.
C                  ARG.    - FUNCT. CLASS.
C                  RESULT - ADT BREAK-OVER POINT FOR THE FUNCT. CLASS.
C         TRAFD - TACS TABLE MMSKIPBN.
C                  ARG.    - FUNCT. CLASS.
C                  RESULT - 18-KIP EQUIV. BREAK-OVER POINT (10**6) FOR
C                                THE FUNCT. CLASS.
C         TF      - FACTOR FROM TRAF RETURNED TO CALLER.
C
      DIMENSION   TRAF(7,4), TRAFC(7), TRAFD(7)
C     DATA TRAF   /1.80,1.80,1.00,1.00,1.80,1.80,1.00,1.00,
C    1             1.80,1.80,1.00,1.00,1.50,1.50,1.00,1.00,
C    2             1.50,1.50,1.00,1.00,1.50,1.50,1.00,1.00/
C     DATA C, D   /4*10000.0, 2*2000.0, 6*6.0/
      IF ( AADT .LT. TRAFC(IC) ) GO TO 1200
      IF ( AKIP .LT. TRAFD(IC) ) GO TO 1100
      TF          = TRAF(IC,1)
      J = 0
      LHI = 4
      GO TO 2000
 1100 TF          = TRAF(IC,2)
      LHI = 2
      GO TO 2000
 1200 IF ( AKIP .LT. TRAFD(IC) ) GO TO 1300
      TF          = TRAF(IC,3)
      LHI = 3
      GO TO 2000
 1300 TF          = TRAF(IC,4)
      LHI = 1
 2000 CONTINUE
      RETURN
      END
      SUBROUTINE MAITRE (DIST,CNTY,HWAY,BMIL,BSIGN,BDISP,EMIL,ESIGN,
     1      EDISP,LANE,IVIS,SRVC,IT,IC,NLANES,WDTH,ADTL,EALT,
     2      PESC, LOWHI, JX, RCOST,RVIS,RVISO,IEXT,ISTE,IALV,
     3       IST, AREA, DST, DAREA, DCOST, JS, TOT)
C
C
C     THIS SUBROUTINE IS USED WHEN A PREVENTIVE MAINTENANCE STRATEGY
C     WILL BE APPLIED.
C
C     THE DESICION CRITERIA IS:
C                           IF PES IS < 75
C                                 OR
C                           IF REHAB. STRAT. < 3
C
C
      DIMENSION IVIS(7), RVIS(8), IEXT(6), RVISO(8)
      DIMENSION IST(9), AREA(9), DST(6), DAREA(6), DCOST(6)
C
      CALL RECODE ( RVIS, IVIS )
C
      CALL TRE ( DIST,CNTY,HWAY,BMIL,BSIGN,BDISP,EMIL,ESIGN,EDISP,
     1           LANE,IVIS,SRVC,IT,IC,NLANES,WDTH,ADTL,EALT,PESC,
     2           LOWHI,JX,RCOST,IEXT,ISTE,IALV,
     3           IST, AREA, DST, DAREA, DCOST, JS, TOT)
C
      RETURN
      END
      SUBROUTINE IMPROV(IEXT,ISTE,RVIS,SRVC)
C
C ****************************************************************
C
C
C     THIS SUBROUTINE IS USED TO REDUCE THE PERCENTAGE OF DISTRESS
C     IN A SECTION OF ROAD WHEN A MAINTENANCE STRATEGY HAS BEEN
C     RECOMENDED.
C
C ****************************************************************
C
C
C     INPUT: MAINTENANCE STRATEGY
```

```
C              ACTUAL DISTRESS
C
C
C         OUTPUT:
C                IMPROVED DISTRESS
C
C
C
C
C
C
C
          DIMENSION IEXT(6), RVIS(8), MXGAIN(8,14), RIDE(14)
          REAL MXGAIN, RIDE
C
          DATA MXGAIN /  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  1.0,  1.0,
     2                   0.0,  0.0,  0.0,  0.0,  1.0,  0.3,  0.0,  0.0,
     3                   0.0,  1.0,  0.0,  0.0,  1.0,  0.5,  0.0,  0.0,
     4                   0.0,  0.0,  1.0,  0.0,  0.0,  0.1,  0.1,  0.1,
     5                   0.0,  0.0,  0.5,  0.5,  0.0,  0.7,  0.0,  0.0,
     6                   0.0,  0.0,  1.0,  1.0,  0.0,  1.0,  1.0,  1.0,
     7                   0.0,  0.0,  1.0,  1.0,  0.0,  1.0,  1.0,  1.0,
     8                   0.0,  0.0,  1.0,  1.0,  0.0,  1.0,  1.0,  1.0,
     9                   1.0,  1.0,  1.0,  1.0,  1.0,  1.0,  1.0,  1.0,
     1                   1.0,  1.0,  1.0,  1.0,  1.0,  1.0,  1.0,  1.0,
     2                   1.0,  1.0,  1.0,  1.0,  0.0,  0.0,  0.0,  0.0,
     3                   0.0,  0.0,  0.5,  0.5,  0.0,  0.5,  0.0,  0.0,
     3                   0.0,  0.0,  1.0,  1.0,  0.0,  1.0,  0.0,  0.0,
     2                   1.0,  1.0,  1.0,  1.0,  1.0,  1.0,  1.0,  1.0/
C
          DATA RIDE /0.0,0.5,1.0,0.0,0.0,0.0,0.0,0.0,1.5,2.0,0.5,0.0,0.5,
     1               2.0/
C
          DO 20 I= 1, ISTE
          IZ = IEXT(I)
          SRVC = SRVC + RIDE(IZ)
          IF (SRVC.GT.4.2) SRVC = 4.2
          DO 30 J = 1,8
          RVIS(J) = RVIS(J) -  MXGAIN(J,IZ) * RVIS(J)
       30 CONTINUE
       20 CONTINUE
          RETURN
          END
          SUBROUTINE TEST (DIST,IT,J,AVUC,SRVC,SKID,FAVU,FSIU,FSKU,LGTH,
     1                     AVU,SIV,SNV,RVIS,ENDVIS,V,FLEXSC,ADTS,WDTH,
     2                     SIBNRY,FUNC,IC,JX,RVISO,TCLS,ISWITH,ECFS,TOT,
     3                     DISL,PSIL,IAVUC,ISIUC,PESC,PESM,INX,V1,SIV1,
     4                 CNTY,IT,TIN,FRTH,AVTP,PLSX,
     1                  OV2,OV3,BB2,BB3,OVTH,ASPH,DMD,
     2                  FLEXL,EALT,HPR2,HPR3,AADT,AKIP,HMAC,IENT)
C
C *****************************************************************
C
C         THIS SUBROUTINE IS USED TO TEST BETWEEN  A MAINTENANCE
C         STRATEGY AND A REHABILITATION STRATEGY.
C
C *****************************************************************
C
C
C
C
C
          DIMENSION DOSL(8,100), PSOL(50), POS(50), TIN(254), FRTH(254)
          DIMENSION AVTP(254), RAIN(254), OV2(4,4), OV3(4,4), BB2(4,2)
          DIMENSION BB3(4,2)
          REAL LGTH
          INTEGER CNTY, EALT
          DIMENSION DISL(8,100),PSIL(50),RVIS(8),TCLS(5,10),RVISO(8)
          DIMENSION V(8), FLEXSC(8,3), SIBNRY(3,3), FUNC(7)
          DIMENSION FAVU(10,5), FSIU(5,5), FSKU(6,5),ENDVIS(8)
          DIMENSION REVIS(8), PESM(7), V1(8), ECFS(25,5)
          THP2 = HPR2
          THP3 = HPR3
          IAS = 0
```

```
      IRE = 0
      ICHEK = 0
      J = 0
      DO 5 I=1,8
    5 REVIS(I) = RVIS(I)
      SERVC = SRVC
      IF ( IENT.EQ.1) GO TO 20
   10 CALL SCORE(REVIS,SERVC,V,FLEXSC,ADTS,SIBNRY,FUNC,IC,IAVUC,
     1           ISIUC,PESC,IT)
C
      KPESC = (PESC + 0.001) * 100
C
      IF (PESC.LT.PESM(IC)) GO TO 20
      IAS = IAS + 1
      CALL AGING (JX,IT,RVISO,TCLS,INX,ISWITH,REVIS,SERVC,DISL,PSIL)
      GO TO 10
   20 IF (IAS.EQ.0) ICHEK = 1
      J = 3
      CALL FINAVU(IT,J,AVUC,SRVC,SKID,FAVU,FSIU,FSKU,
     1           AVU,SIV,SNV,RVIS,ENDVIS)
      DO 30 I=1,8
      V1(I) = ENDVIS(I)
   30 CONTINUE
      SIV1 = SIV
      JX = J
      AREA = LGTH * WDTH
      ACOST = AREA * ECFS(DIST,4)
C
      CALL SCORE (ENDVIS,SIV,V,FLEXSC,ADTS,SIBNRY,FUNC,IC,IAVUC,ISIUC,
     1           PESF,IT)
      PESC = PESF
      PESX = PESF
      IF (ICHEK.EQ.1) GO TO 70
      OVTHI  =  OVTH
      ASPHI  =  ASPH
      HMACI  =  HMAC
      FLEXLI =  FLEXL
      CALL SURVTA (CNTY,JX,IT,PESC,TIN,FRTH,AVTP,PLSX,
     1             OV2,OV3,BB2,BB3,OVTHI,ASPHI,DMD,DOSL,
     2             FLEXLI,PSOL,EALT,THP2,THP3,AADT,AKIP,HMACI)
   40 CALL SCORE (ENDVIS,SIV,V,FLEXSC,ADTS,SIBNRY,FUNC,IC,IAVUC,ISIUC,
     1           PESX,IT)
      IF (PESX.LT.PESM(IC)) GO TO 50
      IRE = IRE + 1
      CALL AGING (JX,IT,RVISO,TCLS,INX,ISWITH,ENDVIS,SIV,DOSL,PSOL)
      GO TO 40
   50 CONTINUE
      REC = IRE/IAS
      IF(REC.LE.1.0) GO TO 60
      AMTOT = REC * TOT
      IF (AMTOT.GT.ACOST)  GO TO 70
   60 J = 0
      GO TO 80
   70  J = 3
   80 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE SORT(A,N)
C
C ********************************************************************
C
C
C     THIS SUBROUTINE SORTS IN AN INCREASING MANNER ANY NUMERICAL
C     ONE DIMENSIONAL ARRAY.
C
C ********************************************************************
C
C
C
      DIMENSION A(N)
      IF (N.LE.1) RETURN
      LAST = N - 1
      DO 20 I = 1,LAST
```

```
      AMIN = A(I)
      JMIN = I
      JFIRST = I + 1
      DO 10 J = JFIRST,N
      IF (AMIN.LE.A(J)) GO TO 10
      AMIN = A(J)
      JMIN = J
   10 CONTINUE
      A(JMIN) = A(I)
      A(I) = AMIN
   20 CONTINUE
      RETURN
      END
```