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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

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| **AREA** | | | | |
| in²     | square inches | 6.5         | square centimeters | cm²    |
| ft²     | square feet   | 0.09        | square meters      | m²     |
| yd²     | square yards  | 0.8         | square meters      | m²     |
| mi²     | square miles  | 2.6         | square kilometers  | km²    |

| **MASS (weight)** | | | | |
| oz      | ounces        | 28          | grams         | g      |
| lb      | pounds        | 0.45        | kilograms     | kg     |
|         | short tons    | 0.9         | tonnes (2000 lb) | 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      |
| ft³     | cubic feet    | 0.03        | cubic meters  | m³     |
| yd³     | cubic yards   | 0.76        | cubic meters  | m³     |

#### Approximate Conversions from Metric Measures

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| **AREA** | | | | |
| cm²     | square centimeters | 0.16    | square inches | in²    |
| m²      | square meters     | 1.2       | square yards  | yd²    |
| km²     | square kilometers | 0.4       | square miles  | mi²    |
| ha      | hectares         | 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     |
| qt      | quarts          | 1.06       | gallons      | gal    |
| gal     | gallons         | 0.26       | cubic feet   | ft³    |
| m³      | cubic meters    | 35         | cubic yards  | yd³    |

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*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 prioritization and documenting the consequences of changes in funding levels.

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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.
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STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

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<th>DIST. NO.</th>
<th>CO. NO.</th>
<th>COUNTY NAME</th>
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</table>

3
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' up to 10' x 10'. (after 1984)

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

\[ U = 1 - a \exp \left( -b/x \right) \]  
(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

\[ AVUC = \left( U_1^{b_1} \right) \left( U_2^{b_2} \right) \ldots \left( U_n^{b_n} \right) \]  
(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.

Pavement Current Score = \[ (\text{Visual Utility})^{a_1} \times \]

\[ (\text{Riding Quality})^{a_2} \times \]

\[ (\text{Maintenance Cost})^{a_3} \]

\[ (\text{Safety Index})^{a_4} \]  
(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.
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
\[ \rho \] = 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.
\[ \beta \] = power that dictates the level of curvature of the curve.

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

\[ g = \frac{p_0 - p}{p_0 - p_t} \]  \hspace{1cm} (5)

where,
\[ p_0 \] = 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

\[ P = P_0 - (P_0 - P_f) (W/\rho)^\beta \]  

(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

\[ g = e^{-\frac{P^\beta}{W}} \]  

(7)

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

\[ P = P_0 - (P_0 - P_f) e^{-\frac{P^\beta}{W}} \]  

(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).

\[ A = A_0 - (A_0 - A_f) e^{-\frac{A^\beta}{W}} \]  

(9)

\[ S = S_0 - (S_0 - S_f) e^{-\frac{S^\beta}{W}} \]  

(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 statewide 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>
<thead>
<tr>
<th>Pavement Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EP-1</td>
<td>Continuously reinforced concrete pavement</td>
</tr>
<tr>
<td>EP-2</td>
<td>Jointed reinforced concrete pavement</td>
</tr>
<tr>
<td>EP-3</td>
<td>Jointed plain concrete pavement</td>
</tr>
<tr>
<td>EP-4</td>
<td>Thick asphaltic concrete pavement (greater than 5 1/2&quot; of hot-mixed asphaltic layers)</td>
</tr>
<tr>
<td>EP-5</td>
<td>Intermediate thickness asphaltic concrete pavement (2 1/2&quot; to 5 1/2&quot; of hot-mixed asphaltic layers)</td>
</tr>
<tr>
<td>EP-6</td>
<td>Thin surfaced flexible base pavement (hot-mixed asphaltic layers less than 2 1/2&quot; thick)</td>
</tr>
<tr>
<td>EP-7</td>
<td>Composite pavement (concrete pavement which has received an asphalt overlay)</td>
</tr>
<tr>
<td>EP-8</td>
<td>Overlaid and/or widened old concrete pavement</td>
</tr>
<tr>
<td>EP-9</td>
<td>Overlaid and/or widened old flexible pavement</td>
</tr>
<tr>
<td>EP-10</td>
<td>Thin surfaced flexible base pavement (surface treatment - seal coat combinations)</td>
</tr>
</tbody>
</table>
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\( (yd^2) \) x depth\( (in) \) x unit cost\( ($/yd^2 \times in) \)

**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\( (yd^2) \) x depth\( (in) \) x unit cost\( ($/yd^2 \times in) \)

**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.

Cost: Width of section\( (yds) \) x length\( (yds) \) x 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 \( yd^2 \) x unit cost\( ($/yd^2) \)
- Medium area - Cost: 500 \( yd^2 \) x unit cost\( ($/yd^2) \)
- Large area - Cost: 1000 \( yd^2 \) x 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\( (yds) \) x width of section\( (yds) \) x 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\( (yds) \) x length\( (yds) \) x 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\( (yds) \) x length\( (yds) \) x 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

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Seal Crack</td>
<td>0.23 ft.</td>
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<tr>
<td>2 - Patching</td>
<td>4.20 yd²/inch</td>
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<tr>
<td>3 - Full Depth Repair</td>
<td>4.45 yd²/inch</td>
</tr>
<tr>
<td>4 - Fog Seal</td>
<td>0.25 yd²</td>
</tr>
<tr>
<td>5 - Strip Seal</td>
<td>0.70 yd²</td>
</tr>
<tr>
<td>6 - Seal Coat</td>
<td>0.60 yd²</td>
</tr>
<tr>
<td>7 - Asphalt-Rubber Seal Coat</td>
<td>1.25 yd²</td>
</tr>
<tr>
<td>8 - Slurry Seal</td>
<td>0.35 yd²</td>
</tr>
<tr>
<td>9 - Level-Up</td>
<td>1.65 yd²</td>
</tr>
<tr>
<td>10 - Thin Overlay</td>
<td>2.40 yd²</td>
</tr>
<tr>
<td>11 - Rotomill</td>
<td>0.85 yd²</td>
</tr>
<tr>
<td>12 - Spot Seal</td>
<td>0.60 yd²</td>
</tr>
<tr>
<td>13 - Rotomill + Seal Coat</td>
<td>2.50 yd²</td>
</tr>
<tr>
<td>14 - Rotomill + Thin Overlay</td>
<td>3.25 yd²</td>
</tr>
</tbody>
</table>
Cost: Width(yds) * 1000 yds * unit cost($/yd²)

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($/yd²)

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>
<thead>
<tr>
<th></th>
<th>Listing of Maintenance Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Do Nothing</td>
</tr>
<tr>
<td>1</td>
<td>Seal Cracks</td>
</tr>
<tr>
<td>2</td>
<td>Partial Patch</td>
</tr>
<tr>
<td>3</td>
<td>Full Depth Patch</td>
</tr>
<tr>
<td>4</td>
<td>Fog Seal</td>
</tr>
<tr>
<td>5</td>
<td>Strip Seal</td>
</tr>
<tr>
<td>6</td>
<td>Seal Coat</td>
</tr>
<tr>
<td>7</td>
<td>Asphalt-Rubber Seal</td>
</tr>
<tr>
<td>8</td>
<td>Slurry Seal</td>
</tr>
<tr>
<td>9</td>
<td>Level-up</td>
</tr>
<tr>
<td>10</td>
<td>Thin Overlay</td>
</tr>
<tr>
<td>11</td>
<td>Rotomill</td>
</tr>
<tr>
<td>12</td>
<td>Spot Seal</td>
</tr>
<tr>
<td>13</td>
<td>Rotomill + Seal Coat</td>
</tr>
<tr>
<td>14</td>
<td>Rotomill + Thin Overlay</td>
</tr>
</tbody>
</table>
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:

\[ PSC = \left[ (AVU)^{a_1} (SIU)^{a_2} (SKU)^{a_3} (SCU)^{a_4} \right]^{1/FC} \]  \hspace{1cm} (11)

where,

\[ PSC \] = Pavement Evaluation System score which represents a highway segment's relative priority for rehabilitation
<table>
<thead>
<tr>
<th></th>
<th>Rehabilitation Strategy Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>PCC Overlay</td>
</tr>
<tr>
<td>2.</td>
<td>AC Overlay</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Inverted Overlay</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Rubber Asphalt plus Overlay</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Hot Recycling</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Heater Remix</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Lane Reconstruction</td>
</tr>
</tbody>
</table>
TABLE 7. Listing of Rehabilitation Funding Strategies

<table>
<thead>
<tr>
<th>Funding Strategy</th>
<th>Description of Equivalent Maintenance or Rehabilitation</th>
<th>Hot Mix Pavement</th>
<th>Surface Treated Pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-1</td>
<td>Seal coat, or fog seal, or extensive patching plus seal</td>
<td></td>
<td>Seal Coat</td>
</tr>
<tr>
<td>R-2</td>
<td>1&quot; ACP overlay, or seal plus level-up</td>
<td></td>
<td>Partial reconstruction</td>
</tr>
<tr>
<td>R-3</td>
<td>2 1/2&quot; ACP overlay</td>
<td></td>
<td>Full reconstruction, reworking and adding additional base and surfacing</td>
</tr>
<tr>
<td>R-4</td>
<td>4&quot; ACP overlay or rotomill plus thin overlay</td>
<td></td>
<td>Not applicable</td>
</tr>
<tr>
<td>R-5</td>
<td>7 1/2&quot; ACP overlay or reconstruction</td>
<td></td>
<td>Not applicable</td>
</tr>
<tr>
<td>Funding Strategy</td>
<td>Equivalent Cost ($/foot-mile)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-1</td>
<td>214</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-2</td>
<td>925</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-3</td>
<td>2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-4</td>
<td>3550</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-5</td>
<td>7000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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)

<table>
<thead>
<tr>
<th>ADT/Lane</th>
<th>Average Daily Traffic Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 or less</td>
<td>1.00</td>
</tr>
<tr>
<td>301 - 750</td>
<td>0.96</td>
</tr>
<tr>
<td>751 - 2000</td>
<td>0.92</td>
</tr>
<tr>
<td>2001 - 7500</td>
<td>0.88</td>
</tr>
<tr>
<td>7501 - 25,000</td>
<td>0.84</td>
</tr>
<tr>
<td>greater than 25,000</td>
<td>0.80</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>18-kip EAL</th>
<th>18-kip EAL Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than $6 \times 10^6$</td>
<td>1.00</td>
</tr>
<tr>
<td>$6 \times 10^6 - 12 \times 10^6$</td>
<td>0.95</td>
</tr>
<tr>
<td>greater than $12 \times 10^6$</td>
<td>0.90</td>
</tr>
<tr>
<td>Rainfall (in./yr.)</td>
<td>Rainfall Factor (RF)</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>20 or less</td>
<td>1.00</td>
</tr>
<tr>
<td>21 - 40</td>
<td>0.97</td>
</tr>
<tr>
<td>greater than 40</td>
<td>0.94</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Freeze Cycles (cycles/year)</th>
<th>Freeze-Thaw Factors (FF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 or less</td>
<td>1.000</td>
</tr>
<tr>
<td>11 - 30</td>
<td>0.973</td>
</tr>
<tr>
<td>31 - 50</td>
<td>0.967</td>
</tr>
<tr>
<td>greater than 50</td>
<td>0.960</td>
</tr>
</tbody>
</table>
AVU = Adjusted visual defect utility.
SIU = Serviceability index utility.
SKU = Skid number utility
SCU = Structural Capacity utility.

\[ a_1, a_2, a_3, a_4 = \text{Weighting factors.} \]

\[ a_1 = \frac{1}{(ADTF)(KEF)} \text{ and } a_2 = a_3 = a_4 = 1 \]

ADTF = Average daily traffic factor, as given in Table 10.
KEF = 18-kip equivalent axle loading factor (Table 11).
FC = Functional Class weighting factor.

<table>
<thead>
<tr>
<th>Functional Class</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.80</td>
</tr>
<tr>
<td>2</td>
<td>0.80</td>
</tr>
<tr>
<td>3</td>
<td>0.80</td>
</tr>
<tr>
<td>4</td>
<td>0.90</td>
</tr>
<tr>
<td>5</td>
<td>0.95</td>
</tr>
<tr>
<td>6</td>
<td>1.00</td>
</tr>
<tr>
<td>7</td>
<td>1.00</td>
</tr>
</tbody>
</table>

\[ AVU = (U_{\text{rutting}})^{b_1} (U_{\text{raveling}})^{b_2} (U_{\text{flushing}})^{b_3} (U_{\text{fail}})^{b_4} \]
\[ (U_{\text{allig.}})^{b_5} (U_{\text{long.}})^{b_6} (U_{\text{trans.}})^{b_7} \]

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"

\[ U_{\text{rutting}} = 1 - 0.323 \, e^{-12.365(1/x)} \]

\[ > 1" \text{ "Severe Rutting"} \]
\( U_{\text{rutting}} = 1 - 0.694 \ e^{-10.132(1/x)} \)  
where \( x \) = percent of area (wheelpath)  

(14)

**Raveling.**

\( U_{\text{raveling}} = 1 - 0.570 \ e^{-24.911(1/x)} \)  
where \( x \) = percent of area (total surface)  

(15)

**Flushing.**

\( U_{\text{flushing}} = 1 - 0.647 \ e^{-34.99(1/x)} \)  
where \( x \) = percent of area (total surface)  

(16)

**Failures.**

\( U_{\text{failures}} = 1 - 1.351 \ e^{-5.778(1/x)} \)  
where \( x \) = number of failures per mile  

(17)

**Alligator Cracking.**

\( U_{\text{alligator cracking}} = 1 - 0.559 \ e^{-4.962(1/x)} \)  
where \( x \) = percent of area (wheelpath)  

(18)

**Longitudinal Cracking.**

\( U_{\text{longitudinal cracking}} = 1 - 0.774 \ e^{-161.98(1/x)} \)  
where \( x \) = lin. ft. per lane per station  

(19)

**Transverse Cracking.**

\( U_{\text{transverse cracking}} = 1 - 0.545 \ e^{-6.798(1/x)} \)  
where \( x \) = number per station  

(20)

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):

\[ b_1 = \frac{1}{RF} \], rutting  
\[ b_2 = \frac{1}{(RF)(FF)} \], patching  
\[ b_3 = \frac{1}{(RF)(FF)} \], failures  
\[ b_4 = \frac{1}{(RF)(FF)} \], block cracking  
\[ b_5 = \frac{1}{(RF)(FF)} \], alligator cracking  
\[ b_6 = \frac{1}{(RF)(FF)} \], longitudinal cracking
\[ b_7 = \frac{1}{(RF)(FF)} \], 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: \((ADT)(SPEED) < 27,500\)**

\[
\begin{align*}
SIU &= 1.0 \\
SIU &= 1.0 - 0.10 \left(\frac{2.5 - SI}{0.5}\right) \text{ if } 2.0 \leq SI < 2.5 \\
SIU &= -0.2666 + 0.58333(SI) \text{ if } 0.8 \leq SI < 2.0 \\
SIU &= 0.20 \left(\frac{SI}{0.8}\right)^2 \text{ if } 0 \leq SI < 0.8 \\
SUU &= 0 \text{ if } SI < 0
\end{align*}
\]

where

- \(SIU\) = Serviceability Index Utility
- \(SI\) = Serviceability Index (obtained by use of the Mays Ride Meter)

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

\[
\begin{align*}
SIU &= 1.0 \\
SIU &= 1.0 - 0.10 \left(\frac{3.0 - SI}{0.5}\right) \text{ if } 2.5 \leq SI < 3.0 \\
SIU &= -0.5583 + 0.58333(SI) \text{ if } 1.3 \leq SI < 2.5 \\
SIU &= 0.20 \left(\frac{SI}{1.3}\right)^2 \text{ if } 0 \leq SI < 1.3 \\
SIU &= 0 \text{ if } SI < 0
\end{align*}
\]
Curve C: \((\text{ADT})(\text{SPEED}) > 165,000\)

\[
\begin{align*}
\text{SIU} &= 1.0 & \text{if } 3.5 \leq \text{SI} \leq 5.0 \\
\text{SIU} &= 1.0 - 0.10 \left(\frac{3.5 - \text{SI}}{0.5}\right) & \text{if } 3.0 \leq \text{SI} < 3.5 \\
\text{SIU} &= -0.85 + 0.58333 (\text{SI}) & \text{if } 1.8 \leq \text{SI} < 3.0 \\
\text{SIU} &= 0.20 \left(\frac{\text{SI}}{1.8}\right)^2 & \text{if } 0 \leq \text{SI} < 1.8 \\
\text{SIU} &= 0 & \text{if } \text{SI} < 0
\end{align*}
\]

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 Rehabilitation Funding Strategies

<table>
<thead>
<tr>
<th>Distress</th>
<th>Maximum % Recovery of Utility Score Following Various Funding Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R-1</td>
</tr>
<tr>
<td>&quot;Slight&quot; Rutting &lt; 1&quot;</td>
<td>33</td>
</tr>
<tr>
<td>&quot;Severe&quot; Rutting &gt; 1&quot;</td>
<td>0</td>
</tr>
<tr>
<td>Raveling</td>
<td>100</td>
</tr>
<tr>
<td>Flushing</td>
<td>100</td>
</tr>
<tr>
<td>Failures</td>
<td>25</td>
</tr>
<tr>
<td>Alligator Cracking</td>
<td>60</td>
</tr>
<tr>
<td>Longitudinal Cracking</td>
<td>60</td>
</tr>
<tr>
<td>Transverse Cracking</td>
<td>75</td>
</tr>
<tr>
<td>Attribute</td>
<td>Current Attribute Measure (before Rehabilitation)</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Serviceability</td>
<td>0.0 - 1.0</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Rutting &lt; 1&quot;</th>
<th>Rutting &gt; 1&quot;</th>
<th>Raveling</th>
<th>Flushing</th>
<th>Failures</th>
<th>Alligator</th>
<th>Longitudinal</th>
<th>Transverse</th>
<th>Serviceability Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>100</td>
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<tr>
<td>M-02</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>M-03</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>M-04</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>M-05</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>70</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>M-06</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>M-07</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>100</td>
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</tr>
<tr>
<td>M-08</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>M-09</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>M-10</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>M-11</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>M-12</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>15</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>M-13</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>M-14</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>200</td>
</tr>
</tbody>
</table>
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 rehabilitation 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:
\[ TMIN = (TMINI)(TF) \]  \hspace{1cm} (21)

where

\[ TMIN = \text{the minimum allowable time (years) to the next application of a rehabilitation funding strategy following the application of the rehabilitation strategy currently being considered.} \]

\[ TMINI = \text{same as TMIN except unadjusted for traffic (Table 19).} \]

\[ TF = \text{traffic factor for the highway segment being considered (Table 19), as explained in the next section.} \]

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:

\[ DS = (DSI)(TF)(CF)(SF) \]  \hspace{1cm} (22)

where

\[ DS = \text{deterioration slope of a funding strategy for a given pavement type after adjustment for traffic and climate conditions} \]

\[ DSI = \text{initial deterioration slope obtained from Table 20} \]

\[ TF = \text{traffic factor for the highway segment being considered (Table 19)} \]

\[ CF = \text{climate factor (Table 21)} \]

\[ SF = \text{soil factor (Table 22)} \]
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:

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

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>
<thead>
<tr>
<th>Highway Functional Classification</th>
<th>F.C. No.</th>
<th>Minimum Acceptable PS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal Arterial (IH and Urban Freeway)</td>
<td>1, 2</td>
<td>0.50</td>
</tr>
<tr>
<td>Minor Arterial (US and SH)</td>
<td>3, 4</td>
<td>0.45</td>
</tr>
<tr>
<td>Major Collector (FM)</td>
<td>5</td>
<td>0.40</td>
</tr>
<tr>
<td>Minor Collector (FM)</td>
<td>6</td>
<td>0.30</td>
</tr>
</tbody>
</table>
TABLE 18. Recommended Minimum Allowable Time (TMINI) Until Next Application of Rehabilitation

<table>
<thead>
<tr>
<th>Functional Class</th>
<th>TMINI (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>AADT</td>
<td>% Trucks</td>
</tr>
<tr>
<td>------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Funding Strategies</td>
<td>Pavement Type (refer to Table 3)</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>R-1</td>
<td>0.10</td>
</tr>
<tr>
<td>R-2</td>
<td>0.083</td>
</tr>
<tr>
<td>R-3</td>
<td>0.083</td>
</tr>
<tr>
<td>R-4</td>
<td>0.083</td>
</tr>
<tr>
<td>R-5</td>
<td>0.059</td>
</tr>
</tbody>
</table>
TABLE 21. Climate Factors (CF)

<table>
<thead>
<tr>
<th>Freeze-thaw cycles (cycles/yr)</th>
<th>Rainfall (in./yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 20</td>
</tr>
<tr>
<td>&gt; 10</td>
<td>1.0</td>
</tr>
<tr>
<td>11 - 30</td>
<td>1.0</td>
</tr>
<tr>
<td>31 - 50</td>
<td>1.0</td>
</tr>
<tr>
<td>&lt; 20</td>
<td>1.0</td>
</tr>
</tbody>
</table>

TABLE 22. Soil Factors

<table>
<thead>
<tr>
<th>Plasticity Index</th>
<th>Rainfall (in./yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 20</td>
</tr>
<tr>
<td>&lt; 20</td>
<td>1.00</td>
</tr>
<tr>
<td>20 - 40</td>
<td>1.02</td>
</tr>
<tr>
<td>&gt; 40</td>
<td>1.05</td>
</tr>
</tbody>
</table>
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:

\[ TMAX = TC + \frac{PSF - PSM}{DS} \]  \( (24) \)

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.

<table>
<thead>
<tr>
<th>Functional Class</th>
<th>Average Daily Traffic</th>
<th>18-kip x 10^6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12,000</td>
<td>8.0</td>
</tr>
<tr>
<td>2</td>
<td>12,000</td>
<td>8.0</td>
</tr>
<tr>
<td>3</td>
<td>8,000</td>
<td>6.0</td>
</tr>
<tr>
<td>4</td>
<td>8,000</td>
<td>6.0</td>
</tr>
<tr>
<td>5</td>
<td>2,000</td>
<td>2.5</td>
</tr>
<tr>
<td>6</td>
<td>2,000</td>
<td>2.5</td>
</tr>
<tr>
<td>7</td>
<td>2,000</td>
<td>2.5</td>
</tr>
</tbody>
</table>

TABLE 24. Low-High Codes for Maintenance Decision Tree

<table>
<thead>
<tr>
<th>Low-High</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL</td>
<td>1</td>
</tr>
<tr>
<td>LH</td>
<td>2</td>
</tr>
<tr>
<td>HL</td>
<td>3</td>
</tr>
<tr>
<td>HH</td>
<td>4</td>
</tr>
</tbody>
</table>
The applicable relationship, equation (7)

\[ g = e^{-\beta W} \]

where

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

Solving for \( W \) yields

\[ W = \frac{\rho}{(-\ln g)^{1/\beta}} \quad (25) \]

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, 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 sigmoidal 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 environmental 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>
<thead>
<tr>
<th>Pavement Type</th>
<th>Performance Equations Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Hot Mix on Black Base (BB)</td>
</tr>
<tr>
<td>5</td>
<td>Hot Mix (HM) on Granular Base</td>
</tr>
<tr>
<td>6</td>
<td>Hot Mix (HM) on Granular Base</td>
</tr>
<tr>
<td>7</td>
<td>Overlay (OV)</td>
</tr>
<tr>
<td>8</td>
<td>Overlay (OV)</td>
</tr>
<tr>
<td>9</td>
<td>Overlay (OV)</td>
</tr>
<tr>
<td>10</td>
<td>Surface Treatment (ST)</td>
</tr>
</tbody>
</table>
TABLE 26. Predicted Growth of Longitudinal Cracking in Differing Climatic Zones

<table>
<thead>
<tr>
<th>% Extent of Distress in Year N</th>
<th>% Extent of Distress (Year N+1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zone 1</td>
</tr>
<tr>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>15</td>
<td>19</td>
</tr>
<tr>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>25</td>
<td>29</td>
</tr>
</tbody>
</table>

| Thornthwaite Index            | 12     | -21    | -47    |
| Air Freeze-Thaw Cycles        | 26     | 80     | 30     |
| 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

$$AVU = (U_{rut})^{b_1} \times (U_{rav})^{b_2} \times (U_{fluence})^{b_3} \times (U_{fail})^{b_4}$$

$$\times (U_{allig})^{b_5} \times (U_{long})^{b_6} \times (U_{trans})^{b_7}$$

58
<table>
<thead>
<tr>
<th>Distress</th>
<th>Area Covered</th>
<th>As coded on Inspection Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight Rutting</td>
<td>0</td>
<td>000</td>
</tr>
<tr>
<td>Severe Rutting</td>
<td>0</td>
<td>000</td>
</tr>
<tr>
<td>Raveling</td>
<td>0</td>
<td>000</td>
</tr>
<tr>
<td>Flushing</td>
<td>0</td>
<td>000</td>
</tr>
<tr>
<td>Failures</td>
<td>0</td>
<td>000</td>
</tr>
<tr>
<td>Alligator Cracking</td>
<td>6-25%</td>
<td>010</td>
</tr>
<tr>
<td>Longitudinal Cracking</td>
<td>100-199 lin. ft.</td>
<td>010</td>
</tr>
<tr>
<td>Transverse Cracking</td>
<td>4 per 100 ft</td>
<td>100</td>
</tr>
</tbody>
</table>
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

\[ a_1 = \frac{1}{ADTF \times EALT} = \frac{1}{0.92 \times 1.0} = 1.087 \]
\[ WVU = (0.35)^{1.087} \approx 0.321 \]
From the SIUC equation for an ADT x Speed = 101,750

\[ \text{SIU} = -0.5583 + 0.58333 (1.6) = 0.375. \]

\[ \text{PSC} = (0.321 \times 0.375 \times 1.00 \times 1.00)^{1/0.95} = 0.108 \]

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.

\[ U_{\text{final}} = U_{\text{initial}} + (1 - U_{\text{initial}}) \times G \]

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

The calculation of the final AVU for strategy R-1 on FM 324 is shown below.
<table>
<thead>
<tr>
<th>Distress</th>
<th>$U_{initial}$</th>
<th>$G$ from Table 14</th>
<th>$U_{final}$ after R-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rutting &lt; 1&quot;</td>
<td>1.000</td>
<td>33</td>
<td>1.000</td>
</tr>
<tr>
<td>Raveling</td>
<td>1.000</td>
<td>100</td>
<td>1.000</td>
</tr>
<tr>
<td>Flushing</td>
<td>1.000</td>
<td>100</td>
<td>1.000</td>
</tr>
<tr>
<td>Failures</td>
<td>1.000</td>
<td>25</td>
<td>1.000</td>
</tr>
<tr>
<td>Alligator Cracking</td>
<td>0.530</td>
<td>60</td>
<td>0.824</td>
</tr>
<tr>
<td>Longitudinal Cracking</td>
<td>0.990</td>
<td>60</td>
<td>0.996</td>
</tr>
<tr>
<td>Transverse Cracking</td>
<td>0.710</td>
<td>75</td>
<td>0.928</td>
</tr>
</tbody>
</table>

$AVU_{final} = (1.000)^{1.06} \times (1.000)^{1.06} \times (1.000)^{1.06} \times (1.000)^{1.06} \times (0.824)^{1.06} \times (0.996)^{1.06} \times (0.928)^{1.06}$

$= 0.745$

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 $T_{max}$ (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

\[ DS = 0.100 \times 1.00 \times 1.00 \times 1.00 \times 1.00 = 0.100 \]

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

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

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

Calculation of \( T_{\text{min}} \) (Minimum Allowable Time).

\[ T_{\text{min}} = T_{\text{mini}} \times TF \]

\( T_{\text{mini}} \) (from Table 18) = 5.0
TF (from Table 19) = 1.0

\[ T_{\text{min}} = 3.0 \times 1.0 = 5.0 \text{ years} \]

**Funding Strategy Selection.** Select first strategy such that

\[ T_{\text{max}} > T_{\text{min}} \]

R-1 \[ T_{\text{max}} = -0.2 \quad T_{\text{min}} = 5.0 \]

R-2 \[ T_{\text{max}} = 4.52 \quad T_{\text{min}} = 5.0 \]

R-3 \[ T_{\text{max}} = 6.00 \quad T_{\text{min}} = 5.0 \]

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 $\rho$'s and $\beta$'s. The constants $\rho$ and $\beta$ 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 $\rho$ and $\beta$ formulas for Alligator Cracking on an Overlay pavement as follows:

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

where,

- FTC = Freeze-Thaw Cycles/yr
- AVT = Average Temperature
- PI = Plasticity Index
- HPR2 = Equivalent Thickness 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.

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

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

$$\rho = 4.2631$$

$$= 0.0185 \times XTI + 0.171 \times HPR3$$

where,

- XTI = Thornthwaite Index + 50.0

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

$$\beta = 1.4834$$
\[ \rho \text{ and } \beta \text{ for Longitudinal Cracking:} \]
\[ \rho = 135.08 \]
\[ \beta = 2.3006 \]

\[ \rho \text{ and } \beta \text{ for Transverse Cracking:} \]
\[ \rho = 154.60 \]
\[ \beta = 0.99673 \]

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)
\[
\beta = -\frac{\rho}{W} \\
g = e^{-\frac{\rho}{W}}
\]

where

\[ g = \text{percent area of distress} \]
\[ W = \text{accumulated 18-kip loads, time, or weather cycles} \]
\[ \rho \text{ and } \beta = \text{regression equations for each specific distress and pavement type} \]

a. Given \( g(\% \text{ area}) \), 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
\[
N(\text{months}) = W \times 1000 \times \frac{240}{\text{EALT}}
\]
\[ \text{EALT} = 20 \text{ year 18 kip ESAL (in thousands)} \]
\[ = 1.5227 \times 1000 \times \frac{240}{2652} \]
\[ = 137.8 \text{ months} \]
\[ N = N + 12 \\
= 137.8 + 12 \\
= 149.8 \]

\[ W = \frac{N \times EALT}{240 \times 1000} = \frac{149.8 \times 2652}{240 \times 1000} = 1.6553 \]

c. Find \( g \) for next year given \( W \).

\[ y = e^{-\left(\frac{W}{3}\right)} \]

\[ y = e^{-\left(\frac{1.6553}{3}\right)} \]

\[ 4.2631 \times 1.4834 \]

\[ g = e^{-\left(\frac{1.6553}{3}\right)} \]

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

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

\[ UVUC = (1.00)(1.00)(1.00)(1.00)(.972)(1.00)(1.00) \]

\[ = .972 \]

\[ AVUC = (1.00) \begin{pmatrix} 1.06 & 1.06 & 1.06 & 1.06 & 1.06 \\ 1.06 \end{pmatrix} \]

\[ \times \begin{pmatrix} 1.00 & 1.06(1.00) \end{pmatrix} \]

66
<table>
<thead>
<tr>
<th>% Area Now</th>
<th>Alligator Cracking</th>
<th>Longitudinal Cracking</th>
<th>Transverse Cracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>1.71</td>
<td>3.90</td>
<td>3.27</td>
</tr>
<tr>
<td>2.00</td>
<td>2.94</td>
<td>5.93</td>
<td>4.88</td>
</tr>
<tr>
<td>3.00</td>
<td>4.17</td>
<td>7.85</td>
<td>6.07</td>
</tr>
<tr>
<td>4.00</td>
<td>5.35</td>
<td>9.44</td>
<td>7.34</td>
</tr>
<tr>
<td>5.00</td>
<td>6.52</td>
<td>10.57</td>
<td>8.66</td>
</tr>
<tr>
<td>6.00</td>
<td>7.63</td>
<td>12.34</td>
<td>9.67</td>
</tr>
<tr>
<td>7.00</td>
<td>8.65</td>
<td>13.57</td>
<td>10.70</td>
</tr>
<tr>
<td>8.00</td>
<td>9.71</td>
<td>14.83</td>
<td>12.90</td>
</tr>
<tr>
<td>9.00</td>
<td>10.80</td>
<td>16.12</td>
<td>13.14</td>
</tr>
<tr>
<td>10.00</td>
<td>11.76</td>
<td>17.43</td>
<td>13.84</td>
</tr>
<tr>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>
= .966  
SIU = 1.00  
PESC = .966

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

<table>
<thead>
<tr>
<th>Distress</th>
<th>t = 1989</th>
<th>t = 1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alligator Cracking</td>
<td>1.71 = 2%</td>
<td>2.94%</td>
</tr>
<tr>
<td>Longitudinal Cracking</td>
<td>3.90 = 4%</td>
<td>9.44%</td>
</tr>
<tr>
<td>Transverse Cracking</td>
<td>3.27 = 4%</td>
<td>7.34%</td>
</tr>
<tr>
<td>SI</td>
<td>3.5</td>
<td>3.3</td>
</tr>
</tbody>
</table>

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.

\[ U_{\text{final}} = 1 - (U_{\text{initial}} - U_{\text{initial}}) \times [\text{Max gain}] \]

where maximum gain is the % gain factor for the maintenance strategy obtained from Table 16 where \( U_{\text{final}} \) has a maximum value of 1.00.
<table>
<thead>
<tr>
<th>Distress</th>
<th>Traffic</th>
<th>PES Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>010</td>
</tr>
<tr>
<td>Slight Rutting</td>
<td>LL</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>LH</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>9</td>
</tr>
<tr>
<td>Severe Rutting</td>
<td>LL</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>LH</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>13</td>
</tr>
<tr>
<td>Raveling</td>
<td>LL</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>LH</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>4</td>
</tr>
<tr>
<td>Flushing</td>
<td>LL</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>LH</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>6</td>
</tr>
<tr>
<td>Failures</td>
<td>LL</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>LH</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>3</td>
</tr>
<tr>
<td>Alligator Cracking</td>
<td>LL</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>LH</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>12</td>
</tr>
<tr>
<td>Longitudinal Cracking</td>
<td>LL</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>LH</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>1</td>
</tr>
<tr>
<td>Transverse Cracking</td>
<td>LL</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>LH</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>HH</td>
<td>1</td>
</tr>
<tr>
<td>Distress</td>
<td>initial</td>
<td>Max Gain from Table 16</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Rutting</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Raveling</td>
<td>0</td>
<td>.5</td>
</tr>
<tr>
<td>Flushing</td>
<td>0</td>
<td>.5</td>
</tr>
<tr>
<td>Failures</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Alligator Cracking</td>
<td>0.91</td>
<td>.5</td>
</tr>
<tr>
<td>Longitudinal Cracking</td>
<td>0.84</td>
<td>.15</td>
</tr>
<tr>
<td>Transverse Cracking</td>
<td>0.88</td>
<td>.15</td>
</tr>
<tr>
<td>SI</td>
<td>3.3</td>
<td>0</td>
</tr>
</tbody>
</table>

$$AVU = (1.00)^{1.06}(1.00)^{1.06}(1.00)^{1.06}(1.00)^{1.06}(0.95)^{1.06}(0.88)^{1.06}(0.90)^{1.06} = 0.75$$

$SIUC = 1$

$PESC = 75$

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**

<table>
<thead>
<tr>
<th>Year</th>
<th>PESM</th>
<th>PES</th>
<th>Strategy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>40</td>
<td>19</td>
<td>R-03</td>
<td>Medium Overlay</td>
</tr>
<tr>
<td>1985</td>
<td>40</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>40</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>40</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>40</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>40</td>
<td>96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>40</td>
<td>84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>40</td>
<td>64</td>
<td>M-12</td>
<td>Seal Coat</td>
</tr>
<tr>
<td>1992</td>
<td>40</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>40</td>
<td>57</td>
<td>M-1, M-12</td>
<td>Seal Cracks, Seal Coats</td>
</tr>
<tr>
<td>1994</td>
<td>40</td>
<td>98</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 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. 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 rehabilitation
TABLE 31. Information on Selected Pavement Sections

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

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

<table>
<thead>
<tr>
<th>Minimum PES Score</th>
<th>Maintenance Cost</th>
<th>Rehabilitation Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>321,214</td>
<td>1,180,000</td>
<td>1,501,214</td>
</tr>
<tr>
<td>75</td>
<td>326,319</td>
<td>1,066,500</td>
<td>1,392,819</td>
</tr>
<tr>
<td>70</td>
<td>334,761</td>
<td>1,032,600</td>
<td>1,367,361</td>
</tr>
<tr>
<td>65</td>
<td>375,240</td>
<td>1,032,600</td>
<td>1,407,840</td>
</tr>
<tr>
<td>60</td>
<td>395,107</td>
<td>1,032,600</td>
<td>1,427,707</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Traffic Level</th>
<th>Maintenance Cost</th>
<th>Rehabilitation Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half Traffic</td>
<td>345,895</td>
<td>608,000</td>
<td>953,895</td>
</tr>
<tr>
<td>Normal Traffic</td>
<td>326,319</td>
<td>1,104,600</td>
<td>1,430,919</td>
</tr>
<tr>
<td>Double Traffic</td>
<td>302,110</td>
<td>1,182,600</td>
<td>1,484,710</td>
</tr>
</tbody>
</table>
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 16. Rehabilitation Cycle for Hot Mix Pavement, Normal Traffic Load
OVERLAY
Half Traffic

Figure 18. Rehabilitation Cycle for Overlays, Half Traffic Load
Figure 20. Rehabilitation Cycle for Overlays, Double Traffic Load
Figure 71. 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>
<thead>
<tr>
<th>District</th>
<th>Maintenance Cost</th>
<th>Rehabilitation Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 (Dry)</td>
<td>363,138</td>
<td>463,000</td>
<td>826,138</td>
</tr>
<tr>
<td>4 (Dry, Cold)</td>
<td>366,370</td>
<td>531,000</td>
<td>897,370</td>
</tr>
<tr>
<td>19 (Wet, Cold)</td>
<td>343,049</td>
<td>761,000</td>
<td>1,114,049</td>
</tr>
</tbody>
</table>
### TABLE 35. Typical Results for Angelina County

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rehabilitation Costs ($)</td>
<td>3,975,000</td>
<td>396,000</td>
<td>302,000</td>
<td>276,000</td>
</tr>
<tr>
<td>Maintenance Costs</td>
<td>1,072,000</td>
<td>687,000</td>
<td>722,000</td>
<td>816,000</td>
</tr>
</tbody>
</table>

### TABLE 36. Consequence of Delaying Preventive Maintenance

<table>
<thead>
<tr>
<th>Criteria</th>
<th>5 year Average Cost per Year (in million $)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rehabilitation</td>
</tr>
<tr>
<td>A</td>
<td>1.01</td>
</tr>
<tr>
<td>B</td>
<td>1.73</td>
</tr>
<tr>
<td>C</td>
<td>2.30</td>
</tr>
<tr>
<td>Traffic (18-kip ESAL)</td>
<td>5 Year Average Cost per Year (in millions)</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
</tr>
<tr>
<td>1/2 Current Level</td>
<td>0.76</td>
</tr>
<tr>
<td>Current Level</td>
<td>1.01</td>
</tr>
<tr>
<td>Twice Current Level</td>
<td>1.70</td>
</tr>
<tr>
<td>Run</td>
<td>Rehab. Level</td>
</tr>
<tr>
<td>-----</td>
<td>--------------</td>
</tr>
<tr>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
</tr>
</tbody>
</table>
### MILES OF ROADWAY BREAKDOWN BY PAVEMENT SCORE AND FUNCTIONAL CLASSIFICATION

#### DISTRICT 11

<table>
<thead>
<tr>
<th>PAVEMENT SCORE</th>
<th>1 INTERS</th>
<th>2 URBANHW</th>
<th>3 PRINCAR</th>
<th>4 MINORAR</th>
<th>5 MAJORCL</th>
<th>6 MINORCL</th>
<th>7 PARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 THRU 9</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.0</td>
<td>4.3</td>
<td>6.0</td>
<td>0.0</td>
</tr>
<tr>
<td>10 THRU 19</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>17.1</td>
<td>12.0</td>
<td>0.0</td>
</tr>
<tr>
<td>20 THRU 29</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.6</td>
<td>49.1</td>
<td>10.5</td>
<td>0.0</td>
</tr>
<tr>
<td>30 THRU 39</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>6.0</td>
<td>59.1</td>
<td>18.2</td>
<td>0.3</td>
</tr>
<tr>
<td>40 THRU 49</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>11.3</td>
<td>62.1</td>
<td>32.3</td>
<td>0.0</td>
</tr>
<tr>
<td>50 THRU 59</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>124.8</td>
<td>47.5</td>
<td>0.0</td>
</tr>
<tr>
<td>60 THRU 69</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>7.1</td>
<td>114.9</td>
<td>90.3</td>
<td>0.0</td>
</tr>
<tr>
<td>70 THRU 79</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>5.8</td>
<td>145.6</td>
<td>80.2</td>
<td>0.0</td>
</tr>
<tr>
<td>80 THRU 89</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>8.1</td>
<td>152.8</td>
<td>105.7</td>
<td>0.0</td>
</tr>
<tr>
<td>90 THRU 99</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>7.6</td>
<td>171.5</td>
<td>130.2</td>
<td>1.7</td>
</tr>
<tr>
<td>100</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>6.2</td>
<td>81.8</td>
<td>87.0</td>
<td>1.8</td>
</tr>
</tbody>
</table>

| 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
<table>
<thead>
<tr>
<th>YEAR</th>
<th>REHABILITATION COST</th>
<th>MAINTENANCE COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>38367488.0</td>
<td>789647.06</td>
</tr>
<tr>
<td>1985</td>
<td>22410000.0</td>
<td>639332.81</td>
</tr>
<tr>
<td>1986</td>
<td>7352500.00</td>
<td>279881.19</td>
</tr>
<tr>
<td>1987</td>
<td>3406000.00</td>
<td>258581.56</td>
</tr>
<tr>
<td>1988</td>
<td>19503488.0</td>
<td>436364.87</td>
</tr>
</tbody>
</table>

| CUMULATIVE COST | 90679500.00 | 2403817.91 |

Figure 25. Rehabilitation and Maintenance Cost per Year
### Maintenance Cost Breakdown by Year and Functional Classification

**District 11**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>1 INTERST</th>
<th>2 URBANFM</th>
<th>3 PRINCAR</th>
<th>4 MINORAR</th>
<th>5 MAJORCI</th>
<th>6 MINORTL</th>
<th>7 PARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>126141.06</td>
<td>614095.19</td>
<td>49411.62</td>
<td>0.0</td>
</tr>
<tr>
<td>1985</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>90.00</td>
<td>355498.12</td>
<td>283745.50</td>
<td>0.0</td>
</tr>
<tr>
<td>1986</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>17999.75</td>
<td>129324.00</td>
<td>132467.69</td>
<td>90.00</td>
</tr>
<tr>
<td>1987</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>2503.20</td>
<td>190312.62</td>
<td>65766.37</td>
<td>0.0</td>
</tr>
<tr>
<td>1988</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>104664.06</td>
<td>170398.06</td>
<td>159303.56</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*Figure 26. Maintenance Cost Breakdown by Year and Functional Classification*
### Figure 27. Rehabilitation Cost Breakdown by Year and Functional Classification

<table>
<thead>
<tr>
<th>YEAR</th>
<th>1 INTERS</th>
<th>2 URBANFM</th>
<th>3 PRINCAR</th>
<th>4 MINORAR</th>
<th>5 MAJORCI</th>
<th>6 MINORCI</th>
<th>7 PARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>1949000</td>
<td>2456496</td>
<td>1173400</td>
<td>60000</td>
</tr>
<tr>
<td>1985</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>200000</td>
<td>1543400</td>
<td>677600</td>
<td>0</td>
</tr>
<tr>
<td>1986</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>412500</td>
<td>524000</td>
<td>170000</td>
<td>0</td>
</tr>
<tr>
<td>1987</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>252600</td>
<td>580000</td>
<td>0</td>
</tr>
<tr>
<td>1988</td>
<td>0 0</td>
<td>0 0</td>
<td>0 0</td>
<td>1076000</td>
<td>1379750</td>
<td>4630000</td>
<td>0</td>
</tr>
</tbody>
</table>
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.

Recommendations

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. **Evaluation of Weighting Factors.** 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. **Adaptation of Program for Use on Microcomputer.** The current system is based on mainframe, efforts are currently underway to transfer it to microcomputer.
REFERENCES


REFERENCES (Cont'd)


15. Finn, F. N. and Epps, J. A. Pavement Failure Analysis with Guidelines for Rehabilitation of Flexible Pavements. Texas Transportation Institute, Texas A&M University, College Station, Texas, Research Report 214-17, August 1980.

TABLE A-1. Variables Used in the Regression Models

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Structural</th>
<th>Pavement History</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thornthwaite Index (TI)</td>
<td>Plasticity Index (PI)</td>
<td></td>
</tr>
<tr>
<td>Freeze/Thaw (F/T)</td>
<td>Equivalent</td>
<td>N-18/month (N-18)</td>
</tr>
<tr>
<td>Average Temperature (T_Avg)</td>
<td>Thickness (H')^1</td>
<td></td>
</tr>
<tr>
<td>Plasticity Index (PI)</td>
<td>Percent Asphalt</td>
<td></td>
</tr>
<tr>
<td>Liquid Limit (LL)</td>
<td>Binder (Binder)^2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overlay Thickness (OVTH)^3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Asphalt Thickness (ASPH)^4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surfacing Thickness (HMAC)^5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dynaflect Mean Deflection (DMD)</td>
<td></td>
</tr>
</tbody>
</table>

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

\[ H' = \sum_{i=1}^{m} \left( \frac{E_i}{E_s} \right)^n t_i \]

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.
- \( n \) = Johansen's constant (0.33) or can be obtained from field data.
Appendix A

0 and 3 Equations for Sigmoidal

\[ g = \exp\left(-\frac{\beta}{N}\right)^3 \]

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.
In the regression models this variable is transformed as follows:

\[ HPR2 = H' \times E_s / 10^5 \]

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

\[ HPR3 = \frac{10^{10}}{E_s \times (H')^3} \]

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**

\[
\begin{align*}
\phi &= -0.02182(F/T) - 0.00831(PI) + 0.04499(Binder) + 0.15019(HPR2) \\
\theta &= 0.01201(TI) - 0.33166(F/T) + 0.13775(T_{AVG}) + 0.00114(PI) \\
&\quad - 0.31331(Binder) - 0.03234(HPR2) \\
P_f &= -0.00637(F/T) - 0.01550(T_{AVG}) - 0.00653(PI) \\
&\quad + 0.27714(Binder) + 0.05097(HPR2)
\end{align*}
\]

**Hot Mix**

\[
\begin{align*}
\phi &= -0.02000(TI) - 0.02481(F/T) - 0.03078(PI) + 0.60781(Binder) \\
&\quad + 0.06424(HPR2) \\
\theta &= 0.04045(F/T) - 0.22931(T_{AVG}) - 0.53013(Binder) \\
P_f &= -0.00665(F/T) - 0.07017(T_{AVG}) - 0.32473(PI) \\
&\quad + 0.57235(Binder) + 0.00722(HPR2)
\end{align*}
\]

**Overlays**

\[
\begin{align*}
\phi &= 0.26503(OVTH) + 0.07180(HPR2) \\
\theta &= 0.00413(TI) + 0.01036(F/T) + 0.04759(T_{AVG}) - 0.01707(Y-13) \\
&\quad - 0.09144(OVTH) - 0.01066(HPR2) \\
P_f &= 0.33037(OVTH) + 0.37627(HPR2)
\end{align*}
\]
TABLE A-3. Logarithmic Regression Models for the Design Parameters (PSI)

### Black Base

\[
\begin{align*}
\delta &= (F/T) - 0.46679 \cdot (T_{AVG}) - 0.86233 \cdot (PI) - 0.26711 \cdot (HPR2)^{1.65694} \\
\beta &= (F/T) - 0.60949 \cdot (T_{AVG}) + 0.93499 \cdot (Binder) - 1.37608 \cdot (HPR2) - 0.72725 \\
P_f &= (F/T) - 1.50634 \cdot (T_{AVG}) - 2.69460 \cdot (Binder)^{4.17755} - (HPR2)^{1.60919}
\end{align*}
\]

### Hot Mix

\[
\begin{align*}
\delta &= (TI) - 0.31419 \cdot (F/T) - 0.69942 \cdot (T_{AVG}) + 0.96204 \cdot (Binder) + 0.44492 \cdot (HPR2)^{1.85110} \\
\beta &= (F/T) + 0.40391 \cdot (T_{AVG}) + 0.44517 \cdot (N-18) - 0.04576 \cdot (Binder)^{1.50340} \\
P_f &= (F/T) + 0.39515 \cdot (T_{AVG}) - 3.14575 \cdot (Binder)^{5.31210} - (HPR2) - 0.44486
\end{align*}
\]

### Overlays

\[
\begin{align*}
\delta &= (F/T) - 0.24351 \cdot (Binder) + 0.71372 \cdot (HPR2) - 0.135059 \\
\beta &= (F/T) + 0.09767 \cdot (N-18) + 0.17402 \cdot (Binder) - 0.30623 \cdot (HPR2) - 0.22523 \\
P_f &= (F/T) + 0.14525 \cdot (T_{AVG}) - 0.25053 \cdot (N-18) - 0.24233 \\
&\quad \cdot (Binder) + 0.32304 \cdot (HPR2) + 0.62508
\end{align*}
\]
TABLE A-4. Regression Equations for Black Base Pavements

Rutting

<table>
<thead>
<tr>
<th>Area</th>
<th>$c = 0.00175 \ F/T - 0.0141 \ T_{AVG} + 0.257 \ ASPH$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>$-0.00493 \ F/T + 0.0262 \ T_{AVG} + 0.0387 \ PI - 0.0433 \ ASPH$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Severity</th>
<th>$c = 0.00263 - 0.0137 \ T_{AVG} + 0.253 \ ASPH$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>$0.00337 \ TI - 0.00928 \ F/T + 0.0341 \ T_{AVG} + 0.0242 \ PI - 0.071 \ ASPH$</td>
</tr>
</tbody>
</table>

Alligator

<table>
<thead>
<tr>
<th>Area</th>
<th>$c = 0.134 \ HPR2 - 0.067 \ HPR3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>$0.856 \ HPR3$</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Severity</th>
<th>$c = -0.00986 \ PI - 0.0422 \ ASPH + 0.0554 \ HPR2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>$1.37 \ HPR3$</td>
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</tbody>
</table>

Longitudinal

<table>
<thead>
<tr>
<th>Area</th>
<th>$c = 5.33 \ ASPH + 29.44 \ BINDER - 6.33 \ HPR3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>$0.0181 \ T_{AVG} + 0.421 \ HPR3$</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Severity</th>
<th>$c = -0.425 \ F/T - 0.0943 \ PI - 2.915 \ ASPH + 22.15 \ BINDER - 11.59 \ HPR3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>$0.118 \ TI + 0.0389 \ F/T - 0.701 \ BINDER + 0.553 \ HPR3$</td>
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</table>

Transverse

<table>
<thead>
<tr>
<th>Area</th>
<th>$c = -1.739 \ PI + 0.423 \ ASPH + 48.88 \ BINDER - 46.7 \ HPR3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>$0.3153 \ F/T + 0.625 \ HPR3$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Severity</th>
<th>$c = -0.502 \ PI + 26.75 \ BINDER - 29.75 \ HPR3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>$0.165 \ TI + 0.0362 \ F/T - 1.047 \ BINDER + 1.148 \ HPR3$</td>
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</tbody>
</table>
TABLE A-5. Regression Equations for Hot Mix Pavements

**Rutting**

<table>
<thead>
<tr>
<th>Area</th>
<th>$c = 0.2776 \text{ HMAC} + 0.0151 \text{ HPR2}$</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>$b = 0.0128 \text{ TI} + 0.0326 \text{ T}_{AVG} - 0.0331 \text{ HMAC}$</td>
</tr>
<tr>
<td></td>
<td>$- 0.00392 \text{ HPR2}$</td>
</tr>
<tr>
<td>Severity</td>
<td>$c = -0.00770 \text{ PI} + 0.386 \text{ HMAC}$</td>
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<tr>
<td></td>
<td>$b = -0.300720 \text{ F/T} - 0.0273 \text{ T}_{AVG} - 0.00267 \text{ HMAC}$</td>
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<tr>
<td></td>
<td>$- 0.000418 \text{ HPR2}$</td>
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</table>

**Alligator**

<table>
<thead>
<tr>
<th>Area</th>
<th>$c = 0.372 \text{ HMAC}$</th>
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<tr>
<td></td>
<td>$b = 2.198 \text{ HPR3}$</td>
</tr>
<tr>
<td>Severity</td>
<td>$c = -0.0000749 \text{ PI} - 0.291 \text{ HMAC}$</td>
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<td>$b = 3.145 \text{ HPR3}$</td>
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**Longitudinal**

<table>
<thead>
<tr>
<th>Area</th>
<th>$c = -0.988 \text{ F/T} - 4.38 \text{ T}_{AVG} - 2.99 \text{ PI} - 7.21 \text{ HMAC}$</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$b = 0.0422 \text{ F/T} - 0.359 \text{ HPR3}$</td>
</tr>
<tr>
<td>Severity</td>
<td>$c = -0.144 \text{ TI} + 3.018 \text{ T}_{AVG} - 3.155 \text{ PI} - 3.331 \text{ HMAC}$</td>
</tr>
<tr>
<td></td>
<td>$b = 0.0343 \text{ TI} + 0.0502 \text{ F/T}$</td>
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</tbody>
</table>

**Transverse**

<table>
<thead>
<tr>
<th>Area</th>
<th>$c = -1.97 \text{ TI} - 0.326 \text{ F/T} - 5.193 \text{ T}_{AVG} - 1.756 \text{ PI}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$b = 0.017 \text{ TI} - 0.0433 \text{ F/T} - 0.115 \text{ HMAC} - 0.0159 \text{ HPR2}$</td>
</tr>
<tr>
<td></td>
<td>$- 0.259 \text{ HPR3}$</td>
</tr>
<tr>
<td>Severity</td>
<td>$c = -0.196 \text{ TI} + 2.90 \text{ T}_{AVG} - 2.690 \text{ PI} - 5.475 \text{ HMAC}$</td>
</tr>
<tr>
<td></td>
<td>$b = 0.0519 \text{ F/T} - 0.537 \text{ HPR3}$</td>
</tr>
</tbody>
</table>
### TABLE A-6. Regression Equations for Overlaid Pavements

#### Rutting

<table>
<thead>
<tr>
<th>Area</th>
<th>$a = -0.00119 , PI + 0.369 , OVTH + 0.0485 , HPR2$</th>
<th>$b = 0.0059 , TI - 0.00217 , F/T + 0.0206 , T_{AVG}$</th>
<th>$- 0.122 , OVTH + 0.0789 , HPR3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity</td>
<td>$a = -0.00507 , PI + 0.233 , OVTH + 0.0705 , HPR2$</td>
<td>$b = 0.000779 , HPR3$</td>
<td>$- 0.00900 , TI + 0.0146 , T_{AVG} + 0.0024 , PI$</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>$- 0.0789 , OVTH + 0.0840 , HPR3$</td>
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</tbody>
</table>

#### Alligator

<table>
<thead>
<tr>
<th>Area</th>
<th>$a = -0.0159 , F/T + 0.00820 , T_{AVG} - 0.0121 , PI$</th>
<th>$b = 0.0185 , TI + 0.171 , HPR3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity</td>
<td>$a = -0.00975 , F/T + 0.0152 , T_{AVG} - 0.0106 , PI$</td>
<td>$b = 0.0301 , TI + 0.2267 , HPR3$</td>
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<td></td>
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</tbody>
</table>

#### Longitudinal

<table>
<thead>
<tr>
<th>Area</th>
<th>$a = -0.0166 , TI - 0.0870 , F/T + 1.63 , T_{AVG} - 0.179 , PI$</th>
<th>$b = 0.0331 , TI + 0.00433 , F/T - 0.00713 , T_{AVG} - 0.0589 , OVTH + 0.399 , HPR3$</th>
</tr>
</thead>
</table>

#### Transverse

<table>
<thead>
<tr>
<th>Area</th>
<th>$a = -0.794 , F/T + 1.922 , T_{AVG} - 22.91 , OVTH$</th>
<th>$b = -3.0097 , TI + 0.0149 , F/T - 0.0229 , T_{AVG} + 0.0441 , PI - 0.129 , OVTH + 0.480 , HPR3$</th>
</tr>
</thead>
</table>
TABLE A-6. Regression Equations for Overlaid Pavements (cont'd)

**Transverse (cont'd)**

<table>
<thead>
<tr>
<th>Severity</th>
<th>( \rho = -0.0627 \frac{F}{T} + 1.23 \frac{T}{T_{AVG}} + 5.273 ) OVT ( \text{OVTH} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta )</td>
<td>( \beta = 0.0187 \frac{TI}{T} + 0.0117 \frac{F}{T} + 0.0109 \ PI = 0.0305 \ HPR2 )</td>
</tr>
<tr>
<td></td>
<td>( + 0.108 \ HPR3 )</td>
</tr>
</tbody>
</table>
### TABLE A-7. Regression Equations for Surface Treated Pavements

**PSI**

\[
\sigma = -0.173 + 0.00687 \times T_{AVG} - 0.000632 \times TI + 0.0133
\]

\[
+ 0.0075 \times FLEXL + 0.00153 \times F/T - 0.0214 \times DMD
\]

\[
\beta = 1.0
\]

\[
P_f = 0.83
\]

**Rutting**

| Area       | \[\sigma = -0.1035 + 0.00544 \times T_{AVG} + 0.0067 \times FLEXL
\] |
<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>[-0.0015 \times LL + 0.00162 \times PI + 0.00077 \times F/T ]</td>
</tr>
<tr>
<td></td>
<td>[\beta = 1.540 - 0.0159 \times TI - 0.072 \times FLEXL ]</td>
</tr>
</tbody>
</table>

| Severity   | \[\sigma = -0.0678 + 0.00320 \times T_{AVG} + 0.00566 \times FLEXL
\] |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[-0.00031 \times LL + 0.00048 \times F/T ]</td>
</tr>
<tr>
<td></td>
<td>[\beta = 1.78 ]</td>
</tr>
</tbody>
</table>

**Ravelling**

<table>
<thead>
<tr>
<th>Area</th>
<th>[\sigma = 1.03 + 0.0146 \times TI + 0.0064 \times F/T - 0.509 \times DMD ]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[\beta = 1.28 ]</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Severity</th>
<th>[\sigma = 0.62 + 0.0129 \times TI + 0.0066 \times F/T - 0.449 \times DMD ]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[\beta = 1.40 ]</td>
</tr>
</tbody>
</table>

**Flushing**

<table>
<thead>
<tr>
<th>Area</th>
<th>[\sigma = 0.488 + 0.013 \times TI + 0.00345 \times F/T - 0.213 \times DMD ]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[\beta = 1.27 ]</td>
</tr>
</tbody>
</table>

| Severity   | \[\sigma = -0.14 + 0.031 \times T_{AVG} - 0.0103 \times TI - 0.062 \times FLEXL
\] |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[-0.201 \times DMD ]</td>
</tr>
<tr>
<td></td>
<td>[\beta = 1.50 ]</td>
</tr>
</tbody>
</table>

**Alligator**

| Area       | \[\sigma = -0.179 + 0.0121 \times T_{AVG} + 0.004 \times FLEXL - 0.0011
\] |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[-0.00153 \times F/T ]</td>
</tr>
<tr>
<td>TABLE A-7. Regression Equations for Surface Treated Pavements (Cont'd)</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Alligator (cont'd)</strong></td>
<td></td>
</tr>
<tr>
<td>Area ( \beta = 1.367 - 0.009 \times TI + 0.144 \times FLEXL - 0.577 \times DMD )</td>
<td></td>
</tr>
<tr>
<td>Severity ( \rho = -0.22 + 0.012 \times T_{AVG} + 0.00033 \times TI + 0.0027 \times FLEXL - 0.00058 \times LL + 0.0017 \times F/T )</td>
<td></td>
</tr>
<tr>
<td>( \beta = 2.91 - 0.099 \times T_{AVG} + 0.013 \times FLEXL - 1.567 \times DMD )</td>
<td></td>
</tr>
<tr>
<td><strong>Longitudinal</strong></td>
<td></td>
</tr>
<tr>
<td>Area ( \rho = -63.1 + 4.52 \times T_{AVG} + 0.541 \times TI + 7.41 \times FLEXL + 1.11 \times F/T )</td>
<td></td>
</tr>
<tr>
<td>( \beta = 1.15 )</td>
<td></td>
</tr>
<tr>
<td>Severity ( \rho = -120 - 8.77 \times T_{AVG} - 1.14 \times TI + 4.78 \times FLEXL + 1.32 \times F/T )</td>
<td></td>
</tr>
<tr>
<td>( \beta = 1.20 )</td>
<td></td>
</tr>
<tr>
<td><strong>Transverse</strong></td>
<td></td>
</tr>
<tr>
<td>Area ( \rho = -66.4 + 2.156 \times TI + 10.1 \times FLEXL + 0.718 \times F/T )</td>
<td></td>
</tr>
<tr>
<td>( \beta = 2.06 + 0.0734 \times FLEXL - 0.06 \times LL + 0.061 \times PI - 0.0037 \times F/T )</td>
<td></td>
</tr>
<tr>
<td>Severity ( \rho = 96.3 - 1.04 \times T_{AVG} - 1.07 \times TI - 3.313 \times F/T )</td>
<td></td>
</tr>
<tr>
<td>( \beta = 1.10 + 0.16 \times LL - 0.24 \times PI - 0.315 \times F/T )</td>
<td></td>
</tr>
<tr>
<td><strong>Patching</strong></td>
<td></td>
</tr>
<tr>
<td>Area ( \rho = 0.308 + 0.0025 \times T_{AVG} + 0.00022 \times TI + 0.0017 \times FLEXL - 0.0012 \times PI )</td>
<td></td>
</tr>
<tr>
<td>( \beta = 1.75 )</td>
<td></td>
</tr>
<tr>
<td>Severity ( \rho = -0.04 + 0.0035 \times T_{AVG} + 0.003 \times FLEXL - 0.0004 \times LL + 0.00039 \times F/T )</td>
<td></td>
</tr>
<tr>
<td>( \beta = -0.16 + 0.050 \times T_{AVG} + 0.090 \times FLEXL - 0.069 \times LL + 0.082 \times PI - 0.027 \times F/T )</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B

Decision Rules proposed to generate maintenance alternatives for flexible pavements.

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**

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>Traffic</th>
<th>PSI</th>
<th>3.0-3.5</th>
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<th>1.5-2.0</th>
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123
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.

Data Set #1 (PESTAC)

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

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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:

Cl - 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.

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<td>113</td>
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Last Card: 99
CURRENT VERSION AS OF MARCH 1, 1985

THIS PROGRAM PREDICTS PAVEMENT PERFORMANCE IN TERMS OF DISTRESS
AND PRESENT SERVICEABILITY INDEX FOR A TWENTY YEAR PERIOD.
THIS IS ACHIEVED THROUGH THE USE OF "S-SHAPED" CURVES OF THE
FORM:

\[ \text{DIST} = \exp(-\text{RHO}/\text{W}) \]

\[ \text{BETA} \]

THE STRUCTURAL PERFORMANCE OF THE PAVEMENT IS EVALUATED IN
TERMS OF THE FOLLOWING DISTRESS TYPES:

<table>
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<th>DISTRESS</th>
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<td>2. RAVELLING</td>
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<td>3. FLUSHING</td>
<td>ADT</td>
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<td>4. FAILURES</td>
<td>N-18</td>
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<td>5. ALLIGATOR CRACKING</td>
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<td>7. TRANSVERSAL CRACKING</td>
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DIMENSION FRLANE(6), STGY(5), T(5), FUNC(7), FESH(7)
DIMENSION PRTY(5), UCOST(5), SCOST(5,5), HMILES(11,7)
DIMENSION AUPL(6), ADTF(6), EUFL(3), EALF(3)
DIMENSION COMPSC(8,3), FLEXSC(8,3), TCLS(5,10)
DIMENSION FWIN(254), RAIN(254), SOILPI(254)
DIMENSION RUPL(3), RPPR(3), EUFL(4), FTPR(4)
DIMENSION FAVU(10,5), FSBU(5,10), ECSF(25,5)
DIMENSION FSIU(5,5), FSKU(6,5), IVIS(7), V(8)
DIMENSION IORDER(8), MMMODE(27), NOINIT(2,7)
DIMENSION SIBNY(3,3), SNBNY(3,3), CBMBRY(3,3),
DIMENSION TRAF(7,4), TRAFD(7)
DIMENSION ATN(7,10), DSMAX(10), CLIP(3,4), SOFL(3,3)
DIMENSION A(20), B(20), ENDVIS(8), V(7), RVIS(8), RVISO(8)
DIMENSION DINS(8,100), PSIL(50), V(8), TIN(254), AVTP(254)
DIMENSION OVS(4,4), OVS(4,4), BBZ(4,4), BBZ(4,2), RYCCOST(20)
DIMENSION MYCOST(20), RYCCOST(20,7), IEXT(6), MFCCOST(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, MMUC, SMUC, RMUC
INTEGER STGY, TPRY, HMPC, DESIGN, LHI
INTEGER DINT, CNTY, SLMT, ADTL, EALT, MOTH
REAL*8 OLDPW, HWAI, RUNDST, MMMODE, MHSIV, CMAT, CTOT
REAL*8 TMSIV, TMSIV, TMAPU, JOCOST, CSUM, SCOST, UCOST
REAL*8 CREHAB, CYNAT
REAL LANE, LGTH, MYCOST, MFCCOST
LOGICAL FLAG, FRMTAG
DATA LINENUM /00/ 540
DATA MSTRAT / 'M-01', 'M-02', 'M-03', 'M-04', 'M-05', 'M-06', 560
1  'M-07', 'M-08', 'M-09', 'M-10', 'M-11', 'M-12', 570
2  'M-13', 'M-14'/
DATA IORDER / 6, 5, 4, 7, 3, 1, 2, 8/ 580
DATA OVS /10.0,14.0,18.0,22.0/ 590
1  18.0,22.0,26.0,30.0, 600
2  18.0,22.0,26.0,30.0, 610
3  14.0,18.0,22.0,26.0/ 620
DATA OVS3 /14.0,12.0,10.0,8.0/ 630
1  8.0, 6.0, 4.0, 2.0, 640
2  8.0, 6.0, 4.0, 2.0, 650
3  10.0, 8.0, 6.0, 4.0/ 660
DATA BB2 /18.0,22.0,26.0,30.0/ 670
1  14.0,18.0,22.0,26.0/ 680
2  14.0,18.0,22.0,26.0/ 690
3  14.0,18.0,22.0,26.0/ 700
4  14.0,18.0,22.0,26.0/ 710
5  14.0,18.0,22.0,26.0/ 720
6  14.0,18.0,22.0,26.0/ 730
7  14.0,18.0,22.0,26.0/ 740

131
DATA BB3 / 1.8, 1.4, 1.0, 0.6,
      2.0, 1.6, 1.2, 0.8/
DATA MNCOOE / 'MHSATRAF', 'MHSCFREZ', 'MHSCONPE', 'MHSANCMAN',
      'MHSFLEXF', 'MHSFREZ', 'MHSFUNCL', 'MHSRAINS',
      'MHSREAVF', 'MHSREFZ', 'MHSREH65', 'MHSREH7',
      'MHSREH75', 'MHSREH85', 'MHSREH95', 'MHSREH995',
      'MHSSCI', 'MHSIN', 'MHSINCC', 'MHSINCCM',
      'MHSACTBN', 'MHSKREZ', 'MHSKPFM', 'MHSKTMI',
      'MHSMTACS' /
DATA OLDHW /
DATA FRNAME / 'A', 'B', 'C', 'X', 'Y', 'Z'/
DATA PRTY / 'R-01', 'R-02', 'R-03', 'R-04', 'R-05'/
110 FORMAT (I3, X, A8) 880
114 FORMAT (T0X, F5.0, 7X, F3.2) 890
118 FORMAT (22X, F2.0) 900
124 FORMAT (22X, F4.3) 910
125 FORMAT (22X, F4.3) 920
134 FORMAT (10X, F2.0, 10X, F4.3) 930
138 FORMAT (22X, F3.2) 940
142 FORMAT (10X, F2.0, 10X, F3.2) 950
156 FORMAT (22X, F5.0) 960
168 FORMAT (22X, F2.1) 970
184 FORMAT (22X, F3.1) 980
190 FORMAT (22X, F5.0) 990
206 FORMAT (22X, F2.2) 1000
515 FORMAT (I4, A8, I3, I3) 1010
560 FORMAT (I2, I3, A7, 2(I3, A2, F2.1), A1, I1, I1, I3, I3, F2.1, F2.0, 212, I2, I2,
600 FORMAT(1X, A) 1030
   'STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION', 1040
   'RUN DATE ', A8, '27X, PAGE', I3, /, 1050
   PAVEMENT EVALUATION SYSTEM (PES) - PROGRAM NO. 413551', /, 1060
   REHABILITATION STRATEGY AND COST ESTIMATES - REPORT RO6', /, 1070
   DISTRICT ', I3, / 1080
605 FORMAT(1X, A, I4, /) 1090
610 FORMAT(1X, A, ' -- DISTRESS --', /) 1100
   'T. ----------- DISTRESS -----------' 1110
   '--------------------- STRATEGY ---------------------', 1120
   ' + & DISP. = FD PVT. + SCO', 1130
   'RE + MAINT REHAB. +', 1140
   'HIGHWAY BEGIN END C WAY TYPE MIN.', 1150
   'CALC RUT1 RUT2 RAWL PLUS FAIL ALIG LONG TNR S PSI', 1160
   'COST COST', 1170
611 FORMAT(1X, A, 'MAINTENANCE STRATEGIES, 40X, REHAB. STRATEGIES', /) 1180
   '15X', 'CODE', '16X', 'STRATEGY', '37X', 'CODE', '16X', 'STRATEGY', / 1190
   '15X', 'M-01', '14X', 'SEAL CRACKS', '36X', 'R-01', '14X', 'SEAL COAT', / 1200
   '15X', 'M-02', '14X', 'PATCH', '42X', 'R-02', '14X', 'THIN OVERLAY', / 1210
   '15X', 'M-03', '14X', 'FULL DEPTH REPAIR', '31X', 'R-03', '14X', 'MEDIUM', 'OVERLAY', / 1220
   '15X', 'M-04', '14X', 'FOG SEAL', '39X', 'R-04', '14X', 'THICK OVERLAY', / 1230
   '15X', 'M-05', '14X', 'STRIP SEAL', '37X', 'R-05', '14X', 'RECONSTRUC', 1240
   'TION', '15X', 'M-06', '14X', 'SEAL COAT', '38X', / 1250
   '15X', 'M-07', '14X', 'ASPHALT-RUBBER SEAL', / 1260
   '15X', 'M-08', '14X', 'SLURRY SEAL', / 1270
   '15X', 'M-09', '14X', 'LEVEL UP', / 1280
   '15X', 'M-10', '14X', 'THING OVERLAY', / 1290
   '15X', 'M-11', '14X', 'ROTOMILL', / 1300
   '15X', 'M-12', '14X', 'SPOT SEAL', / 1310
   '15X', 'M-13', '14X', 'ROTOMILL + SEAL', / 1320
   '15X', 'M-14', '14X', 'ROTOMILL + OVERLAY', // 1330
621 FORMAT(1X, A, '1X, A7') 1340
622 FORMAT (I1X, 7X, 2(I1X, I3, A1, F3.1), 2X, II) 1350
623 FORMAT (1X, A7) 1360
624 FORMAT (1X, A7) 1370
625 FORMAT (1H+, 7X, 2(I1X, I3, A1, F3.1), 2X, I1) 1380
626 FORMAT (1H+, 7X, 7X, 1X, 2X, A1, F3.1) 1390
627 FORMAT (1H+, 7X, I3, A1, F3.1) 1400
628 FORMAT (1H+, 7X, I3, A1, F3.1) 1410
629 FORMAT (1H+, 7X, I3, A1, F3.1) 1420
630 FORMAT (1H+, 7X, 2X, A1, F3.1) 1430
631 FORMAT (1H+, 7X, 2X, A1, F3.1) 1440
632 FORMAT (1H+, 7X, 2X, A1, F3.1) 1450
633 FORMAT (1H+, 7X, 2X, A1, F3.1) 1460
634 FORMAT (1H+, 7X, 2X, A1, F3.1) 1470
635 FORMAT (1H+, 7X, 2X, A1, F3.1) 1480
| 635 FORMAT ( 1H+, 119X, F8.2, //) | 1490 |
| 636 FORMAT ( 43X, 'TOTALS':, 15X, 'MAINT.', | 1500 |
| 2X, F11.2, 3X, 'REHAB.', 2X, F11.2, 2X, //) | 1510 |
| 640 FORMAT ( 1H+, 92X, I4, 2X, A4, 21X, F9.2, //) | 1520 |
| 641 FORMAT ( 24X, 'CUMULATIVE COSTS: ', 5X, 'MAINTENANCE', | 1530 |
| 650 FORMAT ( 14X, I2, 1H+) | 1550 |
| 652 FORMAT ( 14X, I2, 1H+) | 1560 |
| 1 400 MILES OF ROADWAY BREAKDOWN BY PAVEMENT | 1570 |
| 2 36HSCORE AND FUNCTIONAL CLASSIFICATION", 12(1H+), // | 1580 |
| 3 14X, 1H+, 98X, 1H+, // | 1590 |
| 4 14X, 1H+, 42X, 10HDISTRICT , I2, 44X, 1H+, // | 1600 |
| 5 14X, 1H+, 42X, 1H+-------------------, 44X, 1H+, // | 1610 |
| 6 14X, 1H+, 36X, 30HMILES IN EACH FUNCTIONAL CLASS, 32X, 1620 |
| 6 1H+, /, 14X, 1H+, 32X, 1H+, 9X, 1H+, 9X, 1H+, 9X, 1H+, 1630 |
| 7 9X, 1H+, 5X, 1H+, 5X, 1H+, 5X, 1H+, 1640 |
| 8 14X, 1H+, 29X, 7MINIMUM, 3X, 7MURBANIZ, 3X, 1650 |
| 9X, 1H+, 98X, 1H+ // | 1660 |
| 10 4X, 4HPARK, 4X, 1H+, // | 1670 |
| 11 14X, 1H+, 11X, 1HPAVEMENT SCORE, 73X, 1H+, // | 1680 |
| 12 1H+, 98X, 1H+ // | 1690 |
| 13 1H+, 11X, 10HDISTRICT , I2, 5X, 7(F6.1, 4X), 1700 |
| 14 1H+, /, 14X, 1H+, 98X, 1H+) | 1710 |
| 654 FORMAT (14X, 1H+, 13X, I2, 1H+, THRU ', 12, 5X, 7(F6.1, 4X), | 1720 |
| 1H+, /, 14X, 1H+, 98X, 1H+ // | 1730 |
| 656 FORMAT (14X, 1H+, 17X, '100', 8X, 7(F6.1, 4X), 1H+, // | 1740 |
| 2 14X, 1H+, 98X, 1H+, 1H+ // | 1750 |
| 3 14X, 1H+, 98X, 1H+, 1H+ // | 1760 |
| 4 14X, 1H+, 100(1H+) // | 1770 |
| 657 FORMAT (14X, 1H+, 98X, 1H+, 1H+) | 1780 |
| 1 14X, 1H+, 98X, 1H+, /, | 1790 |
| 1 14X, 1H+, 12X, 'MEAN SCORE', 6X, 7(I6,4X), 1H+, /, | 1800 |
| 1 14X, 1H+, 98X, 1H+, 1H+, 1H+, 1H+, 1H+, 1H+, 1H+, 1H+, 1H+, 1H+, 1H+, 1H+, 1810 |
| 1 14X, 1H+, 12X, 'SAMPLE SIZE', 5X, 7(I6,4X), 1H+, /, 1820 |
| 1 14X, 1H+, 98X, 1H+, 1H+, 1H+, 1H+, 1H+, 1H+, 1H+, 1H+, 1830 |
| 1 14X, 1H+, 98X, 1H+, 1H+, 1H+, 1840 |
| 1 14X, 100(1H+) // | 1850 |
| 658 FORMAT (14X, 'NOTE - FRONTAGIE ROADS (ROADWAYS A-C AND X-Z)', 1860 |
| 1 'ARE CONSIDERED AS FUNCTIONAL CLASS 5 (MAJORCL).', 1870 |
| 1 'INSPECTED ' CARE NEEDED WHEN INTERPRETING RESULTS' ) 1880 |
| 660 FORMAT (12X, '47(1H+), 1SHCOST BREAKDOWN, 47(1H+), / // | 1890 |
| 2 12X, 1H+, 107X, 1H+, / | 1900 |
| 3 12X, 1H+, 45X, 9HDISTRICT , I3, 50X, 1H+, / | 1910 |
| 3 12X, 1H+, 45X, 12H+-------------------, 50X, 1H+, 1H+, 1920 |
| 4 12X, 1H+, 107X, 1H+, / | 1930 |
| 4 12X, 1H+, 107X, 1H+, / | 1940 |
| 4 12X, 1H+, 107X, 1H+, / | 1950 |
| 5 12X, 1H+, 4X, 7MURBAP, 14X, 1960 |
| 5 35HCOSTS FOR EACH RECOMMENDED STRATEGY, 1970 |
| 6 20X, 24HSUM OF % OF TOTAL, 3X, 1H+, / 1980 |
| 6 12X, 1H+, 4X, 7HRATING, 7X, 4HR-01, 7X, 4HR-02, 7X, 4HR-03, 1990 |
| 7 7X, 4HR-04, 7X, 4HR-05, 16X, 5HCOSTS, 10X, 5HCOSTS, 8X, 1H+, 2000 |
| 665 FORMAT (14X, '27(1H+), 35HCOST PROJECTION AND MAINTENANCE COST, 2010 |
| 1 9H PER YEAR, 29(1H+), /, 2020 |
| 2 14X, 1H+, 98X, 1H+, /, 14X, 1H+, 98X, 1H+, / 2030 |
| 3 14X, 1H+, 20X, 4YEAR, 15X, 4HREHABILITATION, 15X, 2040 |
| 4 11HMREHABILITATION, 19X, 1H+, /, 14X, 1H+, 44X, 4HREHABILITATION, 23X, 2050 |
| 5 4HCOST, 23X, 1H+, //, 14X, 1H+, 98X, 1H+, // 2060 |
| 666 FORMAT (14X, 1H+, 9X, 1SHCUMULATIVE COST, 13X, F12.2, 16X 2070 |
| 1 F12.2, 21X, 1H+, // 2080 |
| 667 FORMAT (14X, 1H+, 20X, I4, 13X, F12.2, 16X, F12.2, 21X, 1H+, //, 2090 |
| 1 14X, 1H+, 98X, 1H+, // 2090 |
| 668 FORMAT (14X, 100(1H+), // 2100 |
| 669 FORMAT (14X, 1H+, 98X, 1H+, //, 14X, 1H+, 98X, 1H+, // 2110 |
| 670 FORMAT (14X, 1H+, 107X, 1H+, // 2120 |
| 1 12X, 1H+, 5X, A4, 2X, 5(F11.2), 12X, F11.2, 8X, 95.1, 5X, 1H+, 2130 |
| 671 FORMAT (12X, 1H+, 19(1H+), // 2140 |
| 1 35HREHABILITATION COST BREAKDOWN BY YEAR, 2150 |
| 1 28H AND FUNCTIONAL CLASSIFICATION, 18(1H+), // 2160 |
| 2 12X, 1H+, 102X, 1H+, // 2170 |
| 3 12X, 1H+, 45X, 10HDISTRICT , I2, 46X, 1H+, // 2180 |
| 4 12X, 1H+, 45X, 12H+-------------------, 46X, 1H+, // 2190 |
| 5 12X, 1H+, 102X, 1H+, // 2200 |
| 6 12X, 1H+, 102X, 1H+, // 2210 |
6  12X, 1H*, 16X, 1H1, 12X, 1H2, 12X, 1H3, 12X, 1H4, 2230
7  12X, 1H5, 12X, 1H6, 14X, 1H7, 5X, 1H*, /,, 2240
8  12X, 1H*, 13X, 7HINTERST, 6X, 7HURBANFW, 6X, 7HPRINCAR, 2250
9  6X, 7HMNORAR, 6X, 7MAJORCL, 6X, 7HMNORCL, 2260
1  10X, 4HPARK, 3X, 1H*, /,, 2270
1  12X, 1H*, 5X, 4YEAR, 93X, 1H*, /,, 2280
1  12X, 1H*, 102X, 1H*) 2290
672 FORMAT (12X, 1H*, 5X, 1X, 7(F11.2, 2X), 1X, 1H*, /,,
1  12X, 1H*, 102X, 1H*) 2300
673 FORMAT (12X, 104(1H*)) 2310
674 FORMAT (12X, 7(F10.2, 4X)) 2320
675 FORMAT (12X, 20(1H*), 2330
1  35HMANTAINANCE COST BREAKDOWN BY YEAR ,
1  29HAND FUNCTIONAL CLASSIFICATION, 20(1H*),, 2340
1  12X, 1H*, 102X, 1H*,, 2350
3  12X, 1H*, 44X, 10HDISTRICT , 12, 46X, 1H*, /,, 2360
4  12X, 1H*, 44X, 12H-----------, 46X, 1H*, /,, 2370
5  12X, 1H*, 102X, 1H*, /,, 2380
6  12X, 1H*, 102X, 1H*, /,, 2390
7  12X, 1H*, 16X, 1H1, 12X, 1H2, 12X, 1H3, 12X, 1H4, 2400
7  12X, 1H5, 12X, 1H6, 14X, 1H7, 5X, 1H*, /,, 2410
8  12X, 1H*, 13X, 7HINTERST, 6X, 7HURBANFW, 6X, 7HPRINCAR, 2420
8  6X, 7HMNORAR, 6X, 7MAJORCL, 6X, 7HMNORCL, 2430
1  10X, 4HPARK, 3X, 1H*, /,, 2440
1  12X, 1H*, 5X, 4YEAR, 93X, 1H*, /,, 2450
1  12X, 1H*, 102X, 1H*) 2460
680 FORMAT (12X, 1H*, 107X, 1H*, /,, 2470
1  12X, 19(1H*), /,, 2480
2  12X, NOTE - DUE TO ROUNDING, PERCENTAGES MAY NOT SUM ', 2490
3  'TO EXACTLY 100.0.' 2500
681 FORMAT ('/12X, *** END REPORT RO6 ***') 2510
690 FORMAT ('/12X, ' /)
1  38X, 37(1H*), /,, 2520
2  38X, 1H*, 35X, 1H*, /,, 2530
3  38X, 1H*, 2X, 31HNO RECORDS SELECTED FOR REQUEST,2X,1H*, /,, 2540
4  38X, 1H*, 35X, 1H*, /,, 2550
5  38X, 37(1H*) 2560
691 FORMAT ('/12X, ' /)
1  2570
2  '***** END PROGRAM NO. 413551 ' 2580
3  '*****' 2590
4  READ DATA FROM 27 TACTABLES / ANY ORDER 2600
5  '-----------------------------------------------' 2610
6  INVALID TAC TABLE NAME CAUSES RUN TO ABORT WITH MESSAGE 2620
7  INDICATING PROBLEM TABLE NAME. 2630
8  AT END OF TABLEING, THIS FILE IS REMOVED BECAUSE CALLED 2640
9  SUBROUTINE BIGSUB (PGM. NO. 413550) ALSO NEEDS TO 2650
10  READ IN THESE TAC TABLES. 2660
999 READ ( 25, 110, END=240 ) ICODE, MMSIN 2670
1  ( MMSIN .ME. MHCODE (ICODE) ) GOTO 999 2680
2  GOTO ( l, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 2690
3  18, 19, 20, 21, 22, 23, 24, 25, 26, 27, ) ICODE 2700
1  2710
1  2720
1  2730
C  1 DO 112 I = 1, 6 2740
1  READ ( 25, 114, END=99 ) AUPU(I), ADTF(I) 2750
112 CONTINUE 2760
GOTO 999 2770
C  2 DO 116 I = 1, 254 2780
2  READ ( 25, 118, END=99 ) FRTH(I) 2790
116 CONTINUE 2800
GOTO 999 2810
C  2820
C          NOTE - ORDER STORED IS NOT ORDER READ IN. 2830
3  DO 120 I = 1, 8 2840
2  DO 122 J = 1, 3 2850
3  READ ( 25, 124, END=99 ) COMPSC (IORDER(I), J) 2860
122 CONTINUE 2870
120 CONTINUE 2880
GOTO 999 2890
134
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

C 6 DO 132 I = 1, 4
READ ( 25, 134, END=99 ) FUPL(I), FTFR(I)
132 CONTINUE
GOTO 999
C

C 7 DO 136 I = 1, 7
READ ( 25, 138, END=99 ) FUNC(I)
136 CONTINUE
GOTO 999
C

C 8 DO 140 I = 1, 3
READ ( 25, 142, END=99 ) RUPL(I), RFRR(I)
140 CONTINUE
GOTO 999
C

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

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

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

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

C 13 DO 160 I = 1, 6
DO 162 J = 1, 5
READ ( 25, 118, END=99 ) FSUK(I,J)
162 CONTINUE
160 CONTINUE
GOTO 999
C

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), EZPL(I)
170 CONTINUE
GOTO 999
C

135
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 ) SIBMRY(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 ) SMBNRY(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 ) CBMNRY(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, 7
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 ) DMAX(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

INVALID TACs TABLE NAME CAUSES RUN ABORT.

99 WRITE (6,98) MWSIM, MMCODE(ICODE)
98 FORMAT (10X,21ERROR IN READING TACs, //, 1
14HMMSCODE READ ,A8, 12HINSTEAD OF ,A8)
GOTO 6000

REWRITE SEQUENTIAL TACs TABLE FILE FOR SUBROUTINE BISUB,
PGM. NO. 413550, USE.

240 REWRITE 25

---------------------------------------------------------------------
READ YEAR OF INSPECTION AND PGM. RUN DATE.
---------------------------------------------------------------------

READ (2,515) INYEAR, RUNDAT, INOR, IPMNT
DO 50 I = 1, 1254
50 READ(2,55)IN(I),AVTP(I)

---------------------------------------------------------------------
READ FIRST NON-98 AND NON-99 (DISTRICT) RECORD AND BEGIN WORK.
---------------------------------------------------------------------

WRITE (6,611)
770 READ (2,560) DIST, CNTY, HWAY, BMIL, BSIGN, BDISP,
1 EMIL, EDSP, EMIL, EDSP, EDSP, EMIL, EDSP,
2 EMIL, EDSP, EDSP, EMIL, EDSP, EMIL, EDSP,
3 SIUC, SKUC, RMUC, ROADWY, DESIGN

---------------------------------------------------------------------
THIS SUBROUTINE CHANGES THE FIELD RATING, e.g. 100, 010, 001,
TO A PERCENTAGE OF THE AREA. RANGE FROM 0 TO 100.
---------------------------------------------------------------------

CALL DECODE(IVIS,RVIS,RVISO)
IDIST = DIST

DISTRICT = 99 -- END OF RUN.
DISTRICT = 98 -- NO RECORDS SELECTED FOR REPORTING FOR
THE USER-SUBMITTED REPORT REQUEST.

IF(DIST.EQ.99) GO TO 6000
IF(DIST.NE.98) GO TO 780
DIST=1000
IFAGE=1
LINENO=0
WRITE (6,600) RUNDAT, IPAGE, INDIST
WRITE (6,690)
WRITE (6,681)
INDIST=0
IFAGE=0
GOTO 770

780 CONTINUE
INITIALISE COST ARRAYS PREPARATORY TO BEGINNING NEW SEGMENT.

THESE ARRAYS ARE USED IN DETERMINING COST FIGURES FOR OUTPUT AT THE END OF A REPORT REQUEST OR END OF A DISTRICT WHICHEVER COMES FIRST.

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
     MCOST(IZ1, IZ2) = 0.0
     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
     HWTH = 0
     IPAGE = 0
     CREHAB = 0.0

ASSIGN BASIC PROGRAM VARIABLES AND CALCULATE ITEMS SUCH AS ADT, 18-KIP, AND SURFACE WIDTH FOR THE ROADWAY.

ADT IS INPUT TO THIS ROUTINE AS ALL LANES BOTH DIRECTIONS. 18-KIP IS INPUT AS ALL LANES IN ONE DIRECTION ONLY. SURFACE WIDTH (FOR COST COMPUTATIONS) IS JUDGED TO BE ALL LANES FOR HWY. DESIGN 1 AND 2, 0.5 OF TOTAL FOR ALL OTHER HWY. DESGINS, OR EXACTLY 24.0 FEET FOR ANY FRONTAGE LANE ROADWAY NO MATTER WHAT HWY. DESIGN.

895 IT = TYPE
     IFIST = 0
     CYMANT = 0.0
     ISWITH = 0
     FLAG = .FALSE.
Determine if frontage road or not. If so, set flag for further calculations below.

FRNTAG = .FALSE.
DO 902 ILNG = 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 = SOILP(CNTY)
AADT = FLOAT(AADT)/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 PFSM = PSGN(TEAM)
AADTS = AADT * SLMT

SELECT/GENERATE TRANSITION MATRICES BASED ON PAVEMENT TYPE:
DISL --- DISTRESS TRANSITION MATRIX
(100 X 7) R R FF A L T
T(I,J) --- FINAL STATE GIVEN CURRENT STATE I
AND DISTRESS TYPE J
PSIL (50 X 1) T(T) FINAL PSI GIVEN INITIAL PSI VALUE = 1/10

SELECT FROM 4 SUBROUTINES DEPENDING ON PAVEMENT TYPE:

SUBROUTINE

4 BLACK BASE (BB)
5 HOT MIX (HM)
6 HOT MIX (HM)
7 OVERLAY (OV)
8 OVERLAY (OV)
9 SURF. TREAT. (ST)

SURFACE TREATMENT

IF (TYPE.NE.10) GO TO 970
N18MTH = (EALT *.1000.0)/240.0
IF (N18MTH.LT.3000.0) GO TO 659
970 ID = 2
GO TO 989
C 659 CONTINUE
.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

***************BLACK BASE***********************

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
CALL BB(CNTY,IT,PESC,TIN,FRTH,AVTP,ASPH,HPR2,HPR3,PLSX,
1    DISL,PSIL,EALT)
GO TO 995

***************HOT MIX***********************

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,
CONTINUE

ID = IT - 5.0

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

----------------------OVERLAY----------------------
PTCC = FRTH(CNTY)

-----------------------------------------------
CALCULATE CLIMATIC WEIGHTING FACTORS
-----------------------------------------------

CALL FINDRF ( RFAL, RUPL, RFFR, FTCC, FUPL, FTFR, V)

-----------------------------------------------
DO LOOP FOR THE TWENTY YEAR PERIOD
-----------------------------------------------

IYR = INYEAR
DO 7000 IY=1,IHOR
   ISKAP = 0
   ISKIP = 0

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

-----------------------------------------------
DETERMINE TRAFFIC FACTOR (TF) FOR USE ALONG A DETERIORATION
SLOPE IN THE CALCULATION OF A PAVEMENT'S LIFE.

THEN, BRANCH DEPENDING UPON COMPARISON OF PRESENT PAVEMENT
SCORE TO MINIMUM ALLOWABLE FOR THAT FUNCTIONAL CLASSIFICATION.
-----------------------------------------------

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

IF ( KPESC .LT. IPMWT ) GO TO 1600
MNTH = MNTH + 12
IFIST = 0
GO TO 4000

-----------------------------------------------
WHEN PRESENT PAVEMENT SCORE G.T. 75, CALCULATE THE
SCORE FOR THE FOLLOWING YEAR USING THE AGED DISTRESSES.
-----------------------------------------------

WHEN ROADWAY'S PAVEMENT SCORE EXCEEDS THE MINIMUM REQUIRED,
THE PROGRAM CALCULATES THE SCORE FOR THE FOLLOWING YEAR,
AND THE ROUTINE MAINTENANCE COST FOR THAT YEAR USING THE
FOLLOWING SEQUENCE OF SUBRoutines:

SUBROUTINE PURPOSE
ROUTINE ROUTINE MAINTENANCE COST
AGING INCREASE % OF DISTRESS
SCORE OBTAIN PES FOR NEXT YEAR

8150
8160
8170
8180
8190
8200
8210
8220
8230
8240
8250
8260
8270
8280
8290
8300
8310
8320
8330
8340
8350
8360
8370
8380
8390
8400
8410
8420
8430
8440
8450
8460
8470
8480
8490
8500
8510
8520
8530
8540
8550
8560
8570
8580
8590
8600
8610
8620
8630
8640
8650
8660
8670
8680
8690
8700
8710
8720
8730
8740
8750
8760
8770
8780
8790
8800
8810
8820
8830
8840
8850
8860
8870
8880
**When the pavement score is less than 75 but greater than the minimum allowable score, the program will select a preventive maintenance strategy. The only exception to the rule is when it is more cost effective to have a major mitigation that will last X number of years, than to have many maintenance strategies that will last Y number of years where X = NY.**

---

**SUBROUTINE**

**MAITRE**

SUBROUTINE THAT WILL SET UP THE INPUT TO SUBROUTINE TRE

**TRE**

SELECT BEST PREVENTIVE MAINT. STRATEGY (OR UP TO 5 STRAT.)

**IMPROV**

RESET DISTRESSES ACCORDING TO MAINT. STRAT. SELECTED.

**TEST**

ECONOMIC ANALYSIS.

**SORT**

ARRANGE IN NUMERICAL ORDER THE MAINTENANCE STRATEGIES SELECTED.

**SCORE**

CALCULATE THE NEW SCORE.

---

1600 CONTINUE

CALL MAITRE (DIST, CNTY, HWAY, BML, BSEG, ADISP, EMIL, EDISP, LANE, IVIS, SRVC, IT, IC, NLANES, WTH, ADTY, EALT, KPESC, LHI, JX, RCOST, RVIS, RVISO, IEXT, ISTE, IALV,

1

IF (IT.EQ.10) GO TO 1601

2

IF (KPESC.GT.KPESM) GO TO 1603

3

IF (KPESC.GT.KPESM .LT. 7) GO TO 1603

IEXT = 1

IMY = 0

GO TO 1610

1603 IEXT = 0

IF (IEXT(1), EQ.0) GO TO 4000

1602 CALL IMPRVT (IEXT, ISTE, RVIS, SRVC)

CALL SCORE (RVIS, SRVC, V, FLEXSC, ADTS, SIBNR, FUNC, IC, IAVUC,

1

IST= 1

ITEXT(1) = 10

THT = 2.55 * LGTH = WTH = 586.7

GO TO 1602

1604 CONTINUE

1605 CALL IMPRVT (IEXT(1), IAVUC, SRVC, SKID, FAVU, FSIU, FSKU, LGTH,

1

AVU, SIV, SNW, RVIS, ENDVIS, V, FLEXSC, ADTS, WTH, SIBNR, FUNC, IC, JX, RVIISO, TCLS, ISWTH, IECFS, TOT, DISL, PSIL, IAVUC, ISIUC, PESC, PESM, INX, VI, SIV1,

4

CNTT, IT, TIM, FRTH, AVTF, PLSX,

1

OY3, OY3, B3, BB3, OYTH, ASPH, DMD,

2

FLEXL, EALT, HPR2, HPR3, AADT, AKIP, HMAC, IEXT)

INX = 0

1607 CALL TEST (DIST, IT, J, AVUC, SRVC, SKID, FAVU, FSIU, FSKU, LGTH,

1

AVU, SIV, SNW, RVIS, ENDVIS, V, FLEXSC, ADTS, WTH, SIBNR, FUNC, IC, JX, RVIISO, TCLS, ISWTH, IECFS, TOT,

3

DISL, PSIL, IAVUC, ISIUC, PESC, PESM, INX, VI, SIV1,

4

CNTT, IT, TIM, FRTH, AVTF, PLSX,

1

OY3, OY3, B3, BB3, OYTH, ASPH, DMD,

2

FLEXL, EALT, HPR2, HPR3, AADT, AKIP, HMAC, IEXT)

INX = 0

1610 CONTINUE

1611 CALL IMPRVT (IEXT(1), IAVUC, SRVC, SKID, FAVU, FSIU, FSKU, LGTH,

1

AVU, SIV, SNW, RVIS, ENDVIS, V, FLEXSC, ADTS, WTH, SIBNR, FUNC, IC, JX, RVIISO, TCLS, ISWTH, IECFS, TOT,

3

DISL, PSIL, IAVUC, ISIUC, PESC, PESM, INX, VI, SIV1,

4

CNTT, IT, TIM, FRTH, AVTF, PLSX,

1

OY3, OY3, B3, BB3, OYTH, ASPH, DMD,

2

FLEXL, EALT, HPR2, HPR3, AADT, AKIP, HMAC, IEXT)

INX = 0

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) ITR, MSTRAT(IEXT(1)), TOT
GO TO 1775
1700 WRITE(6,626) ITR, (MSTRAT(IEXT(1)), I=1,2), TOT
GO TO 1775
1725 WRITE(6,627) ITR, (MSTRAT(IEXT(1)), I=1,3), TOT
GO TO 1775
1750 WRITE(6,628) ITR, (MSTRAT(IEXT(1)), I=1,4), TOT
GO TO 1775
1755 WRITE(6,629) ITR, (MSTRAT(IEXT(1)), I=1,5), TOT
GO TO 1775
1760 WRITE(6,630) ITR, (MSTRAT(IEXT(1)), I=1,6), TOT
1775 CONTINUE
IF (IST = 1)
CTMNT = CTMNT + TOT
CMNT = CMNT + TOT
MFCOST(X,IC) = MFCOST(X,IC) + TOT
MYCOST(X) = MYCOST(X) + TOT
IF (IMK.EQ.1) GO TO 3030
GO TO 4000

WHEN PRESENT PAVEMENT SCORE L.T. MINIMUM, CALCULATE
REHABILITATION NEEDS.

WHEN THE ROADWAY'S PAVEMENT SCORE IS UNDER THE MINIMUM
ALLOWED FOR THAT PAVEMENT TYPE USED IN THE GIVEN FUNCTIONAL
CLASS, REHAB. IS REQUIRED AND A SERIES OF COMPUTATIONS ARE
MADE. THE MINIMUM ACCEPTABLE LIFE OF A REHABILITATED
PAVEMENT GIVEN THE SAME PAVEMENT TYPE AS IN PLACE AND THE
SAME FUNCTIONAL CLASS AS PRESENT IS GAINED. FOR EACH OF
THE AMOUNT REHAB. STRATEGIES (PROGRESSIVELY MORE ALL-
ENCOMPASING), THE ESTIMATED REHABILITATED PAVEMENT SCORE
IS COMPUTED AND RUN THRU DETERIORATION CALCULATIONS TO
GAIN THE LIFE EXPECTANCY. THIS EXPECTED LIFE IS COMPARED
TO THE MINIMUM ALLOWABLE TO DETERMINE WHICH OF THE 5
STRATEGIES HAS THE NEAREST ABOVE-MINIMUM LIFE AND THAT ONE
IS CHosen AS THE STRATEGY TO USE. GIVEN THE CHOSEN STRATEGY,
COST OF REHABILITATION IS COMPUTED AND RUNNING TOTAL FOR THE
DISTRICT OR REPORT-REQUEST DISTRICT PORTION (WHICHEVER IS
LESS). AN URGENCY-OF-REHAB-NEED IS THEN CREATED
BY DETERMINING JUST HOW FAR BELOW THE MINIMUM ALLOWABLE THE
PRESENT PAVEMENT SCORE IS. THE 5 STRATEGY LIVES, CHOSEN
STRATEGY AND ITS COST, AND THE URGENCY DETERMINATION ARE
THEN PRINTED.
NEW TRANSITION MATRICES ARE CREATED FOR THE REHABILITATED
SECTION AND THEN THE SECTION IS AGED BASED ON THE NEW
MATRIX. IF STRATEGIES 1 OR 2 ARE SELECTED, THE PROGRAM WILL
TRY TO SELECT A MAINTENANCE STRATEGY INSTEAD.

THE SEQUENCE OF SUBROUTINES IS AS FOLLOWS:

SUBROUTINE PURPOSE
FINDTI ASSIGN MINIMUM LIFE FOR MAINTENANCE STRATEGY
FINAVU CALCULATE ESTIMATED ADJUSTED VISUAL UTILITY(AVU), ESTIMATED SKID NUMBER(SN), AND ESTIMATED SERVICEABILITY INDEX(SI) FOR EACH OF 5 MAINTENANCE STRATEGIES.
SCORE CALCULATE THE NEW SCORE FOR EACH MAINTENANCE STRATEGY.
FITMAX CALCULATE EXPECTED LIFE FOR EACH MAINTENANCE STRATEGY.
LIMIT PLACE LIMIT UPON STRAT. SELECTION OF TRANSITION MATRIX AFTER REHAB.
SURVTA ASSIGN NEW VALUES FOR GENERATION OF TRANSITION MATRIX AFTER REHAB.
AGING AGE DISTERSSES
SCORE CALCULATE PES.
2001 CALL FINDTI ( IC, IT, ATNR, TMNI )
    ISWITH = 1
    INX = 0
    MTH = 0
    TMNI = TMNI * TF

LOOP THRU ONCE FOR EACH OF 5 REHAB. STRATEGIES.

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, AVU, SIV, SNV, RVIS, ENDISV)
    GOTO 3020
3010 CALL FINAVU ( IT, J, AVUC, SRVC, SKID, FAVU, FSIU, FSKU, AVU, SIV, SNV, RVIS, ENDISV)
3020 CONTINUE

C
    ISKUC = 1000
    IRMUC = 1000
    CALL SCORE (ENDVIS, SIV, V, FLEXSC, ADTS, SIBNRY, FUNC, IC, IAVUC, ISIUC, PESF, IT)
    CALL FITMAX ( J, IT, RFAL, RUPL, FTCC, FUPL, PLSX, TF, PESF, PSNM, TCLS, FSDS, CLIP, SOLF, TMAX)
    T(JX) = TMAX
    IF ( FLAG ) GO TO 3000
    IRMS = STGY(J)
    JX = J
    PESF = PESF
    WVUC = IAVUC
    SIUC = ISIUC
    SKUC = ISKUC / 10
    RMUC = IRMUC / 10
    DO 2555 I=1,8
    VL(I) = ENDISV(I)
2555 CONTINUE
    SIV1 = SIV
    IF ( TMAX .GE. TMNI ) FLAG = .TRUE.
3000 CONTINUE
    FLAG = .FALSE.

USE SUBROUTINE LIMIT TO CHECK FOR HIGH VOL ROADS WITH NO LOAD
ASSOCIATED DISTRESS OR LOW VOLUME ROADS
FOR EITHER SET JMAX AS MAXIMUM STRATEGY LEVEL

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

CREATE A NEW TRANSITION MATRIX FOR THE REHABILITATED SECTION
USING THE END DISTRESSES AND END PAVEMENT SCORE.

INPUTS TO THIS SUBROUTINE ARE ALL THE NECESSARY VARIABLES FOR
FOR THE SECTION, PLUS, THE REHAB. STRATEGY TO BE USED.
OUTPUT FOR THIS SUBROUTINE IS THE NEW TRANSITION MATRIX.

3200 CONTINUE
IF IST = 1
AREA = LGTH*WDTH
IRMST = STG(y)(JX)

CALL SURVTA (CNY, IT, PESC, TEM, FRTH, AUTC, PLSK, 1
QQV2, QQV3, BBB3, BW3, OVT, ASPH, DMD, DLS, 2
FLEXL, PSIL, EALT, HPF2, HPR2, AADT, AKIP, HMAC)
JCOST = AREA * ECPS(DIT, JX)
IF (IMY.EQ.1) GO TO 4000

ROUND JCOST TO NEAREST 100.00. ENTIRE REPORT WILL THEN SHOW
COST FIGURES IN HUNDREDS.

JCOST = (JCOST + 50.00) / 100.00
KOST = JCOST
KOST = KOST * 100
IF (KOST.LT.100) KOST=100
JCOST = KOST
PDF = (PESM(ICI) - PESC)*10.
IPDF = INT(PDF) + 1
IPDF (.GT. 5) IPDF = 5
URGEC = PRY(IPDF)

COMPUTE Sums FOR TABLEs AT END OF DISTRICT OR REQUEST
WHICHeVER COMES FIRST.

CREHAB = CREHAB + JCOST
CSUM = CSUM + JCOST
SCESS = (IPDF, JX) = SCOST(IPDF, JX) + JCOST
SCOST(IPDF) = UCOST(IPDF, JX) + JCOST
IF (JSET .EQ. 1) GOTO 3040
WRITE (6,640) IYR, IRMS, JCOST
GOTO 3050
WRITE (6,641) IYR, IRMS, JCOST
3040 CONTINUE
INDST = DIST
INF98 = 0
DO 95 I = 1, 8
95 RVIS(I) = VI(I)
SRVC = SRVC
RFCOSt(IY, IC) = RFOSt(IY, IC) + JCOSt
RFOSt(IY) = RFOSt(IY) + JCOSt
GO TO 6998

4000 CONTINUE
INDST = DIST
INF98 = 0

CALCULATE DISTRESSES FOR NEXT YEAR, AND SCORE FOR NEXT YEAR.
INPUT IS: ACTUAL DISTRESSES, PAVEMENT TYPE, STRATEGY, AND
TRANSITION MATRIX.
OUTPUT IS: NEW DISTRESSES, AND PAVEMENT SCORE.

IF (IFIST.EQ.1) GO TO 6990
WRITE (6,634)

CALL AGING (JX, IT, RVI5O, TCLS, INX, ISWITH, RVIS, SRVC, DLS, PSIL)
6990 CONTINUE
CALL SCORE (RVI5, SRVC, V, FLEXSC, ADTS, SBNRY, FUNC, IC, IAVUC, ISIUC, 1
PESC, IT)
IF IST = 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

END OF THE 20 YEAR LOOP

6998 CONTINUE
IYR = INYEAR + IY
7000 CONTINUE
IF (IYR.EQ.1) GO TO 1199
WRITE(6,636) CYMANT, CREHAB
CREHAB = 0.0
CYMANT = 0.0
LINENO = LINENO + 2

1199 CONTINUE

ALL READS OTHER THAN 1ST READ OF NON-98 AND NON-99 DISTRICT
INPUT RECORDS ARE DONE BELOW.

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, NLAMES, WDTH, ADTL,
3    EALT, LGTH, AVUC, WVUC, PESC,
    SIUC, SKUC, RMUC, ROADWT, DESIGN
IF (DIST.EQ.99) GOTO 6000

THIS SUBROUTINE CHANGES THE FIELD RATING, E.G. 100, 010, 001,
TO A PERCENTAGE OF THE AREA. RANGE FROM 0 TO 100.

CALL DECODE(IVIS, RVIS, RVISO)
IF (DIST .NE. 98) GOTO 4020
INF98 = INF98 + 1
IF (INF98.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

OUTPUT MILEAGE AND COST SUMMARY TABLES (AT END OF DISTRICT OR
END OF REPORT REQUEST WHICEVER COMES FIRST.

4100 WRITE (6,650) CMANT, CSUM
    CTOT = CMANT + CSUM

147
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(IDZ = IZ1) IFROM = 0
ITOT = (IZ1 * 10) - 1
WRITE (6, 654) IFROM, ITOT, (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 4495
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, 660) RUNDAT, IPAGE, IDIST
WRITE (6, 665)
IYERS = INYEAR
DO 4220 IZ1 = 1, 20
WRITE (6, 667) IYERS, RYRCOST(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, 660) RUNDAT, IPAGE, IDIST
WRITE (6, 671) IDIST
IYRS = INYEAR
DO 4240 IZ1 = 1, 20
WRITE (6, 672) IYRS, (RFRCOST(IZ1, IZ2), IZ2 = 1, 7)
IYRS = INYEAR + IZ1
4240 CONTINUE
WRITE (6, 673)
WRITE (6, 660) 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, 660) 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 PERCENT = (UCOST(N2)/CSUM) * 100.0
4999 WRITE (6, 670) FRTY(N2), (SCOST(N2, IZ1), IZ1 = 1, 5), UCOST(N2), PERCENT
5000 CONTINUE
WRITE (6, 680) IF (DIST.NE.99) GO TO 840
INDIST = 99
WRITE (6, 681)
GO TO 4010
WHEN DISTRICT = 99, END PROGRAM RUN.
6000 CONTINUE
WRITE(6,691)
STOP
END
SUBROUTINE FINDRF ( RFAL, RUPL, RFFR, FTCC, FUPL, FTFR, V )

*****************************************************
CALCULATE CLIMATIC WEIGHTING FACTORS
*****************************************************

RFAL - ANNUAL RAINFALL FOR COUNTY IN WHICH SEGMENT RESIDES.
RUPL - ARGUMENT VALUES FROM TACS TABLE MMSRAINS. THESE ARE
       INCHES-OF-RAINFALL-PER-YEAR BOUNDARIES.
RFFR - RESULT VALUES FROM TACS TABLE MMSRAINS. THESE ARE FACTORS
       ASSOCIATED WITH EACH BOUNDARY (SEE RUPL).
FTCC - ANNUAL FREEZE-THAW CYCLES FOR COUNTY IN WHICH SEG. RESIDES.
FUPL - ARGUMENT VALUES FROM TACS TABLE MMSFREEZ. THESE ARE
       FREEZE-THAW-CYCLES-PER-YEAR BOUNDARIES.
FTFR - RESULT VALUES FROM TACS TABLE MMSFREEZ. THESE ARE FACTORS
       ASSOCIATED WITH EACH BOUNDARY (SEE FUPL).
V - 8-ELEMENT ARRAY WHICH HOLDS THE FACTORS TO BE APPLIED IN
    COMPUTATION OF ADJUSTED VISUAL UTILITY (AVU) FROM
    UNADJUSTED VISUAL UTILITY (UVU) IN LATER WORK.

DIMENSION V(8), RUPL(3), FUPL(4), RFFR(3), FTFR(4)
DATA RUPL /20.0, 40.0, 99.0/
DATA RFPR /1.00, 0.97, 0.94/
DATA FUPL /10.0, 30.0, 50.0, 99.0/
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(2)
1500 CONTINUE

NOTE - V(1) = RUTTING (1/2 IN. - 1 IN.)
V(2) = RUTTING (OVER 1 IN.)
V(3) = RAVELING
V(4) = FLUSHING
V(5) = FAILURES
V(6) = ALLIGATOR CRACKING
V(7) = LONGITUDINAL CRACKING
V(8) = TRANSVERSE CRACKING

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, THMI )

***************
ASSIGN MINIMUM LIFE FOR MAINTENANCE STRATEGY.
***************

IC - FUNCTIONAL CLASSIFICATION OF ROADWAY FOR REHAB.
IT - PRESENT PAVEMENT TYPE OF ROADWAY FOR REHAB.
ATNR - TACS TABLE MNSRTM.
ARG. - 10 ENTRIES (1 FOR EACH PVT. TYPE) FOR EACH
OF 7 FUNCT. CLASSES.
RESULT - MINIMUM ALLOWABLE LIFE FOR THE PARTICULAR
PAVT. TYPE USED IN THE FUNCT. CLASS.
TMMI - RESULT FROM ATNR RETURNED TO CALLER.

DIMENSION ATNR(7,10)
DATA ATNR /70*3.00/
RETURN
END

SUBROUTINE AGING (JX,IT,RVISO,TCLS,INX,ISWITH,RVIS,RSVR,DISL,
1 PSIL)

---------------------------------------------------------------------

DETERIORATE EACH DISTRESS USING THE TRANSITION MATRIX FOR THE
PAVEMENT TYPE.

---------------------------------------------------------------------

JX - REHABILITATION STRATEGY
IT - PRESENT PAVEMENT TYPE OF ROADWAY FOR REHAB.
RVISO - 8-ELEMENT ARRAY WHICH HOLDS THE DECODED ORIGINAL
DISTRESSES FOR THE SECTION.
TCLS - TACS TABLE MNSRHTC.
ARG. - COMBINATION OF PAVEMENT TYPE (PRESENTLY
IN PLACE) AND STRATEGY UNDER INVESTIGATION.
RES. - TIME CONSTANT IN WHICH THE SECTION WILL
NOT SUFFER ANY DISTRESS.
RVIS - 8-ELEMENT ARRAY WHICH HOLDS THE ACTUAL DISTRESSES
OF THE SECTION.
SRVC - ACTUAL PSI.
DISL (8 X 100) ELEMENT ARRAY WHICH HOLDS THE TRANSITION
MATRIX FOR THE DISTRESSES OF THE SECTION.
PSIL - 50-ELEMENT ARRAY WHICH HOLDS THE TRANSITION MATRIX
FOR THE PSI OF THE SECTION.

DIMENSION DISL(8,100),PSIL(50),RVISO(8),A(8),TCLS(5,10),RVISO(8)

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.0.0.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
10 CONTINUE
11 RVIS(2) = 0.0
12 CONTINUE
IF (RVISO(1).GT.0.01) GO TO 20
IF (INX.GE.TC+5) GO TO 20
30 IF (RVISO(1).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, PSDS, CLIF, SOLF, TMAX)
CALCULATE EXPECTED LIFE FOR MAINTENANCE STRATEGY J...

J - 1 OF 5 STRATEGIES NOW UNDER CONSIDERATION.
IT - PAVEMENT TYPE OF THE ROADWAY FOR REHAB.
RFAL - AVG. ANNUAL INCHES OF RAINFALL FOR COUNTY IN WHICH
ROADWAY RESIDES.
RUPL - TACS TABLE HMSRAINS (ARGUMENT ONLY).
ARG. - BOUNDARIES (IN INCHES OF RAINFALL) WHICH
SEPARATE LOW, MEDIUM, AND HIGH RAINFALL.
RESULT - NOT USED.
FTCC - AVG. ANNUAL FREEZE-THAW CYCLES FOR COUNTY IN WHICH
ROADWAY RESIDES.
FUPL - TACS TABLE HMSFREEZ (ARGUMENT ONLY).
ARG. - BOUNDARIES (IN FREEZE-THAW CYCLES) WHICH
SEPARATE LOW, MEDIUM, AND HIGH CYCLES.
PLSX - SOIL PLASTICITY INDEX FOR COUNTY IN WHICH
ROADWAY RESIDES.
TF - TRAFFIC FACTOR CALCULATED IN SUBROUTINE FINDTF.
PESF - EXPECTED PAVEMENT SCORE OF ROADWAY GIVEN
REHABILITATION USING THE STRATEGY NOW UNDER
CONSIDERATION (COMPUTED IN BIGSUB, 413550).
PSMN - MINIMUM ALLOWABLE PAVEMENT SCORE FOR THE ROADWAY.
TCLS - TACS TABLE HMSRHTC.
ARG. - COMBINATION OF PAVEMENT TYPE (PRESENTLY IN
PLACE) AND STRATEGY UNDER INVESTIGATION.
RESULT - TIME (OR LIFE) CONSTANT USED IN COMPUTATION
OF REHAB. STRATEGY PVT. LIFE.
FSDS - TACS TABLE HMSREDS.
ARG. - COMBINATION OF PAVEMENT TYPE (PRESENTLY IN
PLACE) AND STRATEGY UNDER INVESTIGATION.
RESULT - FACTOR USED IN COMPUTATION OF REHAB.
STRATEGY PVT. LIFE.
CLIF - TACS TABLE HMSREHF.
ARG. - COMBINATION OF RAINFALL BOUNDARIES (RUPL)
AND FREEZE-THAW CYCLE BOUNDARIES (FUPL).
RESULT - CLIMATIC FACTOR FOR EACH RAIN/FREEZE-THAW
COMBINATION.
SOLF - TACS TABLE HMSREHSF.
ARG. - COMBINATION OF RAINFALL BOUNDARIES (RUPL)
AND PLASTICITY INDEX BOUNDARIES.
RESULT - SOIL FACTOR FOR EACH RAINFALL/PLASTICITY
COMBINATION.
TMAX - MAXIMUM PAVEMENT LIFE (IN YEARS) FOR THE STRATEGY
UNDER INVESTIGATION RETURNED TO CALLER.

DIMENSION RUPL(3), FUPL(4)
DIMENSION TCLS(5,10), FSDS(5,10), CLIF(3,4), SOLF(3,3)
TC = TCLS(4,IT)
DSI = FSDS(2,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(4)) GO TO 1200
K = 3
IF (FTCC.GT.FUPL(3)) GO TO 1200
K = 2
1200 CONTINUE
CF = CLIF(L,K)

NO TACS TABLE FOR PLASTICITY INDEX BOUNDARIES.
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)

IMPLEMENTATION FOR MAIN

JMAX IS THE MAXIMUM STRATEGY (1, 2, ..., ) WHICH CAN BE APPLIED
THE RULES ARE:

1) AADT LT 50 THEN JMAX = 1

2) NO SEVERE RUTTING IVIS(1), ALLIGATORING IVIS(5), OR
   FAILURES IVIS(4), AND PSI ABOVE MINIMUM THEN JMAX = 2

3) AS 2) WITH PSI BELOW MINIMUM JMAX = 3

JMAX IS RETURNED TO MAIN WHERE IT IS COMPARED WITH THE CHOSEN
STRATEGY JX

THIS ROUTINE HANDLES THE PROBLEMS OF HIGH VOLUME ROADS WHOSE
Pavement Scores ARE BELOW MINIMUM BUT HAVE NO LOAD ASSOCIATED
DISTRESS AND THOSE VERY LOW VOLUME FM'S FOR WHICH ONLY MINIMUM
STRATEGIES ARE APPOSITE

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(1C) ) GOTO 100
      JMAX = 3.0
   CONTINUE
100 RETURN
END

SUBROUTINE DECODE(IVIS,RVIS,RVISO)

THIS SUBROUTINE TRANSFORMS THE CODED VISUAL READINGS
TO PERCENTAGES

IVIS - 8-ELEMENT ARRAY WHICH HOLDS THE CODED VISUAL READINGS
RVISO - 8-ELEMENT ARRAY WHICH HOLDS THE TRANSFORMED VISUAL
   READINGS. RANGE 0 - 1

REAL W(4),Z(4),F(4),L(4),T(4)
INTEGER X(4),Y(4)
DIMENSION RVISO(8),IVIS(7),RVISO(8)

DATA P/0.0,0.0,10.71,24.99,50.00/
DATA L/0.0,0.0,10.0,30.0,50.00/
DATA F/0.0,0.0,8.33,29.33,17.50,0.0/
DATA W/0.0,0.0,5.0,30.0,45.00/
DATA X/00000,10000,01000,00100/

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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
DO 100 I = 1, 4
RUTTING
  IF (IVIS(I).EQ.X(I)) GO TO 110
  IF (IVIS(I).EQ.Y(I)) RVIS(2) = Z(I)
  GO TO 120
  110 RVIS(1) = Z(I)
  120 CONTINUE
RAVELLING
  IF (IVIS(2).EQ.X(I)) RVIS(3) = Z(I)
FLUSHING
  IF (IVIS(3).EQ.X(I)) RVIS(4) = Z(I)
FAILURES
  IF (IVIS(4).EQ.X(I)) RVIS(5) = F(I)
ALLIGATOR CRACKING
  IF (IVIS(5).EQ.X(I)) RVIS(6) = W(I)
LONGITUDINAL CRACKING
  IF (IVIS(6).EQ.X(I)) RVIS(7) = L(I)
TRANSVERSAL CRACKING
  IF (IVIS(7).EQ.X(I)) RVIS(8) = T(I)
CONTINUE
DO 130 I = 1, 8
  130 RVISO(I) = RVIS(I)
RETURN
END
SUBROUTINE FINAVU ( IT, J, AVUC, SRVC, SKID, FAVU, FSU, FSKU, AVU, SIV, SNV, RVIS, ENDVIS)
1 ---------------------------------------------------------------
<p>| CALCULATE ESTIMATED ADJUSTED VISUAL UTILITY (AVU), ESTIMATED |
| SKID NUMBER (SN), AND ESTIMATED SERVICABILITY INDEX (SI) FOR  |</p>
<table>
<thead>
<tr>
<th>EACH OF 5 MAINTENANCE STRATEGIES.</th>
</tr>
</thead>
<tbody>
<tr>
<td>J - MAINTENANCE STRATEGY NO.</td>
</tr>
<tr>
<td>AVUC - PRESENT AVU OF THE PAVEMENT TO BE REHABILITATED.</td>
</tr>
<tr>
<td>SRVC - PRESENT AVG. SI VALUE OF THE PAV. TO BE REHABILITATED.</td>
</tr>
<tr>
<td>SKID - PRESENT AVG. SN VALUE OF THE PAV. TO BE REHABILITATED.</td>
</tr>
<tr>
<td>FAVU - TACS TABLE MSREAVU.</td>
</tr>
<tr>
<td>ARG. - 10 AVU BOUNDARIES FOR EACH OF 5 STRATEGIES.</td>
</tr>
<tr>
<td>RESULT - ESTIMATED AVU AFTER REHAB. FOR THAT STRATEGY.</td>
</tr>
<tr>
<td>FSIU - TACS TABLE MSRHSI.</td>
</tr>
<tr>
<td>ARG. - 5 SI BOUNDARIES FOR EACH OF 5 STRATEGIES.</td>
</tr>
<tr>
<td>RESULT - ESTIMATED SI OR, FOR STRATEGY 1 ONLY,</td>
</tr>
<tr>
<td>INCREASE IN SI AFTER REHAB. FOR THAT STRATEGY.</td>
</tr>
<tr>
<td>FSKU - TACS TABLE MSRHSI.</td>
</tr>
<tr>
<td>ARG. - 6 SN BOUNDARIES FOR EACH OF 5 STRATEGIES.</td>
</tr>
<tr>
<td>RESULT - ESTIMATED SN AFTER REHAB. FOR THAT STRATEGY.</td>
</tr>
<tr>
<td>AVU - SELECTED ENTRY FROM FAVU RETURNED TO CALLER.</td>
</tr>
<tr>
<td>SIV - SELECTED ENTRY OR, FOR STRATEGY 1 ONLY, COMPUTED ITEM</td>
</tr>
<tr>
<td>FROM FSIU RETURNED TO CALLER.</td>
</tr>
<tr>
<td>SNV - SELECTED ENTRY FROM FSKU RETURNED TO CALLER.</td>
</tr>
<tr>
<td>--------------------------------------------------------------</td>
</tr>
<tr>
<td>DIMENSION FAVU(10,5), FSU(5,5), FSKU(6,5), MSGAIN(8,5)</td>
</tr>
<tr>
<td>DIMENSION RVIS(8), ENDVIS(8)</td>
</tr>
<tr>
<td>--------------------------------------------------------------</td>
</tr>
<tr>
<td>153</td>
</tr>
</tbody>
</table>
REAL MXGAIN
DATA MXGAIN
/0.33, 0.0, 1.0, 1.0, 0.25, 0.6, 0.6, 0.75,
1
1.0, 0.7, 1.0, 1.0, 0.6, 0.8, 0.8, 1.00,
2
1.00, 1.0, 1.0, 1.0, 0.6, 0.8, 0.8, 1.00,
3
1.0, 1.0, 1.0, 1.0, 0.6, 0.8, 0.8, 1.00,
4
1.0, 1.0, 1.0, 1.0, 1.00, 1.0, 1.0, 1.00/
DATA FAVU
/0.79, 0.81, 0.82, 0.84, 0.86, 0.88, 0.89, 0.91, 0.93, 0.94,
1
0.80, 0.83, 0.85, 0.88, 0.90, 0.93, 0.95, 0.98, 1.00, 1.00,
2
40=1.00/
DATA FSU
/0.2, 0.2, 0.1, 0.0, 0.0, 0.5=4.3, 20=4.5/
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 = FSU(K,J)
GO TO 1700
1600 SIV = FSU(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 SV = FSU(K,J)
IJ = J
1999 DO 2000 I = 1, 8
IF ( IJ .NE. 10 ) GOTO 1999
IJ = IJ + 1
IF ( IJ .GT. 5 ) IJ = 5
2000 ENDVIS(I) = RVIS(I) - (MXGAIN(I,IJ)*RVIS(I))
RETURN
END
SUBROUTINE SCORE (RVIS, SRVC, V, FLEXSC, ADTS, SIBNRY, FUNC, IC, IAVUC, IAVUC, PESC, IT)
-------------------------------

THIS SUBROUTINE CALCULATES THE PAVEMENT EVALUATION SCORE BASED ON THE DISTRESSES AND THE PSI.

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THIS SUBROUTINE CALLS TWO OTHER SUBROUTINES:
UTILITY - CALCULATES VISUAL UTILITY VALUE
UTILITY - CALCULATES RIDE UTILITY VALUE

RVIS - 8-ELEMENT ARRAY WHICH HOLDS THE ACTUAL VISUAL DIST.
ADTS - ACTUAL PSI.
SIBNRY - AVERAGE DAILY TRAFFIC.
FLEXSC - FACTOR ASSOCIATED WITH EACH OF 3 SI BOUNDARIES FOR EACH OF 3 EQUATIONS USED IN THE DETERMINATION OF SERVICEABILITY INDEX (SI) UTILITY.
FUNC - FACTOR ASSOCIATED WITH THE FUNCTIONAL CLASSIFICATION OF THE ROAD USED IN THE DETERMINATION OF THE PAVEMENT SCORE.
IC - FUNCTIONAL CLASSIFICATION OF ROADWAY FOR REHAB.
IARYC - CALCULATED ADJUSTED VISUAL UTILITY
IARYC - CALCULATED SERVICEABILITY INDEX.
PESC - CALCULATED PAVEMENT SCORE.
DIMENSION V(8), RVIS(8), FLEXSC(8,3), SIBMRT(3,3), FUNC(7)
CALL UTILITY(V, RVIS, UVUC, AVUC, IT)
CALL UTILITY2(ADTS, SRVC, SIBMRT, SIUC)
UPSC = SIUC * AVUC
FNC = FUNC(IC)
PESC = UPSC ** (1/FNC(IC))
PESC = (PESC + 0.00001)
SIUCS = SIUC * 100.0
ISIUC = INT(SIUCS)
AVUCS = AVUC * 100.0
IVALC = INT(AVUCS)
RETURN
END
SUBROUTINE UTILITY(V, RVIS, UVUC, AVUC, IT)
RVIS = ACTUAL % OF EACH DISTRESS RANGE 0 TO 100%
RVIS 1 AND RVIS 2 ARE FOR RUTTING.

***NOTE: THIS SUBROUTINE NOW USES EQUATIONS RATHER THAN
A TABLE LOOK-UP TO CALCULATE SCORES.

CALCULATE VISUAL UTILITY VALUE
NOTE - V(1) AND V(2) ARE BOTH RUTTING, THEN THE REMAINING
6 VISUAL ITEMS FOLLOW AS V(3) THRU V(8). THIS IS
DUE TO SPECIAL CODING ABILITIES FOR RUTTING.

IVIS = 7-ELEMENT ARRAY CONTAINING THE VISUAL EVALUATION ITEMS
WHICH ARE RUTTING, RAVELING, FLUSHING, FAILURES,
ALLIGATOR, LONGITUDINAL, AND TRANSVERSE CRACKING.
V = 8-ELEMENT ARRAY CONTAINING THE CLIMATIC WEIGHTING FACTORS
FOR EACH OF THE 7 VISUAL EVALUATION ITEMS.
SCORE = 3 FACTORS FOR EACH OF THE 7 VISUAL EVALUATION ITEMS
(8 TOTAL - REMEMBER, RUTTING TAKES UP 1 AND 2) FOR FLEXIBLE
OR COMPOSITE PAVEMENTS.
UVUC = UNADJUSTED VISUAL UTILITY CALCULATED HEREIN.
AVUC = ADJUSTED VISUAL UTILITY CALCULATED HEREIN.

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, 0.5, 0.26/
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(I).GT.RVIS(2)) Go to 20
RVIS(I) = 0.0
Go to 30
20 RVIS(2) = 0.0
30 CONTINUE
DO 100 I = 1, 8
IF(RVIS(I).GT.0.5) Go to 100
U = 1 - A(I)*EXP(-B(I)/XVIS(I))
UVUC = UVUC * U
IF(Z.RW.E.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 UTILITY2 (ADTS, AVGSI, SIBMRT, SIUC)

CALCULATE RIDE UTILITY VALUE

155
AADTS - ADJUSTED ADT FOR LANE * SPEED LIMIT FOR SEGMENT.
AVGSI - AVERAGE RIDER VALUE FOR LANE OR, IF UNAVAILABLE,
FOR ROADWAY.
SIBRM - A FACTOR ASSOCIATED WITH EACH OF 3 SI BOUNDARIES FOR
EACH OF 3 EQUATIONS USED IN DETERMINATION OF
SERVICABILITY INDEX (SI) UTILITY.
SIUC - SERVICABILITY INDEX UTILITY CALCULATED HEREIN.

CNSTNT - ONE CONSTANT FOR EACH SI BNRM EQUATION WHICH IS USED
IN PLACE OF AN ADDITIONAL SI BOUNDARY FACTOR.

DIMENSION SIBRM(3,3), CNSTNT(3)
DATA SIBRM =/0.8, 1.3, 1.8, 2.0, 2.5, 3.0, 2.5, 3.5/8530
DATA CNSTNT /-0.26666, -0.55833, -0.85000/
SUC  = 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 SUC  = 1.00
IF ( AVGSI .GE. SIBRM(NC,3) ) GO TO 2000
IF ( AVGSI .LT. SIBRM(NC,2) ) GO TO 1500
SUC  = 1.00 - ( 0.4 * ( ( SIBRM(NC,3) - AVGSI ) ** 2 ) )
GO TO 2000
1500 SUC  = CNSTNT(NC) - ( 0.58333 * AVGSI )
GO TO 2000
1600 SUC  = 0.20 * ( ( AVGSI / SIBRM(NC,1) ) ** 2 )
2000 CONTINUE
RETURN
END

SUBROUTINE OV(CNTY, IT, PESC, TIN, FRTH, AVTP, HPR2, HPR3, OVTH, PLX, DISL, PSIL, EALT)

---------------------------------------------
THIS SUBROUTINE USES THE SURVIVAL CURVES TO GENERATE TRANSITION MATRIX FOR OVERLAY PAVEMENTS.

---------------------------------------------
CNTY - COUNTY NUMBER
IT - PAVEMENT TYPE
PESC - PAVEMENT SCORE
TIN - THORNTHWAITZ INDEX
FRTH - FREEZE/THAW CYCLES
AVTP - AVERAGE TEMPERATURE
HPR2 - EQUIVALENT THICKNESS X ELASTIC MODULUS OF THE SUBGRADE AS DETERMINED FROM DIASTAP DEFLECT MEASUREMENTS
HPR3 - 10 ** 10 / HPR2
OVTH - OVERLAY THICKNESS
PLX - PLASTICITY INDEX
BINDER - PERCENT ASPHALT BINDER
DISL - (8 X 100)-ELEMENT ARRAY WHICH HOLDS THE TRANSITION MATRIX FOR THE DISTRESSES OF THE SECTION IN ANALYSIS
PSIL - TRANSITION MATRIX FOR THE PSI OF THE SECTION IN ANALYSIS

INTEGER CNTY, EALT
REAL M(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), FIS(50)

WRITE(6,200)
200 FORMAT (F15.1)
ICTY = CNTY
XTI = TIN(ICTY) + 50.0
AVT = AVTP( ICTY )
FTC = FRTH( ICTY )
BINDER = 6.0
PI = PSLK
KRT = 0
P0 = 4.2

XAVT = AVT - 50.0
N18MTH = (EALT * 1000.0)/240.0

OVERLAY PAVEMENTS PSI & DISTRESS

LINEAR RHO & BETA, PSI
X(9) = 0.26503*OVTH + 0.07182*HPR2
X(10) = 0.00413*XTI + 0.01036*FTC - 0.04769*XAVT + 0.01707
& (N18MTH/1000.0) - 0.00914*OVTH - 0.01066*HPR2
X(11) = 0.13037*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

LOG RHO & BETA, PSI
312 X(9) = -0.24351*PI + 0.369*OVTH + 0.0485*HPR2
X(10) = 0.0059*XTI + 0.0121*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

LOG RHO & BETA, RUTTING AREA
313 X(1) = -0.00119*PI + 0.369*OVTH + 0.0485*HPR2
X(2) = 0.0059*XTI + 0.0121*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

LOG RHO & BETA, RUTTING SEVERITY
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

LINEAR RHO & BETA, ALLIGATOR CRACK AREA
323 Y(1) = -0.00507*PI + 0.233*OVTH + 0.0705*HPR2 - 0.000779*HPR3
Y(2) = 0.009*XTI - 0.0146*AVT + 0.0002*PI - 0.0789*OVTH + 0.0848*HPR3
IF (Y(1).LT.0.0 .OR.Y(2).LT.0.0 ) GO TO 332
GO TO 333

LOG RHO & BETA, ALLIGATOR CRACK AREA
332 Y(1) = PI - 0.2342*OVTH + 0.578*HPR2 - 0.1396*HPR3 - 0.4808
Y(2) = XTI - 0.0575*OVTH - 0.1122*HPR3 + 0.1207

LINEAR RHO & BETA, ALLIGATOR CRACK SEVERITY
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

LOG RHO & BETA, ALLIGATOR CRACK AREA
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 + 0.1746

LINEAR RHO & BETA, ALLIGATOR CRACK SEVERITY
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

157
GO TO 353

LOG RHO & BETA, ALLIGATOR CRACK SEVERITY

352 Y(3) = FTC**(0.1235) * AVT**(0.3885) * PI**(-0.4525) * HPR3**(0.6859)
         X(4) = XTI**(0.3689) * FTC**(0.178) * AVT**(-0.3259) * OVTH**(-0.4326)
        & * HPR3**(0.1931)

LINEAR RHO & BETA, LONG. CRACK AREA

353 X(5) = -0.0168 * XTI - 0.087 * FTC - 1.63 * AVT - 0.179 * PI + 2.68 * OVTH + 0.84 * HPR2
        X(6) = 0.0311 * XTI + 0.0043 * FTC - 0.0072 * 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

LOG RHO & BETA, LONG. CRACK AREA

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**(-0.2596) * OVTH**(-0.0808)
        & * HPR3**(0.324) * HPR3**(0.2972)

LINEAR RHO & BETA, LONG. CRACK SEVERITY

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

LOG RHO & BETA, LONG. CRACK SEVERITY

372 Y(5) = XTI**(-0.0015) * FTC**(-0.0989) * AVT**(-1.2089) * PI**(-0.0841)
        Y(6) = XTI**(-0.0159) * FTC**(-0.1175) * AVT**(-0.24) * HPR3**(0.1103)

LINEAR RHO & BETA, TRANS. CRACK AREA

373 X(7) = -0.794 * FTC - 1.922 * AVT - 22.81 * OVTH
       X(8) = -0.0097 * XTI + 0.149 * 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

LOG RHO & BETA, LONG. CRACK AREA

382 X(7) = FTC**(0.1509) * AVT**(1.1947) * OVTH**(-0.4683)
        X(8) = XTI**(-0.018) * FTC**(0.2878) * AVT**(0.3966) * PI**(-0.1576)
        & * OVTH**(0.3127) * HPR2**(0.0719) * HPR3**(0.1899)

LINEAR RHO & BETA, TRANS. CRACK SEVERITY

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
        GO TO 393

LOG RHO & BETA, TRANS. CRACK SEVERITY

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)

393 CONTINUE

RHORA = X(1)
BETA = X(2)
RHOA = X(3)
BETA = X(4)
RHOL = X(5)
BETA = X(6)
RHOTA = X(7)
BETTA = X(8)
RHOH = X(9)
BETAP = X(10)
PF = X(11)
WRITE (6,300) RHORA, BETRA, RHOAA, BETAA, RHOTA, BETA, RHOL, 
1 BETLA, RHOP, BETAF, PFF 
300 FORMAT// IX,10G13.5/IX,10G13.5)
DO 15 I = 1, 5
DD 15 J = 1, 100
15 DISL(I,J) = 0.0

CALCULATE DISTRESS
DO 30 J = 1, 100
IF (J.EQ.100) GO TO 507
W(J) = J
TO = W(J)/100.0
GO TO 508
307 TO = .9910
508 CONTINUE

RUTTING AREA NOW
SO = ALOG (TO)
RO = ABS (SO)
ANW = RO***(1/BETRA)
N = (1/ANW)**RHORA
NX = N*100000.0/N18MTH

RUTTING AREA NEXT YEAR
IN = INT(NX)
IN = IN + 12
N18 = N18MTH**IN/100000.0
PWR = (RHORA/N18)**BETRA
DISL(1,J) = EXP(-PWR) = 100.0
DISL(2,J) = EXP(-PWR) = 100.0

RAVELLING
DISL(3,J) = J + 1.0

FLUSHING
DISL(4,J) = J + 1.0

FAILURES
DISL(5,J) = J + 1.0

ALLIGATOR CRACKING NOW
BA = 1/BETAA
ANW = RO**BA
N = (1/ANW)**RHOAA
NX = N*100000.0/N18MTH

ALLIGATOR CRACKING NEXT YEAR
IN = INT(NX)
IN = IN + 12
N18 = N18MTH**IN/100000.0
PWR = (RHOAA/N18)**BETAA
DISL(6,J) = EXP(-PWR) = 100.0

LONGITUDINAL CRACKING NOW
BD = 1/BETLA
ANW = RO**BD
N = (1/ANW)**RHOLA

LONGITUDINAL CRACKING NEXT YEAR
IN = INT(N)
IN = IN + 12
PWR = (RHOMA/IN)**BETAL
DISL(7,J) = EXP( -PWR ) * 100.0

TRANSVERSAL CRACKING NOW

BL = 1/BETTA
ANW = RO**BL
N = (1/ANW)*RHOTA

TRANSVERSAL CRACKING NEXT YEAR

IN = INT(N)
IN = IN + 12
PWR = (RHOMA/IN)**BETAL
DISL(8,J) = EXP( -PWR ) * 100.0
30 CONTINUE

PSI

WRITE(6,251) XTI, FTC, AVT, PI, OVTH, BINDER, HPR2, HPR3, N18MTH
251 FORMAT(T10,'DATA INPUTS: '/T10,'TI=50 FTC AVT PI OVTH'
& 'BINDER HPR2 HPR3 N18/MTH'/T7,4F7.0,2F7.1,F7.0,F7.2,F10.0)

DO 40 J = 1,50
PSIL(J) = PSTE
IF( RHOP .LE. 0.0 ) GO TO 40
PS(J) = J/10.0
PIS(J) = PS(J)
IF(PS(J).GE.PE) 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
N3 = N2 - 12
N18 = N2 / N18MTH/1000000.0
BETAP = 0.00413*XTI+0.01036*FTC+0.04769*AVT+0.01707*
& (N18MTH/1000.0)-0.009144*OVTH-0.01666*HPR2
IF( BETAP .LT. 0.0 ) GO TO 27
GO TO 28
27 BETAP = FTC**(-0.09767)*XTI/18MTH/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
PSST = PSIL(J)
GO TO 29
29 CONTINUE
PSIL(J) = PIS(J)
30 CONTINUE
40 CONTINUE

WRITE(6,252)
252 FORMAT(T26,'DISTRESS', T60, 'DISTRESS' /T12, 'N ' RUTTING',
& 'RAVL FLUSH FAIL ALIG LONG TRMS ' / T11,
& 'S ACT ONE TWO AREA AREA AREA AREA AREA AREA AREA')

DO 41 J = 1, 100
WRITE(6,255) W(J), (DISL(I,J), I = 1, 8)
255 FORMAT( F14.2, 2X, 8F6.2)
41 CONTINUE
DO 44 J = 1, 50
WRITE(6,257) PS(J), PSIL(J)
257 FORMAT(T28,F5.3,10X,F5.3)
44 CONTINUE
KNT = KNT + 1
IF (KNT .EQ. 1) WRITE(6,200)
IF (KNT .EQ. 1) KNT = 0
RETURN
END

SUBROUTINE MONTHS (B3, NS, RHOP, TISO, FTC, AVT50, OVTN, HPR2, & N18MTH)

-----------------------------------------

THIS SUBROUTINE IS USED BY THE SUBROUTINE OV TO CALCULATE THE
NUMBER OF MONTHS THAT HAVE PASSED FOR THE SECTION OF ROAD TO
HAVE THE PREDICTED PSI SCORE

-----------------------------------------

REAL NS, N18MTH
BQ = B3
BW = 0.0

15
BW = BW+12
NS = N18MTH*BW/1000000.0
BETA = 0.00413*TISO + 0.01036*FTC + 0.04769*AVT50 - 0.09144*
& OVTN - 0.01666*HPR2
BETAP = BETA + (0.01707*NS)
PWR = (RHOP/NS)**BETAP
IF (PWR.LT.BQ) GO TO 10
GO TO 15

10 RETURN
END

SUBROUTINE BB(CNTY, IT, PESC, TIN, FRTH, AVTP, ASPH, HPR2, HPR3, PLX, &
  D, PSIL, SALD)

-----------------------------------------

THIS SUBROUTINE USES THE SURVIVAL CURVES TO GENERATE
TRANSITION MATRIX FOR BLACK BASE PAVEMENTS.

-----------------------------------------

CNTY = COUNTRY NUMBER
IT = PAVEMENT TYPE
PESC = PAVEMENT SCORE
TIN = THORNTMAIZE INDEX
FRTH = FREEZE/THAW CYCLES
AVTP = AVERAGE TEMPERATURE
HPR2 = EQUIVALENT THICKNESS X ELASTIC MODULUS OF THE
  SUBGRADE AS DETERMINE FROM DINAFLCET MEASUREMENTS
HPR3 = 10 -- 10 / HPR2
ASPH = ASPHALT THICKNESS
PLX = PLASTICITY INDEX
BINDER = PERCENT ASPHALT BINDER
D = (8 X 10) ELEMENT ARRAY WHICH HOLDS THE TRANSITION
  MATRIX FOR THE DISTRESSES OF THE SECTION IN ANALYSIS
PSIL = TRANSITION MATRIX FOR THE PSI OF THE SECTION IN
  ANALYSIS

INTEGER CNTY, EALT
REAL M(100), N1, N18MTH, N, NX, NS, PS(50), N1, N2
DIMENSION DISL(8,100), HEADER(10), X(1)
DIMENSION TIN(254), FRTH(254), AVTP(254), RAIN(254)
DIMENSION PSIL(50), PS(50)
WRITE (6,200)
200 FORMAT ('1')
ICTY = CNTY
XTI = TIN(ICTY) + 50.0
AVT = AVTP(ICTY)
FCT = FRET(ICTY)
WLENGTH = (ELAT+1000.0)/240.0
BINDER = 6.0
PI = PLSX
KWT = 0
PO = 4.2
XAVT = AVT - 50.0

LINEAR RHO & BETA, PSI
X(9) = -0.02182*FCT-0.00831*PI+0.04499*BINDER+0.15013*HPR2
& -0.31331*BINDER-0.3234*HPR2
X(10) = 0.01201*XTI+0.03166*FCT+0.13775*XAVT+0.00114*PI
& -0.31331*BINDER-0.3234*HPR2
X(11) = -0.00637*FCT-0.0155*XAVT-0.00658*PI+0.27714*BINDER
& +0.05097*HPR2

IF( X(9).LT. 0.0 OR X(10).LT. 0.0 OR X(11).LT. 0.0 ) GO TO 112
GO TO 113

LOG RHO & BETA, PSI
112 X(9) = FCT**(-0.46679)*XAVT**(-0.86233)*PI**(-0.26711)
& *HPR2**(-1.65694)
X(10) = FCT**(-0.60949)*XAVT**(-0.93499)*BINDER**(-1.37608)
& *HPR2**(-0.72725)
X(11) = FCT**(-1.50634)*XAVT**(-2.69464)*BINDER**(-4.17755)
& *HPR2**(-1.60919)

LINEAR RHO & BETA, RUTTING AREA
113 X(1) = 0.00175*FCT-0.00141*AVT-0.257*ASPH
X(2) = -0.00493*FCT-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

LOG RHO & BETA, RUTTING AREA
122 X(1) = AVT**(-0.68444)*PI**(-0.10211)*ASPH**(-1.47563)*HPR3**(-0.0021)
X(2) = FCT**(-0.16685)*AVT**(-0.12311)*PI**(-0.22381)*ASPH**(-0.02666)

LINEAR RHO & BETA, ALLIGATOR CRACK AREA
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

LOG RHO & BETA, ALLIGATOR CRACK AREA
142 X(3) = FCT**(-0.1961)*PI**(-0.2231)*HPR2**(-0.6444)*HPR3**(-0.31)
X(4) = 1.4686

LINEAR RHO & BETA, LONG. CRACK AREA
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

LOG RHO & BETA, LONG. CRACK AREA
162 X(5) = ASPH**(0.6527) * BINDER**(2.2368)
    X(6) = 1.3178

LINEAR RHO & BETA, TRANS. CRACK AREA

163 X(7) = -1.739 * PI + 0.428 * ASPH + 48.88 * BINDER - 46.7 * HPR3
    X(8) = 0.0183 * FIC + 0.625 * HPR3
    IF (X(7) < 0.0 OR X(8) < 0.0) GO TO 182
    GO TO 183

LOG RHO & BETA, TRANS. CRACK AREA

182 X(7) = PI**(-0.2152) * ASPH**(-0.6152) * BINDER**(-2.4561) * HPR2**(-0.102)
    X(8) = FIC**(-0.1664) * ASPH**(-0.1447) * BINDER**(-0.0495)
    & HPR3**(-0.204)
    183 CONTINUE

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)

WRITE (6, 300) RHORA, BETRA, RHOAA, BETAA, RHOTA, BETTA, RHOLA, BETLA,
& RHOP, BETAP, PF
300 FORMAT (1X, 10E13.5 / 1X, 10E13.5/ )

DO 15 I = 1, 5
   DO 15 J = 1, 100
15  DISL(I, J) = 0.0

CALCULATE DISTRESS

DO 30 J = 1, 100
   IF (J.EQ.100) GO TO 507
   W(J) = J
   W(O) = W(J)/100.0
   GO TO 508
307 TO = .9910
508 CONTINUE

RUTTING AREA NOW

SQ = ALOG (TO)
RO = ABS (SQ)
ANW = RO**(-1/BETRA)
N = (1/ANW)**RHORA
NX = N**1000000.0/N18MTH

RUTTING AREA NEXT YEAR

IN = INT(NX)
IN = IN + 12
N18 = N18MTH*IN/1000000.0
1 = 'IN', 18, 'N18', F11.3, /
FMR = (RHORA/N18)**BETRA
DISL(1, J) = EXP(-FMR) * 100.0
DISL(2, J) = EXP(-FMR) * 100.0

RAVELLING

00000
DISL(3,J) = J + 1.0
FLUSHING
DISL(4,J) = J + 1.0
FAILURES
DISL(5,J) = J + 1.0

ALLIGATOR CRACKING NOW
BA = 1/BETAA
ANW = RO**BA
N = (1/ANW)*RHOAA
NX = N*1000000.0/N18MTH

ALLIGATOR CRACKING NEXT YEAR
IN = INT(NX)
IN = IN + 12
N18 = N18MTH*IN/10000000.0
PWR = (RHOAA/N18)**BETAA
DISL(6,J) = EXP(-PWR) * 100.0

LONGITUDINAL CRACKING NOW
BD = 1/BETLA
ANW = RO**BD
N = (1/ANW)*RHOOLA

LONGITUDINAL CRACKING NEXT YEAR
IN = INT(N)
IN = IN + 12
PWR = (RHOOLA/IN)**BETLA
DISL(7,J) = EXP(-PWR) * 100.0

TRANSVERSAL CRACKING NOW
BL = 1/BETTA
ANW = RO**BL
N = (1/ANW)*RHOTA

TRANSVERSAL CRACKING NEXT YEAR
IN = INT(N)
IN = IN + 12
PWR = (RHOTA/IN)**BETTA
DISL(8,J) = EXP(-PWR) * 100.0
30 CONTINUE

PSI
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(PIS(J).GE.PO) PIS(J) = PO -.001
B1 = (PO-PIS(J))/(PO-PF)
B2 = ALOG(1)
B3 = B2 * (-1.0)
IF( B3.LT.0.0 ) GO TO 99
ANW = B3**(1/BETAP)
N1 = (1/ANW)*RHOOP
N2 = N1*1000000.0/N18MTH
N18 = N2 * 12
N18 = N2 * N18MTH/1000000.0
PWR = (RHOOP/N18)**BETAP

40 CONTINUE

50 CONTINUE
PSIL(J) = PO - (PO - PF) * EXP (-PWR)
IF (PSIL(J) > (.PS(J)) PSIL(J) = PS(J) - 0.15

C
PSTK = PSIL(J)
GO TO 29

39 PSIL(J) = 2.65
GO TO 29
99 PSIL(J) = PS(J)
29 CONTINUE
40 CONTINUE

WRITE (6,251) XTI, FTC, AVT, PI, ASPH, BINDER, HPR2, HPR3, M18MT
251 FORMAT (10, 'DATA INPUTS:', /T10, 'TI=', 5F7.2, 'FTC', AVT, PI, ASPH',
& 'BINDER HPR2', 'HPR3', 'M18/MT/TH', '/T7', '4F7.0', '2F7.1', 'F7.0', 'F7.2', 'F10.0')
WRITE (6,252)
252 FORMAT ('DISTRESS', 'TI60', 'DISTRESS', 'TI12', 'N', 'RUTTING',
& 'RAIL FLUSH', 'PAIL', 'ALIG', 'LONG TRANS', '/ T11',
'S' ACT ONE TWO AREA AREA AREA AREA AREA AREA)
DO 41 J = 1, 100
WRITE (6,255) W(J), (DISL(I,J), I = 1, 8)
41 CONTINUE
DO 44 J = 1, 50
WRITE (6,257) PS(J)
44 CONTINUE
257 FORMAT (T8, 'F5.3', '10X', 'F5.3')

KNT = KNT + 1
IF (KNT .EQ. 1) WRITE (6,200)
IF (KNT .EQ. 1) KNT = 0
RETURN
END

SUBROUTINE ST(CNTY, IT, PESC, TIN, FRTH, AVTP, DMD, PLXK, FLEXL, DISL,
1 CNTY - COUNTY NUMBER
IT - PAVEMENT TYPE
PESC - PAVEMENT SCORE
TIN - THORNTHAILE INDEX
FRTH - FREEZE/THAW CYCLES
AVTP - AVERAGE TEMPERATURE
FLEXL - THICKNESS OF FLEX BASE IN INCHES
DMD - DYNAMETRIC MEAN DEFLECTION
PLXK - PLASTICITY INDEX
DISL - 8 X 100 - ELEMENT ARRAY WHICH HOLDS THE
1 MATRIX FOR THE DISTRESSES OF THE SECTION IN ANALYSIS
PSIL - TRANSITION MATRIX FOR THE PSI OF THE SECTION IN
ANALYSIS
INTEGER CNTY, EALT
REAL W(100), M18, M18MT, N, NS, PS(50), N1, N2, ADT, ADT
REAL LL
DIMENSION DISL(8,100), HEADER(10), X(17), PS(50)
DIMENSION TIN(254), FRTH(254), AVTP(254), MAIN(254), PSIL(50)
WRITE (6,200)
C 200 FORMAT ( '1' )
  ICTY = CNST
  TISO = TITIC(ICTY) + 50.0
  AVT = ATV(ICTY)
  FRC = FRHC(ICTY)
  W18MTH = ARIF * 1000000 ./ 480.0
  PI = PI36
  LL = 20.0 + ( 1.379 * PI )
  KMT = 0
  PO = 4.2

  AVT50 = AVT - 50.0

  X(17) = 0.83

  PSI
  X(15) = -0.173 + 0.00687 * AVT50 - 0.000632 * TISO + 0.0133 * FLEXL
        1 + 0.0075 * LL + 0.00153 * FTC - 0.0214 * DMD
        IF ( X(15) .GT. 0.511 ) X(15) = 0.511
        IF ( X(15) .LT. 0.0009 ) X(15) = 0.0009
  X(16) = 1.0

  RUT AREA
  X(1) = -0.1035 + 0.00549 * AVT50 + 0.0067 * FLEXL - 0.0015 * LL
        - 0.00162 * PI + 0.00077 * FTC
  X(2) = 1.340 + 0.00169 * TISO - 0.072 * FLEXL
        IF ( X(1) .GT. 0.117 ) X(1) = 0.117
        IF ( X(1) .LT. 0.0036 ) X(1) = 0.0036
        IF ( X(2) .GT. 6.27 ) X(2) = 6.27
        IF ( X(2) .LT. 0.615 ) X(2) = 0.615

  RAV AREA
  X(3) = 1.030 + 0.0146 * TISO + 0.0064 * FTC - 0.6389 * DMD
  X(4) = 1.28
        IF ( X(3) .GT. 2.76 ) X(3) = 2.76
        IF ( X(3) .LT. 0.095 ) X(3) = 0.095
        IF ( X(4) .GT. 6.1 ) X(4) = 6.1
        IF ( X(4) .LT. 0.52 ) X(4) = 0.52

  FLUSH AREA
  X(5) = 0.488 + 0.0127 * TISO + 0.00345 * FTC - 0.213 * DMD
  X(6) = 1.27
        IF ( X(5) .GT. 2.84 ) X(5) = 2.84
        IF ( X(5) .LT. 0.062 ) X(5) = 0.062

  ALLIGATOR AREA
  X(7) = -0.179 + 0.0121 * AVT50 + 0.0040 * FLEXL - 0.0011 * LL
        + 0.00153 * FTC
  X(8) = 1.867 - 0.00909 * TISO - 0.144 * FLEXL - 0.572 * DMD
        IF ( X(7) .GT. 0.19 ) X(7) = 0.19
        IF ( X(7) .LT. 0.003 ) X(7) = 0.003
        IF ( X(8) .GT. 7.29 ) X(8) = 7.29
        IF ( X(8) .LT. 0.51 ) X(8) = 0.51

  LONG AREA
  X(9) = -63.1 + 4.52 * AVT50 + 0.541 * TISO + 7.41 * FLEXL + 1.145 * FTC
  X(10) = 1.15
IF( X(9).GT. 172.0 ) X(9) = 172.0
IF( X(9).LT. 30.0 ) X(9) = 30.0

IF( X(10).GT. 2.65 ) X(10) = 2.65
IF( X(10).LT. 0.68 ) X(10) = 0.68

TRANS AREA
X(11) = -66.4 + 2.156*T150 + 10.12*FLEXL + 0.718*FTC
X(12) = 2.039 + 0.0734*FLEXL - 0.08*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

IF( X(12).GT. 2.65 ) X(12) = 2.65
IF( X(12).LT. 0.61 ) X(12) = 0.61

PATCHING
X(13) = 0.00799 + 0.00252*A1V50 + 0.000218*T150 + 0.00166*FLEXL
X(14) = 1.75

IF( X(13).GT. 0.104 ) X(13) = 0.104
IF( X(13).LT. 0.0036 ) X(13) = 0.0036

IF( X(14).GT. 5.36 ) X(14) = 5.36
IF( X(14).LT. 0.63 ) X(14) = 0.63

RHORA = X(1)
BETRA = X(2)
RHORV = X(3)
BETRV = X(4)
RHOFV = X(5)
BETFL = X(6)
RHOAA = X(7)
BETAA = X(8)
RHOLA = X(9)
BETLA = X(10)
RHTA = X(11)
BETTA = X(12)
RHOPT = X(13)
BETPT = X(14)
RHOP = X(15)
BETAF = X(16)
PF = X(17)

WRITE(6,300) RHORA, BETRA, RHORV, BETRV, RHOFV, BETFL, RHOAA, BETAA, & RHTA, BETTA, RHOLA, BETLA, RHOPT, BETPT, & RHOP, BETAF, PF

300 FORMAT( 'X, 10G13.5 / X, 7G13.5'/ )

DO 15 I = 1, 5
DO 15 J = 1, 100
15 DISL(I,J) = 0.0

CALCULATE DISTRESS

DO 30 J = 1, 100
IF (J.EQ.100) GO TO 507

W(J) = J
TO = W(J)/100.0
GO TO 508

507 TO = .9910
508 CONTINUE

RUTTING AREA NOW

SO = ALOG (TD)
RO = ABS (SQ)
ANW = RO**((1/BETRA))
N = (1/ANW)**RHOAR

RUTTING AREA NEXT YEAR

NI8 = N + (NI8MTH - 12.0/1000000.0)
PWR = (RHOAR/NI8)**BETRA
DISL(1,J) = EXP (-PWR) * 100.0
DISL(2,J) = EXP (-PWR) * 100.0

RAVELLING

ANW = RO**((1/BETRV))
ADT = (1/ANW)**RHORV
NADT = ADT - (AADT - 365./1000000.)
PWR = (RHORV/NADT)**BETRV
DISL(3,J) = EXP (-PWR) * 100.0

FLUSHING

ANW = RO**((1/BETFL))
ADT = (1/ANW)**RHOFL
NADT = ADT - (AADT - 365./1000000.)
PWR = (RHOFL/NADT)**BETFL
DISL(4,J) = EXP (-PWR) * 100.0

PATCHING

ANW = RO**((1/BETPT))
N = (1/ANW)**RHOPT

PATCHING AREA NEXT YEAR

NI8 = N + (NI8MTH - 12.0/1000000.0)
PWR = (RHOPT/NI8)**BETPT
DISL(5,J) = J + 3.0

ALLIGATOR CRACKING NOW

BA = 1/BETAA
ANW = RO**BA
N = (1/ANW)**RHOAA

ALLIGATOR CRACKING NEXT YEAR

NI8 = N + (NI8MTH - 12.0/1000000.0)
PWR = (RHOAA/NI8)**BETAA
DISL(6,J) = EXP (-PWR) * 100.0

LONGITUDINAL CRACKING NOW

BD = 1/BETLA
ANW = RO**BD
N = (1/ANW)**RHOLA

LONGITUDINAL CRACKING NEXT YEAR

IN = INT(N)
IN = IN + 12
PWR = (RHOLA/IN)**BETLA
DISL(7,J) = EXP (-PWR) * 100.0

TRANSVERSAL CRACKING NOW

BL = 1/BETTA
ANW = RO**BL
N = (1/ANW)**RHOTA

168
TRANSVERSAL CRACKING NEXT YEAR

IN = INT(W)
IN = IM - 12
PWR = (RHOTA/IN)**BETTA
DISL=8,J) = EXP( -PWR ) = 100.0
30 CONTINUE

PSI

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 = 0.19 (-1.0)
IF (B3.LE.0.0) GO TO 99
ANW = B3**(-1/BETAP)
N1 = (1/ANW)*RHOP
N2 = N1*100000.0/18MTH
N2 = N2 + 12
N18 = N2 - 118MTH/100000.0
PWR = (RHOP/N18)**BETAP
PSIL(J) = PO - (PO - PF) * EXP( -PWR )
IF (PSIL(J).GT.PS(J)) PSIL(J) = PS(J) - 0.15
40 CONTINUE

CONTINUE

GO TO 29
39 PSIL(J) = 2.65
GO TO 29
99 PSIL(J) = PIS(J)
29 CONTINUE
40 CONTINUE

WRITE(6,251) TJSO, FTC, AVT, PI, FLEXL, DMD, LL, N18MTH
251 FORMAT(T10,'DATA INPUTS:'//T10,'TJ=50 FTC AVT PI FLEXL'
& DMD LL N18MTH//T7,4F7.0,2F7.2,F7.0,F10.0)
WRITE(6,252)
252 FORMAT('TJSO', TJSO, 'DISTRESS', TJSO, 'DISTRESS', TJSO, 'RAVL RTING',
& 'RAVL RTING PATCH ALIG LONG TINS'//T11,
5'ACT ONE TW AREA AREA AREA AREA AREA AREA AREA AREA')

DO 41 J = 1, 100
WRITE(6,255) W(J), (DISL(I,J), I = 1, 8)
255 FORMAT( 14.2, 2X, 8F8.2)
41 CONTINUE

DO 44 J = 1, 50
WRITE(6,257) PS(J), PSIL(J)
257 FORMAT(T8,F5.3,10X,F5.3)
44 CONTINUE

KNT = KNT + 1
IF( KNT.EQ.1 ) WRITE(6,200)
IF( KNT .EQ. 1 ) KNT = 0

RETURN

END

SUBROUTINE SURVIV (CNYT, JX, JY, PESC, TIN, PRTH, AVTP, PLSX,
1 OVT, OV3, BB2, BB3, OVTH, ASPH, DMD, DISL,
2 FLEXL, PSIL, EALT, HPR2, HPR3, AADT, AK18, HMAC)

169
HPR3 = BB3(4,IC)
GO TO 25

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

24 ASPH = ASPH + 0.75

25 CALL BB (CNCY, IT, PESC, TIN, FRTH, AVTP, ASPH, HPR2, HPR3, PLSX, 1
DISL, PSIL, EALT)
GO TO 50

HOT MIX

30 IF (IT.NE.5 .AND. IT.NE.6) GO TO 40
HMAC = HMAC - 0.75
CALL HM(CNCY, IT, PESC, TIN, FRTH, AVTP, HMAC, HPR2, HPR3, PLSX, 1
DISL, PSIL, EALT)
GO TO 50

OVERLAY

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

43 IF (JX.NE.4) GO TO 44
OVTH = 4.5
HPR2 = OV2(4,IC)
HPR3 = OV3(4,IC)
GO TO 47

44 IF (JX.NE.3) GO TO 45
OVTH = 3.0
HPR2 = OV2(4,IC)
HPR3 = OV3(4,IC)
GO TO 47

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

46 OVTH = 0.75
47 CALL OV (CNCY, IT, PESC, TIN, FRTH, AVTP, HPR2, HPR3, OVTH, PLSX, DISL, 1
PSIL, EALT)

50 RETURN

END

SUBROUTINE HM(CNCY, IT, PESC, TIN, FRTH, AVTP, HMAC, HPR2, HPR3, PLSX, 1
DISL, PSIL, EALT)

-------------------------------------------------------------------------------------------------

THIS SUBROUTINE USES THE SURVIVAL CURVES TO GENERATE

171
TRANSITION MATRIX FOR BLACK BASE PAVEMENTS.

CNYT = COUNTY NUMBER
IT = PAVEMENT TYPE
PESC = PAVEMENT SCORE
TIN = THORNTHAWEITE INDEX
FRTH = FREEZE/THAW CYCLES
AVTP = AVERAGE TEMPERATURE
HPR2 = EQUIVALENT THICKNESS X ELASTIC MODULUS OF THE
      SUBGRADE AS DETERMINE FROM DINAFLKCT MEASUREMENTS
HPR3 = 10 ** 10 / HPR2
HMAC = HOT MIX ASPHALT THICKNESS
PSK = PLASTICITY INDEX
BIN = PERCENT ASPHALT BINDER
DISL = (8 X 100)-ELEMENT ARRAY WHICH HOLDS THE TRANSITION
      MATRIX FOR THE DISTRESSES OF THE SECTION IN ANALYSIS
PSIL = TRANSITION MATRIX FOR THE PSI OF THE SECTION IN
      ANALYSIS

INTEGER CNYT,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 PSI(50),PS(50)

WRITE (6,200)
200 FORMAT ('1 ')
ICTY = CNYT
XTI = TIN(ICTY) + 50.0
TI = TIN(ICTY)
AVT = AVTP(ICTY)
FRTH = FRTH(ICTY)
N18MTH = (EALT*1000.0)/240.0
BIN = 6.0
PSK = PSK
PO = 4.2
ICK = 0
XAVT = AVT - 50.0

LINEAR RHO & BETA , PSI

X(9) = -0.02*XTI-0.02481*AVT-0.03078*PSI+0.60781*BINDER+0.06424*HPR2
X(10) = 0.04045*FTC+0.22931*XAVT-0.5301*BINDER
X(11) = 0.00665*FTC+0.07917*XAVT+0.02472*PSI-0.57235*BINDER
& +0.00772*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

LOG RHO & BETA, PSI

212 X(9) = XTI**(-0.31419)*AVT**(-0.69942)*XAVT**(-0.96204)
& "BINDER"**(-0.44492)*HPR2**(-1.6511)
X(10) = FTC**(-0.40391)*XAVT**(-0.44517)*N18MTH**(-0.04576)
& "BINDER"**(-1.50304)
X(11) = 1.00

LINEAR RHO & BETA , RUTTING AREA

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

172
IF( X(7) .LT. 0.0 .OR. X(8) .LT. 0.0 ) GO TO 282
GO TO 283

LOG RHO & BETA, TRANS. CRACK AREA

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)

LINEAR RHO & BETA, TRANS. CRACK SEVERITY

283 Y(7) = -0.196*XTI+2.9*AVT-2.69**PI+5.475*HMAC
          Y(8) = 0.059*FTC* 0.537*HPR3
          IF( Y(7) .LT. 0.0 .OR. Y(8) .LT. 0.0 ) GO TO 292
          GO TO 293

LOG RHO & BETA, TRANS. CRACK SEVERITY

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**((-0.0069)

293 CONTINUE

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)
P = X(11)

RHORS = Y(1)
BETRS = Y(2)
RHOAS = Y(3)
BETAS = Y(4)
RHOLS = Y(5)
BETLS = Y(6)
RHOTS = Y(7)
BETTS = Y(8)

WRITE(6,300) RHORA, BETRA, RHOAA, BETAA,
            & RHOTA, BETRA, RHOLA, BETLA,
            & RHOP, BETAP, PF

300 FORMAT( /* LX, 10G13.5 / LX, 1G13.5/ */

DO 13 I = 1, 5
DO 13 J = 1, 100
15 DISL(I,J) = 0.0

CALCULATE DISTRESS

DO 30 J = 1, 100
IF (J.EQ.100) GO TO 507

W(J) = J
TO = W(J)/100.0
GO TO 508
307 TO = .9910
508 CONTINUE

RUTTING AREA NOW

SO = ALOG (TO)
RO = ABS (SO)
ANW = RO**((1/BETRA)

174
N = (I/ANW)*RHORA
NX = N*1000000.0/W18MTH

RAVELLING

RAVELLING

FLUSHING

FAILURES

ALLIGATOR CRACKING NOW

ALLIGATOR CRACKING NEXT YEAR

LONGITUDINAL CRACKING NOW

LONGITUDINAL CRACKING NEXT YEAR

TRANSVERSAL CRACKING NOW

TRANSVERSAL CRACKING NEXT YEAR

PSI

175
DO 40 J = 1, 150
PS(J) = PO
IF (RHOP .LE. 0.0 ) GO TO 40
IF (PF.GE.P0) GO TO 39
PS(J) = J/10.0
PIS(J) = PS(J)
IF (PS(J).GE.P0) PIS(J) = PO - .001
B1 = (PO-PS(J))/PO-PF
B2 = ALQ(B1)
B3 = B2 * (-1.0)
IF (B3 .LT. 0.0 ) GO TO 99
ANW = B3**(1/BETAP)
N1 = (J/ANW)**RHOP
N2 = N1*1000000.0/N1MH
N3 = N2 + 12
N18 = N2 - N1MH/1000000.0
PWR = (RHOP/N18)**BETAP
PS(J) = PO - (PO-PF) * EXP(-PWR)
IF (PS(J) .GE. PS(J)) PS(J) = PS(J) - 0.15
PSTE = PS(J)
GO TO 29
39 PS(J) = 2.65
GO TO 29
99 PS(J) = PIS(J)
29 CONTINUE
40 CONTINUE

WRITE(6,251) KTI, FTC, AVT, PI, HMAC, BINDER, HPR2, HPR3, N18MH
251 FORMAT('DATA INPUTS: ',/T10,'TI','50 FTC AVT PI HMAC'
&,' BINDER HPR2 HPR3 N18/MTH/7.4F7.0,2F7.1,F7.0,F7.2,F10.0)

WRITE(4,253)
253 FORMAT('/226,'DISTRESS', '760, 'DISTRESS' ,/12, 'N RUTTING',
& ' RAVL Flush Fail ALIG Long TRMS ' / T11,
& ' ACT ONE TWO AREA AREA AREA AREA AREA AREA')

DO 41 J = 1, 100
WRITE(6,255) W(J), (DISL(I,J), I = 1, 8)
255 FORMAT( '14.2, 2X, 9F6.2')
41 CONTINUE

DO 44 J = 1, 50
WRITE(6,257) PS(J)
257 FORMAT( '8F5.3,10X,F5.3')
44 CONTINUE

KNT = KNT + 1
IF (KNT .EQ. 1 ) WRITE(6,200)
IF (KNT .EQ. 1 ) KNT = 0
RETURN
END

SUBROUTINE TRE(DIST,CNTY,HWAY,BMIL,BSIGN,BDISP,EMIL,EMSIGN,EDISP,
& LANE,IVIS,SRVC,IT,IC,LANES,WDTH,ADTL,EALT,FESC,
& IST,AREA,DST,DAREA,DCOST,JS,TOT)
1

FROM THE MAINTENANCE STRATEGIES FOR ANY SECTION OF ROAD.
INPUT: DISTRESS, PAVEMENT TYPE, SCORE, SERVICEABILITY
OUTPUT: MAINTENANCE STRATEGIES

MAINTENANCE STRATEGIES:
1. - SEAL CRACKS
2. - PATCHING
3. - FULL DEPTH REPAIR
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
14. - ROTOMILL + OVERLAY

DIMENSION IVIS(7)
DIMENSION TOTALS(9,7), TOTLN(7), IEXT(6)
DIMENSION MTREF(7, 28, 4), CSQYD(12,7), CCOST(12,7)
DIMENSION IST(9), AREA(9), DST(6), DAREA(6), DCOST(6)

INTEGER DIST, CNTY, ADTL, EALT, PESC
INTEGER BML, EMIL, HWFC, DST
REAL LNTH

REAL*8 UWAY
REAL*8 UNIT2

DATA MSTRAT / 'SEAL CRA', 'CRS', 'PATCH', 'FULL DEP', 'TH RPAIR', 'FOG SEAL', 'STRIP SEAL', 'ASPH COAT', 'ASPH-RA', 'ER SEAL', 'SLURRY SEAL', 'LEVEL UP', 'THIN OVE', 'RLAY', 'ROTOMILL', 'SPOT SEAL', 'ROTOMILL + SEAL', 'ROTOMILL + OVERLAY' /


DATA UNITS / 'SQ YDS', 'SQ YDS', 'SQ YDS', 'SQ YDS', 'SQ YDS', 'SQ YDS', 'PER LN/M', 'PER LN/M', 'PER LN/M', 'PER LN/M', 'PER LN/M', '

1 'TOTAL' , 'SQ YDS', 'LN FEET', 'LN FEET', 'MEAN PSI' /

DATA RSTRAT / 'SEAL COA', 'T', 'THIN OVE', 'LAY', 'MEDIUM O', 'VERLAY', 'THICK O', 'VERLAY', 'RECONSTR', 'CTION' /

DATA RST10 / 'SEAL COA', 'T', 'SECTION', 'L RECONSTR', 'CTION', 'FULL REC', 'CONSTRUCTION' /

DATA PTYP / 'THICK HO', 'T MIX', 'INTERMIX', 'LATE HOT', 'MIX', 'THIN HO', 'MIX', '2.5INS', 'COMPOS', 'E', 'WIDENED', 'OLD CONC', 'FF', 'WIDENED', 'OLD FLEX', 'IBLE' /
20 LNH = 2.0
   RCST = RCST - 100.0
   CALL STRAT (IT, IVIS, LOWHI, SRVC, MLINES, WTH, LNH, HITREE, 1
   IST, AREA, DST, DAREA, DCOST, JS)

   IF (JS.EQ.0) GOTO 61
   DO 60 I = 1, JS
      CSQYD(I,IC) = CSQYD(I,IC) + DAREA(I)
      CCOST(I,IC) = CCOST(I,IC) + DCOST(I)
   60 CONTINUE
   61 CONTINUE
   DO 62 I = 1, 8
      TOTALS(I,IC) = TOTALS(I,IC) + AREA(I)
      TOTALS(9,IC) = TOTALS(9,IC) + SRVC
      TOLN(IC) = TOLN(IC) + 1.0
      WRITE (6,600) DIST
      WRITE (6,610) CNTY, HWAY
      WRITE (6,620) BML, BSIGN, BDISP, EML, ESIGN, EDISP,
      1 LANE, PESC
      K = IT - 3
      WRITE (6,630)(PTYPE(J,K),J=1,3), ADTL, EALT
   WRITE (6,635)
   DO 100 I = 1, 8
      IF (AREA(I).EQ.0.0) GOTO 100
      IF (IST(I).EQ.0) GOTO 95
      WRITE (6,640) (DSTRES(J,I),J=1,3), AREA(I), UNITS(I),
      1 (MSTRAT(J,IST(I)),J=1,2)
   95 WRITE (6,641) (DSTRES(J,I),J=1,3), AREA(I), UNITS(I)
   100 WRITE (6,650) (DSTRES(J,I),J=1,3), SRVC,
      1 (MSTRAT(J,IST(I)),J=1,2)
   102 WRITE (6,651) (DSTRES(J,I),J=1,3), SRVC
   103 CONTINUE
   WRITE (6,670)
   IF (JX.EQ.0) GOTO 150
   IF (.IT.EQ.10) GOTO 140
   WRITE (6,675) (MSTRAT(J,JX),J=1,2), RCST
   140 WRITE (6,680) (RST10(J,JX),J=1,3), RCST
   150 WRITE (6,690)
   160 WRITE (6,700)
   TOT = 0.0
   IF (JS.EQ.0) GOTO 175
   ISTE = 0
   DO 170 I = 1, JS
      170 CONTINUE
   WRITE (6,720) TOT
   DO 176 I = 1, JS
      IEXT(I) = DST(I)
      ISTE = ISTE + 1
   176 CONTINUE
   GOTO 180
175 WRITE (6,730)
IEXT(1) = 0
ISTE = 1
C 177 CONTINUE
180 CONTINUE
C
INDIST = DIST
INCHT = CNT
DO 302 I = 1, 7
   IF (TOTALW(I) .EQ. 0.0) GOTO 302
   TOTALS(9,I) = TOTALS(9,I) / TOTALW(I)
302 CONTINUE
DO 304 I = 1, 8
   WRITE (6, 734) (DSTRES(J, I), J=1, 3), UNIT2(I),
   (TOTALS(I, J), J=1, 7)
304 CONTINUE
WRITE (6, 735) (DSTRES(J, 9), J=1, 3), UNIT2(9),
   (TOTALS(9, J), J=1, 7)
WRITE (6, 600) INDIST
WRITE (6, 733)
WRITE (6, 740) INDIST
DO 310 I = 1, 12
   WRITE (6, 750) (MSTRAT(J, I), J=1, 2), UNITSORDER(I),
   (CSQYD(I, J), J=1, 7)
310 CONTINUE
PRINT ESTIMATED COST DATA
ANY SMALL DOLLAR AMOUNTS LT 1000 SET EQUAL TO 0
DO 315 I = 1, 12
   DO 318 J = 1, 7
      IF (COST(I, J) .LT. 1000.0) CCOST(I, J) = 0.0
315 CONTINUE
316 CONTINUE
WRITE (6, 600) INDIST
WRITE (6, 733)
WRITE (6, 760) INDIST
DO 320 I = 1, 12
   WRITE (6, 770) (MSTRAT(J, I), J=1, 2), (CCOST(I, J), J=1, 7)
320 CONTINUE
IF (DIST .NE. 99) GOTO 10
RETURN
END
SUBROUTINE SETUP(MTREE)

THIS SUBROUTINE ASSIGN REHABILITATION STRATEGIES TO EVERY
BRANCH OF THE DECISION TREE.

DIMENSION MTREE(7, 28, 4)
READ (3, 100)((MTREE(I, J, K), K=1, 4), J=1, 28), I=1, 7)
100 FORMAT (4(12, 1X))
RETURN
END
SUBROUTINE STRAT(IT, IVIS, LOWHI, SRVC, NLANES, WIDTH, LWTHT, MTREE,
     IST, AREA, DST, DAREA, DCOST, JS)

THIS SUBROUTINE IS USED BY SUBROUTINE TRE IN THE SELECTION
OF THE BEST MAINTENANCE STRATEGY.
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 LTNH

DIMENSION IST(9), AREA(9), DST(6), DAREA(6), DCOST(6)

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, 12.0, 2.5, 2.5, 2.5, 2.5, 1.5 /
DATA JSEQ1 / 7, 6, 8, 4 /
DATA JSEQ2 / 5, 12, 1 /
DATA PAREA / 0.0, 30.0, 50.0, 2.0, 30.0, 50.0, 2.0, 30.0, 50.0, 2.0, 30.0, 50.0, 2.0, 30.0, 50.0, 2.0, 30.0, 50.0 /
DATA ARECA / 0.25, 1.0, 2.5, 0.5, 0.5, 0.95, 1.2, 0.6, 1.5, 2.4, 1.7, 0.5 /

DO 10 N = 1, 9
AREA(N) = 0.0
IST(N) = 0
10 CONTINUE

DO 11 N = 1, 5
DST(N) = 0
DAREA(N) = 0.0
DCOST(N) = 0.0
11 CONTINUE

K = LOWHI

HANDLE RUTTING SEPARATELY

DO 20 NR = 1, 7
IF ( IVIS(N) .EQ. 0 ) GOTO 30
20 CONTINUE

30 IF ( NR .EQ. 1 ) GOTO 50
J = NR - 1
IF ( J .LT. 4 ) GOTO 40
 IST(2) = MTREE(IST-3, J, K)
 AREA(2) = PAREA(J-3, 2) * 0.01 = LTH = 1760. * WDT = 0.33
 GOTO 50
40 CONTINUE
 IST(1) = MTREE(IT-3, J, K)
 AREA(1) = PAREA(J, 1) * 0.01 = LTH = 1760. * WDT = 0.33
50 CONTINUE

OTHER DISTRESS TYPES

DO 100 M = 2, 7
N = M - 1
DO 110 N = 1, 4
IF ( IVIS(N) .EQ. DIS(N) ) GOTO 120
110 CONTINUE
120 IF ( M .EQ. 1 ) GOTO 100
 J = 6 - (M-2) *3 - N-1
 IST(L) = MTREE(IST-3, J, K)
 AREA(L) = PAREA(N-1, L) * 0.01 = LTH = 1760. * WDT = 0.33
 IF ( M .EQ. 4 ) AREA(L) = PAREA(N-1, L) = NAMES
 IF ( M .EQ. 7 ) AREA(L) = PAREA(N-1, L) = LTH = 5280. * 0.01 = LTH

181
C  PUT IN CASE OF M = 6 AND 7
C
100 CONTINUE
C
J = 23
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) = MTYPE(IT-3, J, K)
AREA(9) = LTH . = 1760. * WDTH . 0.33
C
WRITE(6,201) (IST(I), I=1,9)
WRITE(6,202) (AREA(I), I=1,8)
C201 FORMAT(10X, 9I6)
C202 FORMAT(10X, 8F6.1)
C DOMINANT STRATEGY CALCULATION
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) = LTH . 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) = LTH . 1760. * WDTH . 0.33
DCOST(JS) = DAREA(JS) * COST(10)

182
C
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
480 DO 490 I = 1, 4
IF (JMS(JSEQ1(I)) .EQ. 0) GOTO 490
JS = JS + 1
DST(JS) = JSEQ1(I)
DAREA(JS) = LTH*1760. * WTH*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(3) .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)*O.01 = LTH*1760. * WTH*0.33
DCOST(JS) = DAREA(JS) * COST(2) * SPATCH(IT-3)
1002 CONTINUE

C
LOOK FOR LONGITUDINAL CRACKS
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)*LTH=5280.*0.01
DCOST(JS) = DAREA(JS) * COST(1)
1006 CONTINUE

C
LOOK FOR TRANSVERSE CRACKING
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) * WTH = LTH = 5280. * 0.01
DCOST(JS) = DAREA(JS) * COST(1)
1010 CONTINUE
RETURN
END

C
SUBROUTINE RECODE(RVIS,IVIS)

183
THIS SUBROUTINE TRANSFORMS THE PERCENT VISUAL READINGS TO THE FORM (000, 100, 010, 001)

IVIS - 8-ELEMENT ARRAY WHICH HOLDS THE CODED VISUAL READINGS
Rviso - 8-ELEMENT ARRAY WHICH HOLDS THE TRANSFORMED VISUAL READINGS. RANGE 0 - 1

REAL W(4), Z(4), F(4), L(4), T(4)
INTEGER X(4), Y(4)
DIMENSION RVIS(8), IVIS(7), RVISO(8)

DATA F/50.0, 35.71, 17.89, 0.0/
DATA L/50.0, 40.0, 20.0, 0.0/
DATA Z/50.0, 42.0, 17.0, 0.0/
DATA T/50.0, 25.0, 10.0, 0.0/
DATA X/001, 010, 100, 000/
DATA Y/002, 020, 002, 000/
DATA Z/60.0, 50.0, 25.0, 0.0/

DO 5 I=1, 7
  5 IVIS(I) = 000
  DO 20 I = 1, 4
    RUTTING
      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)
    RAVELLING
      IF ( RVIS(3) .LE. Z(I) ) IVIS(2) = X(I)
    FLUSHING
      IF ( RVIS(4) .LE. Z(I) ) IVIS(3) = X(I)
    FAILURES
      IF ( RVIS(5) .LE. F(I) ) IVIS(4) = X(I)
    ALLIGATOR CRACKING
      IF ( RVIS(6) .LE. W(I) ) IVIS(5) = X(I)
    LONGITUDINAL CRACKING
      IF ( RVIS(7) .LE. L(I) ) IVIS(6) = X(I)

    IF ( RVIS(8) .LE. T(I) ) IVIS(7) = X(I)
  20 CONTINUE
RETURN
END

SUBROUTINE FINDTF ( IC, AADT, AKIP, TRAF, TRAFC, TRAFD, TF, LHI)

CALCULATE DETERIORATION FACTOR FOR TRAFFIC

IC - FUNCTIONAL CLASS. OF ROADWAY FOR REHAB.
AADT - ADJUSTED ADT OF ROADWAY FOR REHAB.
AKIP - ADJUSTED 18-KIP EQUIV. OF ROADWAY FOR REHAB.
TRAF - TACS TABLE HMSTING.
ARG. - 4 FACTORS FOR EACH OF 7 FUNCT. CLASSES.
RESULT - TRAFFIC FACTOR.

TRAFC - TACS TABLE HMSADTEM.
ARG. - FUNCT. CLASS.
RESULT - ADT BREAK-OVER POINT FOR THE FUNCT. CLASS.

TRAFD - TACS TABLE HMSKIPBM.
ARG. - FUNCT. CLASS.
RESULT - 18-KIP EQUIV. BREAK-OVER POINT (10**6) FOR THE FUNCT. CLASS.

TF - FACTOR FROM TRAF RETURNED TO CALLER.

DIMENSION TRAF(7,4), TRAFC(7), TRAFD(7)
DATA TRAF /1.80, 1.80, 1.00, 1.00, 1.80, 1.80, 1.00, 1.00, 1.00,
1 1.80, 1.80, 1.00, 1.00, 1.50, 1.50, 1.00, 1.00, 1.00,
2 1.50, 1.50, 1.00, 1.00, 1.50, 1.50, 1.00, 1.00, 1.00/
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 MAINTRE (DIST, CNTY, HWAY, BMIL, BSIGN, BDISP, EMIL, ESIGN,
EDISP, LANE, IVIS, SRVC, IT, IC, NLAMES, MDTH, ADTL, EALT,
PESC, LOMHI, JX, RCOST, RVIS, RVISO, IEXT, ISTE, IALV,
IST, AREA, DST, DAREA, DCOST, JS, TOT)

THIS SUBROUTINE IS USED WHEN A PREVENTIVE MAINTENANCE STRATEGY WILL BE APPLIED.

THE DECISION CRITERIA IS:
IF PES IS < 75
OR IF REHAB. STRAT. < 3

DIMENSION IVIS(7), RVIS(8), IEXT(6), RVISO(8)
DIMENSION IST(9), AREA(9), DST(6), DAREA(6), DCOST(6)

CALL RECODE ( RVIS, IVIS )

CALL TRE ( DIST, CNTY, HWAY, BMIL, BSIGN, BDISP, EMIL, ESIGN, EDISP,
LANE, IVIS, SRVC, IT, IC, NLAMES, MDTH, ADTL, EALT, PESC,
LOMHI, JX, RCOST, IEXT, ISTE, IALV,
IST, AREA, DST, DAREA, DCOST, JS, TOT)

RETURN
END

SUBROUTINE IMPROV(IEXT, ISTE, RVIS, SRVC)

THIS SUBROUTINE IS USED TO REDUCE THE PERCENTAGE OF DISTRESS IN A SECTION OF ROAD WHEN A MAINTENANCE STRATEGY HAS BEEN RECOMMENDED.

INPUT: MAINTENANCE STRATEGY
ACTUAL DISTRESS

OUTPUT:

IMPROVED DISTRESS

DIMENSION IEXT(6), RVIS(8), MXGAIN(8,14), RIDE(14)
REAL MXGAIN, RIDE

DATA MXGAIN / 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0, 1.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0, 1.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0, 1.0,
0.0, 0.0, 0.5, 0.5, 0.5, 0.0, 1.0, 1.0,
0.0, 0.0, 1.0, 1.0, 1.0, 0.0, 1.0, 1.0,
1.0, 1.0, 1.0, 1.0, 1.0, 0.0, 1.0, 1.0,
1.0, 1.0, 1.0, 1.0, 1.0, 0.0, 1.0, 1.0,
0.0, 0.0, 0.5, 0.5, 0.5, 0.0, 1.0, 1.0,
0.0, 0.0, 0.0, 0.0, 1.0, 1.0, 1.0, 1.0/}

DATA RIDE / 0.0, 0.5, 1.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.1, 0.5, 0.2, 0.0, 0.0, 0.5, 1.0,
2.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0/}

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,
AVU, SIV, SMV, RVIS, EMDIS, V, FLEXSC, ADTS, WDTH,
SIINR, FACN, IC, JX, RVIISO, TCLS, ISMTH, ECFS, TOT,
DISL, PSLI, IAVUC, FSIU, PSEC, PSEM, INX, VI, SIV1,
CNYT, IT, ITM, FRTH, AVTP, FLSX,
OV2, OV3, BB2, BB3, OWTH, ASPH, DMD,
FLEXL, EALT, HPR2, HPR3, AADT, AKIP, HNCAC, IEXT)
1

-----------------------------------------------------------------------
This subroutine is used to test between a maintenance strategy and a rehabilitation strategy.

-----------------------------------------------------------------------

DIMENSION DOSL(8,100), PSOL(50), POS(50), TIN(254), FTHR(254)
DIMENSION AVTP(254), RAIN(254), OV2(4,4), OV3(4,4), BB2(4,2)
DIMENSION BB3(4,2)
REAL LGTH
INTEGER CNTT, EALT
DIMENSION DISL(8,100), PSLI(50), RVIS(8), TCLS(5,10), RVISO(8)
DIMENSION V(8), FLEXSC(8,3), SIINR(3,3), FACN(7)
DIMENSION FAVU(10,5), FSIU(5,5), FSKU(6,5), ENDVIS(8)
DIMENSION REVIS(8), PSEM(7), VI(8), ECFS(25,5)
THF2 = HPR2
THF3 = HPR3
IAS = 0
IRE = 0
ICHEK = 0
J = 0
DO 5 I=1,6
5 REVIS(I) = RVIS(I)
SERVC = SERVC
IF (IENT.EQ.1) GO TO 20
10 CALL SCORE(REVIS, SERVC, V, FLEXSC, ADTS, SIBNRY, FUNC, IC, IAVUC, ISIUC, PESC, IT)
C
C KFESC = (PESC + 0.001) * 100
IF (PESC.LT.PESH(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, PSIU, FSMK, AVU, SIV, SNV, RVIS, ENDVIS)
1 DO 30 I=1,8
2 V1(I) = ENDVIS(I)
30 CONTINUE
SIV = SIV
JX = J
AREA = LGTH * WTHE
ACOST = AREA * ECFS(DIST, 4)
C
CALL SCORE(ENDVIS, SIV, V, FLEXSC, ADTS, SIBNRY, FUNC, IC, IAVUC, ISIUC, PESC, IT)
1 PESC = PESC
PESK = PESK
IF (ICHEK.EQ.1) GO TO 70
OVTHI = OVTH
ASPHI = ASPHI
HMACI = HMAC
FLEXL = FLEXL
CALL SURVTA(CNTY, JX, IT, PESC, TIN, FRTH, AVTP, PLSK, OV2, OV3, BB2, BB3, OVTHI, ASPHI, DMD, DOSL, FLEXL, PSOL, EALT, THP2, THP3, AADT, ARIP, HMACI)
1 CALL SCORE(ENDVIS, SIV, V, FLEXSC, ADTS, SIBNRY, FUNC, IC, IAVUC, ISIUC, PESC, IT)
40 CONTINUE
SUBROUTINE SORT(A, M)
------------------------------------------------------------------
THIS SUBROUTINE SORTS IN AN INCREASING MANNER ANY NUMERICAL
ONE DIMENSIONAL ARRAY.
------------------------------------------------------------------
DIMENSION A(M)
IF (M.LE.1) RETURN
LAST = M - 1
DO 20 I = 1, LAST
20 RETURN
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