Final Report
Volume 2

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Development of a Network Optimization System

Prepared for

Arizona Department of Transportation

by

R. Kulkarni, K. Golabi, F. Finn and E. Alviti

with Consulting Assistance from

L. Nazareth

May 1980

Woodward-Clyde Consultants
Three Embarcadero Center, Suite 700, San Francisco, CA 94111

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Appendix A

A USER MANUAL FOR THE COMPUTER PROGRAMS DEVELOPED FOR THE NETWORK OPTIMIZATION SYSTEM

INTRODUCTION

The network optimization system (NOS) is designed to assist the ADOT formulate the most cost-effective pavement rehabilitation policies. The methodology for the NOS is described in detail in the main body of the report. Details of the set of computer programs that were developed to implement the optimization model for the NOS are provided in this appendix which is organized in the following sections:

- mathematical formulation of the model
- an overview of the process of generation and solution of the model
- input-output characteristics of various programs
- an illustrative example.

MATHEMATICAL FORMULATION OF THE MODEL

Let $w_{i,k}^{\ell}$ denote the proportion of roads of a given road category which are in condition state i at the beginning of ℓ^{th} time period and to which k^{th} rehabilitation action is applied. The long-term proportion of roads in state i and for which k^{th} action is taken is denoted by $w_{i,k}$.

By Markovian properties of the process, it can be shown that such a limiting proportion exists. The objective of the model is to determine $w_{i,k}$ and $w^{\ell}_{i,k}$ for all i, k, and ℓ to minimize the long-term expected average cost of rehabilitation, subject to certain short-term requirements. A major requirement of the model is that it should reach "steady state" within a specified time period. Steady state means that the expected proportion of roads in each condition state should remain constant over time.

The problem of determining the optimum $w^{\ell}_{i,k}$ can be formulated as a linear program (LP). The LP problem is solved in two stages. In the first stage, the optimum steady state solution is obtained. In the second stage, the system is required to reach the steady state solution starting from its current condition within a specified time period, T (e.g., T = 5 years).

The steady state problem is structured as follows:

$$\text{Minimize} \sum_{i,k} w_{i,k} c(i,k) \qquad \text{(A-1)}$$

subject to

$$\sum_{i,k} w_{i,k} = 1 \qquad \text{(A-2)}$$

$$\sum_{k} w_{j,k} = \sum_{i,k} w_{i,k} p_{ij}(a_k) \qquad \text{(A-3)}$$

$$\sum_{j,k} w_{j,k} \leq \gamma_i, \text{ for } i \in I, \; j \in j_1(i) \qquad \text{(A-4)}$$

$$\sum_{j,k} w_{j,k} \geq \varepsilon_i, \text{ for } i \in J, \; j \in j_2(i) \qquad \text{(A-5)}$$

in which $c(i,k)$ = unit average cost of applying k^{th} rehabilitation action to pavements in i^{th} condition state

$p_{ij}(a_k)$ = probability that a unit of road (lane-mile) in condition state i moves to condition state j in one period if k^{th} rehabilitation state is applied

γ_i = maximum proportion of roads allowed to be in the set of undesirable states denoted by $j_1(i)$

I = number of specifications of undesirable states

ε_i = minimum proportion of roads required to be in the set of desirable states denoted by $j_2(i)$

J = number of specifications of desirable states.

Let the optimum solution of the steady state problem be denoted by w^*_{ik} and let c^* be the average cost of this solution. The objective of the second stage is to take the system in its current condition and make it reach the optimum steady state solution within T time periods at a minimum cost. This solution should also satisfy certain performance standards. This problem is formulated as follows.

$$\text{Minimize} \sum_{\ell=1}^{T-1} \sum_{i,k} w^{\ell}_{i,k} d_{\ell}\; c(i,k) \qquad \text{(A-6)}$$

$$\sum_k w^1_{i,k} = q_i \qquad \text{(A-7)}$$

$$\sum_k w^{\ell}_{j,k} = \sum_{i,k} w^{\ell-1}_{i,k}\, p_{ij}(a_k), \text{ for } 1 < \ell \leq T \qquad \text{(A-8)}$$

$$\sum_{k} w_{j,k}^{T} \leq \sum_{k} w_{j,k}^{*}(1+\alpha)$$

$$\sum_{k} w_{j,k}^{T} \geq \sum_{k} w_{j,k}^{*}(1-\alpha) \qquad \text{(A-10)}$$

$$\sum_{j,k} w_{j,k}^{\ell} \leq p_1(\ell)\gamma_i, \text{ for } i \in I, \; j \in j_1(i), \; 2 \leq \ell \leq T \qquad \text{(A-11)}$$

$$\sum_{j,k} w_{j,k}^{\ell} \geq p_2(\ell)\varepsilon_i, \text{ for } i \in J, \; j \in j_2(i), \; 2 \leq \ell \leq T \qquad \text{(A-12)}$$

$$\sum_{i,k} w_{i,k}^{T} c(i,k) \leq (1+\beta)c^* \qquad \text{(A-13)}$$

$$w_{j,k}^{\ell} \geq 0, \text{ for all } j, k, \text{ and } 1 \leq \ell \leq T \qquad \text{(A-14)}$$

in which ℓ = ℓ^{th} time period

d = present worth of one dollar spent during ℓ^{th} time period

q_i = current proportion of roads in i^{th} condition state

α, β = small proportions (e.g., 0.01)

$p_1(\ell)$ = a multiplier ≥ 1 to permit a higher than γ_i proportion of roads in undesirable states at the ℓ^{th} time period

$p_2(\ell)$ = a multiplier ≤ 1 to permit a lower than ε_i proportion of roads in desirable states at the ℓ^{th} time period.

Constraints A-9 and A-10 require the system to achieve steady state probabilities (under the optimum policy) within certain tolerance limits.

Constraint A-13 requires that the cost at the T^{th} time period should be within a small percentage of the cost of the optimum steady state solution.

The second stage of the problem, thus, provides values of w^{ℓ}_{ik}, for $1 \leq \ell \leq T-1$ that minimize the total expected discounted costs during the first (T-1) time periods and which also satisfy the specified limiting proportions of roads in desirable and undesirable states. The values of $w^T_{i,k}$ are as close to $w^*_{i,k}$ as is practically possible and the cost at the the T^{th} time period is within a small percentage of the cost of the optimum steady state solution.

AN OVERVIEW OF MODEL GENERATION AND MODEL SOLUTION

Figure A-1 is a schematic representation of the process of generating the optimization model and solving it. The process consists of the following steps:

- creating the file TRMX that contains the transition probabilities
- creating the file COSTF that contains cost data
- creating the file CURNT that contains the data on current condition of the network
- creating the file SXSIN that contains control input data
- creating an LP matrix suitable for an MPSX program using the matrix generation program developed for this study (the matrix generator program requires the files TRMX, COSTF, CURNT, and SXSIN)

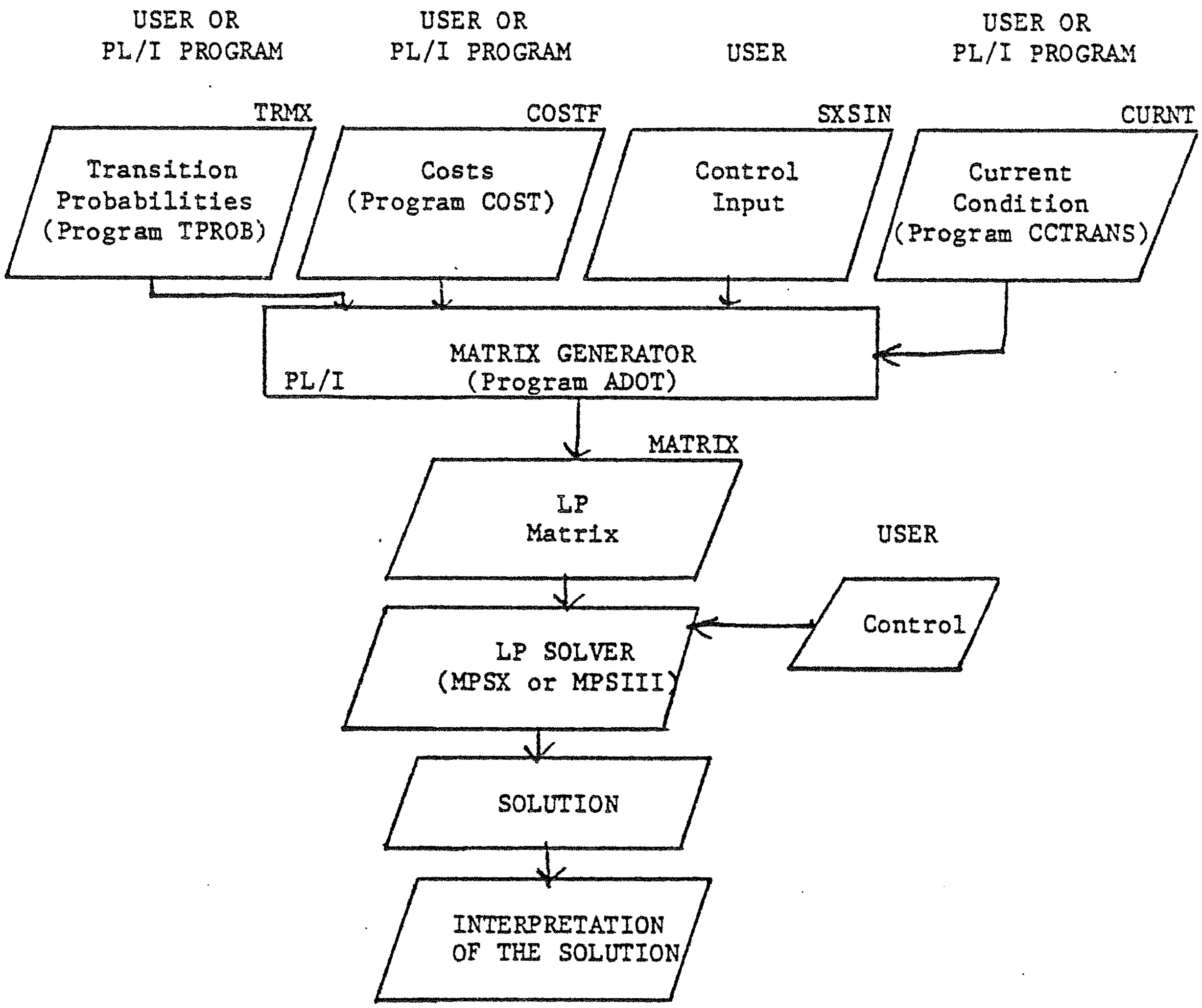

Figure A-1. AN OVERVIEW OF THE OPTIMIZATION MODEL

- accessing the MPSX program with appropriate control data and the LP matrix created in the previous step

- obtaining and interpreting an optimum solution from MPSX.

A brief description of each step follows.

Creating the File TRMX

The file TRMX containing the transition probabilities $p_{ij}(a_k)$ for all i, j, and k has been created using the regression equations of pavement performance. The procedure to calculate the transition probabilities from regression equations is explained in Appendix B. The user will normally create this file by running Program TPROB for the 120-state problem or Program TPROBSP for the 24-state problem. The user can optionally create this file directly. The requirements of Program ADOT with respect to file TRMX are described in a following section.

Creating the File COSTF

The file COSTF has been created using the information on routine maintenance and construction costs of various actions for pavements in different condition states. The file contains c(i,k)--annual unit cost (in dollar/square yard) of pavements in i^{th} condition state to which k^{th} rehabilitation action is applied. The data used to calculate c(i,k) is described in the section on Program COST. The user can optionally create file COSTF directly using the information in the section on Program ADOT.

Creating the File CURNT

The file CURNT has been created using the current condition data provided by the Arizona Department of Transportation. The file contains q_i--the proportion of roads of a given category (i.e., a given combination of traffic and regional factor)--in i^{th} condition state at the beginning of the analysis (i.e., at present time). The total number of square yards of roads in each condition state at present time is also included in this file. The user can create file CURNT directly by referring to the section on Program ADOT.

Creating the File SXSIN

This file should be created by the user prior to using the matrix generator program. The input data required on this file is described in the section on Program ADOT.

Creating the LP Matrix

A matrix generator program was developed for this study to generate a LP matrix suitable for the MPSX program to be used in solving the LP problem. This program, called ADOT, uses the files TRMX, COSTF, CURNT, and SXSIN.

Accessing the MPSX Program

The LP matrix generated in the previous step is input into the MPSX program along with certain control data. The control data specifies various options that can be used by the MPSX routines to solve the LP problem. The necessary control data is described in the next section.

Obtaining and Interpreting an Optimum Solution from MPSX

When feasible, the MPSX program produces an optimal solution to the LP problem in either the first or second stage. Interpretation of the typical output of the MPSX program is discussed in a subsequent section.

INPUT-OUTPUT CHARACTERISTICS OF VARIOUS PROGRAMS

The following computer programs are included in the NOS.

- Program COST - generates cost input data
- Program CCTRANS - generates current condition data

- Program TPROB - generates transition probabilities

- Program TPROBSP - generates transition probabilities for a special case

- Program ADOT - generates the matrix required for the LP package

- Program MPSX - solves the LP problem.

The following sections describe the requirements of input data and organization of program output for each program.

PROGRAM COST

Program COST reads in routine maintenance costs and rehabilitation costs and produces the file COSTF which contains the cost associated with every element of a 120-state by 17-action array. The input data is printed along with the array on the standard system file SYSPRINT. The output file COSTF may then become the input file COSTF to Program ADOT, the matrix generator. It can be used in either the 120-state or 24-state configuration. A user specified identification key is incorporated in file COSTF.

Description of Input File COSTIN

All input data required by Program COST is read from the file COSTIN. The first eight columns constitute an identification key. The next 72 columns are read as heading information. The keyword CNAME in Program ADOT must be set equal to this identification key to permit the use of file COSTF by Program ADOT.

The remainder of the input data must begin on the next record and is read free-format. Therefore, only the sequence is relevant. Permissible values for cost range from 0 to 999.999. Output costs are rounded to the nearest thousandth.

The routine maintenance costs are read in first and are subdivided into three sections. The nine values that correspond to Action 1 are indexed by roughness and cracking levels and are read in the following order.

SEQ #	Roughness	Cracking
1	1	1
2	1	2
3	1	3
4	2	1
5	2	2
6	2	3
7	3	1
8	3	2
9	3	3

A convenient way to specify these values is by placing them in a 3x3 matrix with rows indexed by roughness and columns indexed by cracking.

The three values corresponding to Action 2 are indexed by roughness level and are read in the following order.

SEO #	Roughness
10	1
11	2
12	3

The single value that corresponds to Actions 3 through 17 is read in next.

SEQ #	Cost
13	value

The rehabilitation costs are the last values required by program costs. One value for each of the 17 actions is read in the following order.

SEQ #	Action
14	1
15	2
16	3
17	4
18	5
19	6
20	7
21	8
22	9
23	10
24	11
25	12
26	13
27	14
28	15
29	16
30	17

Two important notes should be kept in mind by the user.

1. The user must ensure that the sum of any routine maintenance cost and rehabilitation cost does not exceed 999.999.

2. An identification key of eight blanks should not be used. A meaningful name is helpful in later identification of the file.

Description of Output File SYSPRINT

The output file SYSPRINT must have a logical record length of 133. It is logically divided into two sections: the first section displays the input data, and the second section displays the computed 120-state by 17-action array.

The first page of output contains all the input data with appropriate headings. The 80-column key and heading information is the first line printed. The routine maintenance costs are displayed next followed by the rehabilitation costs. The word "LOW" is printed on the right hand side of any negative cost. The detection of a negative cost causes the program to print an error message and terminate execution.

The second part begins on Page 2 and is titled "Cost Matrix." The matrix is printed with the columns indexed by action and the rows indexed by state.

The user should check that the input data displayed on Page 1 is in the intended sequence.

Description of Output File COSTF

The output file COSTF must have a logical record length of 80. The first record contains the identification key and heading. The remaining 240 records are desiged so that the 120 pairs of records correspond to the 120 states. The first record of the pair contains the costs for Actions 1 to 9 beginning in Column 1. The second record of the pair contains the costs for Actions 10 to 17 beginning in Column 9. Each field is eight columns wide. This structure permits the 24state configuration of Program ADOT to use this file.

PROGRAM CCTRANS

Program CCTRANS prepares current condition files in a form suitable for the matrix generator, Program ADOT, from the current condition file. Users can specify the levels of traffic and region for which a file is to be prepared. A single user specified identification key is incorporated into all the requested files. All requested files along with any error diagnostics are displayed on the print file SYSPRINT. The requested files and identification key are specified through the input file CTRL. The current condition file is read in through the file CCIN.

Description of the Input File CTRL

The first eight columns constitute an identification key. The next 72 columns are read as heading information. The keyword CURNAME in Program ADOT must be set equal to this identification key (traffic and region levels must match) in order to permit the use of one of the generated current condition files by Program ADOT.

The two values, NUMIN and NUMOUT, are read in from the next record. Permissible values for both are either 24 or 120 with the requirement that NUMIN $\geq$ NUMOUT. NUMIN indicates whether the input file CCIN is in 24-state or 120-state format. NUMOUT indicates whether the output files are to be in 24-state or 120-state format. When NUMIN = 120 and NUMOUT = 24, the output files represent the proportions across all five design lives. NUMOUT must not occupy the last column of the record.

The road categories with which current condition files are prepared are specified in a 3x3 matrix. The rows are indexed by traffic and the columns are indexed by region: Columns 1 to 4 are for Region 1, Columns 6 to 9 are for Region 2, and Columns 11 to 14 are for Region 3. A non-blank entry in these column ranges indicates that a file should be prepared for that region. The row in which the non-blank entry appears indicates the traffic level. In the following illustration, CC23 indicates Traffic Level 2 and Region Level 3.

Column 1	6	11
CC11	CC12	CC13
CC21	CC22	CC23
CC31	CC32	CC33

It is important to re-emphasize that the program only notes whether all four columns in a field are blank.

Description of File CCIN

File CCIN contains the current road conditions in absolute form. There should be 9x27xNUMIN/24 records in CCIN. Setting NUMIN = 120, there are 135 records for each of the nine road categories for a total of 1215 records. The nine categories must be in the following sequence: (traffic, region) = (0,0), (0,1), (0,2), (1,0), (1,1), (1,2), (2,0), (2,1), and (2,2). Therefore, the 135 records that belong to the first category (0,0) are followed by the 135 records that belong to the second category (0,1) and on down ending with the 135 records of the last category (2,2). The 135 records within each category can be in any order.

The contents of each individual record contain the following information.

Column(s)	Description	Range
1 - 5	Ignored	-
6	Traffic Level	0, 1, 2
7	Region Level	0, 1, 2
8	Design Life Level	0, 1, 2, 3, 4*
9	Roughness Level	0, 1, 2
10	Cracking Level	0, 1, 2
11	CP Level	0, 1, 2
12 - 21	Shoulders	≥ 0
22 - 31	Traveled Way	≥ 0

*design life must be set to 0 if NUMIN = 24

Program CCTRANS checks to see that these ranges are not violated.

Description of Output File SYSPRINT

The first printed line contains the program heading "Current Conditions are Translated from Absolute Form to Proportional Form." The next printed line contains the identification key and run heading. The input and output file formats are displayed next. These should be either 120-state or 24-state. If the output file is 120-state then the input file must also be 120-state. A single error message is printed if the file formats are mis-specified. The sequence for checking errors is: (1) NUMOUT $\leq$ NUMIN?, (2) is NUMOUT either 24 or 120?, and (3) is NUMIN either 24 or 120? If the first error exists, the second and third errors are not checked. If the first error is not present but the second one is, then the third error is not checked. If an error is found, the program stops after printing the error message.

The traffic-region output directives are printed next. Output files are generated for non-blank entries in the table. Columns are indexed by region and rows are indexed by traffic. At this point, the program processes each output file request. The printed information for each one begins on a new page. The traffic and region levels are printed first. If no out-of-range values were found and the total is non-zero, then the total is printed. Otherwise, an error message is printed indicating that out-of-range values were found (thus invalidating the total) or the total is zero. The input from file CCIN is printed along with the state identification number and the calculated proportion is truncated to four digits. If they are all error-free, then only non-zero entries are printed. Otherwise they are all printed with the proportion column suppressed because the total is invalid. The erroneous entries are flagged by a "??" on their right hand side. "DUP" indicates that this road state was previously specified.

The program now proceeds to the next requested output file even if previous errors were found. After they are all processed, an error message is printed if any of them had invalid entries. Finally, the program prints the message "END OF PROGRAM" and terminates execution.

Description of Output Files CC11, CC12, ..., CC33

These output files should have a logical record length of 80. The identification key is contained in the first eight columns of the first record. The next 72 columns are used for heading information. The next record contains the traffic level in Column 10 and the region level in Column 20. The next record begins with the words "CURRENT CONDITION" and has the number of current condition specifications in Columns 25 to 27 followed by "TOTAL =", the total for this road category. A semicolon is the last entry on this record. The remainder of the records each contain one road state identification number and proportion of roads in that state.

PROGRAM TPROB

Program TPROB generates transition probability files for use by Program ADOT. These files are in the 120-state format. Users can specify the road categories with which output files are generated. A single user specified identification key is incorporated into all the requested files. Only the information required to generate a file for the specified road categories need be provided when running Program TPROB. If input errors or absence of data prevent the generation of one file, the program will attempt to generate the next requested file. The identification key, heading, input file directives, output file directives, and, optionally, the design file specifications are read from file TPROBIN. The design life specifications can optionally be read from file LIFE. The input cracking and roughness level transition probabilities are read from the files REG1, REG2, and REG3. All input information and the unique portions of the output files are displayed on the file SYSPRINT.

Description of Input File TPROBIN

The first eight columns constitute an identification key. The next 72 columns are read as heading information. The keyword TNAME in Program ADOT must be set equal to this identification key and the traffic and region levels must match in order to permit the use of one of the generated transition probability files by Program ADOT. Program TPROB notes whether the first four columns of the next record are blank. If blank then the design life data is read at the end of file TPROBIN. Otherwise the design life data is read from the file LIFE.

The next record contains three fields of four columns each which correspond to the three region levels. They begin in Column 1 and are separated by a single blank. If there is a non-blank character in the i^{th} field (i = 1, 2, 3), then Program TPROB will read cracking and roughness level transition probabilities from file REGI. If a user wants to generate a transition probability file for any traffic level in Region i, then a non-blank character must be present in Field i.

The road categories with which transition probability files are prepared are specified using nine fields in a 3x3 matrix. Each row of the matrix is represented as three fields of four columns each, beginning in Column 1 and separated by a single blank. The rows of the matrix are indexed by region and the columns are indexed by traffic volume.

The following illustration indicates that (1) the design life information is to be read from file LIFE, (2) data is to be read in for Regions 1 and 3, and (3) transition probability files are to be generated for two road categories: (traffic, region) = (1,1) and (3,3).

```
Column
1    6    11

LIFE
REG1      REG 3
TR11

          TR33
```

It is important to remember that Program TPROB only notes whether the four columns in a field are blank.

If the user indicated that the design life information is to be read from file TPROBIN, then it is placed here, beginning with a new record. Its specification here is identical to that in file LIFE. (Refer to the description of file LIFE for details.)

Description of Input File LIFE

This file is required if the user indicated in file TPROBIN that the design life information is to be read from file LIFE. Each road category must begin on a new record. Each specification consists of two parts: (1) road category identification, and (2) design life information. The road category is identified by traffic and region level using the key-words TRF and REG. Permissible values for TRF and REG are the integers 1, 2, and 3. A semicolon must follow the identification. Afterwards, there must be 16 integer constants ranging from 1 to 5. These values represent the design life level of a road in this category after undergoing Actions 2 to 17, respectively. The 16th value, which corresponds to Action 17, must not occupy the last column of a record. If the traffic or region level is identical to that of the previous specification, then it may be omitted. The specifications can be in any order. Only the road categories for which a transition probabiity file is desired need be specified.

In the following illustration, only four road categories are specified.

```
TRF = 1 REG = 1; 2 2 4 3 3 5 3 4 5 4 4 5 4 5 5 1
        REG = 2; 2 2 4 3 3 4 3 4 4 4 4 5 4 4 5 5
TRF = 2        ; 2 2 3 2 2 4 3 3 4 3 4 4 4 4 4 5
TRF = 3 REG = 3; 2 2 3 2 2 3 3 3 3 3 3 3 3 4 4 5
```

Although not required, it is convenient to place the entire specification on a single record.

Description of Input Files REG1, REG2, REG3

Files REG1, REG2, and REG3 contain the cracking and roughness level transition probabilities for region levels 1, 2, and 3, respectively.

All three files have precisely the same structure so that references to region level are not necessary.

Eighty-eight specifications exist in the file. Each specification consists of an identification area followed by a semicolon and three numbers between zero and one inclusive.

Identification is indexed by action, design life level, cracking or roughness level, and CP level. These factors are denoted by the key words ACTN, LIFE, CRK or RUF, and CP, respectively. Action 1 has 43 specifications among five design life levels. Each level of design life has three levels of cracking to which it corresponds. Cracking Levels 2 and 3 have three levels of CP each, while Cracking Level 1 has two levels of CP. In addition, Design Life Level 1 has three more specifications that correspond to the three levels of roughness.

There cannot be specifications for Action 2 because Action 2 specifications would be a subset of Action 1 specifications.

Actions 3 to 17 require three specifications each which correspond to the three levels of roughness.

Program TPROB considers a specification indexed by roughness rather than cracking when the keyword CP is set to zero. Presence of the keywords CRK and RUF in a specification is not a determinant. The keyword LIFE must be set to zero or one in a roughness specification.

An index whose value is the same as that of the previous specification may be omitted from the current specification. For example, if the 43 specifications for Action 1 are placed consecutively, then the keyword ACTN need only be set to one on the first specification and can be omitted on the following 42 specifications.

The three numbers which follow the semicolon in each cracking specification represent the probability of being in Levels 1, 2, and 3 of cracking after undergoing Action 1 for a road with the current design life, cracking, and CP levels. For roughness specifications they represent the probability of being in Levels 1, 2, and 3 of roughness after undergoing the specified action for a road with the current level of roughness. These probabilities must sum to one. To allow for single precision error, a tolerance of 2.5×10^{-8} is allowed for the sum. The individual probability must range from zero to one. The third probability must not occupy the last column of a record.

The table below gives the ranges for the keywords when giving cracking and roughness specifications.

Keyword	Cracking 1	Cracking 2 and 3	Roughness
ACTN	1	1	1, 3, 4, 5, ..., 17
LIFE	1, 2, 3, 4, 5	1, 2, 3, 4, 5	0, 1
CRK	1, 2, 3	1, 2, 3	—
RUF	—	—	1, 2, 3
CP	1, 2	1, 2, 3	0

The 88 specifications can be in any order and the keywords can be in any order within a specification.

Description of Output File SYSPRINT

The identification key and heading are printed as a heading on the first page. The data input directives are printed next. A blank field for design life means that design life information is to be read from file TPROBIN. Otherwise it is read from file LIFE. A blank field for a region means that no data is read for that region.

The output directives are printed next. Given proper input, Program TPROB will generate a transition probability file for each non-blank entry. The road categories are row-indexed by traffic and column-indexed by region.

A table displaying the design life information is printed next. The first two columns contain the traffic and region levels. These two indices identify the road category. The remaining 16 columns correspond to Actions 2 to 17 for this road category. Any out-of-range values are flagged by "LOW" and "HIGH" on their right hand side. Output files cannot be generated for these road categories. Refer to the section that describes the file LIFE for help in giving valid specification. Should there be multiple specifications for a road category, then the first is retained and the rest are marked "DUP" and ignored. If no design life information was provided by the user, then only the column headings are printed and no output files are generated.

Program TPROB skips to the next page at this time to check whether the user indicated that cracking and roughness level transition probabilities were to be read for Region 1. If so, they are printed here. Any out of range values are noted by "LOW" and "HIGH" and "??". It is important to recall that if CP = 0, then it is a roughness specification. Otherwise, it is a cracking specification. This determines whether the currently active value of CRK or RUF is used in the "CRK/ RUF" column. All the indices are initialized to -99 before the data is read. Duplicate specifications are noted by "DUP." An out-of-range sum for the three probabilities is noted by "LOW" or "HIGH" six columns to the right of the third probability. Any error invalidates the input and prevents output files from being generated for the three road categories in this region. The program now skips to the next page.

If the user requested transition probability files for any level of traffic of Region 1, the message "ACTION MATRICES FOR REGION LEVEL 1" is printed. If an input error in file REG1 was found, or no data was provided for this region, an error message is printed to inform the user that no output files can be generated for this region. Otherwise, the program checks if the user provided design life information for the indicated traffic levels. If any are in error or missing, the user is informed that an output file cannot be generated for that traffic level in this region. If the design life information was correctly specified for any user requested output file in this region, the program proceeds to print the action matrices.

The action matrices are the unique portions of the transition probability matrix for each action. They are indexed by region level, action, and design life level. All five levels of design life are printed for Action 1. The action matrix for Design Life Level 1 represents the probability of going from state i to state j for i = 1 to 24 and j = 1 to 24. The other four action matrices that correspond to Design Life Levels 2 to 5 represent the transition probability of going from one state in that design life to another state in that design life. For convenience, they are printed ranging from 1 to 24 but actually range from 25 to 48, 49 to 72, 73 to 96, and 97 to 120 for Design Lives 2 to 5, respectively.

For Actions 2 to 17, only the first design life action matrix need be illustrated since it is repeated for Design Life Levels 2 to 5, forming a "vertical column" one design life (24 states) wide by five design lives (120 states) high. This vertical column can be in one of five positions in the transition probability matrix which correspond to the five design life levels. The position is determined by the design life level for this action and road category (see file LIFE). Therefore, add (life - 1) x 24 to the column index to determine to which states they correspond.

The program repeats the steps described for Region 1, and for Regions 2 and 3. Finally, the "END OF PROGRAM" message is printed and execution is terminated.

Description of Output Files TR11, TR12, ..., TR33

The first 80 columns of these output files contain the eight column identification key plus a 72 column heading. The next record has the traffic and region levels in Columns 10 and 20, respectively.

Each remaining record has three indices followed by a floating point value in E-format. The first index identifies the action. The second identifies the row or state a road is presently in. The third identifies the column or state the road moves to in one year. The value is the probability of going from state i to state j for this action. Therefore, this is the element in the i^{th} row and j^{th} column of the transition probability matrix pertaining to this action. Only the non-zero elements of each matrix are placed in the file. All 17 transition probability matrices (pertaining to the 17 actions) are in the file with Action 1 first, followed by Action 2 and so on until Action 17. Within an action, the non-zero elements of the first row are followed by the non-zero elements of the second row and so forth up to the non-zero elements of the 120^{th} row. The non-zero elements of a row are placed in the file so that the column index is increasing. There can be anywhere from 1 to 120 non-zero elements in a row.

The last record in the file has an action index of -1, row and column indices of 0, and a value of zero. Program ADOT recognizes this as an end of information mark.

This file must have a logical record length of no less than 28.

PROGRAM TPROBSP

Program TPROBSP generates transition probability files for use by Program ADOT. The files are in the 24-state format. The user is referred to the description of Program TPROB because the two programs are very similar in their operation. What follows is a file-by-file description of the differences between the two programs.

Input File TPROBIN

There are no differences. The user is urged to use a different identification key when running TPROBSP.

Input File LIFE

No differences.

Input Files REG1, REG2, REG3

All 32 specifications pertaining to Design Life Levels 2 to 5 are removed, leaving 56 specifications. References to design life should be removed from the remaining records. There are now 11 specifications for Action 1. CP must still be set to 0 for roughness specifications.

Output File SYSPRINT

The action matrix is now the entire transition probability matrix for that particular action. The action matrices are indexed by action number, region level, and traffic level. These are all printed because they are all different, with the exception of Action 1. Only one traffic level is printed for Action 1 because it is duplicated for the other two traffic levels. Of course, only the requested road categories are computed and printed.

Output Files TR11, TR12,..., TR33

These are identical except that each transition probability matrix has 24 rows and 24 columns.

PROGRAM ADOT

Program ADOT is the matrix generator for the NOS. The user has the flexibility to define the problem in terms of number of states, number of actions, length of horizon, infeasible actions for particular states, and quality standards. These are specified in the control file SXSIN. The transition probabilities are read from the file TRMX. The current conditions are read from file CURNT. And, finally, the cost matrix is specified in the file COSTF. To help the user avoid the inadvertent use of the wrong version of TRMX, CURNT, or COSTF, an identification key must be given for each of these files in file SXSIN. This key is compared to the key in the file and if any of the three keys do not match, an error message is printed and the run is terminated. A further check involves the comparison of the road category specification in the files SXSIN, TRMX, and CURNT. If either TRMX or CURNT do not match SXSIN in this respect, then an error message is printed and the run is terminated. Certain properties of these files, such as whether certain values sum to 1.0, are not checked by the program and therefore are the user's responsibility. These are mentioned in the descriptions of the files themselves.

The generated matrix is written to the file MATRIX. This matrix is in a form suitable for solving by the IBM product, MPSX.

Information pertinent to run specifications and status messages are printed in the file SYSPRINT. Any error messages are also printed in this file.

Input File SXSIN

SXSIN is the primary input file for Program ADOT in which the problem characteristics are defined. Nine sections of information exist, each of which is preceded by a header.

Column

1

Section 1 TITLE

[any 80 characters]

Section 2 ROAD INFORMATION

TRAFFIC = [1, 2, or 3] REGION = [1, 2, or 3];

Section 3 CONTROL INFORMATION

PNAME = '< up to 8 charcter problem name >'

CNAME = '< 8 character identification key on file COSTF >'

TNAME = '< 8 character identification key on file TRMX >'

CURNAME = '< 8 character identification key on file CURNT >'

HORIZON = [integer: length of planning period]

STORAGE = [integer: number of elements of transition probability matrix given in file TRMX (default of 6000)]

OBJECTIVE = 1 for steady state run, i.e., HORIZON = 1
3 for multi-period run, i.e., HORIZON > 1

NUSTAT = [number of states]

NUACT = [number of actions]

OBJVAL = [value of objective from steady state run]

PROPT = 0: no carriage control (default)
1: with carriage control in Column 1 (for output to line printer)

DISCOUNT = [effective discount rate (default = 0.0)];

(mandatory semicolon ends the specification)

Section 4 INFEASIBLE ACTIONS [number of specificaitons - Column 25 or later]

[number of states] [list of states] [number of actions] [list of actions]

.

.

.

Section 5 DESIRABLE STATES [number of specifications - Column 25 or later]

[number of states summed over] [list of states] [level]

.
.
.

Section 6 UNDESIRABLE STATES [number of specifications - Column 25 or later]

[number of states summed over] [list of states] [level]

.
.
.

Section 7 STEADY STATES [number of specifications - Column 25 or later]

[number of state-value pairs] [state] [value]
[state] [value]
.
.
.
[state] [value] [interval size]

[number of state-value pairs] [state] [value]
.
.
.
[state] [value] [interval size]

.
.
.

Section 8 PERCENTAGES [number of specifications - Column 25 or later]

[period] [multiplier for desirable specs] [multiplier for undesirable specs]

.

.

.

Section 9 ENDATA

Notes on Input

1. Only the first four characters of each header are required. Therefore, "DESI" and "DESIRABLE STATES" are equivalent.

2. Headers must begin in Column 1.

3. Headers for Sections 4 through 8 must be 19 characters or less in length. The number of specifications parameter must not precede Column 25 of this record and it must not occupy the last column of a record.

4. Each specification in every section must begin on a new record and must not occupy the last column of a record.

5. A specification may occupy as many records as suits the user. The headers for Sections 1, 2, and 3 are excepted along with the title specification for Section 1.

6. The sequence of the keywords in the ROAD INFORMATION and CONTROL INFORMATION sections is at the user's discretion. Right hand side blanks within the PNAME, CNAME, TNAME, and CURNAME data items may be omitted but the quotes are required. If a default is not mentioned, none is assumed.

7. When HORIZON is set to 1, OBJECTIVE must also be set to 1. If HORIZON > 1, then OBJECTIVE must be set to 3 and OBJVAL must be set to a value slightly greater than the steady state solution.

8. Up to 24 desirable and undesirable state constraints can be specified. Level must be between zero and one, inclusive.

9. The maximum number of states per specification in the INFEASIBLE ACTIONS, DESIRABLE STATES, and UNDESIRABLE STATES section is 75. Up to 75 actions can be specified per specification for INFEASIBLE ACTIONS. Every action is infeasible for each state.

10. STEADY STATES specifications are only required for multiperiod runs. The numbers of STEADY STATE specifications should be set to zero for a steady state run. Also note that the minimum and maximum values of the proportion of roads in each steady state are printed as a part of the program output, but are not required as inputs.

11. The maximum number of state-value pairs per specification in the STEADY STATES section is the number of states in the problem, NUSTAT. The steady state values are obtained from the steady state solution by summing the proportions assigned to each state for various actions. The absolute value of the interval size must be one or less. If it is positive then the interval for that state is a proportion of the given value for that state. If it is negative then the interval for that state is the absolute value of that interval size. If the interval size is zero then there is an equality constraint for that state. A specification is defined as the number of statevalue pairs, the pairs themselves, and the interval size.

12. The period identifier in each specification in the PERCENTAGES section must be in the range of 2 to HORIZON-1, up to a maximum of 20. There must be zero number of specifications when HORIZON = 1.

13. The user is urged to check the information in this file very carefully because only minimal error checking is done by the

program. The only possible negative entry is for interval size in STEADY STATES. The program only checks errors pertaining to notes 1, 2, and 11. The program will indicate the successful generation of the matrix even in the presence of serious errors in this file.

14. Examine the output file, SXSOUT, to see that everything is correctly specified.

Input File COSTF

The first eight columns in this file must match the left-justified CNAME keyword in file SXSIN. Otherwise an error message is printed and execution is terminated.

The cost matrix read from the file COSTF is NUSTAT by NUACT in size. Beginning on the second record of the file, the NUACT costs for state 1 are read free format. These must be in order from 1 to NUACT and the last entry must not occupy the last column of a record. The NUACT costs for each remaining state from 2 to NUSTAT are read beginning on a new record for each state.

It is the user's responsibility to ensure that NUACT costs are provided for each of the NUSTAT states. The user must also ensure that they are in the required form and are all non-negative.

Input File CURNT

The current condition of the roads in the given road category are defined in this file. The first eight columns in this file must match the left-justified CURNAME keyword in file SXSIN. Otherwise, an error message is printed and execution is terminated. The road category identification is read beginning on the next record. The first number is the traffic level and the next number is the region level which must not occupy the last column of a record. If these do not match the traffic and region levels given in the file SXSIN, then an error message is printed and execution is terminated.

The first four columns of the next record must contain the four letters "CURR". A maximum of 19 characters is allowed for this header. The number of current condition specifications must be given in Column 25 or later. If this number is the last entry of a record then it must not occupy the last column of that record.

Each specification consists of a state identification number followed by its proportion of the road category. Each specification must begin on a new record and the proportion must not occupy the last column of a record.

It is the user's responsibility to ensure that each proportion is in the range of zero to one and that the sum of all the given proportions is exactly one. The program will indicate a successful generation of the matrix even if these conditions are violated.

<u>Input File TRMX</u>

The transition probability matrix for each action is specified in file TRMX. The row index in a transition probability matrix represents the state you are in and the entries in that row are probabilities you will be in one of the NUSTAT states after undergoing the action. The sum of every row in each transition probability matrix must be one. Therefore, a minimum of one entry is required for each row. Program ADOT checks to see that there is at least one entry for every row but it is the user's responsibility to ensure that the sum of the entries is one.

The first eight columns of file TRMX must match the left-justified TNAME keyword in file SXSIN. Otherwise, an error message is printed and execution is terminated. The next 72 columns are skipped because they are heading information.

The road category identification is read beginning with the next record. The first number is the traffic level and the next number is the region level which must not occupy the last column of a record. These must match the traffic and region levels given in file SXSIN. If they do not, an error message is printed and execution is terminated.

The transition probability matrices must be entered in sequence beginning with Action 1 and ending with the last action, number NUACT. Each transition probability matrix is entered with each element beginning on a new record. Each non-zero element of the first row is entered, followed by each non-zero element of the second row and so on until the last row, number NUSTAT, is entered.

Each specification consists of three indices followed by a value in the range of zero to one. The first index is the action number. The second is the row number and the third is the column number.

After the last row of the last action has been entered, the following specification must have the three indices -1, 0, and 0 and a value of 0.0. Program ADOT recognizes this as an end of information mark for this file.

<u>Output File SXSOUT</u>

The information read from the files SXSIN and CURNT is displayed here.

1. Title -- heading used to denote a class of problems.

2. Road Information -- the indices of traffic level and traffic and regional factor identifying the road category.

3. Control Information.

   PROBLEM NAME -- name identifying this run.

   CURRENT COND. NAME -- ID key for file CURNT.

   TRANSITION PROB. NAME -- ID key for file TRMX.

   COST NAME -- ID key for file COSTF.

   PLANNING PERIOD -- length of planning horizon.

   ESTIMATED STORAGE -- total number of transition probability matrix elements in file TRMX.

   OBJECTIVE -- must be 1 if planning horizon = 1 and 3 otherwise.

   PRINT OPTION -- if 0, then generated matrix will not have carriage control in Column 1 which is default. If 1, then Column 1 will have carriage control making it unsuitable for use with MPSX.

   NUMBER OF STATES -- must be positive integer.

   NUMBER OF ACTIONS -- must be positive integer.

   DISCOUNT FACTOR -- effective discount rate. Default = 0.0.

   SS CONSTRAINT -- cost from steady state run. Identified as OBJVAL on file SXSIN. Only used if planning period > 1.

4. INFEASIBLE ACTIONS -- the rehabilitation actions which are infeasible for certain condition states are identified here. Each specification is separated by a blank line. Every action within a specification is infeasible for each condition state in that specification.

5. CURRENT CONDITION -- the current proportion of roads in this road category among the various condition states are printed. The user should check to see that their sum is one.

6. DESIRABLE STATES -- the minimum proportion of roads required to be in different sets of desirable states are printed. The proportion for a particular set is printed on the last line of that set.

7. UNDESIRABLE STATES -- the maximum proportion of roads required to be in different sets of undesirable states are printed. The proportion for a particular set is printed on the last line of that set.

8. STEADY STATES -- the states which must be within their specified limits are printed here. The proportion column represents the middle of the acceptable range or interval for the states. The sum of this column should not exceed one. The values in the interval size column represent the width of the interval expressed as a percentage of the proportion for that state or as an absolute amount. The lower and upper bounds of the interval, adjusted to be within the zero to one range if necessary, are printed under the minimum and maximum headings. The proportion of roads in these states must satisfy these constraints in the final time period.

9. PERCENTAGES -- the multipliers for the proportion specified in the DESIRABLE and UNDESIRABLE STATES specifications are printed here.

10. STATUS MESSAGES.

    DATA SUCCESSFULLY READ IN -- indicates that the files SXSIN and CURNT have been successfully read in.

    COSTS SUCCESSFULLY READ IN -- indicates that the file COSTF has been successfully read in.

TRANSITION PROBABILITIES READ IN -- indicates file TRMX has been successfully read in and therefore completes the input requirements of Program ADOT.

ROWS SECTION SUCCESSFULLY GENERATED -- indicates that the rows section of the matrix has been generated.

COLUMNS SECTION SUCCESSFULLY GENERATED -- indicates that the columns section of the matrix has been generated.

RHS GENERATION COMPLETE -- indicates that the RHS section of the matrix has been generated and thereby completes generation of the matrix.

11. ERROR MESSAGES -- the user should refer to the appropriate file description for the explanation to an error message.

Output File MATRIX

The first record of the generated matrix has the problem name. The remainder of the file is divided into three major sections: ROWS, COLUMNS, and RHS. The last record has the word ENDATA.

The rows of the matrix are named in the ROWS section. The row is identified as being a "less than" (L), "greater than" (G), equality (E), or unconstrained (N) constraint. The current conditions are specified with the name TOTAL followed by a three digit code identifying the state. These are equalities. The balance rows for period one come next and they are also equalities. Their name is BAL followed by a two digit period number and a three digit state number. For a single period run, the ROWS section is completed with the desirable (DS) and undesirable (US) state specifications and the cost specification. All DS and US specifications are followed by a two digit period number and a two digit sequence number. The DS are a "greater than" constraint and the US are a "less than" constraint. The cost is unconstrained.

Otherwise, if this is a multi-period run, the balance, desirable, and undesirable rows are given for each period except the last. They are named with the same numbering scheme as those for period one. The last period does not have balance rows but does have desirable, undesirable and steady state minimum and maximum rows. The desirable and undesirable are specified as before. The steady state minimum rows are identified by SSMIN followed by a three digit code identifying the state. They are "greater than" constraints. The steady state maximum are identified by SSMAX followed by a three digit code identifying the state. They are "less than" constraints. The steady state cost row is named SSCOST and is a "less than" constraint. Finally, the cost for all the periods except the last is named TRCOST and is unconstrained.

The column section comes next. Every non-zero element of the LP matrix is here along with some zero elements. Each element is specified by a column name, row name, and value. The column name consists of the letter W followed by a two digit period number, a two digit action number, and a three digit state number. The row names were discribed earlier. The entries are ordered first by period, then by action, and finally by state.

The right hand side (RHS) section comes next. Each record in this section has the name RHS followed by a row name and a value. This value represents an upper or lower bound or an equality constraint depending on how the row was defined in the ROWS section. A row which is not specified in the RHS section has the default RHS value of zero. The "TOTAL" row for each state has its RHS specified first. The user will recognize these values as the current condition values from the file CURNT if this is a multi-period run. The next group of rows is the desirable/undesirable rows. The RHS's for these rows are the values provided by the user in the DESIRABLE/UNDESIRABLE sections multiplied by the multipliers in the PERCENTAGES section for that period as specified in file SXSIN.

The SSMIN and SSMAX rows are assigned their RHS's next. These values match the minimum and maximum columns in the STEADY STATES section of the file SXSOUT.

If this is a multi-period run, the SSCOST row is now assigned its RHS. This value matches OBJVAL in file SXSIN and SS CONSTRAINT in the file SXSOUT.

The user may create a new version of this file via the editor rather than rerunning Program ADOT. The only section which can be edited is the RHS section. Therefore, the structure of the problem will remain unchanged with respect to number of states, number of actions, length of planning period, objective, costs, transition probabilities and infeasible actions. The upper and lower bounds which apply to the "DS", "US", "SSMIN", and "SSMAX" rows can be altered. For multi-period runs, the current conditions may be altered by editing the "TOTAL" rows and the steady state cost may be altered by editing the "SSCOST" row. The user is cautioned to check the editing very carefully before submiting matrix to MPSX.

USING MPSX

The Mathematical Programming System Extended (MPSX) software package solves the linear program (LP) matrix generated by Program ADOT.

MPSX has a control language that allows the user to set up the problem, establish acceptable tolerances, determine feasibility, find optimal solution, and print the solution. These statements must be specified within Columns 10 to 71 of the record. Figure A-2 shows a typical runstream for solving a steady state LP. The MPSX control language statements are located in lines 130 to 250.

```
//RU057    JOB (1000,0584,39,1),'DP500000I 133A NOS',NOTIFY=RU057,
//             MSGCLASS=Q
/*AFTER  RU057A
//JOBLIB    DD DSN=GP551.MPS.SYSTM360,DISP=SHR
//MPSCOMP   EXEC PGM=DJLCOMP,REGION=86K
//SCRATCH1  DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH2 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH3 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH4 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SYSMLCP  DD  UNIT=3350,SPACE=(TRK,(2,2)),DISP=(NEW,PASS)
//SYSPRINT DD  SYSOUT=Q
//SYSABEND DD  DUMMY
//SYSIN    DD  *
           PROGRAM('PM')
           INITIALZ
           MOVE(XDATA,'REAL')
           MOVE(XPBNAME,'PBFILE')
           MOVE(XOBJ,'COST')
           MOVE(XRHS,'RHS')
           CONVERT('SUMMARY')
           SETUP
           TITLE('STEADY STATE RUN ')
           XTOLV= 0.000001
           XTOLDJ=0.00001
           WRITE('XTOLV=',XTOLV,'XTOLDJ=',XTOLDJ,'STEADY STATE RUN')
           OPTIMIZE
           SOLUTION('BASIS')
           EXIT
           PEND
/*
//MPSEXEC  EXEC PGM=DJLEXEC,COND=(0,NE,MPSCOMP),PARM=TASK,REGION=86K
//SCRATCH1 DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//SCRATCH2 DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//PROBFILE DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//MATRIX1  DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//ETA1     DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//SYSMLCP  DD  DSNAME=*.MPSCOMP.SYSMLCP,DISP=(OLD,DELETE)
//SYSPRINT DD  DSN=RU057.S23.DATA,UNIT=3350,VOL=SER=DOT432,
//             DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3591),
//             SPACE=(TRK,(50,25),RLSE),DISP=(NEW,CATLG)
//SYSABEND DD  DUMMY
//SYSPUNCH DD  SYSOUT=B
//SYSIN    DD  DSN=RU057.MATRIX.DATA(S23),DISP=SHR
/*
```

Figure A-2. TYPICAL MPSX INPUT FOR STEADY STATE RUN

Experience has shown that this runstream usually finds an optimal solution. The user need be concerned with only a few statements from one run to another. Line 150 must have the same problem name as was given to the keyword PNAME in file SXSIN of Program ADOT. This is also present on the first record in file MATRIX of Program ADOT. Line 170 must be the name COST for a steady state run and the name TRCOST for a multi-period run. The user may wish to change the title given in line 201. The quotes are mandatory on these lines. Any errors found by MPSX are directed by line 100.

The MPSX control language statements send their output to the file SYSPRINT whose disposition is specified on lines 340 to 342. The optimal solution is located towards the end of the file. The LP matrix is read from file SYSIN as specified on line 370. This is a file generated by Program ADOT.

Figure A-3 shows a typical runstream for a multi-period run.

Tolerances

The tolerances given on lines 210 and 220 for XTOLV and XTOLDJ, respectively, are the MPSX defaults. They should accommodate practically all of the multi-period runs and most of the steady state runs.

MPSX will occasionally run into computational difficulties and fail to find an optimal solution. There are two error messages which indicate computational difficulty:

1. BTRAN/FTRAN DJ CHECK FAILS
2. NON-ZERO BASIS DJ AFTER PRICE.

A different set of tolerances will clear up the problem. Some alternative tolerance settings are:

```
//RU057     JOB (1000,0584,599,1),'DP500000I 133A NOS',NOTIFY=RU057,
//              MSGCLASS=Q
/*AFTER  RU057A
//JOBLIB    DD DSN=GP551.MPS.SYSTM360,DISP=SHR
//MPSCOMP   EXEC PGM=DJLCOMP,REGION=86K
//SCRATCH1   DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH2 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH3 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH4 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SYSMLCP  DD  UNIT=3350,SPACE=(TRK,(2,2)),DISP=(NEW,PASS)
//SYSPRINT DD  SYSOUT=Q
//SYSABEND DD  DUMMY
//SYSIN    DD  *
           PROGRAM('PM')
           INITIALZ
           MOVE(XDATA,'REAL')
           MOVE(XPBNAME,'PBFILE')
           MOVE(XOBJ,'TRCOST')
           MOVE(XRHS,'RHS')
           CONVERT('SUMMARY')
           SETUP
           TITLE('MULTI-PERIOD RUN')
           XTOLV= 0.000001
           XTOLDJ=0.00001
           WRITE('XTOLV=',XTOLV,'XTOLDJ=',XTOLDJ,'MULTI-PERIOD RUN')
           OPTIMIZE
           SOLUTION('BASIS')
           EXIT
           PEND
/*
//MPSEXEC  EXEC PGM=DJLEXEC,COND=(0,NE,MPSCOMP),PARM=TASK,REGION=86K
//SCRATCH1 DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//SCRATCH2 DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//PROBFILE DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//MATRIX1  DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//ETA1     DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//SYSMLCP  DD  DSNAME=*.MPSCOMP.SYSMLCP,DISP=(OLD,DELETE)
//SYSPRINT DD  DSN=RU057.H31A01.DATA,UNIT=3350,VOL=SER=DOT432,
//             DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3591),
//             SPACE=(TRK,(50,25),RLSE),DISP=(NEW,CATLG)
//SYSABEND DD  DUMMY
//SYSPUNCH DD  SYSOUT=B
//SYSIN    DD  DSN=RU057.X31A1.DATA,DISP=SHR
/*
```

Figure A-3. TYPICAL MPSX INPUT FOR MULTI-PERIOD RUN

XTOLV	XTOLDJ
1E-6	1E-5
1E-5	1E-4
1E-7	1E-6
1E-6	1E-4
1E-7	1E-5
1E-7	1E-4
1E-4	1E-3

Infeasible Solution

If the LP is infeasible, MPSX prints the message "INFEASIBLE SOLUTION" and prints the status of the problem. MPSX sometimes runs into computational difficulty when in actuality the problem is infeasible. This generally happens when the tolerances are too large. Try reducing the tolerances to 10^{-7} for XTOLV and 10^{-6} for XTOLDJ.

When an infeasible solution is indicated by MPSX, the user should check the user input to Program ADOT. Are there any contradictory requirements given for any state in the desirable, undesirable, and steady state sections? Was the right objective chosen? Are the infeasible actions correctly specified? Are the multipliers in the percentages section reasonable? Specifying no multipliers means that the desirable and undesirable constraints have to be met from the second period on. Are the HORIZON and OBJVAL reasonable? Altering one or more of these problem specifications should produce an optimal solution.

Output of the MPSX Program

A typical MPSX output is shown in Figure A-4. The parts of the output which are useful in determining the optimum rehabilitation policies are discussed below.

XTOLV= .99999943E-06 XTOLDJ= .99999997E-05 MULTI-PERIOD RUN

SOLUTION (OPTIMAL)
TIME = 5.36 MINS. ITERATION NUMBER = 3090
BASIS

...NAME...	...ACTIVITY...	DEFINED AS
FUNCTIONAL	1.00387	TRCOST
RESTRAINTS		RHS

.MPSX-PTF18. FIVE PERIOD RUN
SECTION 1 - ROWS

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
361	DS0201	BS	.59343	.29343-	.30000	NONE	.
362	US0201	BS	.00313	.19687	NONE	.20000	.
484	US0301	BS	.00150	.15850	NONE	.16000	.
605	DS0401	BS	.81220	.21220-	.60000	NONE	.
606	US0401	BS	.	.13000	NONE	.13000	.
608	US0501	BS	.	.10000	NONE	.10000	.
610	SSMAX025	BS	.74625	.00750	NONE	.75375	.
612	SSMAX028	BS	.07306	.00073	NONE	.07380	.
613	SSMIN033	BS	.15692	.00156-	.15536	NONE	.
616	SSMAX036	BS	.02033	.00020	NONE	.02053	.
617	SSCOST	BS	.20467	.04094	NONE	.24561	.
618	TRCOST	BS	1.00387	1.00387-	NONE	NONE	1.00000

.MPSX-PTF18. FIVE PERIOD RUN
SECTION 2 - COLUMNS

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
619	W0101001	BS	.92451	.06600	.	NONE	.
627	W0101009	BS	.03968	.08700	.	NONE	.
637	W0101019	BS	.03582	.19300	.	NONE	.
2479	W0201001	BS	.59343	.06600	.	NONE	.
2482	W0201004	BS	.12988	.15800	.	NONE	.
2487	W0201009	BS	.18927	.08700	.	NONE	.
2495	W0201017	BS	.00836	.10200	.	NONE	.
2562	W0201093	BS	.00150	.19300	.	NONE	.
2698	W0203012	BS	.04142	.78600	.	NONE	.
2705	W0203019	BS	.03269	.78600	.	NONE	.
2706	W0203020	BS	.00183	.78600	.	NONE	.
2709	W0203023	BS	.00162	.78600	.	NONE	.
2819	W0204023	BS	.00150	2.08600	.	NONE	.
4339	W0301001	BS	.10283	.06600	.	NONE	.
4347	W0301009	BS	.01465	.08700	.	NONE	.
4353	W0301015	BS	.01270	.33200	.	NONE	.
4360	W0301025	BS	.06908	.06600	.	NONE	.
4444	W0302001	BS	.27809	.58600	.	NONE	.
4446	W0302003	BS	.05597	.58600	.	NONE	.
4447	W0302004	BS	.08337	.58600	.	NONE	.
4450	W0302007	BS	.04565	.58600	.	NONE	.
4555	W0303009	BS	.20672	.78600	.	NONE	.
4557	W0303011	BS	.01557	.78600	.	NONE	.
4558	W0303012	BS	.04845	.78600	.	NONE	.
4562	W0303016	BS	.01270	.78600	.	NONE	.
4563	W0303017	BS	.04671	.78600	.	NONE	.
4564	W0303018	BS	.00072	.78600	.	NONE	.
4566	W0303020	BS	.01172	.78600	.	NONE	.
4577	W0303033	BS	.00707	.78600	.	NONE	.
4585	W0303041	BS	.00142	.78600	.	NONE	.
4631	W0303091	BS	.00000	.78600	.	NONE	.
4745	W0304095	BS	.00150	2.08600	.	NONE	.
6199	W0401001	BS	.00584	.06600	.	NONE	.
6220	W0401025	BS	.74619	.06600	.	NONE	.
6229	W0401034	BS	.00001	.08700	.	NONE	.
6304	W0402001	BS	.06016	.58600	.	NONE	.
6410	W0403004	BS	.01445	.78600	.	NONE	.
6415	W0403009	BS	.02729	.78600	.	NONE	.
6418	W0403012	BS	.00597	.78600	.	NONE	.
6423	W0403017	BS	.00304	.78600	.	NONE	.
6432	W0403028	BS	.00676	.78600	.	NONE	.
6437	W0403033	BS	.12603	.78600	.	NONE	.
6440	W0403036	BS	.00188	.78600	.	NONE	.
6445	W0403041	BS	.00237	.78600	.	NONE	.
6468	W0403066	BS	.00272	.78600	.	NONE	.
8059	W0501001	BS	.00375	.	.	NONE	.
8062	W0501004	BS	.00082	.	.	NONE	.
8067	W0501009	BS	.00104	.	.	NONE	.
8080	W0501025	BS	.74625	.	.	NONE	.
8083	W0501028	BS	.07306	.	.	NONE	.
8088	W0501033	BS	.15692	.	.	NONE	.
8096	W0501041	BS	.00032	.	.	NONE	.
9818	W0517012	BS	.00023	.	.	NONE	.
9840	W0517036	BS	.02033	.	.	NONE	.

Figure A-4. TYPICAL MPSX OUTPUT FOR 5-PERIOD RUN

1. Functional Value -- the value of the objective function for the optimum solution is printed. For the steady state solution (i.e., for T = 1), this is the minimum unit cost of of steady state rehabilitation policy. For the multi-period runs (T > 1), the functional value is the minimum sum of the discounted unit costs during the first (T - 1) time periods.

2. Section 1--Rows -- the values of the variables for which constraints were placed are printed. Also, the lower and upper limits specified for these variables are printed.

3. Section 2--Columns -- the values of optimum w_{ik}^{ℓ} and the minimum costs c(i,k) are printed for different i, k, and ℓ. The notation used for w_{ik}^{ℓ} is as follows. The first two digits after "W" indicate the time period (ℓ), the next two digits indicate the rehabilitation action (k), and the last three digits indicate the condition state (i). For programming convenience, the order of i and k was switched. Thus, for example, "W0205007" indicates the proportion of roads in the 7th condition state for which the 5th rehabilitation action is applied at the beginning of the 2nd time period.

AN ILLUSTRATIVE EXAMPLE

The various steps to be followed in using the computer programs are illustrated in this section for one problem.

Problem Statement

Let us assume that we want to find the optimum rehabilitation policy for roads with Traffic Index 3 (i.e., ADT > 10,000) and Region Index 3 (i.e., Regional factor of 3.2 ($\pm$0.5). We want to consider the full size of condition states (i.e., number of states = 120).

For roads with low roughness (120±45) and low percent of cracking (5±5), we do not want the program to select any rehabilitation actions other than routine maintenance and seal coat. On the other hand, for roads with high roughness (300±45) and high percent of cracking (45±15), we do not want the program to select either routine maintenance or seal coat.

The following performance standards should be satisfied by the optiimum rehabilitation policy at steady state.

Pavement Condition	Required Proportion
Roughness = 120±45 and cracking = 5±5 percent	≥ 0.75
Roughness = 300±45 and cracking = 45±15 percent	≥ 0.10

We would like the system to reach steady state at the beginning of the 5th year. For the first 4 years, we are willing to accept relaxed performance standards as indicated by the multipliers $p_1(\ell)$ and $p_2(\ell)$ below.

Time Period	Multiplier $p_2(\ell)$ for Proportions in Desirable States	Multiplier $p_1(\ell)$ for Proportions in Undesirable States
1	Accept current condition	Accept current condition
2	0.4	2.0
3	0.6	1.6
4	0.8	1.3

Considering the net effect of interest rate and inflation, we plan to use an effective interest rate of zero.

Running Programs COST, CCTRANS, and TPROB

The user must first run Programs COST, CCTRANS and TPROB in order to generate three of the four input files required by the matrix generator.

Figure A-5 shows the JCL, input file COSTIN, output file SYSPRINT, and the output file COSTF. COSTF is the input file, COSTF, for the matrix generator. The cost matrix is now ready.

Figure A-6 shows the JCL, input files CTRL and CCIN, and the output files SYSPRINT and CC33 for Program CCTRANS. File CC33 contains the current conditions in proportional form for Traffic Level 3 and Region Factor 3. It becomes input file CURNT to Program ADOT.

Figure A-7 shows the JCL, input files TPROBIN, LIFE, and REG3, and the output files SYSPRINT and TR33 for Program TPROB. The input file TPROBIN actually requests output for three road categories. Only the output pertinent to Traffic Level 3 and Region Factor 3 is shown. For informational proposes only, the same information for doing a similar run with Program TPROBSP (24-state) is shown in Figure A-8. File TR33 becomes input file TRMX to the matrix generator, Program ADOT.

All three input files have been given the identification key, "120STATE". The matrix generator can only access these files if the keywords TNAME, CURNAME, and CNAME are set equal to "120STATE" in the file SXSIN.

Problem Solution

The problem solution is completed in two stages. In the first stage, the steady state solution is obtained. In the second stage, the system is required to reach the steady state solution at the beginning of the 5^{th} year using minimum cost policies for the first 4 years.

```
//RU057    JOB (1000,0584,10,1),'DP500   I 133A NOS',NOTIFY=RU057,
//            MSGCLASS=Q
//CG         EXEC PLIXCLG,LIB=OASORS,PRG=COST,AQ=Q,
//           PARM.PLI='NAG,A(S),NX,SMSG,NOF,GN,NC(E),NONEST'
//PLI.SYSIN DD *
++WRITE WORK,COST
/*
//GO.SYSPRINT DD DSN=RU057.COST120.DATA,UNIT=3350,VOL=SER=DOT432,
//            DCB=(LRECL=133,BLKSIZE=3591,RECFM=FBA),
//            SPACE=(TRK,(5,3),RLSE),DISP=(NEW,CATLG)
//GO.COSTIN DD DSN=RU057.TEMPDATA.DATA(COSTIN),DISP=SHR
//GO.COSTF  DD DSN=RU057.TEMPDATA.DATA(COSTF120),DISP=SHR
//
```

(a)

```
120STATE COST INPUT DATA FOR COST MATRIX GENERATOR
0.066     0.158     0.310
0.087     0.179     0.332
0.102     0.193     0.346
0.036     0.057     0.071
0.036
0
0.55
0.75
2.05
1.75
1.575
2.875
2.575
2.625
3.925
3.625
3.675
4.975
4.675
4.725
5.775
6.30
```

(b)

Figure A-5. PROGRAM COST--(a) JCL; (b) INPUT FILE COSTIN

120STATE COST INPUT DATA FOR COST MATRIX GENERATOR

ROUTINE MAINTENANCE COST INPUT

ACTION 1

ROUGHNESS	CRACKING 1	2	3
1	0.066	0.158	0.310
2	0.087	0.179	0.332
3	0.102	0.193	0.346

ACTION 2

ROUGHNESS	COST
1	0.036
2	0.057
3	0.071

ACTIONS 3 THROUGH 17

COST
0.036

REHABILITATION COST INPUT

ACTION	COST
1	0.000
2	0.550
3	0.750
4	2.050
5	1.750
6	1.575
7	2.875
8	2.575
9	2.625
10	3.925
11	3.625
12	3.675
13	4.975
14	4.675
15	4.725
16	5.775
17	6.300

Figure A-5(c). PROGRAM COST OUTPUT FILE, SYSPRINT. Part 1.

COST MATRIX

STATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
2	0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
3	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
4	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
5	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
6	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
7	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
8	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
9	0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
10	0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
11	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
12	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
13	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
14	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
15	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
16	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
17	0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
18	0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
19	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
20	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
21	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
22	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
23	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
24	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
25	0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
26	0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
27	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
28	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
29	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
30	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
31	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
32	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
33	0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
34	0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
35	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
36	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
37	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
38	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
39	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
40	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
41	0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
42	0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
43	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
44	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
45	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
46	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
47	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
48	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
49	0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
50	0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
51	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
52	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
53	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
54	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
55	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
56	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
57	0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
58	0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
59	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
60	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
61	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
62	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
63	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
64	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
65	0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
66	0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
67	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
68	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
69	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
70	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
71	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
72	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
73	0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
74	0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
75	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
76	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
77	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
78	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
79	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
80	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
81	0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
82	0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
83	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
84	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
85	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
86	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
87	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
88	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
89	0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
90	0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
91	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
92	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
93	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
94	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
95	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
96	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
97	0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
98	0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
99	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
100	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
101	0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
102	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
103	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
104	0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
105	0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
106	0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
107	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
108	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
109	0.179	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
110	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
111	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
112	0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
113	0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
114	0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
115	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
116	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
117	0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
118	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
119	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
120	0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336

Figure A-5(d). PROGRAM COST OUTPUT FILE, SYSPRINT. Part 2.

_20STATE COST INFUT DATA FOR COST MATRIX GENERATOR

0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.066	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.158	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.310	0.586	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.087	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336

.
.
.

0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.332	0.607	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.102	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.193	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336
0.346	0.621	0.786	2.086	1.786	1.611	2.911	2.611	2.661
	3.961	3.661	3.711	5.011	4.711	4.761	5.811	6.336

Figure A-5(e). PROGRAM COST OUTPUT FILE, COSTF

```
//RU057     JOB (1000,0584,10,2),'DP500000I 133A NOS',NOTIFY=RU057,
//          MSGCLASS=Q
//CL       EXEC PLIXCLG,LIB=OASORS,PRG=CCTRANS,AQ=Q,
//             PARM.PLI='NAG,A(S),NX,SMSG,NOF,GN,NC(E),NONEST'
//PLI.SYSIN DD *
++WRITE WORK,CCTRANS
/*
//GO.SYSPRINT DD DSN=RU057.CCOUT.DATA,UNIT=3350,VOL=SER=DOT432,
//             DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3591),
//             SPACE=(TRK,(5,3),RLSE),DISP=(NEW,CATLG)
//GO.CTRL   DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(CTRL)
//GO.CCIN   DD DISP=SHR,DSN=EU209.P.PMSCARDS
//GO.CC33 DD DSN=RU057.TEMPDATA.DATA(CC33),DISP=SHR
//
```

(a)

```
120STATE  CURRENT CONDITIONS FOR 120 STATE IN PROPORTIONAL FORM
   120     120


          CC33
```

(b)

Figure A-6. PROGRAM CCTRANS--(a) JCL; (b) INPUT FILE CTRL

0000	000000	001913166	004731854
0001	000001	000037453	000056179
0002	000002	000000000	000000000
0003	000010	000271943	001037274
0004	000011	000018773	000028160
0005	000012	000000000	000000000
0006	000020	000015335	000097821
0007	000021	000005925	000014221
0008	000022	000000000	000000000
0009	000100	000199396	001008069
0010	000101	000000000	000000000
0011	000102	000000000	000000000
0012	000110	000236297	001144680
0013	000111	000000000	000000000
0014	000112	000000000	000000000

1200	224110	000000000	000000000
1201	224111	000000000	000000000
1202	224112	000000000	000000000
1203	224120	000000000	000000000
1204	224121	000000000	000000000
1205	224122	000000000	000000000
1206	224200	000000000	000000000
1207	224201	000000000	000000000
1208	224202	000000000	000000000
1209	224210	000000000	000000000
1210	224211	800000000	000000000
1211	224212	000000000	000000000
1212	224220	000000000	000000000
1213	224221	000000000	000000000
1214	224222	000000000	000000000

Figure A-6. PROGRAM COST--(c) INPUT FILE CCIN

CURRENT CONDITIONS ARE TRANSLATED FROM ABSOLUTE FORM TO PROPORTIONAL FORM

120STATE CURRENT CONDITIONS FOR 120 STATE IN PROPORTIONAL FORM

FILE FORMATS

INPUT - 120 STATE
OUTPUT - 120 STATE

TRAFFIC-REGION OUTPUT DIRECTIVES

TRAFFIC	REGION 1	REGION 2	REGION 3
1			
2			
3			CC33

TRAFFIC = 3   REGION = 3

TOTAL =   85159

STATE	TRF	REG	LIFE	RUF	CRK	CP	SHOULDERS	TRAV. WAY	PRO
1	3	3	1	1	1	1	23959	54771	.924
9	3	3	1	2	1	1	845	2534	.039
19	3	3	1	3	2	1	1220	1830	.035

E N D   O F   P R O G R A M

(d)

```
120STATE  CURRENT CONDITIONS FOR 120 STATE IN PROPORTIONAL FORM
        3         3
CURRENT CONDITION          3  TOTAL =         85159;
    1  0.9245059242E+00
    9  0.3967871863E-01
   19  0.3581535716E-01
```

(e)

Figure A-6. PROGRAM CCTRANS--(d) OUTPUT FILE SYSPRINT; (e) OUTPUT FILE CC33

```
//RU057      JOB (1000,0584,179,12),'DP500000I 133A NOS',NOTIFY=RU057,
//           MSGCLASS=Q
//CL       EXEC PLIXCLG,LIB=OASORS,PRG=TPROB,AQ=Q,
//             PARM.PLI='NAG,A(S),NX,SMSG,NOF,GN,NC(E),NONEST',
//             REGION.GO=512K
//PLI.SYSIN DD *
++INSERT WORK
* PROCESS;
++WRITE WORK,TPROB
++INSERT WORK
* PROCESS;
++WRITE WORK,PRINT
++INSERT WORK
* PROCESS;
++WRITE WORK,MATRIX
++INSERT WORK
* PROCESS;
++WRITE WORK,INPROB
/*
//GO.SYSPRINT  DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3591)
//GO.TPROBIN  DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(TPROBIN)
//GO.LIFE     DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(LIFE)
//GO.REG1     DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(REG1X)
//GO.REG2     DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(REG2X)
//GO.REG3     DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(REG3X)
//GO.TR11     DD DSN=RU057.TR11.DATA,UNIT=3350,VOL=SER=DOT432,
//            DCB=(RECFM=FB,LRECL=30,BLKSIZE=3600),
//            SPACE=(TRK,(030,25),RLSE),DISP=(NEW,CATLG)
//GO.TR22     DD DSN=RU057.TR22.DATA,UNIT=3350,VOL=SER=DOT432,
//            DCB=(RECFM=FB,LRECL=30,BLKSIZE=3600),
//            SPACE=(TRK,(030,25),RLSE),DISP=(NEW,CATLG)
//GO.TR33     DD DSN=RU057.TR33.DATA,UNIT=3350,VOL=SER=DOT432,
//            DCB=(RECFM=FB,LRECL=30,BLKSIZE=3600),
//            SPACE=(TRK,(030,25),RLSE),DISP=(NEW,CATLG)
//
```

Figure A-7. PROGRAM TPROB--(a) JCL

```
120STATE TRANSITION PROBABILITIES FOR MATRIX GENERATOR
LIFE
REG1 REG2 REG3
TR11
     TR22
          TR33
```

(b)

```
24STATE   TRANSITION PROBABILITIES FOR MATRIX GENERATOR
LIFE
REG1 REG2 REG3
TR11
     TR22
          TR33
```

(c)

```
TRF=1 REG=1 ; 2 2 4 3 3 5 3 4 5 4 4 5 4 5 5 1
      REG=2 ; 2 2 4 3 3 4 3 4 4 4 4 5 4 4 5 5
      REG=3 ; 2 2 4 3 2 4 3 3 4 4 4 4 4 4 4 5
TRF=2 REG=1 ; 2 2 4 3 3 4 3 4 4 4 4 4 4 4 5 5
      REG=2 ; 2 2 3 2 2 4 3 3 4 3 4 4 4 4 4 5
      REG=3 ; 2 2 3 2 2 4 2 3 4 3 3 4 4 4 4 5
TRF=3 REG=1 ; 2 2 4 3 2 4 3 3 4 3 3 5 4 4 4 5
      REG=2 ; 2 2 3 2 2 4 3 3 4 3 4 4 4 4 4 5
      REG=3 ; 2 2 3 2 2 3 3 3 3 3 3 4 3 4 4 5
```

(d)

Figure A-7. PROGRAM TPROB--(b) INPUT FILE TPROBIN
(c) INPUT FILE TPROBIN-24 state version
(d) INPUT FILE LIFE

```
ACTN=1 LIFE=1 CRK= 1 CF =1 ;  .82043395  .17956604  .00000000
                     CF =2 ;  .05748095  .94251904  .00000000
              CRK= 2 CF =1 ;  .00000000  .91270579  .08729421
                     CF =2 ;  .00000000  .55074815  .44925184
                     CF =3 ;  .00000036  .00843243  .99156721
              CRK= 3 CF =1 ;  .00000000  .00000000 1.00000000
                     CF =2 ;  .00000000  .00000000 1.00000000
                     CF =3 ;  .00000000  .00000008  .99999992
              RUF= 1 CF =0 ;  .78237385  .21762615  .00000000
              RUF= 2       ;  .00006155  .74327657  .25666188
              RUF= 3       ;  .00000000  .00000714  .99999286
       LIFE=2 CRK= 1 CF =1 ;  .87484988  .12515012  .00000000
                     CF =2 ;  .01029937  .98970062  .00000000
              CRK= 2 CF =1 ;  .00000000  .98227534  .01772466
                     CF =2 ;  .00000000  .52700585  .47299414
                     CF =3 ;  .00000005  .00180735  .99819259
              CRK= 3 CF =1 ;  .00000000  .00000016  .99999984
                     CF =2 ;  .00000000  .00000000 1.00000000
                     CF =3 ;  .00000000  .00000003  .99999997
       LIFE=3 CRK= 1 CF =1 ;  .88892342  .11107658  .00000000
                     CF =2 ;  .01180314  .98819685  .00000000
              CRK= 2 CF =1 ;  .00000000  .98567107  .01432892
                     CF =2 ;  .00000000  .53637260  .46362739
                     CF =3 ;  .00000006  .00187541  .99812453
              CRK= 3 CF =1 ;  .00000000  .00000032  .99999968
                     CF =2 ;  .00000000  .00000000 1.00000000
                     CF =3 ;  .00000000  .00000003  .99999997
       LIFE=4 CRK= 1 CF =1 ;  .91606124  .08393876  .00000000
                     CF =2 ;  .01568885  .98431113  .00000000
              CRK= 2 CF =1 ;  .00000000  .99066982  .00933017
                     CF =2 ;  .00000000  .55474050  .44525950
                     CF =3 ;  .00000006  .00202164  .99797829
              CRK= 3 CF =1 ;  .00000000  .00000164  .99999836
                     CF =2 ;  .00000000  .00000000 1.00000000
                     CF =3 ;  .00000000  .00000003  .99999996
       LIFE=5 CRK= 1 CF =1 ;  .94750436  .05249563  .00000000
                     CF =2 ;  .02444354  .97555646  .00000000
              CRK= 2 CF =1 ;  .00000007  .99470717  .00529275
                     CF =2 ;  .00000000  .58057824  .41942176
                     CF =3 ;  .00000008  .00226879  .99773113
              CRK= 3 CF =1 ;  .00000000  .00002274  .99997725
                     CF =2 ;  .00000000  .00000000 1.00000000
                     CF =3 ;  .00000000  .00000004  .99999996
ACTN=3 LIFE=1 RUF= 1 CF =0 ;  .99998751  .00001248  .00000000
              RUF= 2       ;  .99890579  .00109422  .00000000
              RUF= 3       ;  .76637331  .19444754  .03917915
ACTN=4        RUF= 1       ; 1.00000000  .00000000  .00000000
              RUF= 2       ;  .99999983  .00000017  .00000000
              RUF= 3       ;  .93121608  .06337267  .00541125
ACTN=5        RUF= 1       ;  .99999997  .00000003  .00000000
              RUF= 2       ;  .99999771  .00000230  .00000000
              RUF= 3       ;  .91176742  .07799660  .01023598
ACTN=6        RUF= 1       ;  .99999468  .00000532  .00000000
              RUF= 2       ;  .99996263  .00003737  .00000000
              RUF= 3       ;  .88589263  .09443071  .01967665
ACTN=7        RUF= 1       ; 1.00000000  .00000000  .00000000
              RUF= 2       ; 1.00000000  .00000000  .00000000
              RUF= 3       ;  .98862512  .01137253  .00000235
ACTN=8        RUF= 1       ; 1.00000000  .00000000  .00000000
              RUF= 2       ; 1.00000000  .00000000  .00000000
              RUF= 3       ;  .96981703  .02998783  .00019515
ACTN=9        RUF= 1       ;  .99998812  .00001187  .00000000
              RUF= 2       ;  .99999838  .00000162  .00000000
              RUF= 3       ;  .93356261  .05981284  .00662455
ACTN=10         RUF=1      ; 1.00000000  .00000000  .00000000
                RUF=2      ; 1.00000000  .00000000  .00000000
                RUF=3      ;  .99990774  .00009226  .00000000
ACTN=11         RUF=1      ; 1.00000000  .00000000  .00000000
                RUF=2      ; 1.00000000  .00000000  .00000000
                RUF=3      ;  .99728353  .00271645  .00000001
ACTN=12         RUF=1      ;  .99995568  .00004431  .00000000
                RUF=2      ;  .99999987  .00000013  .00000000
                RUF=3      ;  .95777792  .04074289  .00147918
ACTN=13         RUF=1      ; 1.00000000  .00000000  .00000000
                RUF=2      ; 1.00000000  .00000000  .00000000
                RUF=3      ; 1.00000000  .00000000  .00000000
ACTN=14         RUF=1      ; 1.00000000  .00000000  .00000000
                RUF=2      ; 1.00000000  .00000000  .00000000
                RUF=3      ;  .99999596  .00000403  .00000000
ACTN=15         RUF=1      ;  .99982503  .00017492  .00000004
                RUF=2      ;  .99999996  .00000003  .00000000
                RUF=3      ;  .97414526  .02546414  .00039060
ACTN=16         RUF=1      ;  .99935490  .00064424  .00000086
                RUF=2      ;  .99999993  .00000006  .00000000
                RUF=3      ;  .98286062  .01688171  .00025767
ACTN=17         RUF=1      ;  .99880271  .00119396  .00000332
                RUF=2      ;  .99999978  .00000022  .00000000
                RUF=3      ;  .98465385  .01504567  .00030048
```

Figure A-7. PROGRAM TPROB—(e) INPUT FILE REG3

120STATE TRANSITION PROBABILITIES FOR MATRIX GENERATOR

DATA IS READ FOR NONBLANK ENTRIES

DESIGN LIFE - LIFE
REGION 1 - REG1
REGION 2 - REG2
REGION 3 - REG3

TRAFFIC-REGION OUTPUT DIRECTIVES

TRAFFIC	REGION 1	REGION 2	REGION 3
1	TR11	TR12	TR13
2	TR21	TR22	TR23
3	TR31	TR32	TR33

DESIGN LIVES FOR ACTIONS 2 THROUGH 17

TRAFFIC	REGION	ACTIONS 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	2	2	4	3	3	5	3	4	5	4	4	5	4	5	5	1
1	2	2	2	4	3	3	4	3	4	4	4	4	5	4	4	5	5
1	3	2	2	4	3	2	4	3	3	4	4	4	4	4	4	4	5
2	1	2	2	4	3	3	4	3	4	4	4	4	4	4	4	5	5
2	2	2	2	3	2	2	4	3	3	4	3	4	4	4	4	4	5
2	3	2	2	3	2	2	4	2	3	4	3	3	4	4	4	4	5
3	1	2	2	4	3	2	4	3	3	4	3	3	5	4	4	4	5
3	2	2	2	3	2	2	4	3	3	4	3	4	4	4	4	4	5
3	3	2	2	3	2	2	3	3	3	3	3	3	4	3	4		5

Figure A-7. PROGRAM TPROB--(f) OUTPUT FILE SYSPRINT, Part 1.

REGRESSION PROBABILITIES FOR REGION LEVEL 3

CARD	ACTION	DESIGN LIFE	CRK/RUF	CP	STATE 1	STATE 2	STATE 3
1	1	1	1	1	0.82043395	0.17956604	0.00000000
2	1	1	1	2	0.05748095	0.94251904	0.00000000
3	1	1	2	1	0.00000000	0.91270579	0.08729421
4	1	1	2	2	0.00000000	0.55074815	0.44925184
5	1	1	2	3	0.00000036	0.00843243	0.99156721
6	1	1	3	1	0.00000000	0.00000000	1.00000000
7	1	1	3	2	0.00000000	0.00000000	1.00000000
8	1	1	3	3	0.00000000	0.00000008	0.99999992
9	1		1		0.78237385	0.21762615	0.00000000
10	1		2		0.00006155	0.74327657	0.25666188
11	1		3		0.00000000	0.00000714	0.99999236
12	1	2	1	1	0.87484988	0.12515012	0.00000000
13	1	2	1	2	0.01029937	0.98970062	0.00000000
14	1	2	2	1	0.00000000	0.98227534	0.01772466
15	1	2	2	2	0.00000000	0.52700585	0.47299414
16	1	2	2	3	0.00000005	0.00180735	0.99819259
17	1	2	3	1	0.00000000	0.00000016	0.99999984
18	1	2	3	2	0.00000000	0.00000000	1.00000000
19	1	2	3	3	0.00000000	0.00000003	0.99999997
20	1	3	1	1	0.88892342	0.11107658	0.00000000
21	1	3	1	2	0.01180314	0.98819685	0.00000000
22	1	3	2	1	0.00000000	0.98567107	0.01432892
23	1	3	2	2	0.00000000	0.53637260	0.46362739
24	1	3	2	3	0.00000006	0.00187541	0.99812453
25	1	3	3	1	0.00000000	0.00000032	0.99999968
26	1	3	3	2	0.00000000	0.00000000	1.00000000
27	1	3	3	3	0.00000000	0.00000003	0.99999997
28	1	4	1	1	0.91606124	0.08393876	0.00000000
29	1	4	1	2	0.01568885	0.98431113	0.00000000
30	1	4	2	1	0.00000000	0.99066932	0.00933017
31	1	4	2	2	0.00000000	0.55474050	0.44525950
32	1	4	2	3	0.00000006	0.00202134	0.99797929
33	1	4	3	1	0.00000000	0.00000164	0.99999836
34	1	4	3	2	0.00000000	0.00000000	1.00000000
35	1	4	3	3	0.00000000	0.00000003	0.99999996
36	1	5	1	1	0.94750436	0.05249563	0.00000000
37	1	5	1	2	0.02444354	0.97555646	0.00000000
38	1	5	2	1	0.00000007	0.99470717	0.00529275
39	1	5	2	2	0.00000000	0.58057824	0.41942176
40	1	5	2	3	0.00000008	0.00226879	0.99773113
41	1	5	3	1	0.00000000	0.00002274	0.99997725
42	1	5	3	2	0.00000000	0.00000000	1.00000000
43	1	5	3	3	0.00000000	0.00000004	0.99999996
44	3		1		0.99998751	0.00001248	0.00000000
45	3		2		0.99890579	0.00109422	0.00000000
46	3		3		0.76637331	0.19444754	0.03917915
47	4		1		1.00000000	0.00000000	0.00000000
48	4		2		0.99999983	0.00000017	0.00000000
49	4		3		0.93121608	0.06337267	0.00541125
50	5		1		0.99999997	0.00000003	0.00000000
51	5		2		0.99999771	0.00000230	0.00000000
52	5		3		0.91176742	0.07799660	0.01023599
53	5		1		0.99999468	0.00000532	0.00000000
54	6		2		0.99996263	0.00003737	0.00000000
55	6		3		0.88589263	0.09443071	0.01967665
56	7		1		1.00000000	0.00000000	0.00000000
57	7		2		1.00000000	0.00000000	0.00000000
58	7		3		0.98862512	0.01137253	0.00000235
59	8		1		1.00000000	0.00000000	0.00000000
60	9		2		1.00000000	0.00000000	0.00000000
61	8		3		0.96981733	0.02998733	0.00019515
62	9		1		0.99998812	0.00001187	0.00000000
63	9		2		0.99999838	0.00000162	0.00000000
64	9		3		0.93356261	0.05981234	0.00662455
65	10		1		1.00000000	0.00000000	0.00000000
66	10		2		1.00000000	0.00000000	0.00000000
67	10		3		0.99990774	0.00009226	0.00000000
68	11		1		1.00000000	0.00000000	0.00000000
69	11		2		1.00000000	0.00000000	0.00000000
70	11		3		0.99728353	0.00271645	0.00000001
71	12		1		0.99995568	0.00004431	0.00000000
72	12		2		0.99999987	0.00000013	0.00000000
73	12		3		0.95777792	0.04074289	0.00147918
74	13		1		1.00000000	0.00000000	0.00000000
75	13		2		1.00000000	0.00000000	0.00000000
76	13		3		1.00000000	0.00000000	0.00000000
77	14		1		1.00000000	0.00000000	0.00000000
78	14		2		1.00000000	0.00000000	0.00000000
79	14		3		0.99999596	0.00000403	0.00000000
80	15		1		0.99982503	0.00017492	0.00000004
81	15		2		0.99999996	0.00000003	0.00000000
82	15		3		0.97414526	0.02546414	0.00039060
83	15		1		0.99535490	0.00464424	0.00000086
84	16		2		0.99999993	0.00000006	0.00000000
85	16		3		0.98286062	0.01688171	0.00025767
86	17		1		0.99880271	0.00119346	0.00000332
87	17		2		0.99999978	0.00000022	0.00000000
88	17		3		0.98465385	0.01504567	0.00030048

Figure A-7. PROGRAM TPROB--(g) OUTPUT FILE SYSPRINT, Part 2.

ACTION MATRICES FOR REGION LEVEL 3

REGION LEVEL 3 ACTION 1 DESIGN LIFE LEVEL 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.641	.000	.000	.140	.000	.000	.000	.000	.178	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.004	.000	.000	.737	.000	.000	.000	.000	.012	.000	.000	.245	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.714	.000	.000	.000	.068	.000	.000	.000	.158	.020	.000	.000	.018	.000	.009	.000	.000	.000	.000	.000	.000	.000
4	.000	.000	.430	.000	.000	.000	.351	.000	.000	.000	.119	.050	.000	.000	.047	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.000	.000	.006	.000	.000	.000	.775	.000	.000	.000	.001	.000	.000	.000	.215	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	.000	.000	.000	.609	.000	.000	.133	.000	.000	.000	.000	.210	.000	.000	.046	.000	.000	.000	.000
10	.000	.000	.000	.000	.000	.000	.000	.000	.042	.000	.000	.700	.000	.000	.000	.000	.014	.000	.000	.241	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.678	.000	.000	.000	.064	.000	.000	.000	.234	.000	.000	.000	.022	.000
12	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.407	.000	.000	.000	.333	.000	.000	.000	.141	.000	.000	.000	.115	.000
13	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.006	.000	.000	.000	.737	.000	.000	.000	.002	.000	.000	.000	.254	.000
14	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
16	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
17	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.820	.000	.000	.179	.000	.000	.000	.000
18	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.057	.000	.000	.942	.000	.000	.000	.000
19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.912	.000	.000	.000	.087	.000
20	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.550	.000	.000	.000	.449	.000
21	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.008	.000	.000	.000	.991	.000
22	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000
23	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000
24	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000

REGION LEVEL 3 ACTION 1 DESIGN LIFE LEVEL 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.684	.000	.000	.097	.000	.000	.000	.000	.190	.000	.000	.027	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.008	.000	.000	.774	.000	.000	.000	.000	.002	.000	.000	.215	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.758	.000	.000	.000	.013	.000	.000	.000	.213	.000	.000	.000	.013	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.000	.000	.412	.000	.000	.000	.373	.000	.000	.000	.114	.000	.000	.000	.102	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.000	.000	.001	.000	.000	.000	.780	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	.000	.000	.000	.650	.000	.000	.093	.000	.000	.000	.000	.224	.000	.000	.032	.000	.000	.000	.000
10	.000	.000	.000	.000	.000	.000	.000	.000	.007	.000	.000	.735	.000	.000	.000	.000	.002	.000	.000	.254	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.730	.000	.000	.000	.013	.000	.000	.000	.252	.000	.000	.000	.004	.000
12	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.391	.000	.000	.000	.351	.000	.000	.000	.135	.000	.000	.000	.121	.000
13	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.741	.000	.000	.000	.000	.000	.000	.000	.256	.000
14	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
16	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
17	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.874	.000	.000	.125	.000	.000	.000	.000
18	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.010	.000	.000	.989	.000	.000	.000	.000
19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.982	.000	.000	.000	.017	.000
20	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.527	.000	.000	.000	.472	.000
21	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.998	.000
22	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000
23	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000
24	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000

REGION LEVEL 3 ACTION 1 DESIGN LIFE LEVEL 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.695	.000	.000	.086	.000	.000	.000	.000	.193	.000	.000	.024	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.009	.000	.000	.773	.000	.000	.000	.000	.002	.000	.000	.215	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.771	.000	.000	.000	.011	.000	.000	.000	.214	.000	.000	.000	.003	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.000	.000	.419	.000	.000	.000	.367	.000	.000	.000	.116	.000	.000	.000	.100	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.000	.000	.001	.000	.000	.000	.780	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	.000	.000	.000	.660	.000	.000	.082	.000	.000	.000	.000	.228	.000	.000	.029	.000	.000	.000	.000
10	.000	.000	.000	.000	.000	.000	.000	.000	.008	.000	.000	.734	.000	.000	.000	.000	.003	.000	.000	.253	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.732	.000	.000	.000	.010	.000	.000	.000	.252	.000	.000	.000	.003	.000
12	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.398	.000	.000	.000	.344	.000	.000	.000	.137	.000	.000	.000	.118	.000
13	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.741	.000	.000	.000	.000	.000	.000	.000	.256	.000
14	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
16	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
17	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.888	.000	.000	.111	.000	.000	.000	.000
18	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.011	.000	.000	.988	.000	.000	.000	.000
19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.985	.000	.000	.000	.014	.000
20	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.536	.000	.000	.000	.463	.000
21	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.998	.000
22	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000
23	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000
24	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000

Figure A-7. PROGRAM TPROB--(h) OUTPUT FILE SYSPRINT, Part 3 (3 pages)

REGION LEVEL 3 ACTION 1 DESIGN LIFE LEVEL 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.716	.000	.000	.065	.000	.000	.000	.000	.199	.000	.000	.018	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.012	.000	.000	.770	.000	.000	.000	.000	.003	.000	.000	.214	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.775	.000	.000	.000	.007	.000	.000	.000	.215	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.000	.000	.434	.000	.000	.000	.348	.000	.000	.000	.120	.000	.000	.000	.076	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.000	.000	.001	.000	.000	.000	.780	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	.000	.000	.000	.080	.000	.000	.062	.000	.000	.000	.000	.235	.000	.000	.621	.000	.000	.000	.000
10	.000	.000	.000	.000	.000	.000	.000	.000	.011	.000	.000	.731	.000	.000	.000	.000	.004	.000	.000	.252	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.736	.000	.000	.000	.006	.000	.000	.000	.254	.000	.000	.000	.002	.000
12	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.412	.000	.000	.000	.330	.000	.000	.000	.142	.000	.000	.000	.114	.000
13	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.741	.000	.000	.000	.000	.000	.000	.000	.256	.000
14	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
16	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
17	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.916	.000	.000	.083	.000	.000	.000	.000
18	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.415	.000	.000	.584	.000	.000	.000	.000
19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.990	.000	.000	.000	.009	.000
20	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.554	.000	.000	.000	.445	.000
21	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000	.000	.000	.997	.000
22	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000
23	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000
24	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000

REGION LEVEL 3 ACTION 1 DESIGN LIFE LEVEL 5

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.741	.000	.000	.041	.000	.000	.000	.000	.206	.000	.000	.011	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.019	.000	.000	.763	.000	.000	.000	.000	.005	.000	.000	.212	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.000	.000	.779	.000	.000	.000	.004	.000	.000	.000	.216	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.000	.000	.454	.000	.000	.000	.329	.000	.000	.000	.126	.000	.000	.000	.091	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.000	.000	.001	.000	.000	.000	.780	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	.000	.000	.000	.704	.000	.000	.039	.000	.000	.000	.000	.243	.000	.000	.013	.000	.000	.000	.000
10	.000	.000	.000	.000	.000	.000	.000	.000	.018	.000	.000	.725	.000	.000	.000	.000	.006	.000	.000	.250	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.739	.000	.000	.000	.003	.000	.000	.000	.255	.000	.000	.000	.001	.000
12	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.431	.000	.000	.000	.311	.000	.000	.000	.149	.000	.000	.000	.107	.000
13	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.741	.000	.000	.000	.000	.000	.000	.000	.256	.000
14	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
16	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000
17	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.947	.000	.000	.052	.000	.000	.000	.000
18	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.724	.000	.000	.275	.000	.000	.000	.000
19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.924	.000	.000	.000	.075	.000
20	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.580	.000	.000	.000	.419	.000
21	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000	.000	.000	.997	.000
22	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000
23	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000
24	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000

REGION LEVEL 3 ACTION 2 DESIGN LIFE LEVEL 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.000
10	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.000
17	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.000
18	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.000
19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.000
20	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.000
21	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.000
22	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.000
23	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.000
24	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.000

REGION LEVEL 3 ACTION 3 DESIGN LIFE LEVEL 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
10	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
11	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
12	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
13	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
14	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
15	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
16	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
17	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000
18	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000
19	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000
20	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000
21	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000
22	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000
23	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000
24	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000

Figure A-7. PROGRAM TPROB--(h) OUTPUT FILE SYSPRINT, Part 3 (Continued)

```
120STATE TRANSITION PROBABILIT
IES FOR MATRIX GENERATOR
          3          3
 1   1    1 0.6418860681E+00
 1   1    4 0.1404877740E+00
 1   1    9 0.1785478819E+00
 1   1   12 0.3907826596E-01
 1   2    1 0.4497159215E-01
 1   2    4 0.7374022500E+00
 1   2    9 0.1250935785E-01
 1   2   12 0.2051167900E+00
 1   3    3 0.7140771428E+00
 1   3    7 0.6829670716E-01
 1   3   11 0.1986286472E+00
 1   3   15 0.1899750284E-01
 1   4    3 0.4308909505E+00
 1   4    7 0.3514828917E+00
 1   4   11 0.1198571995E+00
 1   4   15 0.9776894832E-01
              .
              .
              .
              .
              .
17 114  113 0.3004800000E-03
17 115   97 0.9846538500E+00
17 115  105 0.1504567000E-01
17 115  113 0.3004800000E-03
17 116   97 0.9846538500E+00
17 116  105 0.1504567000E-01
17 116  113 0.3004800000E-03
17 117   97 0.9846538500E+00
17 117  105 0.1504567000E-01
17 117  113 0.3004800000E-03
17 118   97 0.9846538500E+00
17 118  105 0.1504567000E-01
17 118  113 0.3004800000E-03
17 119   97 0.9846538500E+00
17 119  105 0.1504567000E-01
17 119  113 0.3004800000E-03
17 120   97 0.9846538500E+00
17 120  105 0.1504567000E-01
17 120  113 0.3004800000E-03
-1    0    0 .00000000E+00
```

Figure A-7. PROGRAM TPROB--(i) OUTPUT FILE TR33

EGION LEVEL 3 ACTION 16 DESIGN LIFE LEVEL 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
10	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
11	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
12	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
13	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
14	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
15	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
16	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
17	.982	.000	.000	.000	.000	.000	.000	.000	.016	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
18	.982	.000	.000	.000	.000	.000	.000	.000	.016	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
19	.982	.000	.000	.000	.000	.000	.000	.000	.016	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
20	.982	.000	.000	.000	.000	.000	.000	.000	.016	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
21	.982	.000	.000	.000	.000	.000	.000	.000	.016	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
22	.982	.000	.000	.000	.000	.000	.000	.000	.016	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
23	.982	.000	.000	.000	.000	.000	.000	.000	.016	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
24	.982	.000	.000	.000	.000	.000	.000	.000	.016	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

EGION LEVEL 3 ACTION 17 DESIGN LIFE LEVEL 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
10	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
11	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
12	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
13	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
14	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
15	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
16	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
17	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
18	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
19	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
20	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
21	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
22	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
23	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
24	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

E N D O F P R O G R A M

Figure A-7. PROGRAM TPROB--(h) OUTPUT FILE SYSPRINT, Part 3 (Concluded)

Steadv State Solution. The JCL, control input file SXSIN, and output files SXSOUT and MATRIX for Program ADOT are shown in Figure A-9. Careful examination of output file SXSOUT indicates the problem is stated correctly and therefore are ready to run MPSX. Figure A-10 shows the JCL and control language statements for MPSX and the output file SYSPRINT. SYSPRINT has been edited to display the important parts of the solution.

5-Period Solution. The JCL, control input file SXSIN, and output files SXSOUT and MATRIX for Program ADOT are shown in Figure A-11. The "STEADY STATES" and "SS CONSTRAINT" come from the steady state solution. As can be seen in Figure A-10(b), states 24, 23, and 36 each have one action in the steady state solution. For these states the proportion (activity) from the solution is entered into the STEADY STATES section of file SXSIN. For state 28, two actions are found in the steady state solution. The sum of corresponding proportions is entered as a single steady state value for state 28. An interval size of one percent was considered reasonable for this run.

Figure A-12 shows the JCL and control language statements for MPSX and the output file SYSPRINT. SYSPRINT has been edited to display the important parts of the solution.

```
//RU057      JOB (1000,0584,179,12),'DP500000I 133A NOS',NOTIFY=RU057,
//               MSGCLASS=Q
//CL         EXEC PLIXCLG,LIB=OASORS,PRG=TPROB,AQ=Q,
//               PARM.PLI='NAG,A(S),NX,SMSG,NOF,GN,NC(E),NONEST',
//               REGION.GO=512K
//PLI.SYSIN DD *
++INSERT WORK
* PROCESS;
++WRITE WORK,TPROBSP
++INSERT WORK
* PROCESS;
++WRITE WORK,PRINTSP
++INSERT WORK
* PROCESS;
++WRITE WORK,MATRXSP
++INSERT WORK
* PROCESS;
++WRITE WORK,INPRBSP
/*
//GO.SYSPRINT DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3591)
//GO.TPROBIN  DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(TPRBINSP)
//GO.LIFE     DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(LIFE)
//GO.REG1     DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(REG1SPX)
//GO.REG2     DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(REG2SPX)
//GO.REG3     DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(REG3SPX)
//GO.TR11     DD DSN=RU057.TR11SP.DATA,UNIT=3350,VOL=SER=DOT432,
//               DCB=(RECFM=FB,LRECL=30,BLKSIZE=3600),
//               SPACE=(TRK,(005,02),RLSE),DISP=(NEW,CATLG)
//GO.TR22     DD DSN=RU057.TR22SP.DATA,UNIT=3350,VOL=SER=DOT432,
//               DCB=(RECFM=FB,LRECL=30,BLKSIZE=3600),
//               SPACE=(TRK,(005,02),RLSE),DISP=(NEW,CATLG)
//GO.TR33     DD DSN=RU057.TR33SP.DATA,UNIT=3350,VOL=SER=DOT432,
//               DCB=(RECFM=FB,LRECL=30,BLKSIZE=3600),
//               SPACE=(TRK,(005,02),RLSE),DISP=(NEW,CATLG)
//
```

(a)

Figure A-8. PROGRAM TPROBSP--(a) JCL

(b) see Figure A-7(c)

ACTN=1	CRK= 1	CP =1	;	.82043395	.17956604	.00000000
		CP =2	;	.05748095	.94251904	.00000000
	CRK= 2	CP =1	;	.00000000	.91270579	.08729421
		CP =2	;	.00000000	.55074815	.44925184
		CP =3	;	.00000036	.00843243	.99156721
	CRK= 3	CP =1	;	.00000000	.00000000	1.00000000
		CP =2	;	.00000000	.00000000	1.00000000
		CP =3	;	.00000000	.00000008	.99999992
	RUF= 1	CP =0	;	.78237385	.21762615	.00000000
	RUF= 2		;	.00006155	.74327657	.25666188
	RUF= 3		;	.00000000	.00000714	.99999286
ACTN=3	RUF= 1		;	.99998751	.00001248	.00000000
	RUF= 2		;	.99890579	.00109422	.00000000
	RUF= 3		;	.76637331	.19444754	.03917915
ACTN=4	RUF= 1		;	1.00000000	.00000000	.00000000
	RUF= 2		;	.99999983	.00000017	.00000000
	RUF= 3		;	.93121608	.06337267	.00541125
ACTN=5	RUF= 1		;	.99999997	.00000003	.00000000
	RUF= 2		;	.99999771	.00000230	.00000000
	RUF= 3		;	.91176742	.07799660	.01023598
ACTN=6	RUF= 1		;	.99999468	.00000532	.00000000
	RUF= 2		;	.99996263	.00003737	.00000000
	RUF= 3		;	.88589263	.09443071	.01967665
ACTN=7	RUF= 1		;	1.00000000	.00000000	.00000000
	RUF= 2		;	1.00000000	.00000000	.00000000
	RUF= 3		;	.98862512	.01137253	.00000235
ACTN=8	RUF= 1		;	1.00000000	.00000000	.00000000
	RUF= 2		;	1.00000000	.00000000	.00000000
	RUF= 3		;	.96981703	.02998783	.00019515
ACTN=9	RUF= 1		;	.99998812	.00001187	.00000000
	RUF= 2		;	.99999838	.00000162	.00000000
	RUF= 3		;	.93356261	.05981284	.00662455
ACTN=10	RUF=1		;	1.00000000	.00000000	.00000000
	RUF=2		;	1.00000000	.00000000	.00000000
	RUF=3		;	.99990774	.00009226	.00000000
ACTN=11	RUF=1		;	1.00000000	.00000000	.00000000
	RUF=2		;	1.00000000	.00000000	.00000000
	RUF=3		;	.99728353	.00271645	.00000001
ACTN=12	RUF=1		;	.99995568	.00004431	.00000000
	RUF=2		;	.99999987	.00000013	.00000000
	RUF=3		;	.95777792	.04074289	.00147918
ACTN=13	RUF=1		;	1.00000000	.00000000	.00000000
	RUF=2		;	1.00000000	.00000000	.00000000
	RUF=3		;	1.00000000	.00000000	.00000000
ACTN=14	RUF=1		;	1.00000000	.00000000	.00000000
	RUF=2		;	1.00000000	.00000000	.00000000
	RUF=3		;	.99999596	.00000403	.00000000
ACTN=15	RUF=1		;	.99982503	.00017492	.00000004
	RUF=2		;	.99999996	.00000003	.00000000
	RUF=3		;	.97414526	.02546414	.00039060
ACTN=16	RUF=1		;	.99935490	.00064424	.00000086
	RUF=2		;	.99999993	.00000006	.00000000
	RUF=3		;	.98286062	.01688171	.00025767
ACTN=17	RUF=1		;	.99880271	.00119396	.00000332
	RUF=2		;	.99999978	.00000022	.00000000
	RUF=3		;	.98465385	.01504567	.00030048

Figure A-8. PROGRAM TPROBSP—(c) INPUT FILE REG3

24STATE TRANSITION PROBABILITIES FOR MATRIX GENERATOR

DATA IS READ FOR NONBLANK ENTRIES

DESIGN LIFE	- LIFE
REGION 1	- REG1
REGION 2	- REG2
REGION 3	- REG3

TRAFFIC-REGION OUTPUT DIRECTIVES

TRAFFIC	REGION 1	2	3
1	TR11	TR12	TR13
2	TR21	TR22	TR23
3	TR31	TR32	TR33

DESIGN LIVES FOR ACTIONS 2 THROUGH 17

TRAFFIC	REGION	ACTIONS 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	2	2	4	3	3	5	3	4	5	4	4	5	4	5	5	1
1	2	2	2	4	3	3	4	3	4	4	4	4	5	4	4	5	5
1	3	2	2	4	3	2	4	3	3	4	4	4	4	4	4	4	5
2	1	2	2	4	3	3	4	3	4	4	4	4	4	4	4	5	5
2	2	2	2	3	2	2	4	3	3	4	3	4	4	4	4	4	5
2	3	2	2	3	2	2	4	2	3	4	3	3	4	4	4	4	5
3	1	2	2	4	3	2	4	3	3	4	3	3	5	4	4	4	5
3	2	2	2	3	2	2	4	3	3	4	3	4	4	4	4	4	5
3	3	2	2	3	2	2	3	3	3	3	3	3	4	3	4	4	5

Figure A-8. PROGRAM TPROBSP--(d) OUTPUT FILE SYSPRINT, Part 1.

REGRESSION PROBABILITIES FOR REGION LEVEL 3

CARD	ACTION	CRK/RUF	CP	STATE 1	STATE 2	STATE 3
1	1	1	1	0.82043395	0.17956604	0.00000000
2	1	1	2	0.05748095	0.94251904	0.00000000
3	1	2	1	0.00000000	0.91270579	0.08729421
4	1	2	2	0.00000000	0.55074815	0.44925184
5	1	2	3	0.00000036	0.00843243	0.99156721
6	1	3	1	0.00000002	0.00000000	1.00000000
7	1	3	2	0.00000000	0.00000000	1.00000000
8	1	3	3	0.00000000	0.00000008	0.99999992
9	1	1		0.78237385	0.21762615	0.00000000
10	1	2		0.00006155	0.74327657	0.25666188
11	1	3		0.00000000	0.00000714	0.99999286
12	3	1		0.99998751	0.00001248	0.00000000
13	3	2		0.99890579	0.00109422	0.00000000
14	3	3		0.76637331	0.19444754	0.03917915
15	4	1		1.00000000	0.00000000	0.00000000
16	4	2		0.99999983	0.00000017	0.00000000
17	4	3		0.93121608	0.06337267	0.00541125
18	5	1		0.99999997	0.00000003	0.00000000
19	5	2		0.99999771	0.00000230	0.00000000
20	5	3		0.91176742	0.07799660	0.01023598
21	6	1		0.99999468	0.00000532	0.00000000
22	6	2		0.99996263	0.00003737	0.00000000
23	6	3		0.88589263	0.09443071	0.01967665
24	7	1		1.00000000	0.00000000	0.00000000
25	7	2		1.00000000	0.00000000	0.00000000
26	7	3		0.98862512	0.01137253	0.00000235
27	8	1		1.00000000	0.00000000	0.00000000
28	8	2		1.00000000	0.00000000	0.00000000
29	8	3		0.96981703	0.02998783	0.00019515
30	9	1		0.99998812	0.00001197	0.00000000
31	9	2		0.99999838	0.00000162	0.00000000
32	9	3		0.93356261	0.05981284	0.00662455
33	10	1		1.00000000	0.00000000	0.00000000
34	10	2		1.00000000	0.00000000	0.00000000
35	10	3		0.99990774	0.00009226	0.00000000
36	11	1		1.00000000	0.00000000	0.00000000
37	11	2		1.00000000	0.00000000	0.00000000
38	11	3		0.99728353	0.00271645	0.00000001
39	12	1		0.99995568	0.00004431	0.00000000
40	12	2		0.99999987	0.00000013	0.00000000
41	12	3		0.95777792	0.04074289	0.00147918
42	13	1		1.00000000	0.00000000	0.00000000
43	13	2		1.00000000	0.00000000	0.00000000
44	13	3		1.00000000	0.00000000	0.00000000
45	14	1		1.00000000	0.00000000	0.00000000
46	14	2		1.00000000	0.00000000	0.00000000
47	14	3		0.99999596	0.00000403	0.00000000
48	15	1		0.99982503	0.00017492	0.00000004
49	15	2		0.99999996	0.00000003	0.00000000
50	15	3		0.97414526	0.02546414	0.00039060
51	16	1		0.99935490	0.00064424	0.00000086
52	16	2		0.99999993	0.00000006	0.00000000
53	16	3		0.98236062	0.01688171	0.00025767
54	17	1		0.99880271	0.00119396	0.00000332
55	17	2		0.99999978	0.00000022	0.00000000
56	17	3		0.98465385	0.01504567	0.00030048

Figure A-8. PROGRAM TPROBSP--(e) OUTPUT FILE SYSPRINT, Part 2.

ACTION MATRICES FOR REGION LEVEL 3

REGION LEVEL 3 ACTION 1 TRAFFIC LEVEL 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.641	.000	.000	.140	.000	.000	.000	.000	.178	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
2	[illegible]	.000	.000	.737	.000	.000	.000	.000	.012	.000	.000	.205	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
3	.000	.000	.714	.000	.000	.000	.068	.000	.000	.000	.198	.000	.000	.000	.018	.000	.000	.000	.000	.000	.000	.000	.000	.0
4	.000	.000	.430	.000	.000	.000	.351	.000	.000	.000	.119	.000	.000	.000	.097	.000	.000	.000	.000	.000	.000	.000	.000	.0
5	.000	.000	.006	.000	.000	.000	.775	.000	.000	.000	.001	.000	.000	.000	.215	.000	.000	.000	.000	.000	.000	.000	.000	.0
6	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
7	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
8	.000	.000	.000	.000	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
9	.000	.000	.000	.000	.000	.000	.000	.000	.605	.000	.000	.133	.000	.000	.000	.000	.210	.000	.000	.046	.000	.000	.000	.0
10	.000	.000	.000	.000	.000	.000	.000	.000	.042	.000	.000	.700	.000	.000	.000	.000	.014	.000	.000	.241	.000	.000	.000	.0
11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.678	.000	.000	.000	.064	.000	.000	.000	.234	.000	.000	.000	.022	.0
12	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.409	.000	.000	.000	.333	.000	.000	.000	.141	.000	.000	.000	.115	.0
13	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.006	.000	.000	.000	.737	.000	.000	.000	.002	.000	.000	.000	.254	.0
14	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.0
15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.0
16	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.0
17	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.820	.000	.000	.179	.000	.000	.000	.0
18	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.057	.000	.000	.942	.000	.000	.000	.0
19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.912	.000	.000	.000	.087	.0
20	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.550	.000	.000	.000	.449	.0
21	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.008	.000	.000	.000	.991	.0
22	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.0
23	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.0
24	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.0

REGION LEVEL 3 ACTION 2 TRAFFIC LEVEL 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
2	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
3	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
4	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
5	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
6	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
7	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
8	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
9	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.0
10	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.0
11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
12	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
13	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
14	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
16	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
17	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.0
18	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.0
19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0
20	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0
21	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0
22	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0
23	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0
24	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0

REGION LEVEL 3 ACTION 2 TRAFFIC LEVEL 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
2	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
3	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
4	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
5	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
6	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
7	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
8	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
9	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.0
10	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.0
11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
12	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
13	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
14	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
16	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.0
17	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.0
18	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.0
19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0
20	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0
21	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0
22	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0
23	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0
24	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.0

Figure A-8. PROGRAM TPROBSP--(f) OUTPUT FILE SYSPRINT, Part 3 (2 pages)

REGION LEVEL 3 ACTION 2 TRAFFIC LEVEL 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.000	.782	.000	.000	.000	.000	.000	.000	.000	.217	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.000
10	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000	.000
11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000
14	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000
15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	.000	.000	.000	.000	.000	.000	.743	.000	.000	.000	.000	.000	.000	.000	.256	.000	.000	.000	.000	.000	.000
17	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.000
18	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000	.000
19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000
20	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000
21	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000
22	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000
23	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000
24	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.999	.000	.000	.000	.000	.000	.000

REGION LEVEL 3 ACTION 3 TRAFFIC LEVEL 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.000	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.000	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.000	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.000	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.000	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.000	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
10	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
11	.000	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
12	.000	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
13	.000	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
14	.000	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
15	.000	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
16	.000	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
17	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000
18	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000	.000
19	.000	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000
20	.000	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000
21	.000	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000
22	.000	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000
23	.000	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000
24	.000	.766	.000	.000	.000	.000	.000	.000	.000	.194	.000	.000	.000	.000	.000	.000	.000	.039	.000	.000	.000	.000	.000	.000

REGION LEVEL 3 ACTION 17 TRAFFIC LEVEL 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
10	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
11	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
12	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
13	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
14	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
15	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
16	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
17	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
18	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
19	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
20	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
21	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
22	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
23	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
24	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

REGION LEVEL 3 ACTION 17 TRAFFIC LEVEL 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
4	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
5	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
6	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
7	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.998	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
10	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
11	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
12	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
13	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
14	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
15	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
16	.999	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
17	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
18	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
19	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
20	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
21	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
22	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
23	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
24	.984	.000	.000	.000	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

Figure A-8. PROGRAM TPROBSP—(f) OUTPUT FILE SYSPRINT, Part 3 (Concluded)

E N D O F P R O G R A M

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24STATE   TRANSITION PROBABILI
TIES FOR MATRIX GENERATOR

            3          3
 1    1     1 0.6418860681E+00
 1    1     4 0.1404877740E+00
 1    1     9 0.1785478819E+00
 1    1    12 0.3907826596E-01
 1    2     1 0.4497159215E-01
 1    2     4 0.7374022500E+00
 1    2     9 0.1250935785E-01
 1    2    12 0.2051167900E+00
 1    3     3 0.7140771428E+00
 1    3     7 0.6829670716E-01
 1    3    11 0.1986286472E+00
 1    3    15 0.1899750284E-01
 1    4     3 0.4308909505E+00
 1    4     7 0.3514828917E+00
 1    4    11 0.1198571995E+00
 1    4    15 0.9776894832E-01

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17   18     1 0.9846538500E+00
17   18     9 0.1504567000E-01
17   18    17 0.3004800000E-03
17   19     1 0.9846538500E+00
17   19     9 0.1504567000E-01
17   19    17 0.3004800000E-03
17   20     1 0.9846538500E+00
17   20     9 0.1504567000E-01
17   20    17 0.3004800000E-03
17   21     1 0.9846538500E+00
17   21     9 0.1504567000E-01
17   21    17 0.3004800000E-03
17   22     1 0.9846538500E+00
17   22     9 0.1504567000E-01
17   22    17 0.3004800000E-03
17   23     1 0.9846538500E+00
17   23     9 0.1504567000E-01
17   23    17 0.3004800000E-03
17   24     1 0.9846538500E+00
17   24     9 0.1504567000E-01
17   24    17 0.3004800000E-03
-1    0     0 .00000000E+00
```

Figure A-8. PROGRAM TPROBSP--(g) OUTPUT FILE TR33

```
//RU057    JOB (1000,0584,79,1),'DP500000I 133A NOS',NOTIFY=RU057,
//           MSGCLASS=Q
//CL       EXEC PGM=ADOTD,REGION=512K
//STEPLIB DD DSN=EU209.P.LOADLIB,DISP=SHR
//SXSIN  DD DISP=SHR,DSN=RU057.ADOTIN.DATA(S33)
//COSTF  DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(COSTF120)
//TRMX   DD DISP=SHR,DSN=RU057.TR.DATA(TR33)
//CURNT  DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(CC33)
//MATRIX DD DSN=RU057.X33.DATA,UNIT=3350,VOL=SER=DOT432,
//           DCB=(RECFM=FB,LRECL=40,BLKSIZE=3600),
//           SPACE=(TRK,(9,9),RLSE),DISP=(NEW,CATLG)
//SXSOUT DD DSN=RU057.A33.DATA,UNIT=3350,VOL=SER=DOT432,
//           DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3591),
//           SPACE=(TRK,(5,3),RLSE),DISP=(NEW,CATLG)
//
```

(a)

```
TITLE
    REAL LIFE PROBLEM
ROAD INFORMATION
  TRAFFIC=3  REGION=3;
CONTROL IHFORMATION
 PNAME='REAL' HORIZON=1 STORAGE=6000 OBJECTIVE=1 NUSTAT=120 CURNAME='120STATE'
 CNAME='120STATE' TNAME='120STATE' DISCOUNT=0.0 NUACT=17 ;
INFEASIBLE ACTIONS        2
 10   1 2 25 26 49 50 73 74 97 98     15    3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
 15   22 23 24 46 47 48 70 71 72 94 95 96 118 119 120    2    1 2
DESIRABLE STATES          1
   10        1   2
            25  26
            49  50
            73  74
            97  98     0.75
UNDESIRABLE STATES        1
  15       22  23  24
           46  47  48
           70  71  72
           94  95  96
          118 119 120     0.1
STEADY STATES             0
PERCENTAGES               0
ENDATA
```

(b)

Figure A-9. PROGRAM ADOT--(a) JCL; (b) INPUT FILE SXSIN

```
          1. TITLE
     REAL LIFE PROBLEM
          2. ROAD INFORMATION
TRAFFIC       3           REGION       3
          3. CONTROL INFORMATION
PROBLEM NAME                 REAL
CURRENT COND. NAME           120STATE
TRANSITION PROB. NAME        120STATE
COST NAME                    120STATE
PLANNING PERIOD                 1
ESTIMATED STORAGE            6000
OBJECTIVE                       1
PRINT OPTION                    0
NUMBER OF STATES              120
NUMBER OF ACTIONS              17
DISCOUNT FACTOR                0.00
          4. INFEASIBLE ACTIONS                          2
STATES                                               ACTIONS
    1    2   25   26   49   50                           3    4    5    6    7
   73   74   97   98                                     9   10   11   12   13   1
                                                        15   16   17

   22   23   24   46   47   48                           1    2
   70   71   72   94   95   96
  118  119  120

          5. CURRENT CONDITION                           3
STATE           PROPORTION
   1            0.92450592
   9            0.03967872
  19            0.03581536
          6. DESIRABLE STATES                            1
STATES                                                             PROPORTION
    1    2   25   26   49   50   73   74   97   98                   0.7500
          7. UNDESIRABLE STATES                          1
STATES                                                             PROPORTION
   22   23   24   46   47   48   70   71   72   94
   95   96  118  119  120                                           0.1000
          8. STEADY STATES                               0
          9. PERCENTAGES                                 0
          STATUS MESSAGES
DATA SUCCESSFULLY READ IN
COSTS SUCCESSFULLY READ IN
TRANSITION PROBABILITIES SUCCESSFULLY READ IN
ROWS SECTION SUCCESSFULLY GENERATED
COLUMNS SECTION SUCCESSFULLY GENERATED
RHS GENERATION COMPLETE
```

Figure A-9. PROGRAM ADOT--(c) OUTPUT FILE SXSOUT

```
NAME            REAL
ROWS
 E  TOTALL
 E  BAL01001
 E  BAL01002
 E  BAL01003

       .
       .
       .

 E  BAL01120
 G  DS0101
 L  US0101
 N  COST
COLUMNS
    W0101001  TOTALL         1.0000000
    W0101001  BAL01001   -.3581139319
    W0101001  BAL01004   0.1404877740
    W0101001  BAL01009   0.1785478819
    W0101001  BAL01012   0.0390782660
    W0101001  DS0101         1.0000000
    W0101001  COST           0.0660000
    W0101002  TOTALL         1.0000000

                  .
                  .
                  .

    W0101117  TOTALL         1.0000000
    W0101117  BAL01105   0.0000000000
    W0101117  BAL01107   0.0000000162
    W0101117  BAL01111   0.0000071238
    W0101117  BAL01113   0.0000000800
    W0101117  BAL01115   0.0022687738
    W0101117  BAL01119   0.9977240062
    W0101117  BAL01117      -1.0000000
    W0101117  COST           0.1930000
    W0102001  TOTALL         1.0000000

                  .
                  .
                  .

    W0116120  TOTALL         1.0000000
    W0116120  BAL01073   0.9828606200
    W0116120  BAL01081   0.0168817100
    W0116120  BAL01089   0.0002576700
    W0116120  BAL01120      -1.0000000
    W0116120  US0101         1.0000000
    W0116120  COST           5.8110000
    W0117003  TOTALL         1.0000000
    W0117003  BAL01097   0.9988027100
    W0117003  BAL01105   0.0011939600
    W0117003  BAL01113   0.0000033200
    W0117003  BAL01003      -1.0000000
    W0117003  COST           6.3360000
    W0117004  TOTALL         1.0000000

                  .
                  .
                  .

    W0117120  TOTALL         1.0000000
    W0117120  BAL01097   0.9846538500
    W0117120  BAL01105   0.0150456700
    W0117120  BAL01113   0.0003004800
    W0117120  BAL01120      -1.0000000
    W0117120  US0101         1.0000000
    W0117120  COST           6.3360000
RHS
    RHS       TOTALL         1.0000000
    RHS       DS0101         0.7500000
    RHS       US0101         0.1000000
ENDATA
```

Figure A-9. PROGRAM ADOT--(d) OUTPUT FILE MATRIX

```
//RU057    JOB (1000,0584,39,1),'DP500000I 133A NOS',NOTIFY=RU057,
//             MSGCLASS=Q
/*AFTER  RU057A
//JOBLIB   DD DSN=GP551.MPS.SYSTM360,DISP=SHR
//MPSCOMP  EXEC PGM=DJLCOMP,REGION=86K
//SCRATCH1  DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH2 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH3 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH4 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SYSMLCP  DD  UNIT=3350,SPACE=(TRK,(2,2)),DISP=(NEW,PASS)
//SYSPRINT DD  SYSOUT=Q
//SYSABEND DD  DUMMY
//SYSIN    DD  *
          PROGRAM('PM')
          INITIALZ
          MOVE(XDATA,'REAL')
          MOVE(XPBNAME,'PBFILE')
          MOVE(XOBJ,'COST')
          MOVE(XRHS,'RHS')
          CONVERT('SUMMARY')
          SETUP
          TITLE('STEADY STATE RUN ')
          XTOLV= 0.000001
          XTOLDJ=0.00001
          WRITE('XTOLV=',XTOLV,'XTOLDJ=',XTOLDJ,'STEADY STATE RUN')
          OPTIMIZE
          SOLUTION('BASIS')
          EXIT
          PEND
/*
//MPSEXEC  EXEC PGM=DJLEXEC,COND=(0,NE,MPSCOMP),PARM=TASK,REGION=86K
//SCRATCH1 DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//SCRATCH2 DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//PROBFILE DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//MATRIX1  DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//ETA1     DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//SYSMLCP  DD  DSNAME=*.MPSCOMP.SYSMLCP,DISP=(OLD,DELETE)
//SYSPRINT DD  DSN=RU057.S23.DATA,UNIT=3350,VOL=SER=DOT432,
//             DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3591),
//             SPACE=(TRK,(50,25),RLSE),DISP=(NEW,CATLG)
//SYSABEND DD  DUMMY
//SYSPUNCH DD  SYSOUT=B
//SYSIN    DD  DSN=RU057.MATRIX.DATA(S23),DISP=SHR
/*
```

Figure A-10. MPSX—(a) JCL AND CONTROL LANGUAGE

```
XTOLV=    .99999966E-07     XTOLDJ=    .99999997E-05     STEADY STATE RUN


SOLUTION   (OPTIMAL)
TIME =   0.54 MINS. ITERATION NUMBER =  1347
    BASIS
         ...NAME...     ...ACTIVITY...       DEFINED AS
         FUNCTIONAL           .23391          COST
         RESTRAINTS                           RHS
.MPSX-PTF18.   STEADY STATE RUN                                                                     PAGE     48
SECTION 1 - ROWS
 NUMBER  ...ROW..  AT  ...ACTIVITY...  SLACK ACTIVITY  ..LOWER LIMIT.  ..UPPER LIMIT.  .DUAL ACTIVITY
     39  BAL01038  BS        .                .               .               .               .
    123  US0101    BS        .              .10000           NONE           .10000            .
    124  COST      BS      .23391           .23391-          NONE            NONE          1.00000
.MPSX-PTF18.   STEADY STATE RUN                                                                     PAGE     49
SECTION 2 - COLUMNS
 NUMBER  .COLUMN.  AT  ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.

    146  W0101025  BS      .75000           .06600            .             NONE              .
    254  W0102028  BS      .06043           .58600            .             NONE              .
    358  W0103028  BS      .01300           .78600            .             NONE              .
    363  W0103033  BS      .15614           .78600            .             NONE              .
    366  W0103036  BS      .02043           .78600            .             NONE              .


EXIT - TIME =   0.55
```

Figure A-10. MPSX—(b) OUTPUT FILE SXSPRINT

```
//RU057     JOB (1000,0584,79,1),'DF500000I 133A NOS',NOTIFY=RU057,
//             MSGCLASS=Q
//CL        EXEC PGM=ADOTD,REGION=512K
//STEPLIB DD DSN=EU209.P.LOADLIB,DISP=SHR
//SXSIN DD DISP=SHR,DSN=RU057.ADOTIN.DATA(H33A1)
//COSTF DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(COSTF120)
//TRMX  DD DISP=SHR,DSN=RU057.TR.DATA(TR33)
//CURNT DD DISP=SHR,DSN=RU057.TEMPDATA.DATA(CC33)
//MATRIX DD DSN=RU057.X33A1.DATA,UNIT=3350,VOL=SER=DOT432,
//             DCB=(RECFM=FB,LRECL=40,BLKSIZE=3600),
//             SPACE=(TRK,(9,9),RLSE),DISP=(NEW,CATLG)
//SXSOUT DD DSN=RU057.A33A1.DATA,UNIT=3350,VOL=SER=DOT432,
//             DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3591),
//             SPACE=(TRK,(5,3),RLSE),DISP=(NEW,CATLG)
//
```

(a)

```
TITLE
   REAL LIFE PROBLEM
ROAD INFORMATION
  TRAFFIC=3  REGION=3;
CONTROL IHFORMATION
 FNAME='REAL' HORIZON=5 STORAGE=6000 OBJECTIVE=3 NUSTAT=120 CURNAME='120STATE'
 CNAME='120STATE' TNAME='120STATE' DISCOUNT=0.0 NUACT=17 OBJVAL=0.24561;
INFEASIBLE ACTIONS         2
 10   1 2 25 26 49 50 73 74 97 98    15   3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
 15   22 23 24 46 47 48 70 71 72 94 95 96 118 119 120   2   1 2
DESIRABLE STATES           1
   10        1   2
            25  26
            49  50
            73  74
            97  98     0.75
UNDESIRABLE STATES         1
  15       22  23  24
           46  47  48
           70  71  72
           94  95  96
          118 119 120     0.1
STEADY STATES              1
 4         25     .75
           28     .07343
           33     .15614
           36     .02043    .01
PERCENTAGES                3
 2    0.4    2.0
 3    0.6    1.6
 4    0.8    1.3
ENDATA
```

(b)

Figure A-11. PROGRAM ADOT--(a) JCL; (b) INPUT FILE SXSIN

```
          1. TITLE
     REAL LIFE PROBLEM
          2. ROAD INFORMATION
TRAFFIC       3          REGION       3
          3. CONTROL INFORMATION
PROBLEM NAME              REAL
CURRENT COND. NAME        120STATE
TRANSITION PROB. NAME     120STATE
COST NAME                 120STATE
PLANNING PERIOD               5
ESTIMATED STORAGE          6000
OBJECTIVE                     3
PRINT OPTION                  0
NUMBER OF STATES            120
NUMBER OF ACTIONS            17
DISCOUNT FACTOR               0.00
SS CONSTRAINT                 0.24561
          4. INFEASIBLE ACTIONS                      2
STATES                                           ACTIONS
   1    2   25   26   49   50                       3    4    5    6    7
  73   74   97   98                                 9   10   11   12   13   1
                                                   15   16   17

  22   23   24   46   47   48                       1    2
  70   71   72   94   95   96
 118  119  120

          5. CURRENT CONDITION                      3
STATE          PROPORTION
  1            0.92450592
  9            0.03967872
 19            0.03581536
          6. DESIRABLE STATES                       1
                                                              PROPORTION
STATES
   1    2   25   26   49   50   73   74   97   98               0.7500
          7. UNDESIRABLE STATES                     1
                                                              PROPORTION
STATES
  22   23   24   46   47   48   70   71   72   94
  95   96  118  119  120                                        0.1000
          8. STEADY STATES                          1
STATE     PROPORTION     INTERVAL SIZE     MINIMUM      MAXIMUM
  25       0.750000        1.000000 %      0.746250     0.753750
  28       0.073430        1.000000 %      0.073063     0.073797
  33       0.156140        1.000000 %      0.155359     0.156921
  36       0.020430        1.000000 %      0.020328     0.020532
          9. PERCENTAGES                            3
PERIOD          DESIRABLE       UNDESIRABLE
  2               0.4000          2.0000
  3               0.6000          1.6000
  4               0.8000          1.3000
          STATUS MESSAGES
DATA SUCCESSFULLY READ IN
COSTS SUCCESSFULLY READ IN
TRANSITION PROBABILITIES SUCCESSFULLY READ IN
ROWS SECTION SUCCESSFULLY GENERATED
COLUMNS SECTION SUCCESSFULLY GENERATED
RHS GENERATION COMPLETE
```

Figure A-11. PROGRAM ADOT--(c) OUTPUT FILE SKSOUT

```
NAME          REAL
ROWS
 E  TOTAL001
 E  TOTAL002
 E  TOTAL003
 E  TOTAL004
      .
      .
      .
 E  TOTAL120
 E  BAL01001
 E  BAL01002
 E  BAL01003
      .
      .
      .
 E  BAL01120
 E  BAL02001
 E  BAL02002
 E  BAL02003
      .
      .
      .
 E  BAL02120
 G  DS0201
 L  US0201
 E  BAL03001
 E  BAL03002
      .
      .
      .
 E  BAL04120
 G  DS0401
 L  US0401
 G  DS0501
 L  US0501
 G  SSMIN025
 L  SSMAX025
 G  SSMIN028
 L  SSMAX028
 G  SSMIN033
 L  SSMAX033
 G  SSMIN036
 L  SSMAX036
 L  SSCOST
 N  TRCOST
COLUMNS
    W0101001  TOTAL001     1.0000000
    W0101001  BAL01001  0.6418860681
    W0101001  BAL01004  0.1404877740
    W0101001  BAL01009  0.1785478819
    W0101001  BAL01012  0.0390782660
    W0101001  TRCOST       0.0660000
    W0101002  TOTAL002     1.0000000
                 .
                 .
                 .
    W0117120  TOTAL120     1.0000000
    W0117120  BAL01097  0.9846538500
    W0117120  BAL01105  0.0150456700
    W0117120  BAL01113  0.0003004800
    W0117120  TRCOST       6.3360000
    W0201001  BAL01001    -1.0000000
    W0201001  BAL02001  0.6418860681
    W0201001  BAL02004  0.1404877740
    W0201001  BAL02009  0.1785478819
    W0201001  BAL02012  0.0390782660
    W0201001  DS0201       1.0000000
    W0201001  TRCOST       0.0660000
    W0201002  BAL01002    -1.0000000
    W0201002  BAL02001  0.0449715921
    W0201002  BAL02004  0.7374022500
                 .
                 .
```

Figure A-11. PROGRAM ADOT--(d) OUTPUT FILE MATRIX (2 pages)

```
    W0417120   BAL03120     -1.0000000
    W0417120   BAL04097   0.9846538500
    W0417120   BAL04105   0.0150456700
    W0417120   BAL04113   0.0003004800
    W0417120   US0401        1.0000000
    W0417120   TRCOST        6.3360000
    W0501001   BAL04001     -1.0000000
    W0501001   DS0501        1.0000000
    W0501001   SSCOST        0.0660000
    W0501002   BAL04002     -1.0000000
    W0501002   DS0501        1.0000000
    W0501002   SSCOST        0.0660000
    W0501003   BAL04003     -1.0000000
    W0501003   SSCOST        0.1580000

                  .
                  .
                  .

    W0501021   BAL04021     -1.0000000
    W0501021   SSCOST        0.1930000
    W0501025   BAL04025     -1.0000000
    W0501025   DS0501        1.0000000
    W0501025   SSMIN025      1.0000000
    W0501025   SSMAX025      1.0000000
    W0501025   SSCOST        0.0660000
    W0501026   BAL04026     -1.0000000
    W0501026   DS0501        1.0000000
    W0501026   SSCOST        0.0660000

                  .
                  .
                  .

    W0517120   BAL04120     -1.0000000
    W0517120   US0501        1.0000000
    W0517120   SSCOST        6.3360000
RHS
    RHS        TOTAL001   0.9245059242
    RHS        TOTAL002   0.0000000000
    RHS        TOTAL003   0.0000000000
    RHS        TOTAL004   0.0000000000
    RHS        TOTAL005   0.0000000000
    RHS        TOTAL006   0.0000000000
    RHS        TOTAL007   0.0000000000
    RHS        TOTAL008   0.0000000000
    RHS        TOTAL009   0.0396787186
    RHS        TOTAL010   0.0000000000
    RHS        TOTAL011   0.0000000000
    RHS        TOTAL012   0.0000000000
    RHS        TOTAL013   0.0000000000
    RHS        TOTAL014   0.0000000000
    RHS        TOTAL015   0.0000000000
    RHS        TOTAL016   0.0000000000
    RHS        TOTAL017   0.0000000000
    RHS        TOTAL018   0.0000000000

                  .
                  .
                  .

    RHS        TOTAL120   0.0000000000
    RHS        DS0201        0.3000000
    RHS        US0201        0.2000000
    RHS        DS0301        0.4500000
    RHS        US0301        0.1600000
    RHS        DS0401        0.6000000
    RHS        US0401        0.1300000
    RHS        DS0501        0.7500000
    RHS        US0501        0.1000000
    RHS        SSMIN025   0.7462500000
    RHS        SSMAX025   0.7537500000
    RHS        SSMIN028   0.0730628500
    RHS        SSMAX028   0.0737971500
    RHS        SSMIN033   0.1553593000
    RHS        SSMAX033   0.1569207000
    RHS        SSMIN036   0.0203278500
    RHS        SSMAX036   0.0205321500
    RHS        SSCOST        0.2456100
ENDATA
```

Figure A-11. PROGRAM ADOT--(d) OUTPUT FILE MATRIX (Concluded)

```
//RU057     JOB (1000,0584,599,1),'DP500000I 133A NOS',NOTIFY=RU057
//             MSGCLASS=Q
/*AFTER  RU057A
//JOBLIB    DD DSN=GP551.MPS.SYSTM360,DISP=SHR
//MPSCOMP   EXEC PGM=DJLCOMP,REGION=86K
//SCRATCH1  DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH2 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH3 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SCRATCH4 DD  UNIT=3350,SPACE=(TRK,(2,2))
//SYSMLCP  DD  UNIT=3350,SPACE=(TRK,(2,2)),DISP=(NEW,PASS)
//SYSPRINT DD  SYSOUT=Q
//SYSABEND DD  DUMMY
//SYSIN     DD  *
            PROGRAM('PM')
            INITIALZ
            MOVE(XDATA,'REAL')
            MOVE(XPBNAME,'PBFILE')
            MOVE(XOBJ,'TRCOST')
            MOVE(XRHS,'RHS')
            CONVERT('SUMMARY')
            SETUP
            TITLE('MULTI-PERIOD RUN')
            XTOLV= 0.000001
            XTOLDJ=0.00001
            WRITE('XTOLV=',XTOLV,'XTOLDJ=',XTOLDJ,'MULTI-PERIOD RUN')
            OPTIMIZE
            SOLUTION('BASIS')
            EXIT
            PEND
/*
//MPSEXEC  EXEC PGM=DJLEXEC,COND=(0,NE,MPSCOMP),PARM=TASK,REGION=86
//SCRATCH1 DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//SCRATCH2 DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//PROBFILE DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//MATRIX1  DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//ETA1     DD  UNIT=3350,SPACE=(CYL,(4),,CONTIG)
//SYSMLCP  DD  DSNAME=*.MPSCOMP.SYSMLCP,DISP=(OLD,DELETE)
//SYSPRINT DD  DSN=RU057.H31A01.DATA,UNIT=3350,VOL=SER=DOT432,
//             DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3591),
//             SPACE=(TRK,(50,25),RLSE),DISP=(NEW,CATLG)
//SYSABEND DD  DUMMY
//SYSPUNCH DD  SYSOUT=B
//SYSIN    DD  DSN=RU057.X31A1.DATA,DISP=SHR
/*
```

Figure A-12. MPSX—(a) JCL AND CONTROL LANGUAGE STATEMENTS

XTOLV= .99999943E-06 XTOLDJ= .99999997E-05 MULTI-PERIOD RUN

SOLUTION (OPTIMAL)
TIME = 5.36 MINS. ITERATION NUMBER = 3090
BASIS

...NAME...	...ACTIVITY...	DEFINED AS
FUNCTIONAL	1.00387	TRCOST
RESTRAINTS		RHS

.MPSX-PTF18. FIVE PERIOD RUN PA(
SECTION 1 - ROWS

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
361	DS0201	BS	.59343	.29343-	.30000	NONE	.
362	US0201	BS	.00313	.19687	NONE	.20000	.
484	US0301	BS	.00150	.15850	NONE	.16000	.
605	DS0401	BS	.81220	.21220-	.60000	NONE	.
606	US0401	BS	.	.13000	NONE	.13000	.
608	US0501	BS	.	.10000	NONE	.10000	.
610	SSMAX025	BS	.74625	.00750	NONE	.75375	.
612	SSMAX028	BS	.07306	.00073	NONE	.07380	.
613	SSMIN033	BS	.15692	.00156-	.15536	NONE	.
616	SSMAX036	BS	.02033	.00020	NONE	.02053	.
617	SSCOST	BS	.20467	.04094	NONE	.24561	.
618	TRCOST	BS	1.00387	1.00387-	NONE	NONE	1.00000

.MPSX-PTF18. FIVE PERIOD RUN PAC
SECTION 2 - COLUMNS

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
619	W0101001	BS	.92451	.06600	.	NONE	.
627	W0101009	BS	.03968	.08700	.	NONE	.
637	W0101019	BS	.03582	.19300	.	NONE	.
2479	W0201001	BS	.59343	.06600	.	NONE	.
2482	W0201004	BS	.12988	.15800	.	NONE	.
2487	W0201009	BS	.18927	.08700	.	NONE	.
2495	W0201017	BS	.00836	.10200	.	NONE	.
2562	W0201093	BS	.00150	.19300	.	NONE	.
2698	W0203012	BS	.04142	.78600	.	NONE	.
2705	W0203019	BS	.03269	.78600	.	NONE	.
2706	W0203020	BS	.00183	.78600	.	NONE	.
2709	W0203023	BS	.00162	.78600	.	NONE	.
2819	W0204023	BS	.00150	2.08600	.	NONE	.
4339	W0301001	BS	.10283	.06600	.	NONE	.
4347	W0301009	BS	.01465	.08700	.	NONE	.
4353	W0301015	BS	.01270	.33200	.	NONE	.
4360	W0301025	BS	.06908	.06600	.	NONE	.
4444	W0302001	BS	.27809	.58600	.	NONE	.
4446	W0302003	BS	.05597	.58600	.	NONE	.
4447	W0302004	BS	.08337	.58600	.	NONE	.
4450	W0302007	BS	.04565	.58600	.	NONE	.
4555	W0303009	BS	.20672	.78600	.	NONE	.
4557	W0303011	BS	.01557	.78600	.	NONE	.
4558	W0303012	BS	.04845	.78600	.	NONE	.
4562	W0303016	BS	.01270	.78600	.	NONE	.
4563	W0303017	BS	.04671	.78600	.	NONE	.
4564	W0303018	BS	.00072	.78600	.	NONE	.
4566	W0303020	BS	.01172	.78600	.	NONE	.
4577	W0303033	BS	.00707	.78600	.	NONE	.
4585	W0303041	BS	.00142	.78600	.	NONE	.
4631	W0303091	BS	.00000	.78600	.	NONE	.
4745	W0304095	BS	.00150	2.08600	.	NONE	.
6199	W0401001	BS	.00584	.06600	.	NONE	.
6220	W0401025	BS	.74619	.06600	.	NONE	.
6229	W0401034	BS	.00001	.08700	.	NONE	.
6304	W0402001	BS	.06016	.58600	.	NONE	.
6410	W0403004	BS	.01445	.78600	.	NONE	.
6415	W0403009	BS	.02729	.78600	.	NONE	.
6418	W0403012	BS	.00597	.78600	.	NONE	.
6423	W0403017	BS	.00304	.78600	.	NONE	.
6432	W0403028	BS	.00676	.78600	.	NONE	.
6437	W0403033	BS	.12603	.78600	.	NONE	.
6440	W0403036	BS	.00188	.78600	.	NONE	.
6445	W0403041	BS	.00237	.78600	.	NONE	.
6468	W0403066	BS	.00272	.78600	.	NONE	.
8059	W0501001	BS	.00375	.	.	NONE	.
8062	W0501004	BS	.00082	.	.	NONE	.
8067	W0501009	BS	.00104	.	.	NONE	.
8080	W0501025	BS	.74625	.	.	NONE	.
8083	W0501028	BS	.07306	.	.	NONE	.
8088	W0501033	BS	.15692	.	.	NONE	.
8096	W0501041	BS	.00032	.	.	NONE	.
9818	W0517012	BS	.00023	.	.	NONE	.
9840	W0517036	BS	.02033	.	.	NONE	.

Figure A-12. MPSX—(b) OUTPUT FILE SXSPRINT

Appendix B

DEVELOPMENT OF TRANSITION PROBABILITIES

A major input to the network optimization system (NOS) is the set of transition probabilities, $p_{ij}(a_k)$. The probability, $p_{ik}(a_k)$ can be interpreted as the proportion of roads in state i that move to state j in one year if the k^{th} rehabilitation action is applied. A complete set of transition probabilities is generated for each combination of traffic and regional factors.

If available, transition probabilities are usually calculated directly from data about pavement performance. For this study, such data was not available. Consequently, a sample of pavement performance data was collected, regression equations based on the analysis of sample data were developed, and transition probabilities were then calculated from the regression equations. These three steps are discussed in this appendix.

Collection of Sample Data of Pavement Performance

Roughness and cracking are the two performance variables that were included in the NOS. Thus, the data required for performance models was the behavior of these two variables over time for pavements in different conditions and under different rehabilitation actions. In order that representative sample data was collected, a fractional factorial design, shown in Figure B-1, was used. The variables used for this design were conventional engineering variables (deflection, traffic, age, etc.). The objective was to select one or two projects from each "cell" (i.e., each combination of given variables). It was recognized, however, that it

1/3 FACTORIAL DESIGN: FILL THE CELLS WHICH ARE MARKED.
(Requires a total of 27 units.)

Ride Index	Deflection	Environment 1: 3 to 7	1: 8 to 12	1: 13 to 17	2: 3 to 7	2: 8 to 12	2: 13 to 17	3: 3 to 7	3: 8 to 12	3: 13 to 17
H	H		X		X					X
	M	X					X		X	
	L			X		X		X		
M	H	X					√		X	
	M			X		√		X		
	L		X		X					X
L	H			√		X		X		
	M		√		X					√
	L	X					X		√	

Figure B-1. Factorial Design for Data Collection

X = Main Experiment √ = Replicates

might be difficult to find roads in the uncommon combinations of variables. Therefore, the experimental design was used primarily as a guideline for the selection of projects rather than a strict requirement for data collection.

Previous experience has shown that it is useful to develop two sets of performance models--one for roads on which only routine maintenance is performed and one for roads on which an overlay is applied. For this reason, separate sample data that corresponded to the two sets of roads were collected.

Details of data collection and compilation are described in a research report prepared by the ADOT.

Development of Regression Equations

Two sets of regression equations were developed--one for newly constructed roads on which only routine maintenance is performed and one for roads on which an overlay was applied. Each set contained two equations--one for predicting the annual change in roughness and one for predicting the annual change in cracking. Thus, four regression equations were developed.

To keep the size of the NOS within manageable limits, it was necessary to restrict the total number of independent variables in all regression equations to no more than four. The initial efforts in developing the necessary regression equations attempted to correlate the dependent variables (change in roughness or cracking) with conventional engineering variables including traffic, regional factors, deflection, age, and AC thickness. However, very low correlation coefficients were obtained for the corresponding regression equations.

Therefore, an alternative approach was used. In this approach, it was argued that the influence of a number of engineering and regional factors was manifested in pavement performance. Hence, present values of performance variables and the rate of change in these variables should show a strong correlation with future pavement performance. This approach was consistent with the NOS because the primary requirement of the NOS was to predict what happened to pavements (i.e., how pavements performed) rather than why it happened (i.e., causes of specific pavement performance). It should also be recognized that although engineering causes of pavement distress may not be considered in the planning and management aspects, such causes would be included in the preparation of site-specific overlay designs based on detailed field investigations.

With the alternative approach in mind, the independent variables considered were present pavement condition (roughness or cracking), and change in pavement condition during the previous year. The engineering variables used previously were also included to see if any of them became significant with the inclusion of the pavement condition variables.

The C_p-search technique described in Daniel and Wood (1971)* was used to select the best set of independent variables. Regression equations for all possible combinations of independent variables are developed in this procedure. These equations are ranked in the increasing order of the estimate of total squared error, C_p. Equations with smaller C_p values are better from the viewpoint of estimating values of the dependent variable. The C_p-search technique is considered more useful than the conventional stepwise multiple regression analysis. The C_p-search generally provides several alternative equations that have about the same C_p value. Other factors (judgmental) can then be used to select one of

*Daniel C. and F.S. Wood. 1971. Fitting Equations to Data, Wiley-Interscience.

these equations. Such factors may include number of independent variables in an equation and signs of regression coefficients.

The details of the four regression equations selected for this study are shown below.

1. Change in roughness under routine maintenance:

$$R_N = -0.125 + 0.138R_o + 2.65R_G^2 - 0.046R_G x R_o \qquad \text{(B-1)}$$

in which:

R_N = change in roughness in 1 year
R_o = present roughness
R_G = regional factor.

<u>Summary Statistics</u>

R^2 = 0.54
Standard Error = 10.4
F-Value = 38.

2. Change in amount of cracking of newly constructed roads under routine maintenance:

$$C_N = 0.198 + 0.56C_p + 0.05C_p^2 + 0.009R_G^2 + 0.049R_G x C_o - 0.0035C_o^2 \qquad \text{(B-2)}$$

in which:

C_N = change in percent cracking in next year
C_p = change in percent cracking in previous year.

Summary Statistics

$$R^2 = 0.70$$
Standard Error = 0.64
F-Value = 84.

3. Change in roughness following an overlay:

$$R_o' = C_F(R_o - R_N) \quad \text{(B-3)}$$

in which:

R_o' = roughness at the end of 1 year following an overlay

C_F = correction factor for special treatment (such as heater scarifier or asphalt rubber)

R_o = roughness just prior to the overlay

R_N = difference between R_o and R_o' for an overlay without special treatment, predicted from an equation shown below.

Table B-1 shows values of C_F for various rehabilitation actions. In this table, C_F = 1 implies on overlay without any special treatment. The variable R_N is predicted from

$$R_N = 0.44 + 9.3t_h + 1.04R_o - 1.77t_h^2 - 0.0012R_o^2 + 0.059(R_o x t_h) \quad \text{(B-4)}$$

Table B-1. CORRECTION FACTORS FOR REHABILITATION ACTIONS

Action Index	Action Description	Correction Factor C_F
1	Routine Maintenance	1.0
2	Seal Coat	1.0
3	ACFC	1.0
4	ACFC + (AR)	0.75
5	ACFC + (HS)	0.80
6	1.5 inches AC	1.0
7	1.5 inches AC + AR	0.6
8	1.5 inches AC + HS	0.7
9	2.5 inches AC	1.0
10	2.5 inches AC + AR	0.5
11	2.5 inches AC + HS	0.6
12	3.5 inches AC	1.0
13	3.5 inches AC + AR	0.4
14	3.5 inches AC + HS	0.5
15	4.5 inches AC	1.0
16	5.5 inches AC	1.0
17	Recycling	1.0

in which:

t_h = overlay thickness.

Summary Statistics

$$R^2 = 0.71$$
$$\text{Standard Error} = 23.8$$
$$\text{F-Value} = 51.$$

Once the roughness at the end of the first year following an overlay is determined, the subsequent roughness of a road with routine maintenance is predicted from Equation B-1. Thus, the overlay roughness equation provides a "starting" value which, in turn, is used with Equation B-1 to estimate the succeeding roughness values.

4. Change in amount of cracking following an overlay:

$$C_N = 0.507 + 0.0687C_o + 0.52C_p - 0.0034I_c^2 - 0.003C_o^2 + 0.0681C_p^2 \qquad \text{(B-5)}$$

in which:

I_c = index to first crack (expressed in number of years to the first crack following an overlay).

The variable I_c is a function of traffic volume, regional factor, and type of rehabilitation action.

If I_c of a rehabilitation action is greater than 16, Equations B-2 and B-5 predict similar changes in cracking. This means that such a rehabilitation action is equivalent to new construction with regard to cracking.

Summary Statistics

R^2 = 0.68

Standard Error = 0.71

F-Value = 77.

Calculation of Transition Probabilities

The calculation of transition probabilities for a given combination of traffic volume and region factor was based on the regression equations described above. The calculation was completed in the following three steps.

(1) The probability of going from the roughness value of one state (say i) to the roughness value of another state (say j) was calculated for each i, j, and every rehabilitation action.

(2) The probability of going from the cracking value of state i to the cracking value of state j was calculated for each i, j, and every rehabilitation action.

(3) The above probabilities were multiplied to obtain the transition probability of going from state i to state j under a given rehabilitation action.

These three steps are repeated for each combination of traffic volume and regional factor to obtain the transition probabilities for that combination. The calculations involved in each step are discussed below.

Calculation of probabilities of going from one range of roughness value to another. Let R_o denote the present roughness of a road in a category with a regional factor R_G. The expected change in roughness, R_N, of this road in the following year, after routine maintenance, is given by Equation B-1. The variance of R_N, can be calculated from the variance-covariance matrix of the regression coefficients and the standard error term. Assuming a normal distribution for R_N, the probability that R_N will be in a given range can be calculated from the expected value and variance of R_N.

For a discrete-state model assumed for this study, each state was defined by a range of values for each variable included in the analysis. The ranges of roughness values were: ≤ 165, 165.1 to 255, and > 255. In order to improve the accuracy of calculating probabilities of going from one range of roughness to another, each range was further divided into finer subranges and each subrange was represented by a single value as shown below.

Range of Roughness	Subranges of Roughness	Representative Value for the Subrange
< 165	0 - 40	20
	40.1 - 80	60
	80.1 - 120	100
	120.1 - 165	142.5
165.1 - 255	165.1 - 190	177.5
	190.1 - 210	200
	210.1 - 235	222.5
	235.1 - 255	245
> 255	255.1 - 300	277.5
	300.1 - 350	325
	350.1 - 400	375
	400.1 - 500	450

Next, the probability of going from one range of roughness to each of the three roughness ranges in 1 year is calculated. To do this, the representative value of each subrange for the given range of roughness is considered and the probability of going from this representative value to each of the ranges is calculated. Then, each probability is weighed by the proportion of all roads in the range that belongs to the given subrange, and the weighted probabilities are summed. Mathematically, this can be expressed as follows.

$$P_{ij} = \sum_k P'_{kj}\, \Theta_{ik}, \quad \begin{array}{l} i,j = 1,2,3 \\ k = 1,2,3,4 \end{array} \tag{B-6}$$

in which P_{ij} = probability of going from i^{th} range of roughness to j^{th} range of roughness

P'_{kj} = probability of going from the representative value of k^{th} subrange of i^{th} range to j^{th} range

and Θ_{ik} = proportion of all roads of given category in i^{th} range that belong to k^{th} subrange.

The proportions, Θ_{ik} were estimated for each regional factor from the 1979 pavement condition survey. The probabilities P'_{kj} can be calculated from the distribuiton of R_N for the given regional factor and the representative value of k^{th} subrange. For example, consider the first subrange of the first range for which the representative value is 20. The probabilities P'_{kj} for this case are given by:

P'_{11} = Prob. (going from a roughness of 20 to a roughness of no more than 165)

$$= \text{Prob. } (R_N \leq 145). \qquad \text{(B-7)}$$

The probability on the right hand side of Equation B-7 can be calculated from the expected value and variance of R_N and assuming normal distribution for R_N.

Similarly,

P'_{12} = Prob. (going from a roughness of 20 to a roughness in the range of 165.1 to 225)

$$= \text{Prob. } (145 < R_N \leq 235) \qquad \text{(B-8)}$$

and P'_{13} = Prob. (going from a roughness of 20 to a roughness of greater than 255)

$$= \text{Prob. } (R_N > 235). \qquad \text{(B-9)}$$

Equation B-1 gives the probabilities of going from one range of roughness to another for an existing road under the policy of routine maintenance. If an overlay is applied to a pavement, the same procedure is used except that the equations predicting the roughness following an overlay are now used (Equations B-3 and B-4).

To illustrate this procedure, consider the representative roughness value of 325 just before a 2.5-inch overlay. The probabilities of going to each of the three ranges of roughness in 1 year following the overlay (i.e., probabilities P'_{21}, P'_{22}, and P'_{23}) should be calculated. First, from Equation B-4, the expected value and variance of R_N, $E[R_N]$ and $V[R_N]$, respectively are calculated. In this equation, we set $R_o = 325$ and $t_h = 2.5$. Next, the expected value and variance of R'_o can be calculated from Equation B-3 as follows:

$$E(R'_o) = C_F(R_o - E[R_N]) \quad \text{(B-10)}$$

and $$V(R'_o) = C_F^2 V(R_N). \quad \text{(B-11)}$$

Now, the required probabilities are given by:

$$P'_{21} = \text{Prob.}(R'_o \leq 165) \quad \text{(B-12)}$$

$$P'_{22} = \text{Prob.}(165 < R'_o \leq 255) \quad \text{(B-13)}$$

and $$P'_{23} = \text{Prob.}(R'_o > 255). \quad \text{(B-14)}$$

These probabilities are used in Equation B-6 to obtain the desired probabilities P_{ij}.

Calculation of probabilities of going from one range of cracking to another. Two factors related to cracking are important to the definition of condition state--present amount of cracking, C_o, and change in cracking in previous year, C_p. Each factor is represented by three levels resulting in a total of nine combinations of the two factors. However, the combination of low C_o (<10 percent) and high C_p (>15 percent) is not possible. Hence, only eight combinations of C_o and C_p have to be considered. The probability, Q_{ij}, of going from i^{th} combination of C_o and C_p to j^{th} combination of C_o and C_p in 1 year (for all i and j) should be calculated. The calculations of Q_{ij} following routine maintenance and following a rehabilitation action are described below.

Calculation of Q_{ij} following routine maintenance. It is reasonable to assume that, following routine maintenance, a significant reduction in the amount of cracking is not possible. Thus, the amount of cracking would either remain at its present level or increase. In addition, C_o and C_p are closely tied in the sense that the prediction of C_o at next year implies what C_p would be next year. For example, if the present amount of cracking is low (5 ± 5) and the amount of cracking next year is predicted to be high (45 ± 15), then this implies the change in cracking in 1 year (C_p next year) will be high (20 ± 5). Table B-2 shows the present present cracking, cracking at next year, and change in cracking at the beginning of next year.

The calculation of Q_{ij}, therefore, involves calculating the probability of going from a combination of C_o and C_p to a specified C_o next year, and the implied C_p next year.

An equation similar to Equation B-6 was used to calculate the probability Q_{ij}, of going from i^{th} combination of C_o and C_p to j^{th} combination of C_o and C_p in 1 year. Thus:

$$Q_{ij} = \sum_k Q'_{kj} \beta_{ik} \qquad \text{(B-15)}$$

in which Q'_{kj} = probability of going from the representative value of k^{th} subrange of i^{th} range of cracking to j^{th} range of cracking

and β_{ik} = proportion of all roads of given catregory in i^{th} range that belong to k^{th} subrange.

Equation B-15 is applicable for a given value of C_p, index to first crack, and regional factor. The subranges of cracking for each range of cracking and the representative value of each subrange are shown in Table B-3.

Table B-2. INTERRELATIONSHIP BETWEN C_o AT PRESENT TIME, AND C_o AND C_p AT NEXT YEAR

C_o at Present Time	C_o at Next Year	C_p at Next Year
5 (±5)	5 (±5)	2.5 (±2.5)
	20 (±10)	10 (±5)
	45 (±15)	20 (±5)
20 (±10)	20 (±10)	2.5 (±2.5)
	45 (±15)	10 (±5)
45 (±10)	45 (±15)	2.5 (±2.5)

Table B-3. REPRESENTATIVE VALUES FOR DIFFERENT SUBRANGES OF CRACKING

Range of Cracking	Subranges of Cracking	Representative Value of the Subrange
0 - 10	0 - 2	1
	2.1 - 5	2.5
	5.1 - 10	7.5
10.0 - 30	10.1 - 14	12
	14.1 - 20	17
	20.1 - 25	22.5
	25.1 - 30	27
30.1 - 60	30.1 - 35	32.5
	35.1 - 40	37
	40.1 - 45	42.5
	45.1 - 50	47.5
	50.1 - 60	55

The proportions, β_{ik}, were estimated for each region from the 1979 pavement condition survey. The Q_{ik} can be calculated from the distribution of cracking at next year, C_o', given the cracking at present time, C_o. The variable C_o' is related to C_o as follows:

$$C_o' = C_o + C_N \tag{B-16}$$

in which c_N, the change in cracking in next year, is obtained from Equation B-5.

To illustrate the calculation of Q_{kj}', consider the first subrange of the first range of cracking for which the representative cracking value is 1 percent. Let the value of C_p be 2.5 ($\pm$2.5) and the value of index to first crack be 2($\pm$ 2).

Then,

Q_{11}' = Prob. (going from a cracking of 1 percent to a cracking of no more than 10 percent)

$$= \text{Prob. } (C_N \leq 9). \tag{B-17}$$

The probability on the right hand side of Equation B-17 can be calculated from the expected value and variance of C_N using Equation B-5 and assuming normal distribution for C_N. In using Equation B-5, a representative value of C_p, C_o, and I_c are assumed. For the example, these values are 2.5, 5, and 2, respectively.

If the index to the first crack of the last rehabilitation action is greater than 16 years, Equation B-2 is used to obtain the distribution of C_N. If the index to the first crack of the last rehabilitation action is less than 16 years, Equation B-5 is used to obtain the distribution of C_N.

Similarly,

$$Q'_{12} = \text{Prob.}(9 < C_N \leq 29) \tag{B-18}$$

and $$Q'_{13} = \text{Prob.}(C_N > 29). \tag{B-19}$$

Thus, for this example, Q_{11} represents the probability of going from $C_o = 5\ (\pm 5)$ and $C_p = 2.5\ (\pm 2.5)$ to $C_o = 5\ (\pm 5)$ and $C_p = 2.5\ (\pm 2.5)$ in 1 year, following routine maintenance.

Calculation of Q_{ij} following a rehabilitation action. Following rehabilitation action, the amount of cracking in 1 year will be very small. Hence, $C_o = 5\ (\pm 5)$ and $C_p = 2.5\ (\pm 2.5)$ will be the condition of a pavement at the end of 1 year, following any rehabilitation action. The subsequent prediction of cracking is made from Equation B-5. Note that the index to first crack of the most recent rehabilitation action is an important factor in Equation B-5. For example, if the last action was a seal coat, the pavement is likely to show cracking sooner than if the last action was, say, a 2.5 inch overlay.

Calculation of transition probabilities from P_{ij} and Q_{ij}. It was reasonable to assume that the probabilities of changes in roughness were independent of the probabilities of changes in amount of cracking. Hence, the transition probabilities, $p_{ij}(a_k)$ of going from i^{th} state to j^{th} state in 1 year following the k^{th} rehabilitation action can be obtained by multiplying the corresponding probabilities P_{ij} and Q_{ij}. Thus,

$$p_{ij}(a_k) = (P_{ij} \text{ for } a_k) \times (Q_{ij} \text{ for } a_k). \tag{B-20}$$

In the following paragraphs, the general structure of the matrix transition probabilities is described first and then the specific structure of the matrix of transition probabilities under various rehabilitation actions.

General structure of the matrix transition probabilties. A state is defined as a specific combination of four factors: index to first crack (I_c), present roughness (R_o), present amount of cracking (C_o), and change in amount of cracking in last year (C_p). Each factor can assume one of several discrete levels. The various levels of R_o, C_o, and C_p produce a total 27 combinations; however, since the combination of low C_o and high C_p is not possible, a total of 24 combinations need to be considered. These combinations are shown in Table B-4. The variable I_c has five levels and hence a total of (24 x 5) = 120 combinations (states) are defined on the basis of all possible combinations of the four factors considered in the study. The 24 combinations of R_o, C_o, and C_p are repeated for each level of I_c. The states are numbered as shown below.

Level of I_c	State Numbers
18 (± 2)	1 - 24
2 (± 2)	25 - 48
6 (± 2)	49 - 72
10 (± 2)	73 - 96
14 (± 2)	97 - 120

Note that I_c of a rehabilitation action is estimated as a function of traffic and regional factor.

Structure of the matrix of transition probabilities for routine maintenance. Routine maintenance is only a temporary measure and is not expected to improve the pavement condition significantly. Hence, the index to first crack of the most recent rehabilitation action remains unchanged under routine maintenance. Only the diagonal boxes in the matrix of transition probabilities are, therefore, potentially filled under routine maintenance. This structure is shown in Figure B-2.

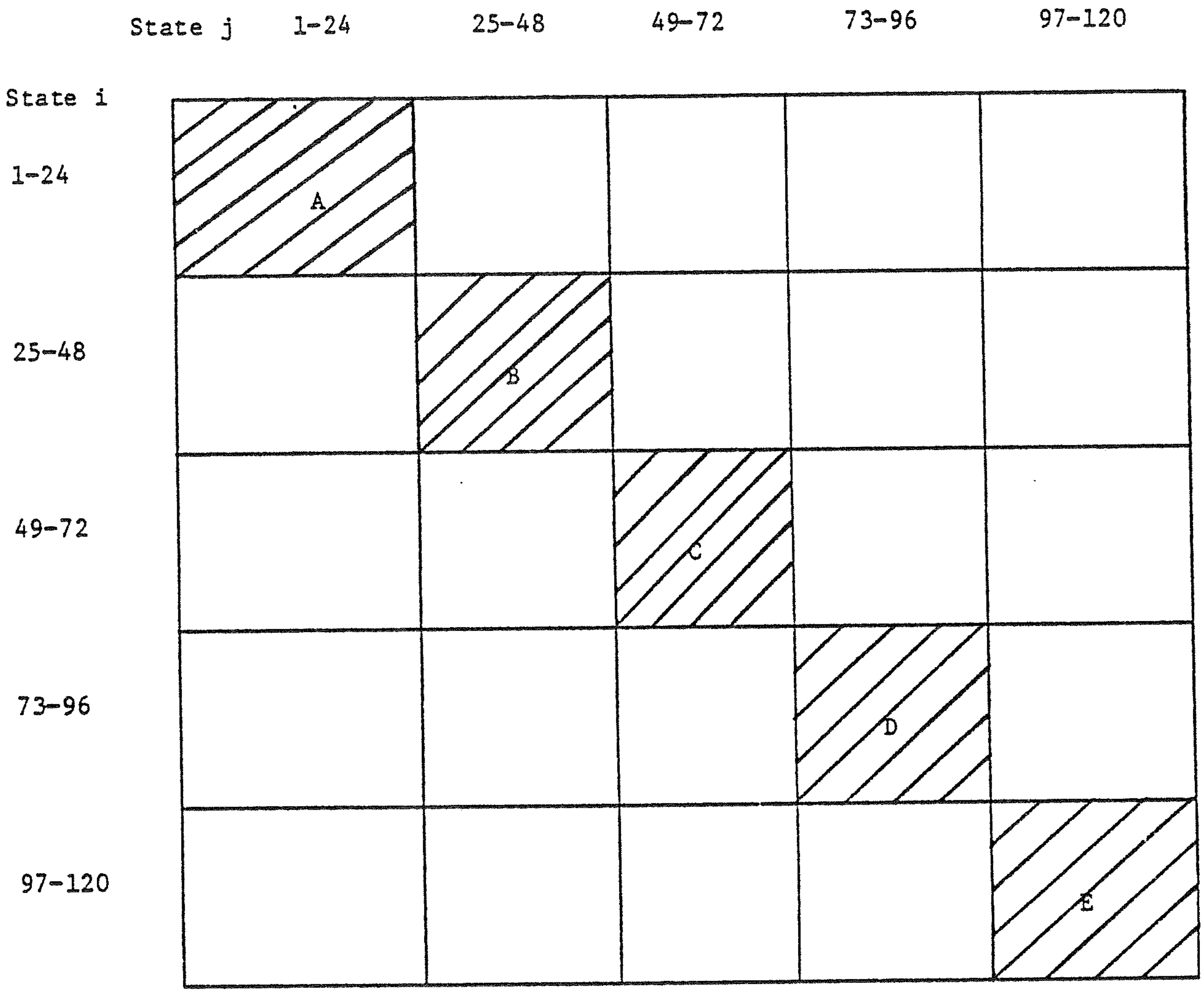

Figure B-2. STRUCTURE OF TRANSITION PROBABILITIES FOR ROUTINE MAINTENANCE

Table B-4. POSSIBLE COMBINATIONS OF R_o, C_o, AND C_p

State Index	Level of R_o	Level of C_o	Level of C_p
1	1	1	1
2	1	1	2
3	1	2	1
4	1	2	2
5	1	2	3
6	1	3	1
7	1	3	2
8	1	3	3
9	2	1	1
10	2	1	2
11	2	2	1
12	2	2	2
13	2	2	3
14	2	3	1
15	2	3	2
16	2	3	3
17	3	1	1
18	3	2	1
19	3	2	1
20	3	2	2
21	3	2	3
22	3	3	1
23	3	3	2
24	3	3	3

Only the probabilities related to change in cracking are dependent on the index to first crack of the most recent rehabilitation action. The probabilities related to change in roughness are independent of the index to first crack. Consequently, Q_{ij} are different for the different boxes in Figure B-2, while P_{ij} are the same for all boxes.

Let us now examine the organization of transition probabilities within each box in Figure B-2. Because of the interrelationship between C_o at present time, and C_o and C_p at next year shown in Table B-2, a pavement from any given state i can only go to some of all the possible states j. Consider, for example, transition from state 1 in box A. Considering the only possible combinations of C_o and C_p next year shown in Table B-2, the pavement in state 1 can only go states 1, 4, 8, 9, 12, 16, 17, 20, and 24. Of course, the probabilities of going to some of these states may be zero. Similar determinations can be made about the possible transition states, j from each given state, i for all boxes in Figure B-2.

The probabilities Q_{ij} for box A are obtained from Equation B-2, while probabilities P_{ij} for box A are obtained from Equation B-1. For any other box, Q_{ij} are obtained from Equation B-5, while P_{ij} are the same as those for box A.

As an illustration of the above procedure, let us consider the calculation of $p_{1,9}(1)$, i.e., the probability of going from state 1 to state 9. Let the probability of going from roughness level 1 to roughness level 2 in 1 year under routine maintenance be 0.5, and the probability of going from cracking level 1 to cracking level 1 in 1 year under routine maintenance may be 0.3. Then:

$$p_{1,9}(1) = 0.5 \times 0.3 = 0.15.$$

<u>Structure of the matrix of transition probabilities for seal coat.</u>

A seal coat corrects pavement cracking but has no significant effect on pavement roughness. In the first year following a seal coat, the cracking would be 0 to 5 percent, while the change in roughness would be equal to the change under routine maintenance. The index to first crack following a seal coat is estimated to be 1 to 4 years for any combination of traffic and regional factor.

Since the cracking in the first year following a seal coat would be 0 to 5 percent, the only possible states to which a pavement in any state i could make a transition are 25, 33, and 41. Since the probabilities of changes in cracking depend only on the most recent action, I_c of the rehabilitation action prior to the seal coat has no effect on the transition probabilities. The structure of the transition probabilities, therefore, would be as shown in Figure B-3. Note in this figure that the same transition probabilities are repeated for all levels of I_c.

<u>Structure of the matrix of transition probabilities under any rehabilitation action other than routine maintenance and seal coat.</u>

Any rehabilitation action other than routine maintenance and seal coat corrects both cracking and roughness problems. Cracking in 1 year would be 0 to 5 percent and roughness in 1 year would be as estimated from Equation B-3. The only possible states that a pavement in state i can make a transition to are 24(n-1) + 1, 24(n-1) + 9, 24(n-1) + 17, where n is the level of I_c for the rehabilitation action under consideration.

The structure of the matrix of transition probabilities for this case is similar to that shown in Figure B-3. As an example, let us consider the rehabilitation action of "ACFC plus Asphalt Rubber (AR)" applied to a road with ADT less than or equal to 2000 and regional factor of 1.2. For this category of traffic and region, the level of index to first crack for (ACFC + AR) was estimated to be 3 (this corresponds to

State i \ State j	1 - 24	25 - 48	49-72	73-96	97 - 120
1 - 24		F			
25 - 48		F			
49 - 72		F			
73 - 96		F			
97 - 120		F			

Figure B-3. STRUCTURE OF TRANSITION PROBABILITIES FOR SEAL COAT

6 ± 2 years to first crack). A road in any state prior to the rehabilitation action can only go to states 49, 57, and 65. The probabilities of going to these states are calculated from Equations B-3, B-4, and B-6, using the procedure described before. Note that the transition probabilities for the first level of I_c are repeated for all other levels of I_c.