Development And Implementation Of Washington State's Pavement Management System

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16. Abstract

This report describes the pavement management system developed by WSDOT staff over a period of five years. Both project-level and network-level pavement management are represented within the four broad areas of data processing which combine to constitute the foundation of the system.

The design of a pavement data file is laid out together with the process of assembling it. Also shown are the methods used to analyze and convert the file data from pavement condition ratings to pavement performance curves for each project. The performance curves are then used, together with appropriate cost data, to determine the most cost-effective type and time of fix. The network-level program then summarizes the needed work for each year of a rehabilitation program. Means are provided for adjusting the program to fit budget constraints or minimum acceptable levels of average pavement condition.

It is concluded that the system, operating on biennial pavement condition ratings, provides a good solid framework for orderly analysis to estimate the economic benefits of the type, timing, and sequence of rehabilitation activities applied to a pavement.

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WASHINGTON STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS LABORATORY

DEVELOPMENT AND IMPLEMENTATION OF WASHINGTON STATE'S PAVEMENT MANAGEMENT SYSTEM

by
T. L. Nelson
Pavement Management Engineer
and
R. V. LeClerc
Consultant (Formerly WSDOT Materials Engineer)

A. J. Peters
Materials Engineer

Materials Laboratory
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CREDIT REFERENCE

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The authors also wish to express their sincere appreciation to Mrs. Ruth Renaud for typing, editing, re-typing, and re-editing this report; and to Dennis Crimmins whose diligence and data processing skills were invaluable in bringing this system to fruition.

DISCLAIMER

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SUMMARY

This report describes the pavement management system developed by WSDOT over a period of five years. It represents an organized approach to providing the Department's administration with the necessary information for more efficiently managing its investment in roadway pavements. Both project-level and network-level pavement management are represented within the four broad areas of data processing which combine to constitute the foundation of the system.

Functional Aspects

There are four basic components of this system:

1. Master File
2. Interpreting Program
3. Project-Level Optimizing Program
4. Network-Level Program

Master File

The foundation of this system is the Master File which combines information from five other existing data files:

1. Roadlife History (construction history)
2. Roadway Inventory (geometric data)
3. Annual Traffic File
4. Surface Friction File
5. Pavement Condition Rating File

The Master File is indexed according to milepost limits of the most recent paving contracts and is utilized in two ways:

1. To track the progression of distress over the service life of a pavement.
2. As input to the first of three computer programs in the system, the interpreting program.

Interpreting Program

The interpreting program translates the raw distress codes contained in the Master File into average ratings for each project. This is accomplished by applying weighting values to the extent and severity of each distress category. Regression analysis is then applied to the ratings to fit a performance curve which is used for predicting future pavement performance and the potential time of rehabilitation.

The output listing from the interpreting program consists of the following for each project:

1. A tabulated summary of the performance history.
2. A summary of traffic information for the project.
3. The constants for the performance equation with related statistical data.
4. A plot of average ratings with high and low ratings for each survey year shown and the performance curve fitted to the points.

The interpreting program also generates a new data processing file that contains all of the above-noted information on a project-by-project basis. This file is used in two ways:

1. To study the correlation of other parameters such as design mixes, environmental effects, traffic characteristics, etc., with trends in pavement performance.
2. As input to the second major program in the system, the project-level optimizing program.

Project-Level Optimizing Program

This program utilizes the performance equations produced in the interpreting phase to establish the most probable period of rehabilitation for each project. After selecting a set of viable alternatives and developing their associated performance equations, the program generates all possible rehabilitation strategies which might be considered within a specified period. These strategies are defined as a combination of rehabilitation alternatives designated by type, sequence, and application time. Each strategy is evaluated on the basis of economics and the best are tabulated on an output listing for each project.

Categories of cost considered in the evaluation process are:

1. Construction cost of rehabilitation.
2. Annual cost of routine maintenance.
3. Cost incurred by the highway user due to pavement condition.
4. Cost of delay time incurred by the highway user due to traffic interruption during rehabilitation.
5. Salvage value of the pavement at the end of the consideration period.

This program also generates a new data processing file which is used as input to the next program in line, the Network-Level Program.

Network-Level Program

The function of this last program is to establish a network-level six-year rehabilitation program based on the optimum strategies as determined by project-level optimizing. Through a system of aggregating the recommended rehabilitation alternatives and performance of all project segments on the network, a schedule of anticipated action, cost, and performance can be tabulated for a future number of years. By applying budget and condition-level constraints for each year, the network program will produce an entire balanced rehabilitation program. By varying the budget and condition-level constraints and tabulating the results in projected performance with proposed budgets, good comparisons are demonstrated for what can be obtained with different budget levels and most of the "what if" questions faced by administrators are answered.

The system is currently in operation within WSDOT. The performance curves produced by the interpreting phase are used to prioritize pavement sections for rehabilitation. The optimizing program and network-level program are both used by the districts to influence their decisions in preparing rehabilitation programs.

CONCLUSIONS AND RECOMMENDATIONS

It is concluded that the system, operating on biennial pavement condition ratings, provides a good solid framework for orderly analysis to estimate the economic benefits of the type, timing, and sequence of rehabilitation activities applied to a pavement. As such, it is expected to be a great aid to WSDOT in providing the citizens of the state with the best pavements for their tax dollars.

During the course of development, the importance of maintaining pavement condition ratings in their raw coded form became very obvious. By doing this, weighting values can be recalibrated as each pavement survey is completed, greater insight to the interplay of pavement distress is acquired, and the expertise in performance analysis is improved.

In this system, "optimization" is applied at the project level. All work at the network level is related to gauging the effectiveness of different programs by applying constraints--either budget or pavement condition-level. It is concluded that network optimization would involve "trade-offs" between alternatives applied on all projects in order to make the greatest gains in long-term pavement condition for the dollars available. This process was not developed in the scope of this study, but represents an objective of further research and development.

Successful development and implementation of this pavement management system were accomplished with three basic considerations:

1. The production of a feasibility study by an outside consultant which determined adequate information and expertise were available within WSDOT to develop and implement a PMS.
2. The assignment of developing the system to the Materials Laboratory which has responsibility for pavement design approval, and pavement materials and construction specifications, as well as conducting the biennial pavement condition survey.
3. The formation of a steering committee consisting of top-level management personnel was considered essential for implementation.

The data base and interpreting system provide the necessary tools for further research. The possibility exists for correlating design parameters, materials and construction methods, and surfacing types and thicknesses to such factors as projected pavement life, area under the performance curve, degree of curvature, etc.

The performance model was developed with a strong consideration for simplicity and may not be accurate in the low ranges of pavement rating (severe distress). It is recommended that typical performance curve tails be developed for specific pavement types when they approximate this low range of rating.

The cost models relating user-incurred costs are weak and based on outdated information. It is recommended that better models be developed in the future if user costs are to be a consideration.

It should be noted that the framework of this system could be utilized by any agency that has the two basic constituents for the master file:

1. A construction history file with construction dates, types of surfacing, etc.
2. A pavement rating history file that relates to severity and extent of different distress types.

With this information available, it would be possible to calibrate distress weightings to relate to any combination of distress types and to represent the genesis of pavement deterioration in almost any geographical area. Once performance curves are developed, the mechanics of the rest of this system fall into line.

Chapter 1

HISTORY AND BACKGROUND

Purpose

This report presents a method for accomplishing one of the foremost goals in pavement management--that of maintaining the condition of the pavement for the least cost to all concerned. The phrase "pavement management" encompasses many disciplines of highway engineering. Haas and Hudson[1] define pavement management as "a comprehensive, coordinated set of activities associated with the planning, design, construction, maintenance, evaluation, and research of pavements". This report addresses the assessment of pavement performance, the selection of the most cost-effective rehabilitation alternative and its timing, and the development of a six-year rehabilitation program on a system basis.

The highway industry appears to be heading for a restrained effort of maintaining those facilities which already exist, or improving them as best they can with the limited amount of funding available. Little new construction will be accomplished in the future. The reasons for this are evident. Funding will be severely limited and there are other modes of transportation which must act in concert with the automobile. The price of oil is spiraling upward, strongly influencing national economy, and the effect of oil price increases on the highway industry is far more severe than other areas of the national economy. With inflation limiting the amount of construction possible and the gas-tax revenue decreasing from reduced sales, the funding picture for the highway industry does not look promising. The need for an efficient method of allocating highway funds is very obvious.

In the past, the Washington State Department of Transportation, WSDOT, has utilized a priority programming procedure for the selection of projects and the allocation of funds. It consisted of a complex procedure which prioritized by functional classification all anticipated projects in several construction categories. This procedure can respond to present needs, but there is no recognition of the long-term economic benefits or consequences associated with each action. To make and administer funding decisions for a budget as large as the WSDOT construction budget, the benefits and consequences of such decisions should be considered. The procedures presented in this report will accomplish that task.

Procedure

How can the basic needs for optimizing the results of expenditures and improving the management of pavement condition be realized? The answer to this question is developed throughout the remainder of this report and is founded on relating operating and rehabilitation costs to pavement condition. As Marshall and LeClerc[2] pointed out in 1968, "It is an unfortunate fact that pavements wear out, and highway officials have been working for years to produce a method whereby the present serviceability of a pavement could be rated, levels of satisfactory service established, and predictions made as to the most economical time for any particular section of pavement to be reconditioned".

Figure 1 is a typical performance curve relating the pavement rating to the age of the pavement. As a pavement ages, its condition gradually deteriorates to the point where some type of rehabilitation is applied. This brings about an increased pavement rating and the beginning of a new cycle. Over the total life of a pavement, many applications of rehabilitation can be made and thus many cycles of resulting pavement performance are possible. These cycles are determined by the type, timing, and application sequence of rehabilitation alternatives (see Figure 2). By evaluating several different cycle combinations (rehabilitation strategies) over a set time span or consideration period, the least expensive combination (strategy) may be identified and compared to others on the basis of economy.

This approach precipitates two basic problems:

1. The performance of existing pavement as well as each successive rehabilitation alternative must be accurately predicted and forecast.
2. Accurate cost modeling must be accomplished in order to develop realistic costs.

The method demonstrated in the following pages provides a good, solid framework for systematic analysis--one which, because of the system and programming design, can be easily modified for use by other agencies or for updating functions and models. The system is designed to improve with time and the acquisition of new data.

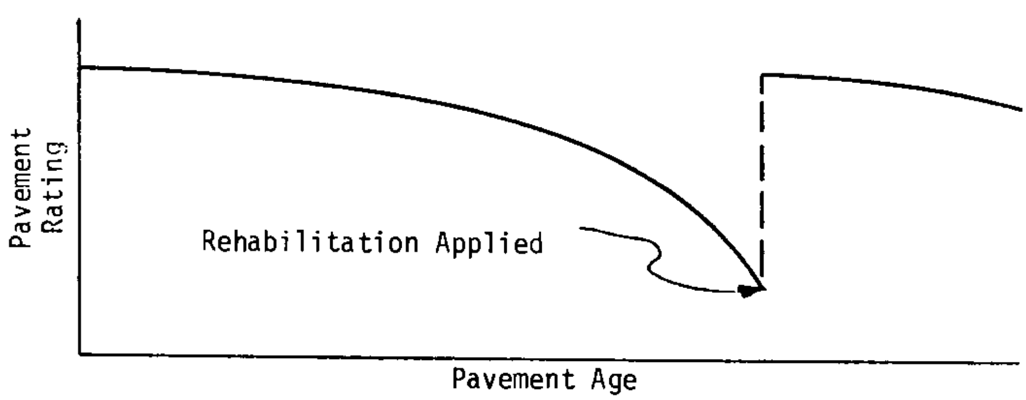


Figure 1. Typical Performance Curve

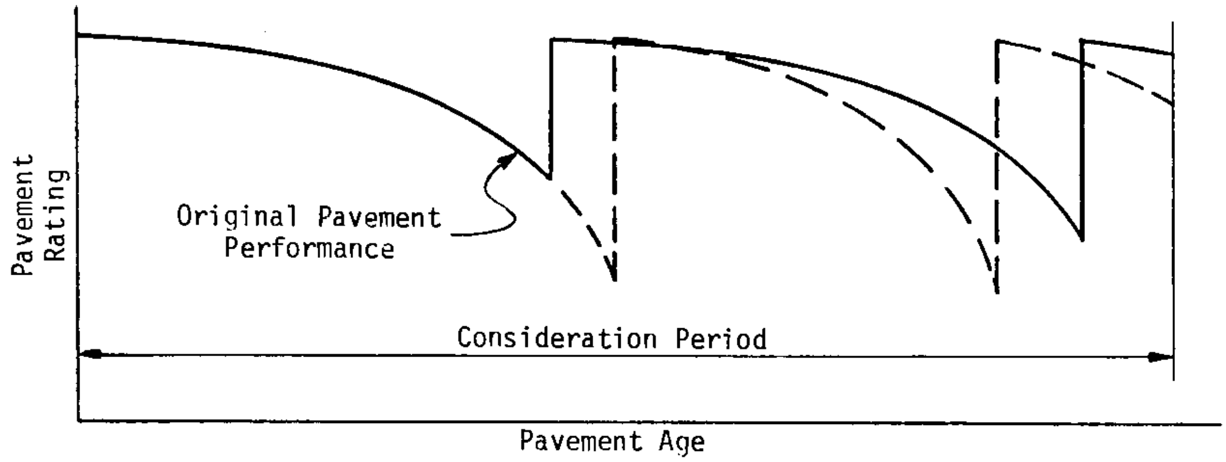


Figure 2. Application of Rehabilitation Alternatives

History of Development

The need for this approach to managing pavements was recognized very early by key administrators within WSDOT as evidenced by correspondence dating back into the 60's. Since the department has been rating pavements from about 1965, it was thought that these data could be used for developing performance curves. A consultant was hired in 1973 to study the proposal and determine the feasibility of initiating a pavement management system. A report[3] was submitted by the consultant in August of 1974. The report indicated that most of the resources required for a pavement management system were present and that it was feasible to attempt pavement management on a trial basis. The feasibility study did much more than study feasibility, however. It provided a pavement performance model, documented cost functions for use in the economic evaluation, and provided computer programs which could be used for the analysis. As is often the case in feasibility studies, it also pointed out many needs. If a pavement management system were to be developed, the acquisition of new cost data and coordination of existing data-processing files would be required.

Based on the recommendations and findings in the feasibility study, the WSDOT administration authorized a research study for developing a pavement management system in May of 1975. However, because of personnel movement within the agency, the project only sputtered until April of 1977.

At that time, much work was dedicated to investigating the applicability of the consultant's model to its intended purpose of predicting performance. This model, the Markov chain model, was described in the consultant's study and recommended because of its ease of handling probability and updating. Unfortunately, the Markov model did not predict pavement performance within an acceptable range for individual projects on our system. It appeared more applicable to system performance prediction, but with lower correlation factors.

Concurrently, there was difficulty in comparing pavement rating data from one generation to the next. As would be common, the department made improvements to the rating system over a period of time--expanding rating categories for some types of distress, dropping or adding some distress types, revising weighting values for distresses, changing ride meters, and revising the rating equation which combined ride data with distress data. To further complicate this situation, mileposting on many sections was revised between generations of rating data. This occurred whenever there were geometric realignments or system realignments. Because of this problem, mileposting on the entire state highway system had to be traced back to the first generation of data in order to establish the pertinent time of revision on each section.

In the beginning, computer programs were written to convert each generation of rating data to a common rating base. The mileposting problem was handled manually by hand-tabulating the rating for selected projects, generation by generation. Needless to say, this was a very time-consuming approach. A great amount of time was spent identifying project limits and tabulating pavement condition ratings to find projects with consistent performance. From a large number of surfacing projects, only a few could be shown to have deteriorating ratings related to time. One of these, a section of SR 395 north of Spokane, was used in the example for the paper[4] presented at the Tumwater workshop. It was obvious, though, that there were significant problems with the ratings.

The WSDOT pavement rating is composed of a ride rating, determined objectively with a modified PCA ride meter, and a structural distress rating, determined subjectively by rating the extent and severity of several distress categories such as cracking, rutting, flushing, etc. Since any or all of the rating components were candidates for the cause of inconsistency, a strategy was outlined to identify that cause. A portion of Interstate 90 from near Ellensburg to the Idaho border was selected as a test section since it was predominantly asphalt concrete built on new alignment in the late 60's.

By tabulating the trend of each distress category for the history of each project in the test section, the consistent and inconsistent items were identified. Those most consistent were the distress categories of transverse cracking, longitudinal cracking, alligator cracking, and patching. Other distress categories proved to be very inconsistent and were identified as being responsible for the random fluctuation in pavement ratings. The ride component was also found to have little correlation with time.

These findings supported our conclusion that the cause for overlaying a pavement is most often severe cracking and patching.

With the more consistent distress categories identified, a new rating equation was developed which incorporated only those categories of cracking and patching. This equation was applied to all projects in the test section and it was found that most then had consistent performance with time. A few projects still had poor time-related performance, but there were identifiable reasons for these.

A subjective evaluation obviously cannot be perfect and repeatable. A section of pavement is not always rated by the same crew year after year, and even when it is, the same crew may render a different evaluation the following year. Another problem which may have contributed to the inconsistent projects was that of data organization. Pavement rating is done by even mileposts, not by project limits. In order to associate ratings with a project, there will usually be some overlap involved at the beginning and end of each project. And if the project is relatively short, the ratings may not be associated with the project at all.

Much was learned by studying the I-90 projects: new rating equations were developed; a great amount of experience was gained in regression and correlation analysis; and it was realized that the consultant's program was no longer adequate for accomplishing the original objectives. Probably the most important benefit gained was some insight on the required constituents of a data file. A tremendous amount of time was spent retrieving and tabulating the input data required for the computer program. For pavement management to be efficient, a data file would have to be built and maintained for quick access. A complete data file is the foundation of any pavement management system.

It also became apparent that a step should be provided prior to optimizing the rehabilitation treatment for each project. In studying the I-90 projects, too much time was used in analyzing the yearly performance ratings and developing performance equations for each project. Although it was necessary to do this at the time to understand the processes involved, this analysis phase was considered best applied in a new computer program. By providing this step in the system, a great amount of flexibility was added. A data base could now be maintained, with all data stored in original format. By using another input data set for interpreting parameters, the data file could be translated into project performance in an almost infinite number of ways. Some of the interpreting parameters included are weighting values for the extent and severity of each distress type, and different transformation constants for the regression analysis. By simply editing the interpreting parameters, it is possible to change the influence each distress type has on the resulting equation. It is also possible to look at the extent and severity of each distress type as it progresses through time. This aspect had been missing in maintaining only the numerical (weighted) ratings from year to year.

With the realization that the optimizing program developed by the consultant was no longer adequate, an entirely new "optimizing program" was written. The analysis path is similar, but is modularized for ease of updating and modifying, and was written to process output from the interpreting program. It is also composed in much the same way as the interpreting program in that it utilizes optimizing parameters. By doing this, constants for the cost models could be changed for different geographical areas, or the effective interest rate can be changed to provide a different outlook. Other items and controls are included in the parameters to consider different sets of rehabilitation alternatives.

Figure 3 is an example of the "system" as it was conceived in August of 1978. Three main phases were recognized: building a data file; interpreting the data; and optimizing each project based on total cost over an analysis period.

Writing the new optimizing program proved to be a much easier task than designing and building the data file. An initial version of the new program was completed in just over a month's time. Designing the data file was probably the single largest obstacle faced in developing a PMS; building the data file was an easy second. The winter of 1978-79 saw many milestones reached: the data file was designed and built for the statewide system; the interpreting program was written and used to improve the weighting values for the distress categories; and the optimizing program was modified a number of times as our expertise improved in that area.

By July of 1979 a substantially assembled and workable framework was at hand for accomplishing the original goal--to determine the least costly method of maintaining an acceptable level of pavement condition on any project. In addition, there was a better perspective of pavement management and a much clearer picture of what was needed. Pavement management data, to be most effective, must be made available to all areas of design, construction,

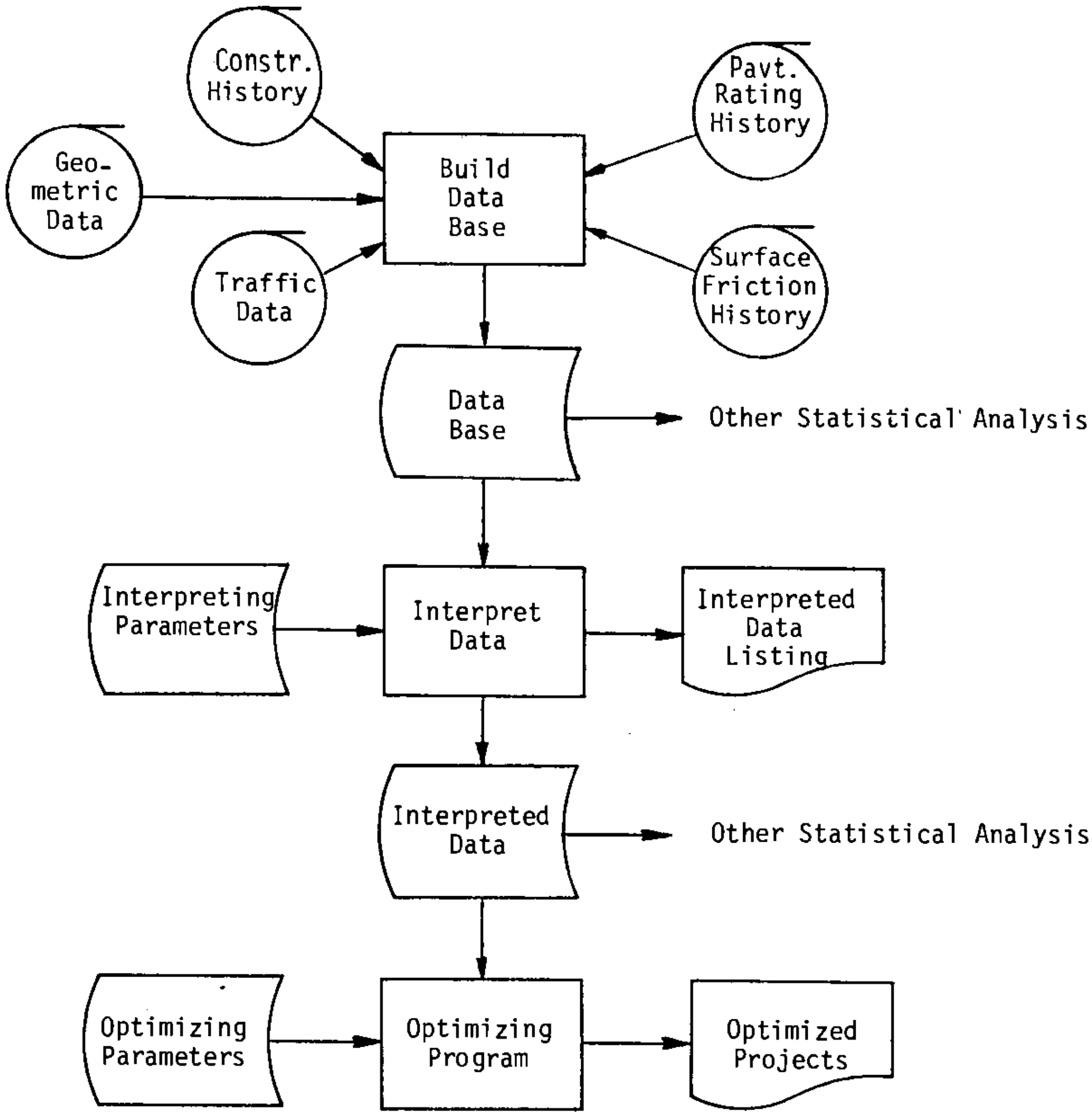


Figure 3. Conceptual Flow Chart of PMS at Early Stage

maintenance, and budgeting. To function properly, detailed information, results of several types of analysis, and feedback must all be utilized in those areas.

The framework being developed fulfilled most of these criteria, but fell short in others. All programs and files were run or accessed through batch processing, and it was necessary to make the data accessible so it could be used in the everyday functions of the department. It was realized that there were two levels of pavement management--project level and network level--and that all efforts had been directed toward the project level. Another problem surfaced in determining how this new system would be implemented in conjunction with the priority programming procedures already in use. A remaining concern was the accuracy of the cost models.

The fall of 1979 and winter of 1979-80 again saw some significant advances. All cost models were analyzed and polished in detail. Most of the project-level programs and data were installed as an interactive, on-line version for ease of access from any remote terminal. In this way all of the department's offices had access to and could make use of all available pavement-related information.

The biggest achievement of this period, however, was the development of network-level programming. Although there was an awareness of what was to be gained through this level of analysis, the method was not entirely clear until complete development of project-level optimizing had been attained. The completion of this level provided added insight.

Network-level programming is based on the optimum rehabilitation strategy as determined by project-level optimizing. Through a system of aggregating the recommended rehabilitation alternatives and performance of all project segments on the network, a schedule of anticipated action, cost, and performance can be tabulated for a future number of years. If adequate funding is available, no further information would be required--the anticipated rehabilitation program would be established. But this is not reality for most public agencies. Some further recourse is required when there is a limit on available funds. This action consists of: assigning a priority to each rehabilitation project for the first year; accumulating cost for each project in priority order until the budget limit is reached; delaying the residual projects to the following year and prioritizing the projects for that year; and repeating this process in an iterative manner until a rehabilitation program is established. The problem with this approach is the prioritizing formula. This formula must consist of the criteria deemed most desirable for the good of the system as a whole--not just the section with the lowest rating.

Budget constraints in terms of limited funding only present one side of the network problem. The other side is precipitated when funding is so limited that an acceptable level of pavement condition cannot be sustained. The approach to this problem is much the same as the first. When tailoring a program to fit available funding, the cost of each project is accumulated until the total dollars reach the funding limitation. A program constrained with limited funds will provide some specific level of average pavement condition. In the latter case, however, each project is gauged for its effect on the overall average pavement condition, with each raising the average to an increasingly higher level. Ultimately, of course, a specified level of "acceptable" average pavement condition is reached. A rehabilitation program compiled to provide a minimum level of pavement condition will require a certain level of funding. So it is obvious there are two types of constraints involved at the network level:

1. Budget Constraint - A funding limitation which restricts the number of possible projects and provides a specific level of average pavement condition.
2. Condition-Level Constraint - A specified level of average pavement condition deemed to be a minimum which requires sufficient projects to be implemented and demands a certain level of funding.

By preparing several programs, each with a different level of constraint, graphs can be plotted to demonstrate the effects of limited funding or the demand on funding required to sustain minimum levels of pavement condition.

Network-level programming is that part of the system which informs upper level management of the potential impact to be derived from varying certain levels of budget constraint, from raising or lowering the minimum acceptable level of pavement condition, or from the effects of projected interest and inflation rates. With this part of the system in operation, the WSDOT has detailed information both at the project level and at the network level to aid and influence cost-effective decision-making for maintaining pavement condition.

Figure 4 represents a conceptual flow chart of the operations involved in the final system. These operations are separated into four basic phases:

1. Building the data file
2. Interpreting the data file (performance analysis)
3. Optimizing the proposed action on each project (economic analysis)
4. Preparing a network rehabilitation program

Chapters 2 through 5 describe in detail how and why each phase was designed. It is hoped these chapters will serve not only to describe what has been done in the WSDOT system, but also to aid other agencies in their PMS development.

In the spring of 1980, two meetings were held with district representatives to present the PMS. District reception was mixed. Some could see the PMS as a great help; others were skeptical about it working with old roadways; and still others reserved judgment until they could see examples of how it would function on certain roadways within their own districts. The PMS that had been developed was a fairly comprehensive system, and it was asking quite a bit for people unfamiliar with it to fully appreciate the benefits on the strength of a 1½-hour presentation and subsequent discussion. However, it was felt that examples of its use within each district would enable the district people to appreciate its potential.

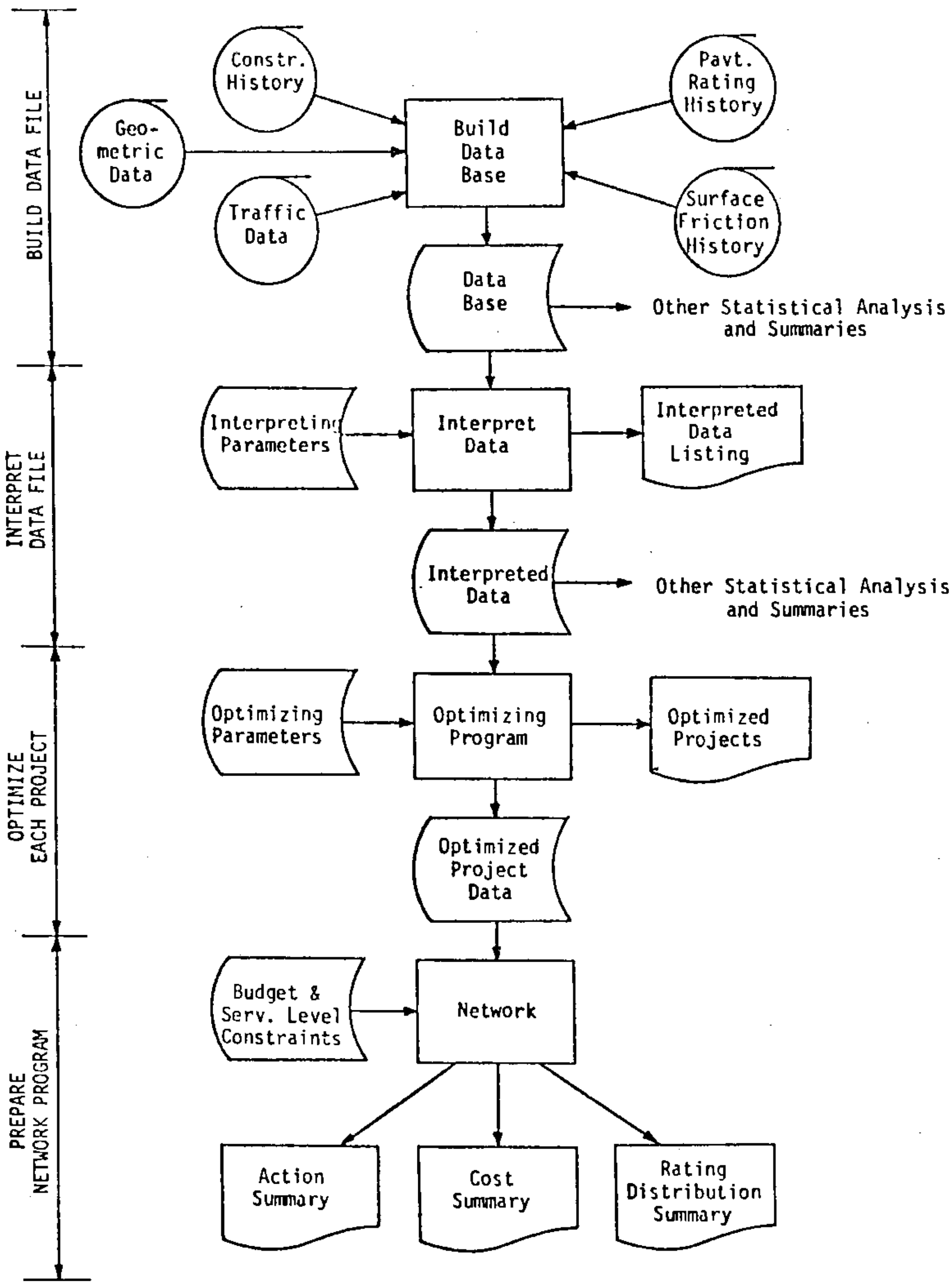


Figure 4. A Conceptual Flow Chart of PMS Operations

In order to ensure an adequate indoctrination and ultimate acceptance within the department, a PMS Steering Committee was formed in early June of 1980. This committee consisted of:

Construction Engineer (Chairman)
Maintenance and Operations Engineer
Roadway Development Engineer
Materials Engineer
District Administrator (D-3)
Program Development Engineer
Deputy Secretary of Transportation

Subsequent meetings with the Steering Committee generated many requests and further examination of the PMS influence on departmental operations. Of particular interest to the Committee were:

1. The difference between pavement ratings--old and new.
2. The difference between programs resulting from use of project limits vs. analysis units.
3. Implementing the PMS in conjunction with the existing Priority Array System.
4. A correlation of pictures to pavement ratings.

Approximately one year elapsed in this phase of the project--answering all the questions and assuring upper level management of satisfactory operation.

Finally in the fall of 1981, the WSDOT staff gave approval and direction to apply the PMS in establishing the pavement-related portions of the Priority Array for the 83-89 Legislative Program and the 83-85 Operating Program. The Pavement Management System is now an integrated part of WSDOT operations.

Chapter 2

ASSEMBLING THE DATA FILE

Background

Designing and building the required data file was probably the greatest obstacle faced in developing this system. Selection of the specific data items and design of the record layout and file structure presented some very perplexing problems. This selection and design also had to recognize certain functional specifications, or how the file was to be used. Because the evolution of this system began with a cost-optimizing program, the items included in this file were originally selected as input data for that program. The record layout and file structure were then dictated by the type of data available and how it was to be used.

Many organizations involved in the development of a PMS have been bogged down in their attempts to assemble a data base. Their problems stem from attempting to include far too many items in order to ensure that data required in subsequent programs will be available when needed. By doing this, the problem becomes far more complex. More items imply greater coordination in file design and record structure, i.e., not all items can be associated in the same way. The amount of time dedicated to acquiring the information also amplifies this endeavor to an almost insurmountable task. By limiting the data file to little more than the essentials, the task at hand can be managed.

This method of assembling the data file did have its drawbacks, however. With the file containing only those items required as input to a specific program, subsequent modifications to the program often required expanding or even rebuilding the data file to include new data.

Available Data Files

After the essential elements were identified, current data processing files were studied to locate and retrieve the required data items. Fortunately, almost all items were available in department files. The only missing item was annual pavement maintenance cost associated with specific projects.

The files recognized as having desirable data items were:

1. Roadlife History
2. Roadway Inventory
3. Annual Traffic File
4. Surface Friction File
5. Pavement Condition Rating Files

Following is a brief description of each file:

Roadlife History

The Roadlife History is basically a milepost-by-milepost breakdown of the entire construction history of every mile of roadway on the state system. Record layout is such that each record represents a homogeneous roadway section. Every surfacing action from the data of original construction to the most recent rehabilitation is noted by type, depth, and date. Also recorded are contract numbers, functional classification, type of highway configuration, base material types and depths, and provisions for locating added lanes and old PCC pavements.

Roadway Inventory

The Roadway Inventory represents a collection of geometric, physical, and other descriptive features of the state highway system. Items included in the file are: state route milepost; equivalent control section milepost; description of the nearest physical landmark; lane widths; shoulder widths; median widths; type of terrain; junctions with other city, county, or state roads; federal aid classification; and others which describe characteristics of the highway system. This file is used in producing the State Route Log and in various needs studies.

Annual Traffic File

The Annual Traffic File is maintained by the Public Transportation and Planning Division and provides traffic volumes at all locations throughout the network. Items contained in this file include: average annual daily traffic, growth rate, single unit truck percentages, combination truck percentages, K factor for reducing AADT to a design hour volume, D factor for splitting the DHV into a directional volume, and three previous years' AADT. This file is the source of the Annual Traffic Report.

Surface Friction File

All past and present friction measurements are recorded for each state route milepost of the system. Items also recorded include: surface type, direction of test, test lane, test speed, and month and year of testing. Data from this file are used to identify hazardous locations and represent one source of input to the department's Priority Array relating to safety conditions.

Pavement Condition Rating Files

These files (one for each pavement condition survey) are a collection of the raw coded ratings for each of several surface distress categories, together with roughness data acquired with a modified PCA ride meter. Items coded in this file include ratings for: pavement rutting and wear, alligator cracking, ravelling or flushing, longitudinal cracking, transverse cracking, and patching--all associated with bituminous pavements; cracking, ravelling-disintegration-popouts-scaling, joint spalling, pumping and blowing, blowups, faulting-curling-warping-settlement, patching, and pavement rutting and wear--all associated with portland cement concrete pavements. This file has been the basis for establishing pavement rehabilitation priorities.

Data Problems

On inspection of these files, several problems became evident, two of which were of paramount concern: the problem of mileposting structure used to index records; and the problem of overlap relating project limits to rating sections or other required records. These problems represented significant obstacles to overcome in designing and building the data base.

Mileposting Problem

The WSDOT employs two uniquely different systems of mileposting. The first, state route mileposting, might be considered as conventional mileposting. Under this system, mileposts begin at the southernmost or westernmost terminus and increase in a northerly or easterly direction respectively. This system is perhaps the most common and the easiest to comprehend. The other type of mileposting utilized is a system of segregating the highway network into small sections called control sections. The purpose for doing this is to establish cost association with jurisdictions, legal entities, or specific boundaries such as city limits, county limits, urban areas, legislative districts, congressional districts, etc. Each of these sections has its own set of mileposting.

The problems arise when each division maintaining a file utilizes its own indexing system. Different methods include: beginning control section mileposts (BCSMP); ending control section mileposts (ECSMP); beginning state route mileposts (BSRMP); ending state route mileposts (ESRMP); or inclusive mileposts in either system. Features may be recorded consecutively through a control section on the left side and then repeated for the right side. Another method involved alternate records from left to right throughout the section.

To further complicate the problem, each time a highway is realigned for one reason or another, the mileposting is updated or an equation is inserted. Trackability of recorded information from one year to the next then becomes a formidable task.

Overlap Problem

The prime objective of the pavement management system is to track performance of pavements so a time to failure can be projected, and cost effectiveness of rehabilitation gauged. For the past 12 to 15 years, the State of Washington has been evaluating its entire network of pavements each two years. These ratings together with construction history constitute the major requirements for tracking performance relative to project limits. However, when the sections rated do not coincide with project limits, a major problem is sometimes encountered.

Pavement condition is evaluated on maximum one-mile intervals starting at the beginning of each control section. Should the rating team observe a significant change in the pavement condition before completing a one-mile section, they are instructed to begin a new section. In all cases, a break is noted at the even milepost: 1, 2, 3, 4, 5, etc., ± 0.1 mile. This is done to maintain continuity from one generation of ratings to the next. When several years have passed since construction or rehabilitation, the rating teams may no longer notice the distinct breaks in pavement condition. Project limits no longer stand out with a great degree of contrast between old and new. When this break in project limits is not picked up in the rating limits, a problem of overlap occurs. Figure 5 is an illustration of the overlap problem indicating three possible cases of overlap and the ideal situation where no overlap occurs (Case 4).

A recent modification of the rating forms will help eliminate this problem in time. By precoding rating limits to match rating limits from previous years and recent rehabilitation limits, the raters will be alerted to these breaks during the time of pavement condition survey.

Designing the Master File

The information previously described represents all data used to assemble the master file. The basis for coordinating these files was eventually determined to be the limits of the last paving contract applied. Since the ratings are primarily indicative of surface distress, all data are related to a surface age and other construction parameters such as type and thickness of surfacing.

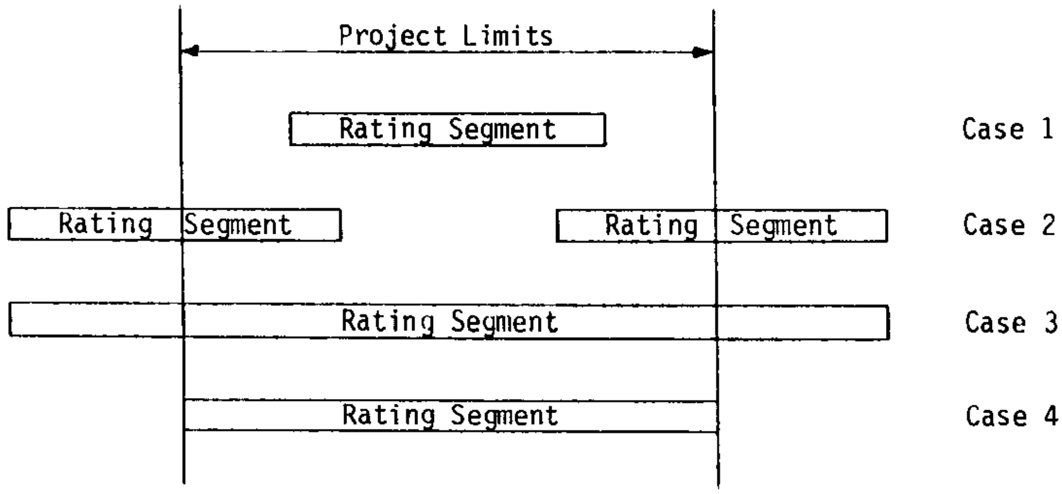


Figure 5. Overlap Problem

The first step in designing the file was the determination of broad fields for layout and organization. These fields represented general areas and were not refined to specific data items. Project identification and description represented the most obvious items since everything else is naturally related. Traffic data, friction data, and pavement condition data comprise the other broad fields. Construction history is included in the project description and identification. Figure 6 is an illustration of the general record structure for one record in the master file.

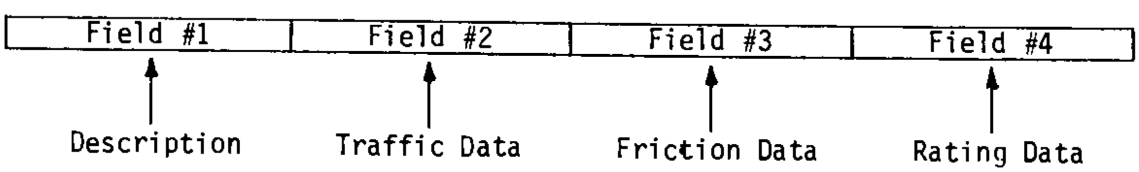


Figure 6. Typical Record - Broad Fields

This appears to be a rather simple record layout. However, because there are several generations of data to be related to each project, the file structure was not quite so easy to perceive. Each project differs in age and length. This tends to vary the amount of data to be related for each project. Several methods of combining records for assembling the master file were considered: assembling coordinated files; building records with variable record lengths; or stacking records in a hierarchical structure. In the interest of keeping the programming as simple as possible, the hierarchical structure was selected.

Figure 7 depicts the hierarchical structure developed. At the top are all data related to the project itself, regardless of year or specific location. This includes project description, identification, construction parameters, and traffic information. Since traffic is not available for previous years, it was decided to utilize the most recent traffic available. This prevents correlation with past performance, but with growth factors included, does allow future projection of traffic. The top of the hierarchy thus combined the first two broad fields into one, designated the master index field since everything is related to it.

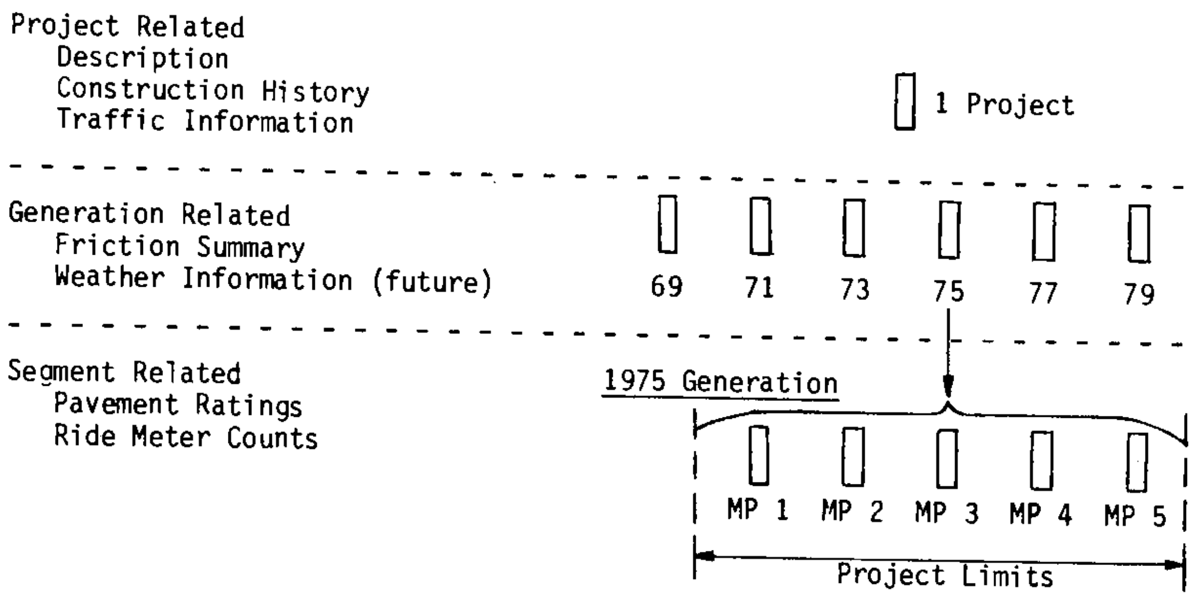


Figure 7. Hierarchical Record Structure

Next in order of the hierarchy are data associated with each generation involved. It is possible to relate much of the available project data to generations, or years. Data fitting into this category include friction summaries. Traffic information would also logically fit at this level if it were available. Future considerations include historic weather information.

At the lowest level of the hierarchy are all data that can be tied down to specific segments for each generation of a project. This includes pavement condition ratings and roughness measurements which are recorded by one-mile increments.

Assembling the Data File

The hierarchical structure is evident in Figure 8 which is an example of the master file layout. This system of stacking records presents a much simpler method of assembly than the other file structures considered. The file is built through a series of record-matching programs and available system utility programs. Figure 9 is a conceptual flow chart which portrays each step in this building process. The steps are simply named to relate the specific operations involved. Although the actual assembly is much more complex, involving many more steps, a conscious effort has been made to explain the purpose of each step and avoid some of the superfluous details.

	1ST FIELD	2ND FIELD	3RD FIELD
Record #	Master Index Portion	Generation Related	Segment Related
1	1st Project Descr. & Traffic	1st Gen. Summary	1st Gen. 1st Mile
2	" "	" "	2nd Mile
3	" "	" "	3rd Mile
4	" "	" "	Nth Mile
5	" "	2nd Gen. Summary	2nd Gen. 1st Mile
6	" "	" "	2nd Mile
7	" "	" "	3rd Mile
8	" "	" "	Nth Mile
	" "	Xth Gen. Summary	Xth Gen. 1st Mile
	" "	" "	2nd Mile
	" "	" "	3rd Mile
	" "	" "	Nth Mile
	2nd Project Descr. & Traffic	1st Gen. Summary	1st Gen. 1st Mile
	" "		
	" "		
	" "		
	" "		
	" "		
	" "	Xth Gen. Summary	Xth Gen. Nth Mile
	Mth Project Descr. & Traffic	Xth Gen. Summary	Xth Gen. Nth Mile

Figure 8. General Layout of Master File

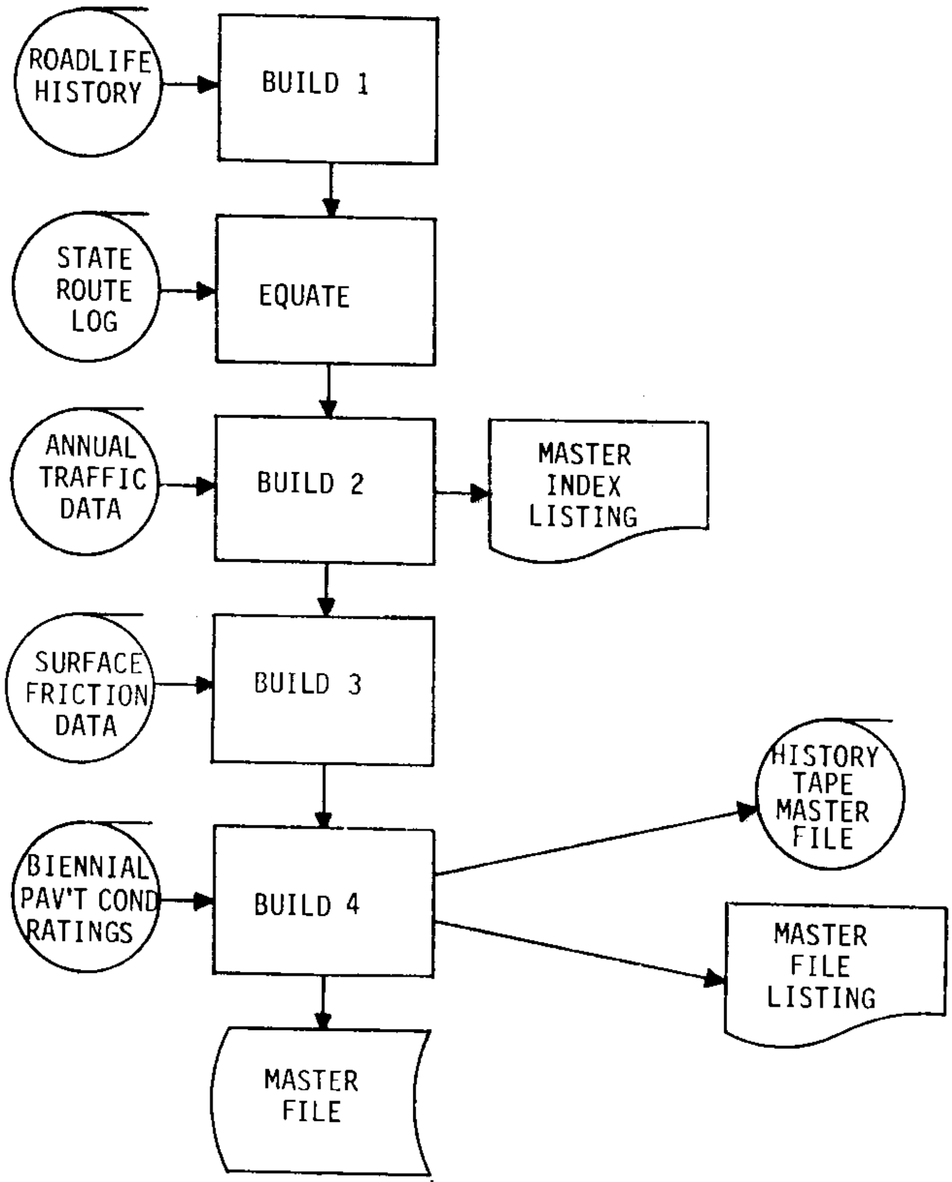


Figure 9. Conceptual Flow Chart of Building Process

Each of the steps indicated in the flow chart is briefly explained below:

<u>Build 1</u>

This step represents a program which uses the Road Life History File as input to produce a file containing the project limits for the most recent consecutive surfacing contracts throughout the entire state highway network. With the data in this file, the pavement surface age as well as the type and depth of material present can be determined for any location. The specific contract number is recorded together with a code representing the underlying materials. In the case of rehabilitation applications, prior project limits will not match up, causing the new limits to represent a non-homogeneous section. For this reason, a two-digit code is recorded to indicate the predominant or most representative type of material under the surfacing.

Equate

This step utilizes the file produced with Build 1 and the Roadway Inventory File. Because WSDOT uses two different sets of mileposting, a necessary step in the process is identifying project limits with both sets of mileposting. Limits generated in Build 1 are beginning and ending control section mileposts. The Roadway Inventory File contains dual mileposting for all identifiable locations on the highway system, thus making it possible to equate project limits in terms of both mileposting systems. With project limits identified by both methods, it is then possible to relate all other files to each project segment.

Other data provided in this process are the roadway and shoulder widths, plus other geometric features. These are items needed for cost modeling in project-level optimizing.

Build 2

This program assigns relevant traffic data to the project limits developed. By using the Annual Traffic File as one source of input and the file produced by Equate as the other, traffic is matched to project limits. Realizing that traffic data is a point-associated quantity, a weighted average is applied to each project.

The output file produced with Build 2 is a file containing project limits, description and date of last surfacing contract, number of lanes, roadway and shoulder widths, base material type, and all required traffic information. This output file is known as the Master Index since it represents all data in the top of the hierarchical record structure. Figure 10 represents one page from a listing of the Master Index. Figure 11 is a decoding table for the Master Index.

Build 3

This step represents the first move down in the hierarchical structure. Build 3 is a program which associates yearly summaries of friction data with each project. A decision was made at this point to include only yearly summaries instead of mile-by-mile data because friction data is not included in the performance equation. Friction information recorded includes the high, R67710MI

06/22/82

CS	BEG	END	D	SR	BEG	END	LENG	FC	L	HT	RDW	RSH	LSH	CONT#	TY	SF	TK	M	YR	BASE	80 ADT	GRW	SU	CM
****	****	****	*	***	*****	*****	****	**	*	**	***	***	***	*****	**	**	**	*	**	****	******	***	**	**
2303	0	707	3	101	31023	32170	1146	R1	R	02	22	2	2	02061	20	40	12	9	81	11	2800	49	5	5
2303	707	1005	3	101	32170	32468	298	P1	R	02	22	2	2	08493	20	40	4	0	68	11	2800	49	5	5
2303	1005	1225	3	101	32468	32883	415	R1	R	02	22	4	6	00555	20	40	6	4	77	11	5000	38	5	5
2303	1225	1710	3	101	32883	33173	290	R1	R	02	23	4	4	00555	20	40	12	4	77	11	5800	31	5	5
2303	1710	2237	3	101	33173	33700	527	R1	R	02	23	4	4	02018	20	40	8	7	81	11	5800	31	5	5
2302	0	245	3	101	33700	33945	245	P1	R	02	23	3	3	09022	20	40	15	8	71	11	4600	43	5	5
2302	245	430	3	101	33945	34130	185	R1	R	02	23	4	4	02018	20	40	8	7	81	10	5400	43	5	5
2302	430	790	3	101	34130	34490	360	R1	R	02	23	4	4	09022	20	40	15	8	71	10	5400	43	5	5
2302	790	811	3	101	34490	35020	451	U1	R	02	24	11	11	09361	0	40	50	1	75	10	4900	56	5	5
2301	430	507	3	101	35020	35097	77	P1	L	32	24	10	4	07573	0	40	25	9	65	10	12300	56	5	5
2301	507	670	3	101	35097	35260	163	R1	L	32	30	0	0	01289	20	40	6	0	78	11	12500	56	5	5
2301	670	1009	3	101	35260	35599	339	P1	L	32	24	10	4	01907	20	40	6	-	80	32	10800	56	5	5
2301	1009	1104	3	101	35599	35694	95	R1	L	32	24	10	4	01289	20	40	6	0	78	32	10800	56	5	5
2301	0	430	3	101	34490	35020	451	U1	R	02	24	10	4	09361	0	40	50	1	75	10	4900	56	5	5
2301	430	507	3	101	35020	35097	77	R1	R	32	24	10	4	07573	0	40	25	9	65	10	12300	56	5	5
2301	507	670	3	101	35097	35260	163	R1	R	32	30	0	0	01289	20	40	6	0	78	11	12500	56	5	5
2301	670	1010	3	101	35260	35600	340	R1	R	32	24	10	4	01907	20	40	6	-	80	32	10800	56	5	5
2301	1010	1104	3	101	35600	35694	94	P1	R	32	24	10	4	01289	20	40	6	0	78	32	10800	56	5	5
3406	0	448	3	101	35692	36140	448	P1	L	32	24	10	4	00150	20	40	6	7	76	32	9300	61	5	5
3406	0	448	3	101	35692	36140	448	R1	R	32	24	10	4	00150	20	40	6	7	76	32	9300	61	5	5
3405	0	589	3	101	36152	36741	589	R1	L	32	24	10	4	09509	20	40	6	8	73	32	22600	68	5	5
3405	0	589	3	101	36152	36741	569	U1	R	32	24	10	4	09509	20	40	6	8	73	32	22600	68	5	5

Figure 10. Master Index Listing

Shown on the Master Index Listing from left to right are: CS = Control Section, Beginning CSMP, Ending CSMP, D = District, SR = Sign Route, Beginning SRMP, Ending SRMP, LENG = Length of Project, FC = Functional Classification (see below), L = Lane (Right or Left; for simple two-lane roads R is always shown), HT = Highway Type (1st character represents highway type [see below], 2nd character indicates the number of lanes), RDW = Roadway Width, RSH = Right Shoulder Width, LSH = Left Shoulder Width, CONT# = Most Recent Surfacing Contract Number, TY = Type of Construction (see below), SF = Type of Surfacing (see below), TK = Thickness of surfacing built on last contract, M = Month of year completed (see below), YR = Year completed, Base = Predominant type of surfacing below last contract (see below), the most recently available ADT, GRW = annual traffic growth rate (expressed as a percentage with one decimal point implied), SU = single unit truck percentage, and CM = combination truck percentage.

Functional Classes

U = Urban
R = Rural
1 = Principal Arterial
2 = Minor Arterial
3 = Major Collector
4 = Unclassified
5 = Interstate

Highway Type, HT

0 = Simple Highway
1 = Extra Lane
2 = Undivided
3 = Divided
4 = One-Way City
5 = Independent Line and Grade

Months

1-9 = January-September
0 = October
- = November
+ or & = December

Type of Construction, TY

00 = New Construction
10 = Reconstruction
20 = Resurfacing
30 = Bridge
40 = City or County Road Project
01 = First Stage Construction
02 = Second Stage Construction

Type of Surfacing, SF

10 = CSTC
20 = BST
21 = Mixed Bituminous
22 = Penetration Macadam
23 = SAM
30 = PCC
40 = ACP
41 = w/SAM I
42 = w/Fabric
43 = Open-Graded Friction Course
44 = Open-Graded Emulsion ACP
45 = Slurry Seal
46 = Recycled

Base Type

10 = Gravel and/or CSTC (original construction)
11 = Gravel and/or CSTC (overlaid old ACP)
12 = Gravel and/or CSTC (overlaid old PCC)
13 = Gravel and/or CSTC (overlaid old Bit.)
21 = Asphalt Treated Base (original construction)
22 = Asphalt Treated Base (overlaid old ACP)
23 = Asphalt Treated Base (overlaid old PCC)
31 = Cement Treated Base (original construction)
32 = Cement Treated Base (overlaid old ACP)
33 = Cement Treated Base (overlaid old PCC)
41 = Old PCC with Cushion Course of CSTC
42 = Old AC with Cushion Course of CSTC

Figure 11. Master Index Decoding Table

low, and average friction number of each year that surface friction was tested. It is worthy to note that for each year of friction data available for each project, a new record is created with an identical Master Index field. Until other yearly summary data are identified, Build 3 completes all processing necessary at the second level of the hierarchical structure.

Build 4

This is the final step in the file-building process and is applied at the lowest level of the hierarchical structure. In Build 4, the pavement condition ratings are matched to each year for each project. However, since pavement condition ratings are acquired by the mile, each rating creates a new record with the proper output record from Build 3 filling the Master Index field and generation field. With completion of Build 4 on each year's pavement condition ratings, the Master File is essentially built.

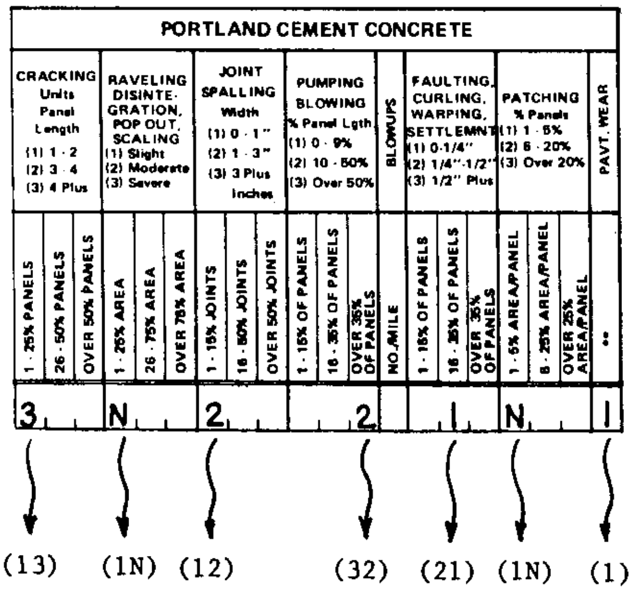
Master File

The ratings in the Master File are listed as raw data, not numerical score, for each distress category. The first digit indicates the column that was coded (extent, or percentage of area affected in most cases), and the second number is the digit that was coded on the recording sheet (severity in most cases). If there is no distress present for a specific distress type, an "N" is coded in the first column to indicate the raters considered that distress. This concept is depicted in Figure 12.

Figure 13 is an example of the Master File listing. The top line of data is representative of the Master Index field. Below that are all pavement condition ratings for each year and each mile in that particular project. To the right of the raw ratings are: the raw unadjusted roughness measurements; the speed at which the counts were acquired; an adjusted count for the speed, meter, and vehicle used; and a ride rating (scale 0.0 to 1.0) related to the adjusted bump count.

Figure 14 is an example of the coding form used for rating pavement condition. Note that by inspecting the trends in distress codings as shown on the Master File listing, the consistent and inconsistent categories can be quickly identified.

With the file, as it is now assembled, it is possible to distinguish the gradual deterioration of pavements in terms of order of occurrence and magnitude of distress types from year to year. Basically, this is all that is required to gauge the performance aspect in a pavement management system.



Coding: (AB) A = Column Coded
B = Number Coded

Note: "N" indicates no distress present.

Figure 12. Representation of Pavement Rating Raw Coding

R67714MF

06/14/82

CS	BEG	END	D	SR	BEG	END	LENG	FC	L	HT	RDW	RSH	LSH	CONT#	TY	SF	TK	M	YR	BASE	80 ADT	GRW	SU	CM
2331	343	591	3	3	72	320	248	U1	R	02	23	3	3	01437	20	40	15	8	80	11	4400	53	5	2

GEN	SIDE	ECSMP	RUTT WEAR	WAVE SAGS	ALG CRK	RAV FLU	LONG CRK	TRNS CRK	PTCH	BUMPS	BUMP SPEED	ADJ BUMPS	RIDE RATNG
69	B	371	N	11	1N	11	11	1N	1N	0	0	0	1.00
69	B	471	N	11	1N	11	11	1N	1N	0	0	0	1.00
69	B	571	N	11	1N	11	11	1N	1N	0	0	0	1.00
69	B	671	N	11	1N	11	11	1N	11	0	0	0	1.00
71	B	371	1	12	12	13	31	31	11	667	40	518	1.00
71	B	471	1	12	12	13	31	31	11	1435	50	2254	0.94
71	B	571	1	12	12	13	31	31	1N	1184	50	1825	0.96
71	B	671	1	12	1N	13	21	1N	11	910	50	1356	0.98
73	B	371	1	12	22	31	33	31	21	665	30	153	1.00
73	B	471	1	12	22	31	33	1N	1N	512	30	63	1.00
73	B	571	1	12	22	31	33	1N	1N	763	50	420	1.00
73	B	671	1	12	21	31	33	1N	21	975	50	589	1.00
75	B	400	R	12	12	13	31	1N	1N	979	30	1658	0.97
75	B	500	R	12	12	22	31	21	1N	1648	50	1648	0.97
75	B	600	R	13	22	32	31	1N	1N	1680	50	1680	0.97
77	B	400	N	12	13	21	21	21	23	1540	40	1926	0.96
77	B	500	1	11	22	11	21	1N	22	2118	50	2118	0.95
77	B	600	N	12	12	11	21	1N	22	1233	40	1554	0.97
79	B	400	N	21	12	12	21	1N	23	2102	50	2102	0.95
79	B	500	N	12	12	31	21	1N	23	1747	50	1747	0.96
79	B	600	N	12	12	12	21	1N	23	1358	50	1358	0.98
81	B	344	N	11	1N	21	1N	1N	1N	1854	50	1418	0.98
81	B	400	N	11	1N	21	1N	1N	1N	1731	50	1331	0.98
81	H	500	N	11	1N	21	1N	1N	1N	1618	50	1251	0.98
81	B	509	N	11	1N	21	1N	1N	1N	949	50	764	0.99
81	H	600	N	11	1N	11	1N	1N	1N	1101	50	876	0.99

Figure 13. Master File Listing

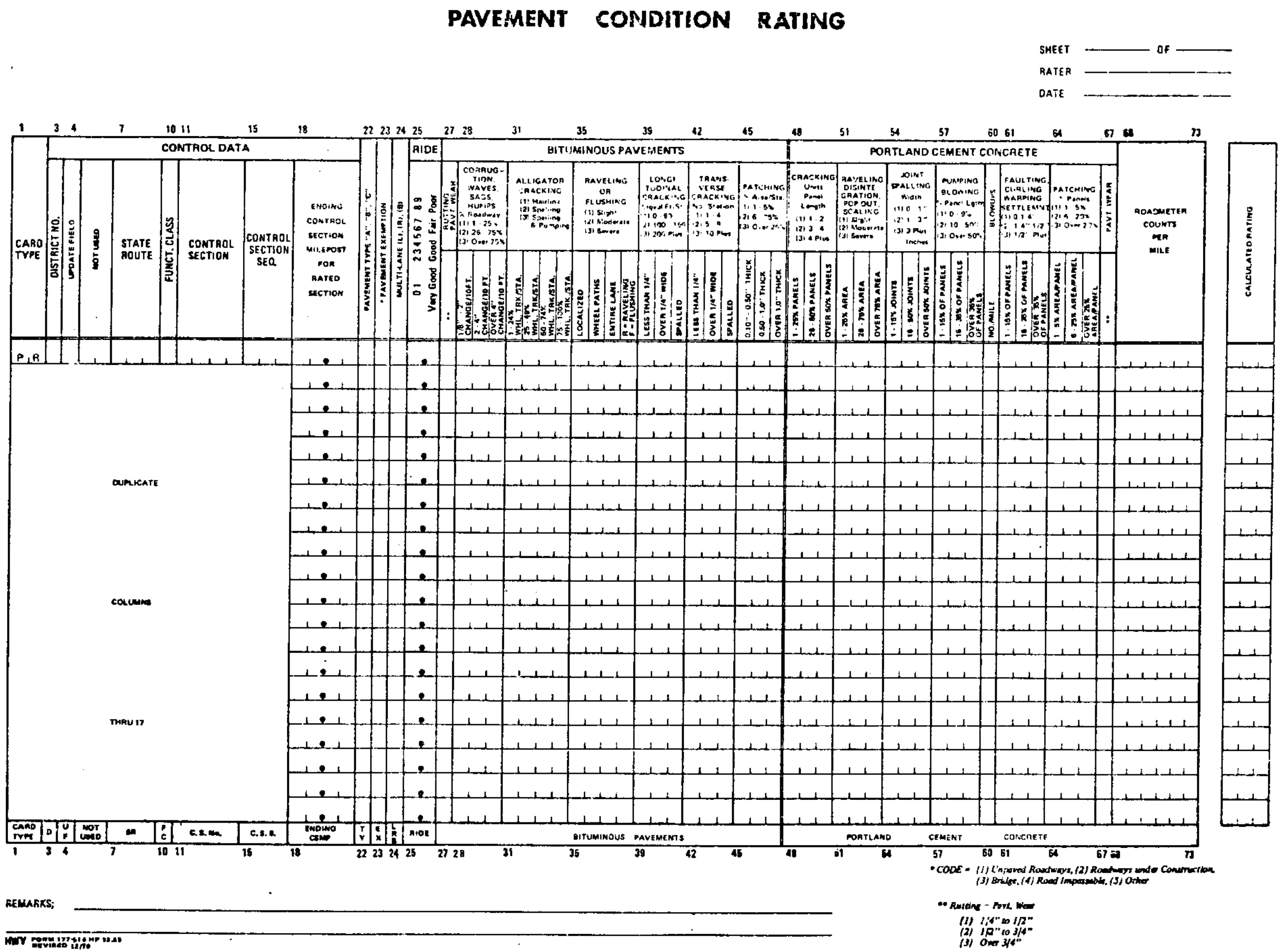


Figure 14. Pavement Rating Form

Chapter 3

INTERPRETING THE DATA BASE

Background

Early in the development of this system, it became apparent that a step should be provided to analyze the performance of each project in the master file prior to any consideration of rehabilitation alternatives. Bartell and Kampe[5], who were working on development of a PMS for the California DOT, were concerned about the usefulness of a combined rating that does not identify specific distress problems. Their reasoning was based on the importance of knowing what is specifically wrong with a pavement in order to provide the proper fix. A major objective in the development of this system, however, was to achieve a predictive capability--something that could only be accomplished with a combined rating. Without overlooking the importance of specific types of distress, some type of combined rating was necessary to rank projects and provide a pavement rating vs. age relationship so that time to failure might be predicted.

This dichotomy of opinion was recognized and the interpreting phase was developed to accommodate both approaches. With this method, raw coded data indicating severity and extent of each distress type are maintained in the master file. These data are then translated into a combined rating in the interpreting phase, giving this system flexibility and the utility of an analytical tool. By utilizing parameters that are not an integral part of the interpreting program, distress weightings can be altered or adjusted after inspection of an initial run. This is an asset in calibrating weighting values for the types of distress rated, or studying any combination of distress types since weighting values can be zeroed for no influence.

An additional aspect of the interpreting phase is the potential for statistical analysis of performance trends. Since the interpreting program generates a file of performance data related to project segments, the results can be analyzed with SPSS[6] or BMD[7] software packages. Topics of particular interest might include correlation of pavement performance to specific measures of construction quality, geographic location, pavement type, rehabilitation type, or even a specific version of construction specifications. Information gained from these studies could lead to improvement of the currently used design formulas for surfacing depths or rehabilitation methods.

Interpreting Program

The interpreting program performs five basic functions:

1. Converts raw distress codings into numerical ratings.
2. Computes biennial mean ratings for each project and indicates the high and low ratings for each period.
3. Produces a performance curve for each project.
4. Plots the past ratings together with the performance curve for each project.
5. Generates a file with all results stored for further analysis and use.

Input for this program comes from two sources:

1. The master file previously described.
2. A direct access data set that contains the distress weighting matrix and other interpreting parameters. (See Figure 25.)

Control of the interpreting program is administered by editing the parameters in the small direct access data set.

The first function of the program is to translate the raw coded distress data and bump count for each record into a combined numerical rating. These ratings are calculated with the following equation:

$$\text{Combined Pavement Rating} = (100 - \Sigma D) \cdot \left(1.0 - 0.3\left(\frac{CPM}{5000}\right)^2\right)$$

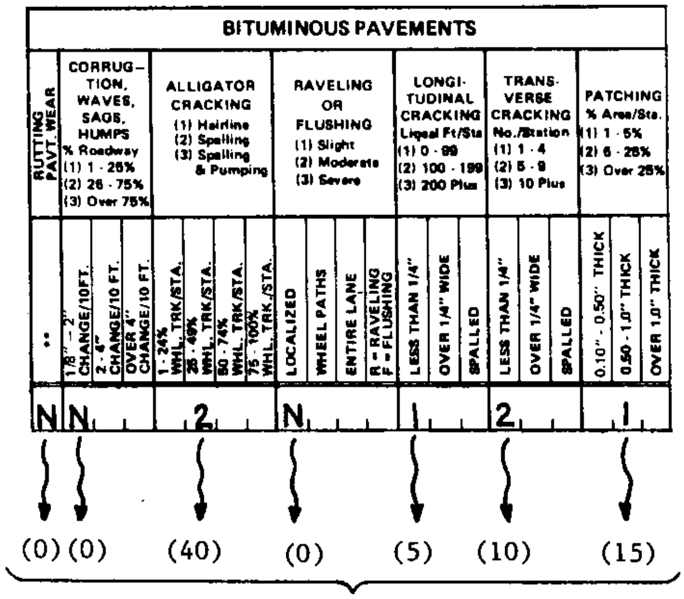
$$\text{Combined Pavement Rating} = (\text{distress rating}) \cdot (\text{ride rating})$$

Explaining the evolution of this formula is most simply done by addressing the distress rating and ride rating separately before describing the relationship between them.

As stated earlier, pavement surface distress is rated by judging the severity and extent of several types of distress. Each of these distress ratings has an associated weighting value. Since a pavement in perfect condition (no signs of distress) has a rating of 100, the sum of weighting values, ΣD, is subtracted from 100 to establish the overall distress rating (see Figure 15). Since we are most concerned with rehabilitation related to distress, the distress rating is the major part of the formula.

The ride rating portion of the formula actually plays a minor role. The combination of the ride rating with the distress rating has long represented much concern to us. However, the department fully recognizes that while distress bears significance to the highway engineer, pavement roughness, or rideability, relates to the user.

Early in PMS development it was determined that there is little or no correlation between the progression of distress and the deterioration of ride



Weighting Values

$$\Sigma D = 0+0+40+0+5+10+15 = 70$$

$$\text{Distress Rating} = 100 - \Sigma D = 30$$

Figure 15. Association of Weighting Values with Distress Categories

in the State of Washington. Even though extensive longitudinal cracking or alligator cracking exists, the pavements still ride well. Only when the pavements begin to break up do they demonstrate poor ride.

The State of Washington has a system of approximately 6900 lineal miles of highway: ∿ 4000 miles of asphalt concrete; ∿ 2500 miles of mixed bituminous pavement; and only about 400 miles of portland cement concrete pavement. Since our effort has almost exclusively been directed to flexible pavements, the above statement does not relate to PCC.

The average ride for asphalt concrete pavement = ∿ 1100 CPM, maximum count = ∿ 3000 CPM; the average ride for bituminous mix pavements = ∿ 1700 CPM, maximum count = 5000. (CPM = counts per mile acquired with a Cox Ride Meter.) Given this information and Figure 16 produced from the ride formula,

$$1.0 - 0.3 \left(\frac{CPM}{5000}\right)^2$$

it should be quickly realized that ride plays a very minor role in the equation. Only when the ride is extremely poor does it significantly reduce the combined rating--and, if the ride is extremely poor, the pavement almost always has severe distress.

CPM	Ride Rating	CPM	Ride Rating
≤500	1.00	6450	.50
2000	.95	7050	.40
2900	.90	7650	.30
4100	.80	8150	.20
5000	.70	8650	.10
5750	.60	≥9100	0

Figure 16. Ride Rating vs. Roughness (CPM)

WSDOT has been evaluating pavement roughness with ride meters since approximately 1970. Prior to, during, and after each survey the meter is run through a "standard" section to ensure its repeatability and calibration. There have been changes in meters and vehicles over this time. As each change occurred, much effort was dedicated to producing accurate equations for relating the old meter setup to the new. These equations are utilized in the interpreting program. All counts are related to one common count base for use in the rating formula.

The second function of the program is to compute mean, high, and low ratings for each occasion the pavement is rated. To accomplish this, the program determines the length for each section rated based on the beginning and ending limits of the project, the ending milepost read on each record, and the ending milepost read on the preceding record. Each converted rating is then weighted by this length to compute the mean project rating for the year. As the averaging process is applied, the program compares each rating with previous ratings to determine the high and low for the year.

The third function of the program is to produce a performance curve which best represents the pavement's anticipated performance. This curve can be used to predict future performance for that section.

Figure 17 illustrates the general shape of a performance curve. From this illustration it is seen that a pavement deteriorates with age, the rate usually increasing each year, until it reaches a state of slower deterioration. This decelerated rate of deterioration can be attributed to application of temporary fixes to hold the pavement together until a major remedy can be applied. These temporary fixes tend to cause short duration, random fluctuations in the pavement rating--probably best represented by a curve which passes through the mean value in this phase. The performance model developed for use in the interpreting program presently ignores the maintenance or temporary fix influence because it is assumed the Department will initiate action prior to reaching the lower portion of the curves. A contemplated improvement in the future is to enhance the performance model by incorporating better representation in the lower range.

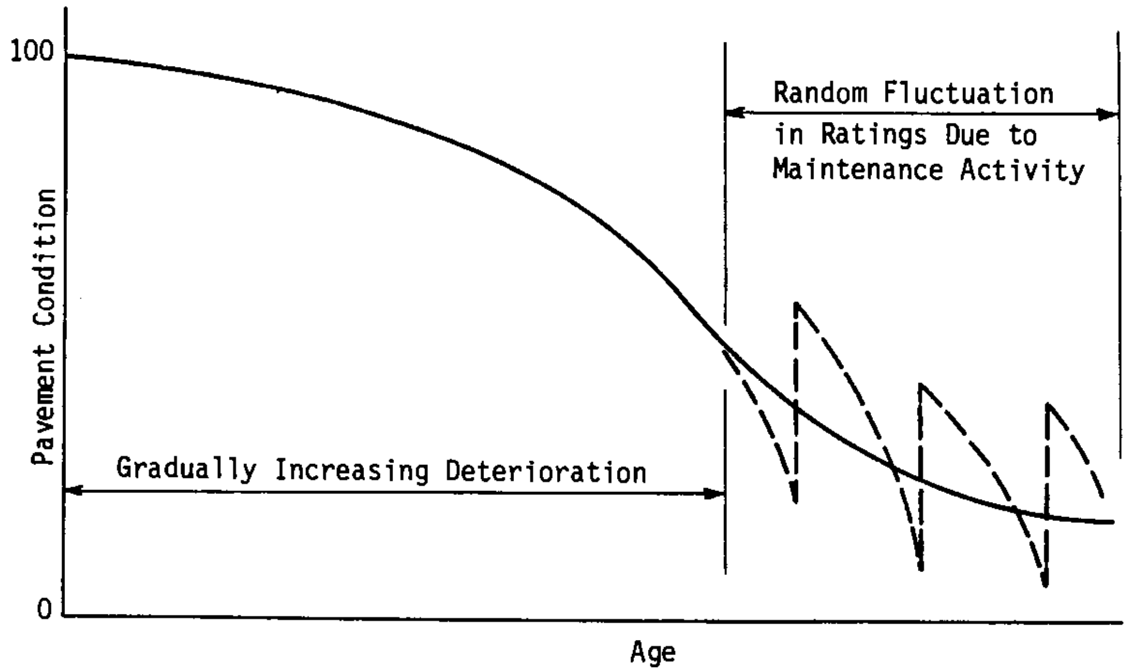


Figure 17. Typical Performance Curve

Figure 18 is an illustration of this model relating pavement rating to age. The general form of the performance equation adapted is:

$$R = C - mA^B$$

where R and A represent rating and age respectively, C is the model constant for maximum rating (∿ 100), m is the slope coefficient, and B is a constant that controls the degree of curvature.

Figure 19 is an example of different shapes the curve might assume. Curves 1 and 2 are linear and demonstrate the influence of the slope, m. Curves 2, 3, and 4 demonstrate the control that B exerts on the degree of curvature. Note that exponents greater than 1 indicate convex curvature, while exponents less than 1 indicate concave curvature.

In fitting the best curve to the pavement ratings, the program substitutes a number of different exponents (B) to transform the independent variable, age. The best fit is determined by the highest R^2 value (coefficient of determination) using the sum of least squares method. Statistics associated with the curve equation are the R^2 value and the standard error of estimate.

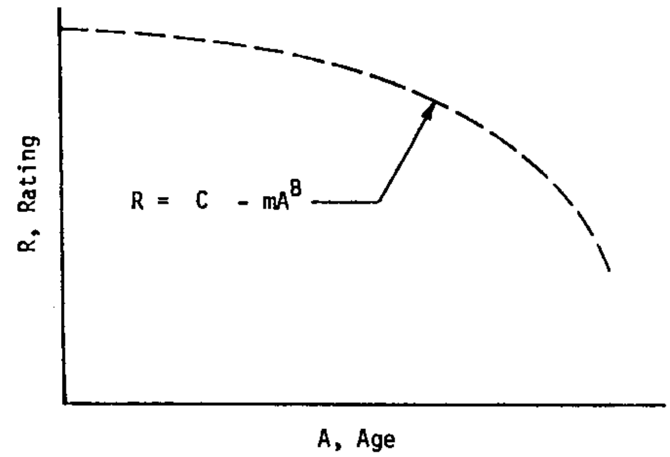


Figure 18. Performance Curve Model

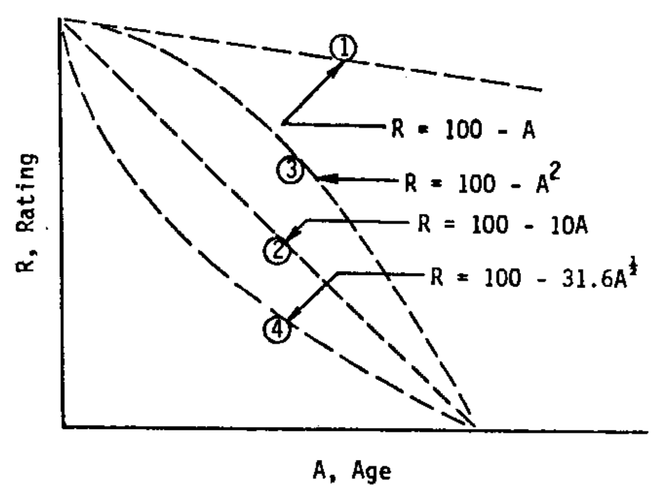


Figure 19. Example of Curve Model Shapes

Regression analysis is the initial approach employed in generating a performance equation. However, regression analysis may not always produce acceptable equations. The project being analyzed may have been in existence for only a few years--thus providing too few rating values for the application of regression analysis. Another problem encountered is the random fluctuation of ratings for some projects. Inconsistent ratings cause a bad fit (low R^2) when using regression analysis.

These problems are addressed in the interpreting program by utilizing three different methods of producing performance curves:

1. When the project being considered does not have at least three ratings, a typical equation for the specific pavement type, surfacing depth, and geographical area is assigned. This is justifiable because the pavement would be relatively new and should not need rehabilitation for some time. The equation generated is used primarily in network analysis. Should the project have only two ratings, with the second rating falling beyond that allowed for in the typical equation, the performance equation is modified so as to reflect that rating.
2. Regression analysis is applied to all projects that have at least three ratings. This is the primary method of developing performance equations.
3. When regression analysis does not produce a reasonably good fit, R^2 value less than minimum acceptable, a "typical" curve is fitted through the first and last values.

These three methods of developing performance equations are incorporated in the interpreting program as an algorithm for automation. They may not always produce acceptable equations. For this reason, all projects are reviewed and the resulting interpreted data file is edited to reflect engineering judgment.

The fourth function of the program is to tabulate and plot the annual mean, high, and low ratings with the mathematically fitted performance curve. Figures 20, 21, and 22 are examples of the listing produced. The top line on each describes the project with the same format as that used in the Master Index listing and the Master File listing. Below the description is a tabulation of performance and traffic data. The lower half of the listing is dedicated to the plot. By inspecting this plot, it is possible to see how well the curve fits the rating, how long the pavement might last until rehabilitation is required, and how much variation there is in the ratings by noting the high and low values for each year. Note that each of these three projects demonstrates different performance.

The last function of the program is directed at generating an output file that includes the results of all processing. This file is used for several purposes, the principal ones being:

1. Input to the optimizing program.
2. Correlation analysis with various factors such as pavement type, surfacing depth, geographical area, climate, etc.
3. Statistical analysis using SPSS[6], BMD[7], or other available statistical programs.

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D	SR	BEG SRMP	END SRMP	CS	BEG CSMP	END CSMP	PROJ LENG	FNC CLS	SIDE	HWY TYP	NUM LNS	RDW-RSH-LSH WIDTHS	LAST CONTR	COMPL M-YR	CNT TYP	SURFACE TYP-THK	BASE TYPE
3	8	1613	1892	3404	559	838	279	R-1	1	3	2	24 10 4	09509	8-73	76	6 6	32

PERFORMANCE HISTORY

YEAR	73	75	77	79
AGE	0	2	4	6
RIDE RATING	1.00	1.00	1.00	1.00
STPUCR RATING	100.0	97.5	92.6	73.8
COMBD RATING	100.0	97.3	92.1	73.6
HIGH RATING	100.0	99.8	99.5	84.9
LOW RATING	100.0	89.7	69.7	59.8
HIGH FRICTION	55	58	58	51
LOW FRICTION	52	53	53	49
AVG FRICTION	53	56	55	50

APPROXIMATE TRAFFIC DATA

79 ADT	10300
GROWTH RATE	6.0%
SINGLE UNITS	4%
COMBINATIONS	7%
TRAFFIC INDEX	7.1
K = 19%	D = 75%
2 AXLE TRUCKS =	2.7 %
3 AXLE TRUCKS =	2.7 %
4 AXLE TRUCKS =	0.9 %
5 AXLE TRUCKS =	4.7 %

PERFORMANCE EQUATION

EQUA CONST =	99.30
EQUA COEFF =	-0.11857
EQUA POWER =	3.00
R SQUARE =	0.99575
STD ERROR =	0.95
TIME TO 60 =	6.92
TIME TO 50 =	7.46
TIME TO 40 =	7.94
TIME TO 30 =	8.36
TIME TO 20 =	8.75

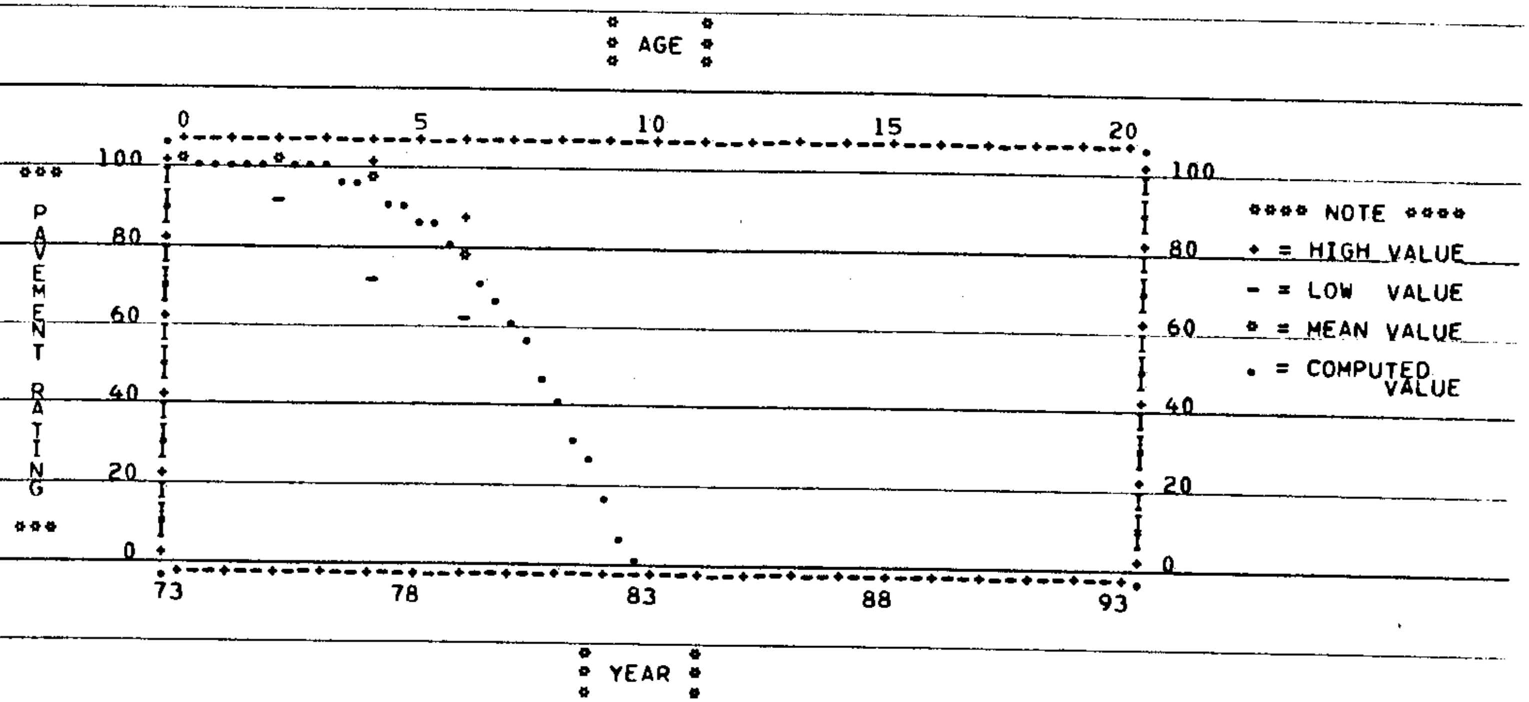

Figure 20. Example 1 of Performance Listing

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D	SH	BEG SRMP	END SRMP	CS	BEG CSMP	END CSMP	PROJ LENG	ENC CLS	SIDE	HWY TYP	NUM LNS	RDW-RSH-LSH WIDTHS	LAST CONTR	COMPLT M-YR	CNT TYP	SURFACE TYP-THK	BASE TYPE
*	***	*****	*****	****	****	****	****	***	****	***	***	***********	*****	******	***	*******	****
3	3	2066	2228	2331	2335	2497	162	R-1	R	0	2	23 3 3	09497	--73	3	6 15	10

PERFORMANCE HISTORY

YEAR	73	75	77	79
AGE	0	2	4	6
RIDE RATING	0.99	0.99	0.97	0.98
STRUCR RATING	100.0	100.0	97.3	88.0
COMBD RATING	100.0	98.6	94.8	85.9
HIGH RATING	100.0	99.2	98.7	98.4
LOW RATING	100.0	98.1	91.4	77.5
HIGH FRICTION	0	62	51	48
LOW FRICTION	0	60	49	46
AVG FRICTION	0	60	50	46

APPROXIMATE TRAFFIC DATA

79 ADT	3800
GROWTH RATE	6.8%
SINGLE UNITS	5%
COMBINATIONS	2%
TRAFFIC INDEX	6.3
K = 17%	D = 58%
2 AXLE TRUCKS =	3.3 %
3 AXLE TRUCKS =	2.0 %
4 AXLE TRUCKS =	0.3 %
5 AXLE TRUCKS =	1.3 %

PERFORMANCE EQUATION

EQUA CONST =	99.77
EQUA COEFF =	-0.15711
EQUA POWER =	2.50
R SQUARE =	0.99846
STD ERROR =	0.30
TIME TO 60 =	9.15
TIME TO 50 =	10.01
TIME TO 40 =	10.77
TIME TO 30 =	11.45
TIME TO 20 =	12.09

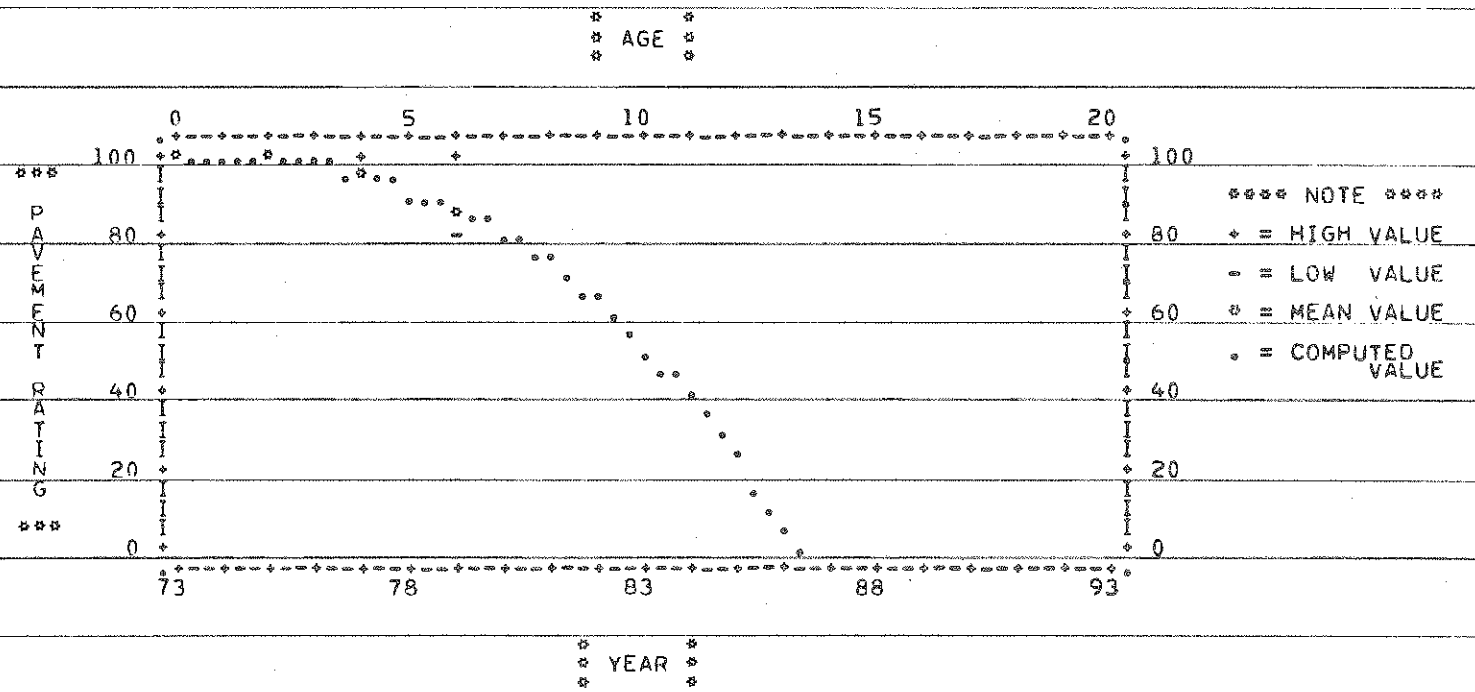

Figure 21. Example 2 of Performance Listing

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D	SR	BEG SRMP	END SRMP	CS	SEQ	BEG CSMP	END CSMP	PROJ LENG	FNC CLS	SIDE	HWY TYP	NUM LNS	ROW-RSH-LSH WIDTHS	LAST CONTR	COMPLT M-YR	CNT TYP	SURFACE TYP-THK	BASE TYPE
*	***	*****	*****	****	***	****	****	****	***	****	***	***	***********	*****	******	***	*******	****
6	90	25529	25713	3201	170	0	184	184	R-5	L	3	2	24 10 4	08007	7-67	0	40 67	10

PERFORMANCE HISTORY

YEAR	69	71	73	75	77	79
AGE	2	4	6	8	10	12
RIDE RATING	1.00	1.00	0.99	1.00	0.99	0.99
STRUCR RATING	100.0	93.2	81.8	72.3	72.3	48.6
COMBD RATING	100.0	92.8	81.3	72.0	71.9	48.2
HIGH RATING	100.0	99.9	89.9	74.5	74.4	59.6
LOW RATING	100.0	84.3	74.1	69.9	69.8	34.6
HIGH FRICTION	0	0	0	0	0	0
LOW FRICTION	0	0	0	0	0	0
AVG FRICTION	0	0	0	0	0	0

APPROXIMATE TRAFFIC DATA

79 ADT	10400
GROWTH RATE	5.6%
SINGLE UNITS	5%
COMBINATIONS	15%
TRAFFIC INDEX	7.4
K = 12% D =	60%
2 AXLE TRUCKS =	3.3 %
3 AXLE TRUCKS =	4.6 %
4 AXLE TRUCKS =	1.9 %
5 AXLE TRUCKS =	10.1 %

PERFORMANCE EQUATION

EQUA CONST =	101.42
EQUA COEFF =	-1.18510
EQUA POWER =	1.50
R SQUARE =	0.95267
STD ERROR =	4.46
TIME TO 60 =	10.69
TIME TO 50 =	12.35
TIME TO 40 =	13.90
TIME TO 30 =	15.37
TIME TO 20 =	16.77

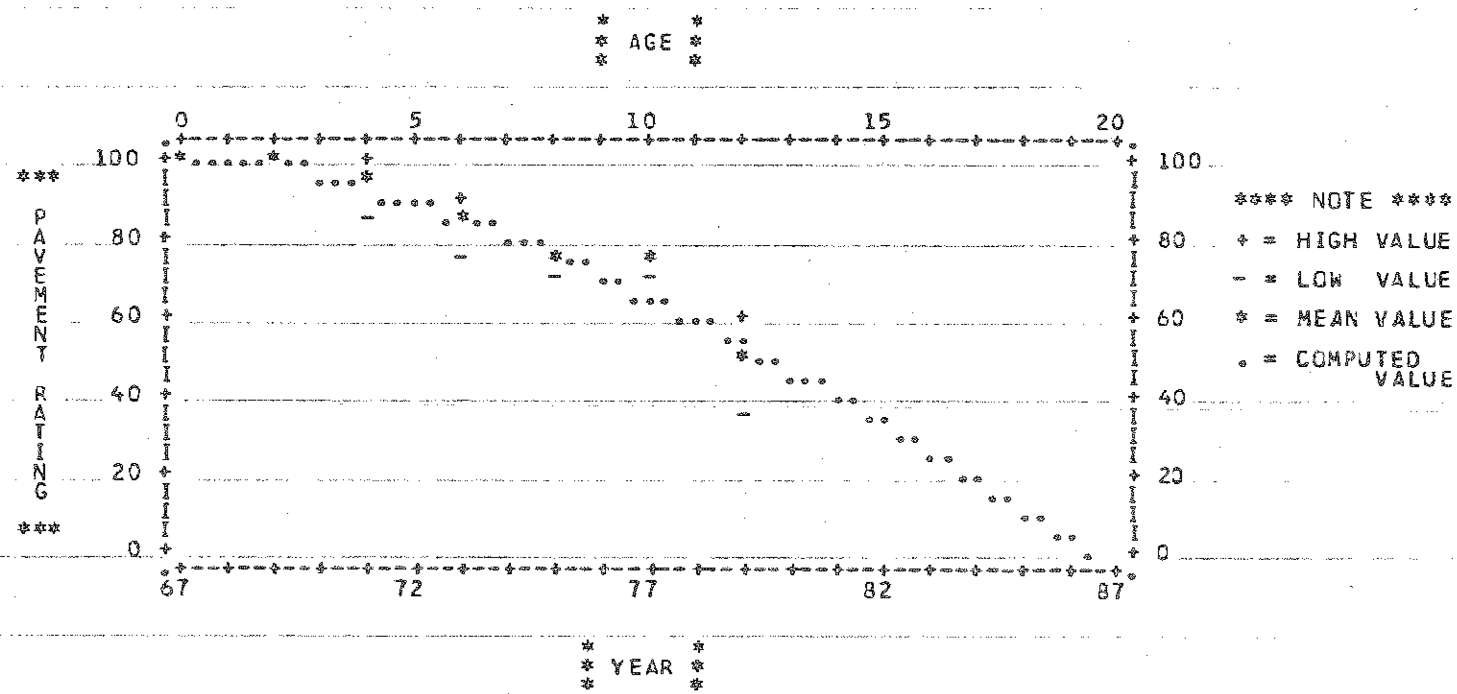

Figure 22. Example 3 of Performance Listing

Figure 23 is an example of items included in this file with the general layout scheme. Figure 24 is an example of a summary listing generated from this file.

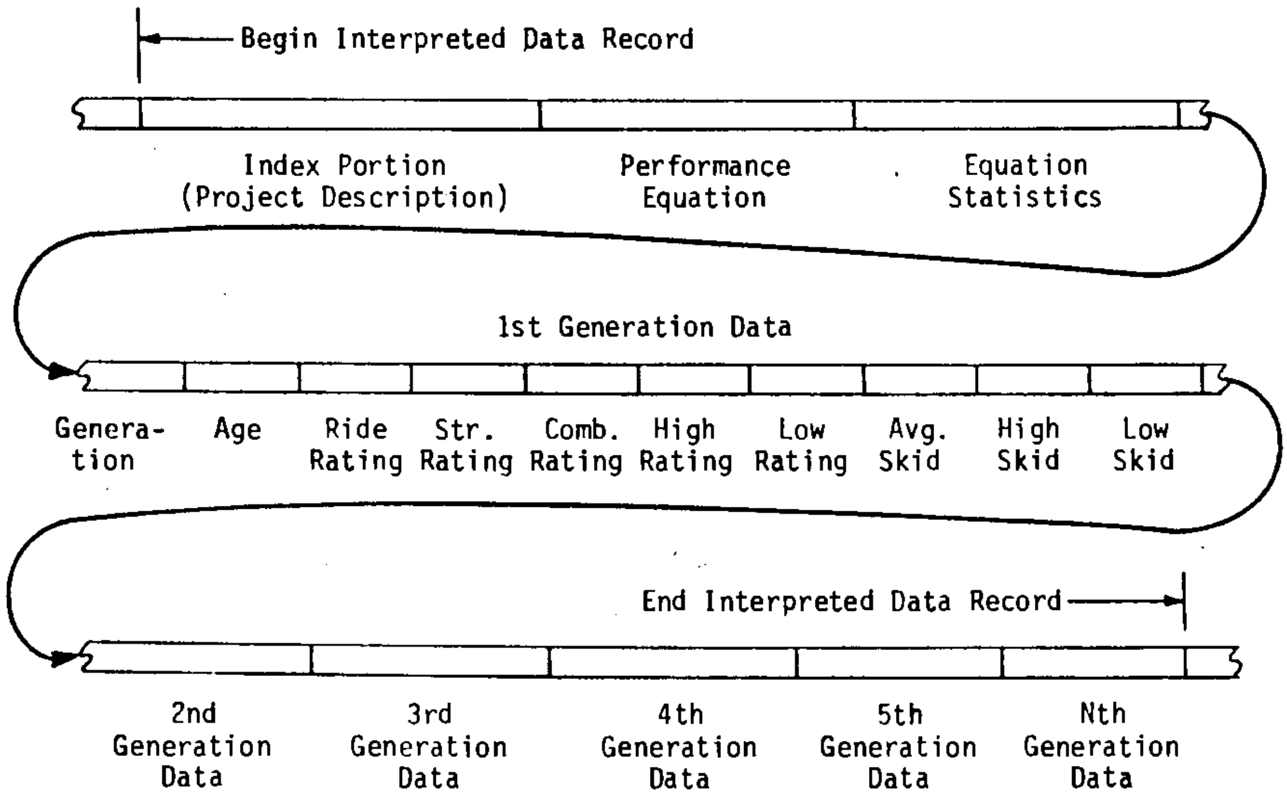

Figure 23. Interpreted Data File Layout

When analyzing specific items with the statistical software packages such as SPSS[6] or BMD[7], composition of a small FORTRAN program is necessary for reformatting the data into a file which conforms to their particular specifications.

With each distress category rated by severity and extent, it became obvious while writing the interpreting program that the corresponding weighting values could be stored in a two-dimensional array, or matrix. As each distress code is read, the two digits in each raw coding point to the address within the weighting matrix. This matrix contains the weighting value for the extent and severity of each specific distress type. Consider the category of longitudinal cracking which is rated with three levels of severity: cracks less than 1/4"; cracks greater than 1/4"; and spalled cracks. It is also rated with three areas of extent: 0-99 lineal feet per station; 100-199 lineal feet per station;

D	SR	FSRMP	ESRMP	LENG	CONTR	TY	SF	TK	YR	RS	ADT	GRW	SU	CM	TI	ECONS	EVAR	EPOW	RSQ	LF 60	LF 40
3	3	0	23	23	09361	0	40	70	74	10	9300	58	5	2	6.7	100.00	-0.02808	3.00	0.0	11.25	12.88
3	3	23	143	120	01907	20	40	8	80	11	10000	58	5	2	6.7	100.00	-0.27777	3.00	0.0	5.24	6.00
3	3	72	320	248	01437	20	40	15	80	11	4400	53	5	2	6.4	100.00	-0.02743	3.50	0.0	8.02	9.00
3	3	143	72	200	01907	20	40	12	80	11	9400	54	5	2	6.7	100.00	-0.02743	3.50	0.0	8.02	9.00
3	3	320	425	105	01437	0	40	35	80	10	4200	54	5	2	6.4	100.00	-0.00289	4.00	0.0	10.85	12.00
3	3	425	488	63	01437	20	40	15	80	11	4200	56	5	2	6.4	100.00	-0.02743	3.50	0.0	8.02	9.00
3	3	488	553	59	01800	0	40	35	80	10	4200	56	5	2	6.4	100.00	-0.00289	4.00	0.0	10.85	12.00
3	3	553	631	78	01800	20	40	15	80	11	4100	56	5	2	6.4	100.00	-0.02743	3.50	0.0	8.02	9.00
3	3	631	959	326	02010	20	40	8	81	11	3100	56	5	2	6.2	100.00	-0.27777	3.00	0.0	5.24	6.00
3	3	959	1737	778	03863	20	40	15	73	11	2500	56	5	2	6.1	99.26	-0.00193	4.00	0.91097	11.94	13.23
3	3	1737	2067	330	00366	20	40	15	76	11	3400	66	5	2	6.3	100.74	-4.28382	1.00	0.98937	9.51	14.18
3	3	2067	2228	161	09497	20	40	15	73	11	3800	68	5	2	6.3	100.11	-1.13594	1.25	0.92594	17.31	23.93
3	3	2228	2375	147	09022	20	40	10	71	11	6100	39	5	2	6.5	100.00	-1.04630	1.75	0.0	8.02	10.11
3	3	2375	2957	582	01540	20	40	12	80	11	7000	52	5	2	6.6	100.00	-0.02743	3.50	0.0	8.02	9.00
3	3	2957	3180	223	00135	20	40	15	76	11	8500	53	5	2	6.7	100.00	-0.02743	3.50	0.0	8.02	9.00
3	3	3180	3187	7	00665	20	40	10	77	11	8500	53	5	2	6.7	100.01	-1.45205	1.50	0.99990	9.12	11.95
3	3	3187	3223	36	00665	20	40	10	77	11	39000	54	5	2	7.3	100.13	-0.15453	4.00	0.99996	4.01	4.44
3	3	3223	3398	175	00572	20	40	8	77	11	39200	56	5	2	7.3	100.00	-0.27777	3.00	0.0	5.24	6.00
3	3	3398	3495	97	09203	0	40	60	73	10	14100	56	5	6	7.3	100.00	-0.00289	4.00	0.0	10.85	12.00
3	3	3495	3752	78	09476	0	40	60	75	10	14500	56	4	4	7.1	100.00	-0.00289	4.00	0.0	10.85	12.00
3	3	3752	3786	34	09476	20	40	15	75	11	22000	56	4	2	7.0	99.08	-0.02649	4.00	0.99595	6.20	6.87
3	3	3752	3774	22	09476	20	40	15	75	11	22000	56	4	2	7.0	100.00	-0.02753	4.00	0.97896	6.17	6.83
3	3	3774	4022	248	08328	0	40	58	66	10	21100	60	4	2	7.0	102.08	-0.00131	4.00	0.82123	13.36	14.75
3	3	3786	4022	236	08328	0	40	58	66	10	20600	60	4	2	7.0	100.88	-0.00138	4.00	0.95707	13.12	14.50
3	3	4023	4324	301	09269	0	40	35	74	10	16900	65	4	2	6.9	100.00	-0.00289	4.00	0.0	10.85	12.00
3	3	4023	4324	301	09269	0	40	35	74	10	16900	65	4	2	6.9	99.18	-0.05541	3.00	0.98035	8.91	10.22
3	3	4324	4475	151	00729	0	40	60	78	10	9300	69	4	2	6.6	100.00	-0.00289	4.00	0.0	10.85	12.00
3	3	4324	4475	151	00729	0	40	60	78	10	9300	69	4	2	6.6	100.00	-0.00289	4.00	0.0	10.85	12.00

Figure 24. Interpreted Data Listing

and over 200 lineal feet per station. These divisions of severity and extent can be represented by a 3 x 3 weighting matrix. Each cell in the matrix is assigned a certain weighting value corresponding to the extent and severity of the particular distress.

As was mentioned earlier, control of the interpreting program is exercised by editing the data set which contains the interpreting parameters. Included in these parameters are the weighting matrices for each distress category in each pavement type, the present year, the number of exponents to be used in applying transformations to the independent variable in regression analysis, the minimum R^2 acceptable, an identification number to be used when making several runs on the same data (each with different weighting values), and an array of the exponents to be used for the transformation. Figure 25 is an illustration of the interpreting parameter layout. Figure 26 is a conceptual flow chart of the interpreting phase.

Performance Analysis

In order to be assured that the performance curves and equations for each section are reasonable and represent the best forecast of future pavement condition, each curve is thoroughly reviewed. The performance of most sections conforms to the algorithm utilized in the interpreting program. Pavement sections with rating histories that do not fall in line with this algorithm are individually analyzed and provided with typical performance curves which are intended only to forecast future ratings and may not fit past ratings at all. Sections that fit into this category are not considered good prospects for the optimizing analysis. Instead, they are subjected to an engineering analysis to develop a sufficient fix.

Several aspects of the performance curves are considered in the review process. These include:

- the shape and length of curve for the type of pavement it represents
- the variance in high and low ratings indicated for each year
- the performance curves for the adjacent sections
- cycling of pavement ratings that may indicate unrecorded rehabilitation or maintenance.

When a high degree of variance is noted between the high and low ratings for each year, the Master File listing and the construction history (K-9) file are studied. The Master File indicates where the high and low ratings are located, while the construction history file demonstrates past surfacing contract limits that might be correlated with the break in high and low ratings.

	Rutting Pavt Wear	Corrug. Waves Sags Humps			Alligator Cracking				Raveling or Flushing			Longitud. Cracking			Transv. Cracking			Patching		
AC	0	0	0	0	20	25	30	35	0	0	0	5	15	30	5	10	15	10	15	20
	0	0	0	0	35	40	45	50	0	0	0	15	30	45	10	15	20	15	20	25
	0	0	0	0	50	55	60	65	0	0	0	30	45	60	15	20	25	20	25	30

	Rutting Pavt Wear	Corrug. Waves Sags Humps			Alligator Cracking				Raveling or Flushing			Longitud. Cracking			Transv. Cracking			Patching		
BIT	0	0	0	0	20	25	30	35	0	0	0	5	15	30	5	10	15	10	15	20
	0	0	0	0	35	40	45	50	0	0	0	15	30	45	10	15	20	15	20	25
	0	0	0	0	50	55	60	65	0	0	0	30	45	60	15	20	25	20	25	30

	Rutting Pavt Wear	Blowups	Cracking			Raveling Disinteg. Pop-Out Scaling			Joint Spalling			Pumping Blowing			Faulting Curling Warping Settlemt			Patching		
PCC	0	0	5	10	20	0	0	0	5	10	15	0	0	0	5	10	20	0	0	0
	0	0	10	20	35	0	0	0	10	20	30	0	0	0	10	20	30	0	0	0
	0	0	15	30	50	0	0	0	15	30	50	0	0	0	15	30	40	0	0	0

1	2	3	4
82	15	0.75	01

1 Present Year

2 Number of Exponents Used

3 Minimum R^2 acceptable

4 Weighting ID - used in testing different weighting values.

Exponents used as transformations - 20 max.

0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	0	0	0	0	0

INTERPRETING PARAMETERS

Figure 25. Interpreting Parameter Layout

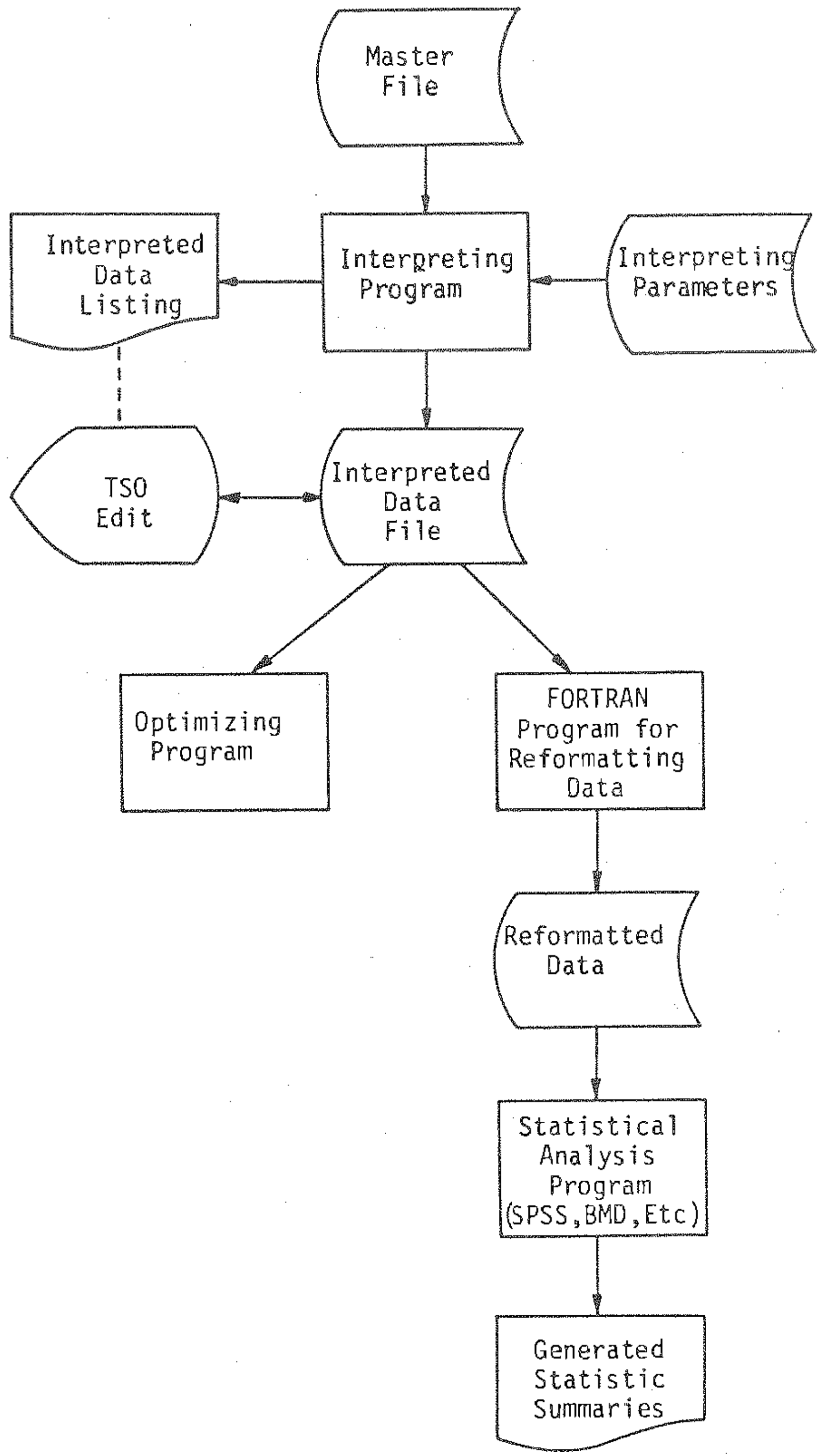

Figure 26. Conceptual Flow Chart of Interpreting Phase

A good example of cycling is shown in Figure 27. This occurs when there is undocumented maintenance or a rehabilitation project has been overlooked and subsequently was not coded.

When the performance of a specific portion of the section is substantially different from the rest, the project may be divided into two or more projects with new project limits.

As was mentioned in the chapter describing the data base, there is a problem with relating some pavement ratings to smaller projects because of overlap. The ratings indicated in the Master File may not be related to that section at all. To allow for this during performance analysis, sections which are extremely short are combined with adjacent sections demonstrating similar performance.

After the first review, the Master File is edited to reflect changes in mileposting for specific sections and then reanalyzed with the interpreting program. This process is reiterated until satisfaction is obtained that all performance sections and the curves representing them are as good as they can be. Some curves will obviously be synthetic since some of the pavements are structurally inadequate. Ultimately, performance curves for the entire state highway system are stored in the Interpreted Data File. It is important to note that although the Master File is originally based on past surfacing contract limits, these limits may eventually be adjusted to represent the best divisions of pavement performance. However, these changes represent a very small percentage of the system.

Determination of Distress Weightings

Many man-months were invested both in identifying the significant categories of distress and how each should be weighted. Two considerations were emphasized in identifying the significant categories of distress:

1. The consistency of ratings with time.
2. The relationship of each to rehabilitation criteria.

With the master file assembled to track raw coded ratings (purely extent and severity--no weighted or combined ratings), it was apparent after studying many sections which categories best fulfilled these considerations. These were transverse cracking, longitudinal cracking, alligator cracking, and patching. All other categories of distress are presently unweighted and employed as supplemental information only. They will, however, continue to be rated and may prove beneficial in correlation and multiple regression analysis at a later time.

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D	SR	BEG SRMP	END SRMP	CS	SEQ	BEG CSMP	END CSMP	PROJ LENG	FNC CLS	SIDE	HWY TYP	NUM LNS	RDW-RSH-LSH WIDTHS	LAST CONTR	COMPLT M-YR	CNT TYP	SURFACE TYP-THK	BASE TYPE
*	***	*****	*****	****	***	****	****	****	***	****	***	***	***********	*****	******	***	*******	****
6	2	2281C	23016	2203	220	721	927	2C6	R-1	R	0	2	24 8 8	07593	0-64	20	20 4	42

PERFORMANCE HISTORY

YEAR	69	71	73	75	77	79
AGE	5	7	9	11	13	15
RIDE RATING	1.00	0.88	0.92	1.00	1.00	1.00
STRUCR RATING	62.4	60.2	3.3	99.8	81.9	60.9
COMBD RATING	62.4	53.7	3.3	99.3	81.7	60.7
HIGH RATING	95.0	92.4	39.9	99.9	99.8	74.5
LOW RATING	60.0	47.1	-5.0	53.9	69.7	49.8
HIGH FRICTION	0	0	0	0	0	0
LOW FRICTION	0	0	0	0	0	0
AVG FRICTION	0	0	0	0	0	0

APPROXIMATE TRAFFIC DATA

79 ADT	2400
GROWTH RATE	5.4%
SINGLE UNITS	7%
COMBINATIONS	4%
TRAFFIC INDEX	6.4
K = 13%	D = 58%
2 AXLE TRUCKS =	4.7 %
3 AXLE TRUCKS =	3.1 %
4 AXLE TRUCKS =	0.5 %
5 AXLE TRUCKS =	2.7 %

PERFORMANCE EQUATION

EQUA CONST =	100.00
EQUA COEFF =	-2.61966
EQUA POWER =	1.00
R SQUARE =	0.0
STD ERROR =	0.0
TIME TO 60 =	15.27
TIME TO 50 =	19.09
TIME TO 40 =	22.90
TIME TO 30 =	26.72
TIME TO 20 =	30.54

****

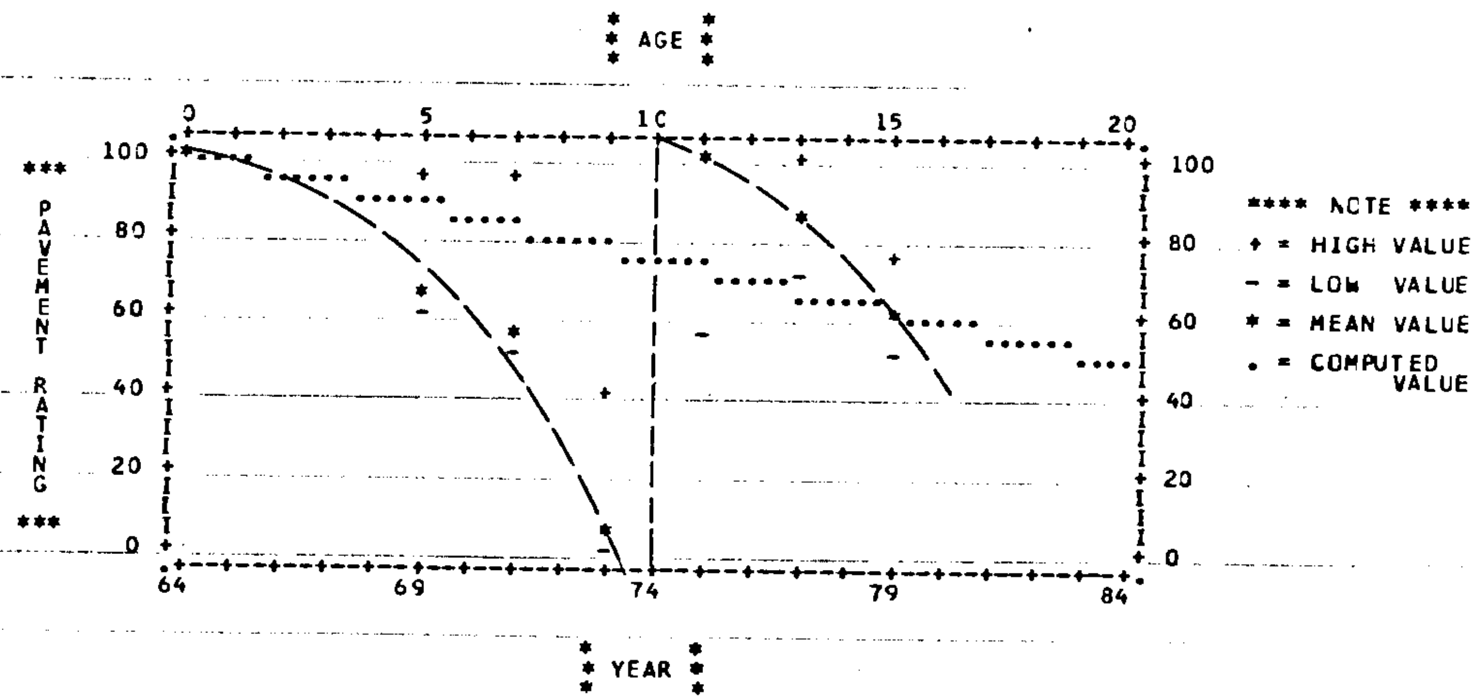

Figure 27. Example of Performance Cycling

Development of the proper weighting values was much more complicated, although simply described here. Essentially, expert personnel working in pavement design and rehabilitation provided initial weightings related to:

- the genesis of distress development
- maximum values required to trigger rehabilitation.

However, this only represented a starting point. A large number of pavement sections with consistent ratings (gradually deteriorating with time--no random fluctuations) and meeting several other criteria such as minimum length = 2 miles, minimum age = 8 years, etc., were selected to test the initial weighting values with the interpreting program. Several modifications were made on the original weighting values through successive program runs to obtain the highest R^2 (coefficient of determination) and lowest average standard error of estimate. In each iterative run of the program much consideration was given to the interplay of distress states. For instance, when a pavement section has been rated with the greatest extent and severity of longitudinal cracking with little or no alligator cracking one year, the following year the longitudinal cracking may have evolved into alligator cracking, and thus the longitudinal cracking actually is shown to decrease while alligator cracking increases. After many such evaluations, the present weighting values were selected.

Figures 28 and 30 represent the weightings used by WSDOT for many years in the operation of the Priority Programming System. Figures 29 and 31 represent the distress weightings presently being used. It is interesting to note that several categories were zeroed because of random ratings. It is felt that improvement can still be made in these weighting values. Rutting and pavement wear, for instance, were "eyeballed" prior to the 1975 survey. Since that time this rating has been physically measured with a straightedge and drop pin. Eventually, enough information will be acquired to associate weighting values commensurate with varying degrees of rutting and pavement wear.

A prime consideration in this system is to reevaluate the weighting values after each survey and, based on the entire rating history, to verify, improve, and fine tune the weighting values currently in use. This aspect is made possible by maintaining historical pavement ratings in their raw coding form in the master file and providing the weighting association later in the interpreting program.

PAVEMENT CONDITION RATING
BITUMINOUS PAVEMENTS
DEFECT DEDUCTIONS

<u>Priority Programming</u>

Negative Values are Assigned to the Failures by Degree

Defect	Measure	Degree						
RUTTING PAVEMENT WEAR	Average Depth in Inches		Throughout Rated Section: None	1/4-1/2	1/2-3/4	3/4+		
		(1) 1/4-1/2"		5				Negative Values
		(2) 1/2-3/4"			12			
		(3) Over 3/4"				20		
CORRUGATIONS WAVES SAGS HUMPS	Percent of Roadway		Change Per 10 Feet in Inches: None	1/4-2	2-4	4+		
		(1) 1-25		0	2	3		Negative Values
		(2) 26-75		0	3	4		
		(3) 76+		0	4	5		
ALLIGATOR CRACKING			Percent of Wheel Track Per Station: None	1-24	25-49	50-74	75+	
		(1) Hairline		2	5	10	15	Negative Values
		(2) Spalling		5	10	15	20	
		(3) Spalling & Pumping		10	15	20	25	
RAVELING OR FLUSHING				Localized	Wheel Paths	Entire Lane		
		(1) Slight		0	0	0		Negative Values
		(2) Moderate		5	10	15		
		(3) Severe		10	15	20		
LONGITUDINAL CRACKING	Lineal Feet Per Station		Average Width in Inches: None	1/8-1/4	1/4+	Spalled		
		(1) 1-99		10	15	20		Negative Values
		(2) 100-199		15	20	25		
		(3) 200+		20	25	30		
TRANSVERSE CRACKING	Number Per Station		Average Width in Inches: None	1/8-1/4	1/4+	Spalled		
		(1) 1-4		8	10	15		Negative Values
		(2) 5-9		9	12	17		
		(3) 10+		10	15	20		
PATCHING	Percent Area Per Station		Average Depth in Inches: None	0-1/2	1/2-1	1+		
		(1) 1-5		2	5	7		Negative Values
		(2) 6-25		5	7	10		
		(3) 26+		7	10	15		

Figure 28. Table of Weighting Values for Bituminous Pavements Used Prior to PMS Development

PAVEMENT CONDITION RATING
BITUMINOUS PAVEMENTS
DEFECT DEDUCTIONS

PMS

Negative Values are Assigned to the Failures by Degree

Defect	Measure	Degree						
			Throughout Rated Section					
			None	1/4-1/2	1/2-3/4	3/4+		
RUTTING PAVEMENT WEAR	Average Depth in Inches	(1) 1/4-1/2"		0				Negative Values
		(2) 1/2-3/4"			0			
		(3) Over 3/4"				0		
			Change Per 10 Feet in Inches					
			None	1/4-2	2-4	4+		
CORRUGATIONS WAVES SAGS HUMPS	Percent of Roadway	(1) 1-25		0	0	0		Negative Values
		(2) 26-75		0	0	0		
		(3) 76+		0	0	0		
			Percent of Wheel Track Per Station					
			None	1-24	25-49	50-74	75+	
ALLIGATOR CRACKING		(1) Hairline		20	25	30	35	Negative Values
		(2) Spalling		35	40	45	50	
		(3) Spalling & Pumping		50	55	60	65	
				Local-ized	Wheel Paths	Entire Lane		
RAVELING OR FLUSHING		(1) Slight		0	0	0		Negative Values
		(2) Moderate		0	0	0		
		(3) Severe		0	0	0		
			Average Width in Inches					
			None	1/8-1/4	1/4+	Spalled		
LONGITUDINAL CRACKING	Lineal Feet Per Station	(1) 1-99		5	15	30		Negative Values
		(2) 100-199		15	30	45		
		(3) 200+		30	45	60		
			Average Width in Inches					
			None	1/8-1/4	1/4+	Spalled		
TRANSVERSE CRACKING	Number Per Station	(1) 1-4		5	10	15		Negative Values
		(2) 5-9		10	15	20		
		(3) 10+		15	20	25		
			Average Depth in Inches					
			None	0-1/2	1/2-1	1+		
PATCHING	Percent Area Per Station	(1) 1-5		10	15	20		Negative Values
		(2) 6-25		15	20	25		
		(3) 26+		20	25	30		

Figure 29. Table of Weighting Values for Bituminous Pavements Developed for PMS

PAVEMENT CONDITION RATING
CEMENT CONCRETE PAVEMENT
DEFECT DEDUCTIONS

	<u>Priority Programming</u>		Negative Values are Assigned to the Failures by Degree				
			Percent of Panels				
			None	1-25	26-50	51+	
CRACKING AVERAGING 1/8+	Units Per Panel Length	(1) 1-2		5	10	20	
		(2) 3-4		10	20	35	Negative
		(3) 4+		15	30	50	Values
			Percent of Area				
			None	1-25	26-75	76+	
RAVELING DISINTEGRATION POPOUTS SCALING		(1) Slight		5	10	20	
		(2) Moderate		10	20	35	Negative
		(3) Severe		15	30	50	Values
			Percent of Joints				
			None	1-15	16-50	51+	
SPALLING AT JOINTS AND CRACKS	Average Width in Inches	(1) 1/4-1		5	10	20	
		(2) 1-3		10	20	35	Negative
		(3) 3+		15	30	50	Values
			Percent of Panels				
			None	1-15	16-35	36+	
PUMPING BLOWING	Percent of Panel Length	(1) 1-9		5	20	35	
		(2) 10-50		10	25	40	Negative
		(3) 51+		15	30	45	Values
			Blowups Per Mile				
			None	1	2-3	4+	
BLOWUPS	Number Per Mile	(1) 1		5			
		(2) 2-3			10		Negative
		(3) 4+				15	Values
			Percent of Panels				
			None	1-15	16-35	36+	
FAULTING CURLING WARPING SETTLEMENT	Average Displacement in Inches	(1) 1/8-1/4		0	10	20	
		(2) 1/4-1/2		5	15	25	Negative
		(3) 1/2+		10	20	30	Values
			Percent of Area Per Panel				
			None	1-5	6-25	26+	
PATCHING	Percent of Panels	(1) 1-5		2	5	7	
		(2) 6-20		5	7	10	Negative
		(3) 21+		7	10	15	Values
			Throughout Rated Section				
			None	1/4-1/2	1/2-3/4	3/4+	
RUTTING PAVEMENT WEAR	Average Depth in Inches	(1) 1/4-1/2"		5			
		(2) 1/2-3/4"			12		Negative
		(3) Over 3/4"				20	Values

Figure 30. Table of Weighting Values for Portland Cement Concrete Pavements Used Prior to PMS Development

PAVEMENT CONDITION RATING
CEMENT CONCRETE PAVEMENT
DEFECT DEDUCTIONS

PMS

Negative Values are Assigned to the Failures by Degree

Defect	Measure	Degree	None				
CRACKING AVERAGING 1/8+	Units Per Panel Length		Percent of Panels: None	1-25	26-50	51+	
		(1) 1-2		5	10	20	
		(2) 3-4		10	20	35	
		(3) 4+		15	30	50	Negative Values
RAVELING DISINTEGRATION POPOUTS SCALING			Percent of Area: None	1-25	26-75	76+	
		(1) Slight		0	0	0	
		(2) Moderate		0	0	0	
		(3) Severe		0	0	0	Negative Values
SPALLING AT JOINTS AND CRACKS	Average Width in Inches		Percent of Joints: None	1-15	16-50	51+	
		(1) 1/4-1		5	10	15	
		(2) 1-3		10	20	30	
		(3) 3+		15	30	50	Negative Values
PUMPING BLOWING	Percent of Panel Length		Percent of Panels: None	1-15	16-35	36+	
		(1) 1-9		0	0	0	
		(2) 10-50		0	0	0	
		(3) 51+		0	0	0	Negative Values
BLOWUPS	Number Per Mile		Blowups Per Mile: None	1	2-3	4+	
		(1) 1		0			
		(2) 2-3			0		
		(3) 4+				0	Negative Values
FAULTING CURLING WARPING SETTLEMENT	Average Displacement in Inches		Percent of Panels: None	1-15	16-35	36+	
		(1) 1/8-1/4		5	10	20	
		(2) 1/4-1/2		10	20	30	
		(3) 1/2+		15	30	40	Negative Values
PATCHING	Percent of Panels		Percent of Area Per Panel: None	1-5	6-25	26+	
		(1) 1-5		0	0	0	
		(2) 6-20		0	0	0	
		(3) 21+		0	0	0	Negative Values
RUTTING PAVEMENT WEAR	Average Depth in Inches		Throughout Rated Section: None	1/4-1/2	1/2-3/4	3/4+	
		(1) 1/4-1/2"		0			
		(2) 1/2-3/4"			0		
		(3) Over 3/4"				0	Negative Values

Figure 31. Table of Weighting Values for Portland Cement Concrete Pavements Developed for PMS

Other Programs in the Interpreting Phase

Although the reason for the interpreting phase evolved primarily to generate performance equations for projects, there are many other functions inherent to this level.

With the weighting values determined, another program called LISTMSTR (an acronym for List Master File) was developed to list the master file with the distress ratings and combined ratings for each mile listed. An example of this listing is shown in Figure 32.

In order to gauge the condition status of the system, it is important to be cognizant of the distribution picture of distress types and pavement ratings. There is a need to compare pavement status in different functional classifications, different districts, and from one year to the next. To do this, a program called RATGRP (an acronym for ratings by group) was developed. This program applies the distress weighting matrix to one generation of survey data and produces several distribution tables and summaries. The output data from this program can be divided into eight major sets of tables: seven sets of tables (one for each of six districts and one statewide) summarized by Functional Classification; one set of tables statewide summarized by district. Each set of tables consists of:

Rating distribution summaries for
- asphalt concrete pavement
- bituminous pavement
- portland cement concrete pavements
- all pavements combined

Distress summaries for
- asphalt pavements
- bituminous pavements
- portland cement concrete pavements

Figures 33 through 38 are included to provide examples of the type of tables produced by RATGRP.

Figure 33 is a rating distribution table for the miles of asphalt pavement rated in District 1. This table is divided into three sections: distress rating ($100 - \Sigma D$); ride rating (bump count or surface roughness); and combined rating. Each table is summarized by Functional Classification vertically (see Figure 11 for explanation of FC codes) and by 10 even divisions of rating listed horizontally across the page. Each number in the table represents the miles of pavement rated in that category.

Figure 34 is a summary table for the miles of asphalt pavement rated within each distress range (extent and severity for District 1). This table

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CS	REG	END	D	SR	REG	END	LENG	FC	L	HT	RDW	RSH	LSH	CONT#	TY	SF	TK	M	YR	BASE	80 ADT	GRW	SU	CM
2331	343	591	3	3	72	320	248	U1	R	02	23	3	3	01437	20	40	15	8	80	11	4400	53	5	2

GFN	SIDE	FCSMP	RUTT WEAR	WAVE SAGS	ALG CRK	PAV FLU	LONG CRK	TRNS CRK	PTCH	BUMPS	BUMP SPEED	ADJ BUMPS	RIDE RATNG	STRUC RATNG	COMBD RATNG
69	R	371	N	11	1N	11	11	1N	1N	0	0	0	1.00	95	95.0
69	R	471	N	11	1N	11	11	1N	1N	0	0	0	1.00	95	95.0
69	R	571	N	11	1N	11	11	1N	1N	0	0	0	1.00	95	95.0
69	R	671	N	11	1N	11	11	1N	11	0	0	0	1.00	85	85.0
71	R	371	1	12	12	13	31	31	11	667	40	518	1.00	10	10.0
71	R	471	1	12	12	13	31	31	11	1435	50	2254	0.94	10	9.4
71	R	571	1	12	12	13	31	31	1N	1184	50	1825	0.96	20	19.2
71	R	671	1	12	1N	13	21	1N	11	910	50	1356	0.98	75	73.3
73	R	371	1	12	22	31	33	31	21	665	30	153	1.00	-30	-30.0
73	R	471	1	12	22	31	33	1N	1N	512	30	63	1.00	0	0.0
73	R	571	1	12	22	31	33	1N	1N	763	50	420	1.00	0	0.0
73	R	671	1	12	21	31	33	1N	21	975	50	589	1.00	0	0.0
75	R	400	R	12	12	13	31	1N	1N	979	30	1658	0.97	35	33.8
75	R	500	R	12	12	22	31	21	1N	1648	50	1648	0.97	25	24.2
75	R	600	R	13	22	32	31	1N	1N	1680	50	1680	0.97	30	29.0
77	R	400	N	12	13	21	21	21	23	1540	40	1926	0.96	0	0.0
77	R	500	1	11	22	11	21	1N	22	2118	50	2118	0.95	25	23.7
77	R	600	N	12	12	11	21	1N	22	1233	40	1554	0.97	30	29.1
79	R	400	N	21	12	12	21	1N	23	2102	50	2102	0.95	25	23.7
79	R	500	N	12	12	31	21	1N	23	1747	50	1747	0.96	25	24.1
79	R	600	N	12	12	12	21	1N	23	1358	50	1358	0.98	25	24.4
81	R	344	N	11	1N	21	1N	1N	1N	1854	50	1418	0.98	100	97.6
81	R	400	N	11	1N	21	1N	1N	1N	1731	50	1331	0.98	100	97.9
81	R	500	N	11	1N	21	1N	1N	1N	1618	50	1251	0.98	100	98.1
81	R	509	N	11	1N	21	1N	1N	1N	949	50	764	0.99	100	99.3
81	R	600	N	11	1N	11	1N	1N	1N	1101	50	876	0.99	100	99.1

Figure 32. List Master File

DISTRICT 1   81 DEFECT RATING SUMMARY FOR ASPHALT PAVTS

FC	100-91	90-81	80-71	71-60	60-51	50-41	40-31	30-21	20-11	10-0	AVG
1	204.0	54.1	44.9	40.7	20.7	26.5	17.3	6.7	14.0	23.3	76.6
2	210.0	32.9	34.6	40.7	26.3	30.6	18.6	19.6	13.4	34.3	72.0
3	48.4	16.6	21.9	12.8	10.0	5.5	5.2	3.4	1.1	5.0	76.4
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	127.5	16.0	5.1	13.2	3.5	4.9	0.8	1.9	3.7	0.0	90.6
TOTAL	589.9	119.7	106.5	107.5	60.4	67.5	41.8	31.6	32.3	62.6	76.9

BUMP COUNT SUMMARY FOR ASPHALT PAVTS

FC	LT 500	.5K-1K	1K-1.5K	1.5K-2K	2K-3K	3K-4K	4K-5K	5K-7.5K	7.5-10K	GT 10K	AVG
1	24.4	119.8	100.6	79.1	80.5	34.2	9.6	3.7	0.2	0.2	1643.7
2	41.9	130.1	127.0	68.3	55.2	17.8	9.7	6.9	0.5	0.0	1455.2
3	4.0	43.9	42.5	16.6	16.3	5.6	0.1	0.7	0.2	0.0	1382.9
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	85.0	69.2	11.0	4.9	4.9	1.4	0.1	0.1	0.0	0.0	661.3
TOTAL	155.4	363.0	281.2	168.9	156.9	59.0	19.5	11.4	0.9	0.2	1402.1

COMBINED RATING SUMMARY FOR ASPHALT PAVTS

FC	100-91	90-81	80-71	71-60	60-51	50-41	40-31	30-21	20-11	10-0	AVG
1	187.4	56.1	44.3	48.3	23.8	27.0	20.4	7.4	14.0	23.5	73.6
2	203.7	35.2	34.3	38.6	27.5	33.4	19.4	20.8	13.7	34.4	70.0
3	47.8	15.7	22.7	11.9	10.7	5.9	5.5	3.5	0.9	5.4	74.4
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	126.5	16.7	4.7	13.8	3.5	5.0	0.8	1.9	3.7	0.0	90.0
TOTAL	565.4	123.8	106.0	112.6	65.5	71.3	46.0	33.7	32.3	63.4	74.7

Figure 33. Rating Distributions - Districtwide by Functional Class

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81 PAVEMENT CONDITION DEFICIENCY SUMMARY

ASPHALT CONCRETE PAVEMENT

ALLIGATOR CRACKING

FUNCTIONAL CLASS	NONE	1-24 PERCENT			25-49 PERCENT			50-74 PERCENT			75-100 PERCENT			TOTAL
		WHEEL H-LINE	TRACK/STA SPAL	PUMP	WHEEL H-LINE	TRACK/STA SPAL	PUMP	WHEEL H-LINE	TRACK/STA SPAL	PUMP	WHEEL H-LINE	TRACK/STA SPAL	PUMP	
1 MILES	349.	77.	15.	0.	5.	4.	0.	0.	1.	0.	0.	1.	0.	452.
PERCENT	77.	17.	3.	0.	1.	1.	0.	0.	0.	0.	0.	0.	0.	
2 MILES	296.	76.	23.	0.	16.	30.	0.	4.	13.	0.	0.	3.	0.	461.
PERCENT	64.	16.	5.	0.	3.	7.	0.	1.	3.	0.	0.	1.	0.	
3 MILES	86.	30.	10.	0.	3.	1.	0.	0.	0.	0.	0.	0.	0.	130.
PERCENT	66.	23.	8.	0.	2.	1.	0.	0.	0.	0.	0.	0.	0.	
4 MILES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PERCENT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
5 MILES	168.	6.	1.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	177.
PERCENT	95.	3.	1.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	
TOTAL MILES	899.	188.	45.	0.	23.	37.	0.	5.	14.	0.	0.	4.	0.	1220.
PERCENT	74.	15.	4.	0.	2.	3.	0.	0.	1.	0.	0.	0.	0.	

Figure 34. Distress Type Distribution - Districtwide by Functional Class

is tabulated by Functional Classification vertically and distress range horizontally. Numbers listed in the table represent miles of pavement rated in each category (top number in each row) and the percentage of that FC (bottom number of each row).

Figures 35, 36, 37, and 38 are similar to the two figures just described. Figures 35 and 36 are identical, but represent the entire statewide system.

Figures 37 and 38 are tabulated by district instead of Functional Classification.

Figures 34, 36, and 38 illustrate only the distress type of alligator cracking. All distress categories are summarized the same way.

It is important to realize that all of these tables are produced each time a pavement condition survey has been completed. By comparing tables from one year to the next, many interesting plots and tables can be produced. Examples of these are shown in Figures 39, 40, and 41.

While RATGRP provides information on rating distributions, another program named RATGEN (an acronym for ratings by generation) provides a consecutive listing of raw ratings with their translated score. This listing provides basically the same type of distress information shown on the Master File listing but only represents one generation of survey data and is not related to performance sections.

Figure 42 is an example of the RATGEN listing. Note that different column headings appear across the top of the page than across the bottom. The top heading is related to asphalt or bituminous pavements, while the bottom heading is related to portland cement concrete pavement. This was done because different distress categories are rated for the different pavement types. The columns are staggered to easily and quickly differentiate between the ratings and to denote the separations of pavement types.

It is important to note that both of these programs, RATGRP and RATGEN, utilize the same interpreting parameters used in the main interpreting program, INTERP. This includes the weighting matrix. By editing the interpreting parameters, control over all three programs is exercised. This is illustrated in Figure 43.

Summary of the Interpreting Phase

The purpose of the interpreting phase is to maintain pavement rating data in its raw coded form and then translate it into a numerical rating through the application of a weighting matrix. This enables the engineer to inspect the present extent and severity of each distress category as well as track the progression of distress over a period of time. The weighting matrix allows total flexibility in controlling the influence each type of distress exerts on the final rating.

The three computer programs involved at this level are:

1. INTERP - translates mile-by-mile raw distress ratings into yearly average ratings and uses these primarily in regression analysis to produce a performance curve.
2. RATGEN - translates mile-by-mile raw distress ratings into a mile-by-mile listing of the raw and weighted ratings for one survey year.
3. RATGRP - translates mile-by-mile raw distress ratings into distribution summaries of miles rated.

All three programs utilize the same weighting matrix, thus assuring consistency in relating all results.

The main interpreting program, INTERP, generates a file of all results including performance equations. This file is used as input to the subsequent optimizing and network programs as well as providing a data base for further statistical analysis. The data base may be edited after inspection of the generated performance curves, thus ensuring the most reasonable forecasting possible.

STATEWIDE 81 DEFECT RATING SUMMARY FOR ASPHALT PAVTS

FC	100-91	90-81	80-71	71-60	60-51	50-41	40-31	30-21	20-11	10-0	AVG
1	988.1	241.7	199.8	144.7	116.6	125.0	109.9	72.1	63.9	166.8	73.1
2	699.0	115.1	108.2	88.4	67.3	79.2	59.6	46.4	37.0	52.2	77.8
3	283.3	68.4	68.0	36.9	24.8	32.7	18.3	22.2	9.4	47.6	75.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	386.4	145.3	39.8	44.8	45.8	17.8	41.3	30.5	14.9	18.9	80.8
TOTAL	2356.7	570.5	415.8	314.8	254.4	254.7	229.1	171.2	125.2	285.6	75.8

BUMP COUNT SUMMARY FOR ASPHALT PAVTS

FC	LT 500	.5K-1K	1K-1.5K	1.5K-2K	2K-3K	3K-4K	4K-5K	5K-7.5K	7.5-10K	GT 10K	AVG
1	459.9	853.8	443.4	208.7	172.5	59.4	14.7	12.5	1.7	0.7	1109.3
2	242.4	428.5	315.0	166.8	119.9	40.3	18.2	11.9	0.5	0.0	1233.0
3	47.9	185.0	120.3	101.6	89.7	27.2	13.0	4.1	0.3	0.2	1457.9
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	527.6	205.8	25.4	9.1	11.0	2.2	0.1	0.3	0.0	0.0	505.1
TOTAL	1277.8	1673.0	904.1	486.2	393.0	129.1	46.0	28.8	2.5	0.9	1094.0

COMBINED RATING SUMMARY FOR ASPHALT PAVTS

FC	100-91	90-81	80-71	71-60	60-51	50-41	40-31	30-21	20-11	10-0	AVG
1	962.0	248.3	197.6	152.2	121.6	124.8	113.7	76.2	63.4	168.8	71.6
2	688.4	116.7	108.3	89.4	65.2	82.9	60.8	50.0	38.2	52.5	76.1
3	278.5	56.6	74.1	42.6	26.8	33.0	19.1	22.9	9.6	48.4	72.8
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	383.7	147.2	39.9	45.3	45.7	18.0	41.3	30.5	14.9	18.9	80.4
TOTAL	2312.6	568.7	419.9	329.5	259.4	258.6	234.9	179.7	126.1	288.6	74.4

Figure 35. Rating Distributions - Statewide by Functional Class

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81 PAVEMENT CONDITION DEFICIENCY SUMMARY

ASPHALT CONCRETE PAVEMENT

ALLIGATOR CRACKING

FUNCTIONAL CLASS	NONE	1-24 PERCENT WHEEL H-LINE	1-24 PERCENT TRACK/STA SPAL	1-24 PERCENT PUMP	25-49 PERCENT WHEEL H-LINE	25-49 PERCENT TRACK/STA SPAL	25-49 PERCENT PUMP	50-74 PERCENT WHEEL H-LINE	50-74 PERCENT TRACK/STA SPAL	50-74 PERCENT PUMP	75-100 PERCENT WHEEL H-LINE	75-100 PERCENT TRACK/STA SPAL	75-100 PERCENT PUMP	TOTAL
1 MILES	1532.	371.	123.	5.	52.	68.	17.	8.	37.	1.	1.	15.	0.	2229.
PERCENT	69.	17.	6.	0.	2.	3.	1.	0.	2.	0.	0.	1.	0.	
2 MILES	954.	210.	68.	0.	33.	52.	0.	8.	21.	0.	2.	6.	0.	1352.
PERCENT	71.	16.	5.	0.	2.	4.	0.	1.	2.	0.	0.	0.	0.	
3 MILES	401.	102.	36.	0.	19.	24.	0.	5.	6.	0.	0.	0.	0.	594.
PERCENT	68.	17.	6.	0.	3.	4.	0.	1.	1.	0.	0.	0.	0.	
4 MILES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PERCENT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
5 MILES	608.	112.	10.	2.	14.	6.	0.	22.	1.	0.	10.	0.	0.	785.
PERCENT	77.	14.	1.	0.	2.	1.	0.	3.	0.	0.	1.	0.	0.	
TOTAL MILES	3495.	794.	236.	7.	118.	151.	17.	42.	65.	1.	13.	21.	0.	4958.
PERCENT	70.	16.	5.	0.	2.	3.	0.	1.	1.	0.	0.	0.	0.	

Figure 36. Distress Type Distribution - Statewide by Functional Class

STATEWIDE 81 DEFECT RATING SUMMARY FOR ASPHALT PAVTS

DIST	100-91	90-81	80-71	70-61	60-51	50-41	40-31	30-21	20-11	10-0	AVG
1	589.9	119.7	106.5	107.5	60.4	67.5	41.8	31.6	32.3	62.6	76.9
2	197.3	96.9	43.6	34.2	28.2	10.4	25.1	15.8	11.3	25.0	75.5
3	448.0	83.1	99.3	65.4	67.3	90.6	66.8	59.0	37.7	87.3	68.9
4	562.3	74.7	81.4	33.1	30.3	25.8	17.5	9.5	8.5	22.0	86.7
5	256.8	50.1	39.0	23.7	27.0	9.8	31.2	19.2	10.5	9.7	80.2
6	302.4	145.9	45.9	50.9	41.1	50.5	46.7	36.1	24.9	79.0	69.8
TOTAL	2356.7	570.5	415.8	314.8	254.4	254.7	229.1	171.2	125.2	285.6	75.8

BUMP COUNT SUMMARY FOR ASPHALT PAVTS

DIST	LT 500	.5K-1K	1K-1.5K	1.5K-2K	2K-3K	3K-4K	4K-5K	5K-7.5K	7.5-10K	GT 10K	AVG
1	155.4	363.0	281.2	168.9	156.9	59.0	19.5	11.4	0.9	0.2	1402.1
2	278.7	175.0	20.5	8.9	3.5	1.2	0.0	0.0	0.0	0.0	555.2
3	138.6	329.4	257.7	170.5	135.8	43.0	15.5	11.0	1.0	0.5	1384.8
4	124.1	320.3	211.6	106.9	65.4	17.3	4.0	3.6	0.1	0.0	1155.5
5	239.7	150.6	46.2	11.4	8.1	1.0	0.1	0.2	0.0	0.0	627.1
6	341.2	334.8	87.0	19.6	23.3	7.5	6.8	2.5	0.4	0.2	762.9
TOTAL	1277.8	1673.0	904.1	486.2	393.0	129.1	46.0	28.8	2.5	0.9	1094.0

COMBINED RATING SUMMARY FOR ASPHALT PAVTS

DIST	100-91	90-81	80-71	70-61	60-51	50-41	40-31	30-21	20-11	10-0	AVG
1	565.4	123.8	106.0	112.6	65.5	71.3	46.0	33.7	32.3	63.4	74.7
2	196.6	97.5	43.2	34.8	28.2	10.4	25.1	15.8	11.3	25.0	75.2
3	439.1	83.2	99.5	66.7	68.7	90.1	67.9	63.3	37.3	88.6	67.0
4	555.8	70.4	83.5	38.9	30.9	26.0	16.5	11.6	9.5	22.2	85.0
5	255.9	49.8	39.9	23.5	27.2	10.0	31.2	19.3	10.4	9.8	79.7
6	299.9	144.1	47.8	53.0	38.9	50.9	48.2	36.0	25.2	79.6	69.1
TOTAL	2312.6	568.7	419.9	329.5	259.4	258.6	234.9	179.7	126.1	288.6	74.4

Figure 37. Rating Distributions - Statewide by District

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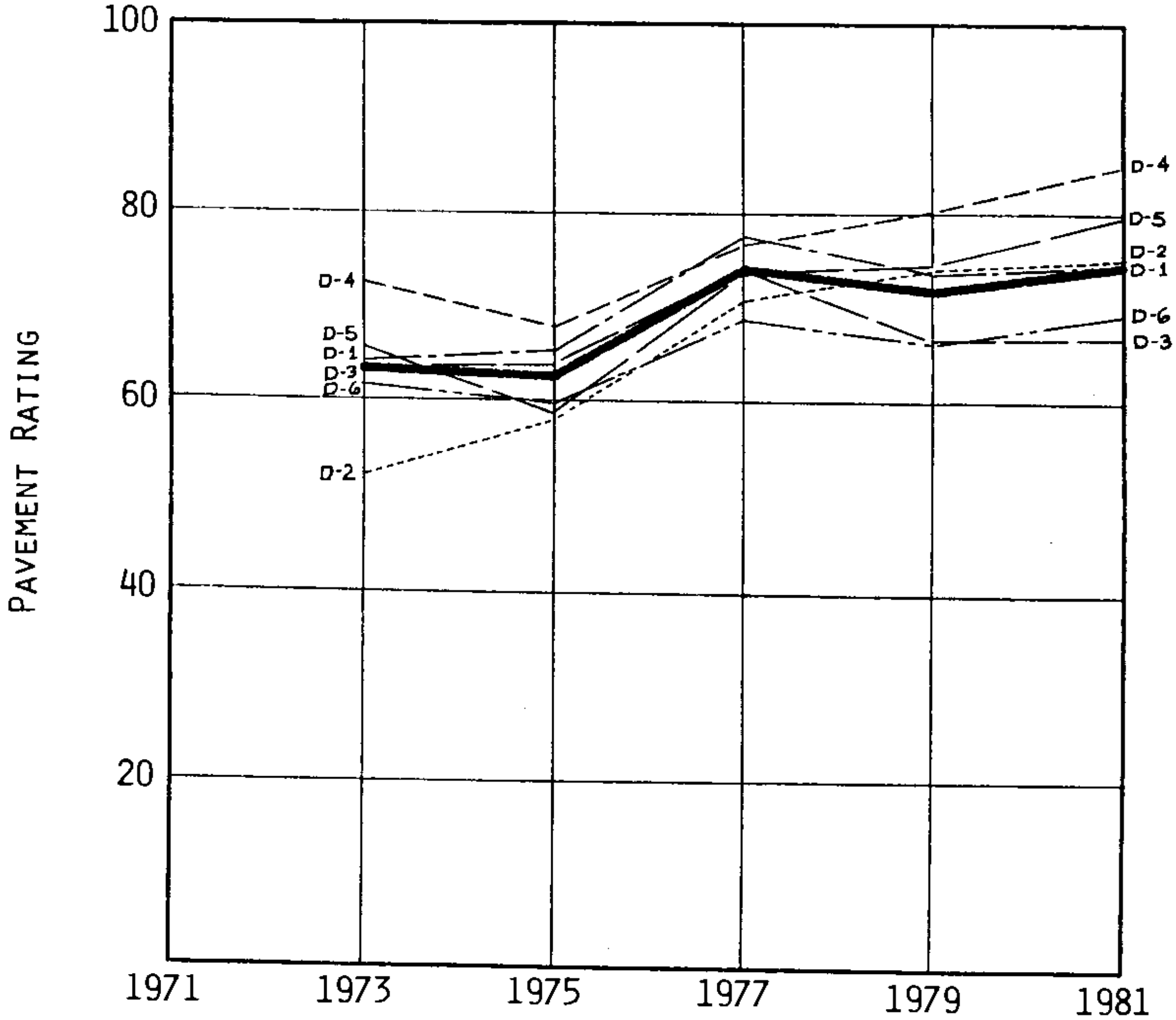
81 PAVEMENT CONDITICN DEFICIENCY SUMMARY

ASPHALT CCNCRETE PAVEMENT

ALLIGATOR CRACKING

DISTRICT	NONE	1-24 PERCENT WHEEL H-LINE	TRACK/STA SPAL	PUMP	25-49 PERCENT WHEEL H-LINE	TRACK/STA SPAL	PUMP	50-74 PERCENT WHEEL H-LINE	TRACK/STA SPAL	PUMP	75-100 PERCENT WHEEL H-LINE	TRACK/STA SPAL	PUMP	TOTAL
1 MILES	899.	188.	49.	0.	23.	37.	0.	5.	14.	0.	0.	4.	0.	122C.
PERCENT	74.	15.	4.	0.	2.	3.	0.	0.	1.	0.	0.	0.	0.	
2 MILES	357.	83.	12.	0.	7.	16.	0.	2.	10.	0.	0.	1.	0.	48E.
PERCENT	73.	17.	2.	0.	2.	3.	0.	0.	2.	0.	0.	0.	0.	
3 MILES	626.	235.	91.	2.	53.	55.	4.	11.	25.	1.	1.	1.	0.	11C4.
PERCENT	57.	21.	8.	0.	5.	5.	0.	1.	2.	0.	0.	0.	0.	
4 MILES	719.	104.	19.	1.	12.	5.	0.	0.	1.	0.	0.	0.	0.	865.
PERCENT	83.	12.	2.	0.	1.	1.	0.	0.	0.	0.	0.	0.	0.	
5 MILES	340.	64.	24.	2.	8.	6.	1.	10.	0.	0.	5.	0.	0.	455.
PERCENT	74.	14.	5.	0.	2.	1.	0.	2.	0.	0.	1.	0.	0.	
6 MILES	555.	120.	41.	2.	14.	29.	13.	14.	15.	0.	7.	14.	0.	823.
PERCENT	67.	15.	5.	0.	2.	3.	2.	2.	2.	0.	1.	2.	0.	
TOTAL MILES	3495.	794.	236.	7.	118.	151.	17.	42.	65.	1.	13.	21.	0.	4958.
PERCENT	70.	16.	5.	0.	2.	3.	0.	1.	1.	0.	0.	0.	0.	

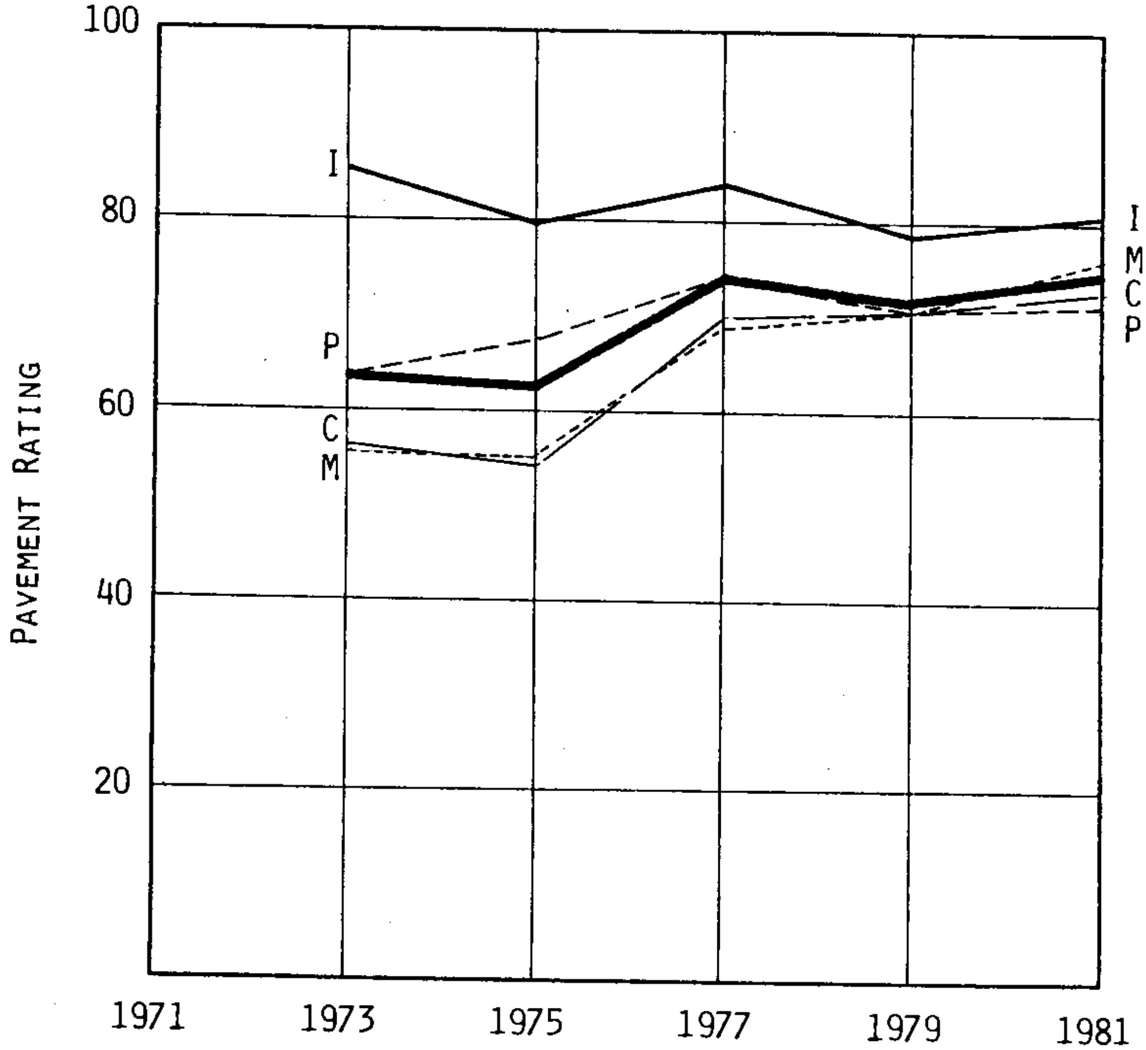
Figure 38. Distress Type Distribution - Statewide by District



AC Pavements

District	1973	1975	1977	1979	1981
1	63.8	65.3	77.5	73.4	74.7
2	52.2	58.1	70.4	73.7	75.2
3	63.5	63.4	74.2	66.5	67.0
4	72.4	67.9	76.4	80.1	85.0
5	65.4	58.8	73.6	74.3	79.7
6	61.8	59.8	68.7	66.4	69.1
All	63.5	62.8	74.2	71.9	74.4

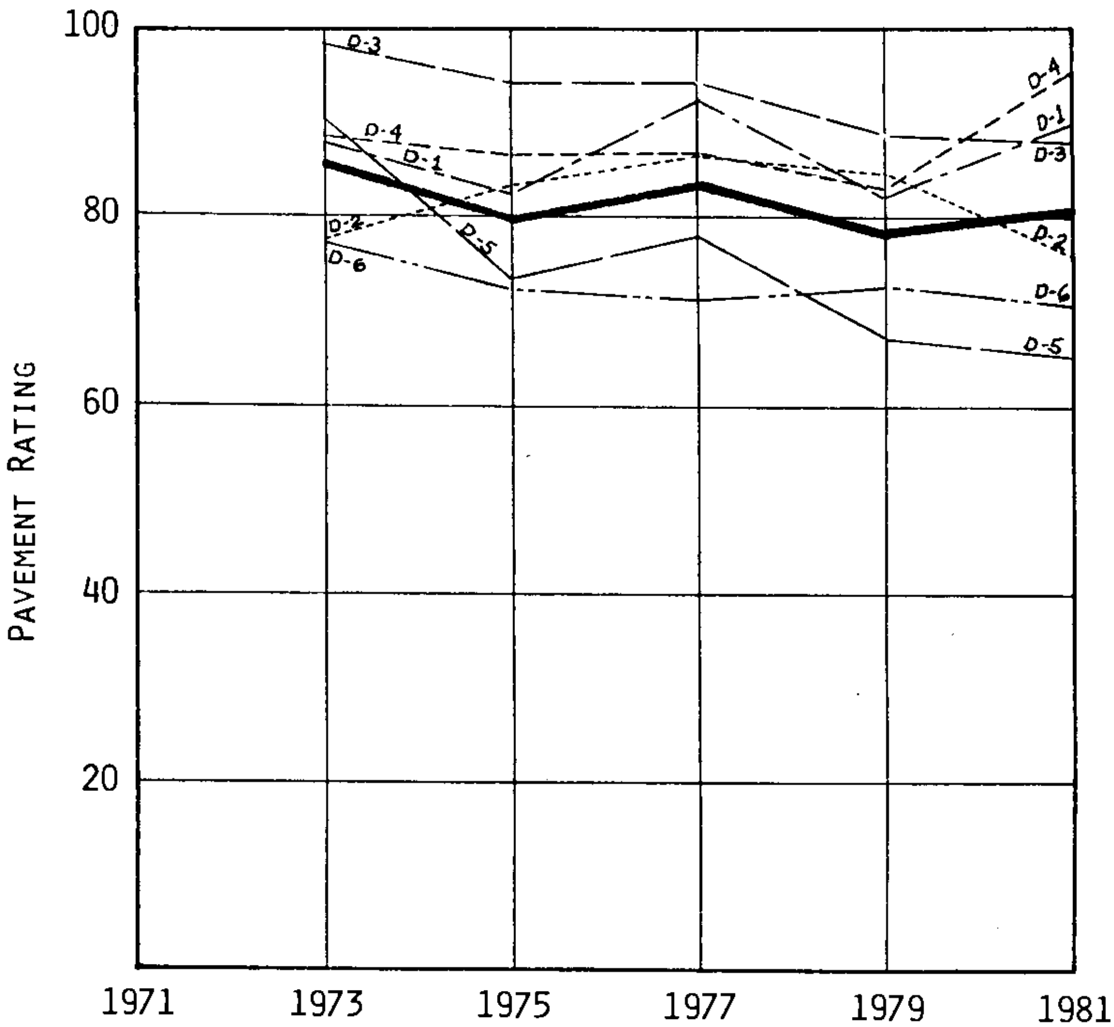
Figure 39. Table and Plot of AC Pavement Performance by District



AC Pavements

Functional Class	1973	1975	1977	1979	1981
Interstate	85.3	79.9	83.6	78.4	80.4
Prin. Art.	63.7	67.4	74.8	70.7	71.6
Minor Art.	55.7	55.4	68.9	70.7	76.1
Collector	55.9	54.4	70.0	70.8	72.8
All	63.5	62.8	74.2	71.9	74.4

Figure 40. Table and Plot of AC Pavement Performance by Functional Class



ASPHALT - INTERSTATE

DISTRICT	1973	1975	1977	1979	1981
1	87.5	82.3	92.8	82.0	89.8
2	77.5	83.2	86.5	84.5	76.0
3	98.7	94.6	94.6	88.4	88.0
4	88.4	86.4	86.8	82.7	95.3
5	90.4	73.5	77.9	67.3	65.3
6	77.0	72.5	71.1	72.9	70.6
ALL	85.3	79.9	83.6	78.4	80.4

Figure 41. Table and Plot of AC Pavement Performance on Interstate Routes by District

SP	CS	ECSMP	LN	PV TP	RUTT WEAR	WAVE SAGS / BLOW UPS	ALG CRK / CPR	RVL FLU / RVL	LONG CRK / JNT SPAL	TRNS CRK / PUMP BLOW	PTCH / FALT WARP	PTCH	BUMPS	BUMP SPD	ADJ BUMPS	RIDE RATNG	STRUC RATNG	COMBO RATNG
012	0202	0500	B	A	N	11	1N	21	1N	1N	1N		339	0		1.00	100	99.9
012	0202	0600	B	A	N	11	1N	21	1N	1N	1N		304	0		1.00	100	99.9
012	0202	0700	B	A	N	11	1N	21	1N	1N	1N		198	0		1.00	100	100.0
012	0202	0800	B	A	N	11	1N	21	1N	1N	1N		235	0		1.00	100	99.9
012	0202	0900	B	A	N	11	1N	21	1N	1N	1N		207	0		1.00	100	99.9
012	0202	1000	B	A	N	11	1N	21	1N	1N	1N		237	0		1.00	100	99.9
012	0202	1100	B	A	N	11	1N	21	1N	1N	1N		929	0		0.99	100	99.0
012	0202	1200	B	A	N	1N	1N	1N	1N	1N	1N		1201	0		0.98	100	98.3
012	0202	1210	R	A	N	1N	1N	1N	1N	31	1N		4537	0		0.75	85	64.0
012	0203	0009	L	C	N	N	11	32	21	1N	21	11	3340	0		0.87	38	32.9
012	0203	0009	P	C	N	N	11	32	21	1N	21	0	3714	0		0.83	40	33.4
014	0604	0100	L	A	1	11	1N	22	21	21	1N		1315	0		0.88	75	73.4
014	0604	0100	R	A	1	1N	1N	13	11	11	1N		1626	0		0.97	90	87.1
014	0604	0200	L	A	1	11	12	22	12	11	1N		1333	0		0.98	45	44.0
014	0604	0200	R	A	1	11	1N	22	11	11	1N		865	0		0.99	90	89.2
014	0604	0221	L	A	1	11	1N	22	1N	1N	21		2405	0		0.93	85	79.1
014	0604	0221	R	A	1	11	1N	22	21	11	1N		895	0		0.99	80	79.2
014	0604	0300	L	C	N	N	11	31	21	1N	21	1N	443	0		1.00	55	54.9
014	0604	0300	P	C	N	N	11	31	21	1N	21	1N	547	0		1.00	55	54.8
014	0604	0400	L	C	N	N	11	31	21	1N	21	1N	445	0		1.00	55	54.9
014	0604	0400	R	C	N	N	11	31	21	1N	21	1N	568	0		1.00	55	54.8
014	0604	0500	L	C	N	N	11	31	21	1N	21	1N	502	0		1.00	55	54.8
014	0604	0500	R	C	N	N	21	31	21	1N	21	1N	762	0		0.99	50	49.7
014	0604	0600	L	C	N	N	11	31	21	1N	21	1N	510	0		1.00	55	54.8
014	0604	0600	R	C	N	N	11	31	21	1N	21	1N	606	0		1.00	55	54.8
014	0604	0700	L	C	N	N	11	31	21	1N	21	1N	339	0		1.00	55	54.9
014	0604	0700	R	C	N	N	11	31	21	1N	21	1N	440	0		1.00	55	54.9
014	0604	0800	L	C	N	N	11	31	21	1N	21	1N	535	0		1.00	55	54.8
014	0604	0800	R	C	N	N	11	31	21	1N	21	1N	649	0		0.99	55	54.7
014	0604	0900	L	C	N	N	11	31	21	1N	21	1N	526	0		1.00	55	54.8
014	0604	0900	P	C	N	N	11	31	21	1N	21	1N	540	0		1.00	55	54.8
014	0604	1000	L	C	N	N	11	21	21	1N	21	1N	549	0		1.00	63	62.8
014	0604	1000	P	C	N	N	11	21	21	1N	21	11	1018	0		0.99	65	64.2
014	0604	1100	L	C	N	N	11	21	21	1N	21	1N	653	0		0.99	65	64.7
014	0604	1100	R	C	N	N	11	21	21	1N	11	1N	533	0		1.00	75	74.7
014	0604	1190	P	C	N	N	11	21	21	1N	11	1N	611	0		1.00	75	74.7
014	0604	1200	R	A	1	11	1N	22	1N	21	1N		2160	0		0.94	90	85.0
014	0604	1206	L	C	N	N	11	21	21	1N	21	1N	719	0		0.99	65	64.6
014	0604	1249	L	A	1	11	1N	22	1N	11	1N		1200	0		0.98	95	93.4
014	0604	1249	R	A	N	1N	11	22	21	21	1N		1278	0		0.98	55	53.9
014	0604	1262	R	A	N	1N	11	22	21	21	1N		2046	0		0.95	55	52.2
014	0604	1282	R	C	N	N	31	11	1N	1N	1N	1N	1015	0		0.99	75	74.1
014	0604	1300	R	A	1	1N	11	21	21	11	1N		900	0		0.99	60	59.4
014	0604	1400	P	A	1	11	11	21	11	21	1N		670	0		0.99	65	64.6
014	0604	1500	R	A	1	1N	11	21	21	21	1N		528	0		1.00	55	54.8
014	0604	1528	B	A	1	1N	1N	21	11	21	1N		483	0		1.00	85	84.8
014	0604	1600	R	A	N	1N	1N	21	1N	1N	1N		892	0		0.99	100	99.0
014	0604	1610	B	A	N	1N	1N	21	1N	1N	1N		850	0		0.99	100	99.1

Figure 42. RATGEN Listing

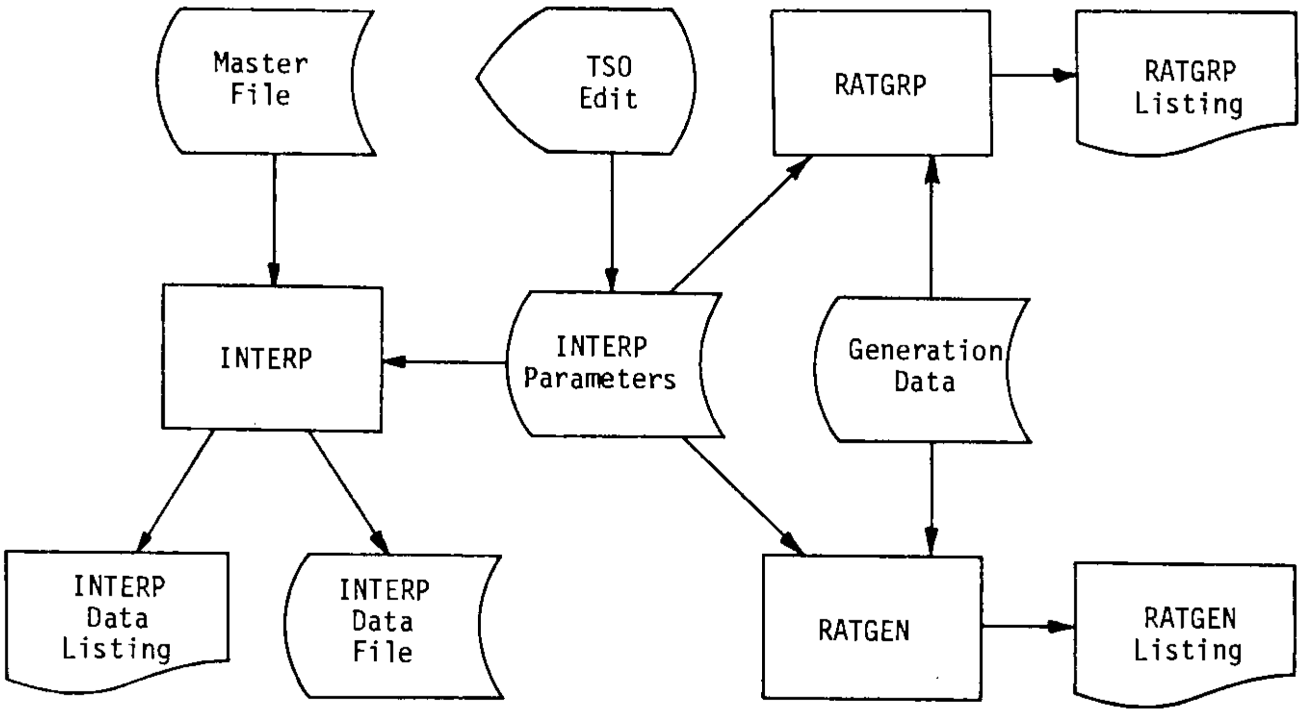


Figure 43. Coordinating Programs with Interpreting Parameters

Chapter 4

OPTIMIZING AT THE PROJECT LEVEL

It should be noted that the cost-effective rehabilitation strategy identified with this optimizing procedure for each project is suitable for planning and budgeting purposes. However, further evaluation and engineering are required during the development of the actual construction project. This may lead to a rehabilitation strategy which is significantly different in scope than what was originally identified by the system.

There is a fear by many engineers and administrators that people responsible for project scheduling and budgeting will accept outputs from programs such as this as the final design. It is important to make it absolutely clear that this is not the intent and that in-depth analysis of each project will be required to assure that the work is both necessary and the design adequate.

This phase utilizes the performance equations produced by the interpreting program to establish the most cost-effective rehabilitation strategy for each project.

Figure 44 is a typical performance curve relating the pavement rating to the age of the pavement. As a pavement ages, its condition gradually deteriorates to a point where some type of rehabilitation <u>should</u> be applied. This is a state of deterioration at which distress is showing, but might not yet be severe enough to call for immediate remedial action. Unfortunately, this point is all too often passed and the pavement continues to deteriorate until something <u>must</u> be done to rehabilitate it. These two points on the performance curve, aptly named the "should" and "must" levels, define a probable rehabilitation period. In the event that the "must" level is surpassed without action, maintenance forces are then faced with applying temporary fixes until a major remedy can be applied. Temporary fixes tend to retard the rate of deterioration and flatten out the performance curves. However, the frequency of application and associated cost of a temporary fix are high compared to the benefit returned.

When rehabilitation treatment is eventually applied, the pavement rating increases abruptly, marking the beginning of a new cycle. Over the total existence of a pavement, many restorative actions like this occur, demonstrating a new performance cycle each time rehabilitation is applied. Obviously many different fixes are possible when the need for rehabilitation is faced, and each fix generates its own performance curve following application. Not only are many fixes possible, but a tremendous number of different combinations are possible when the timing, sequence, or type of action are changed over an extended period. In this report a rehabilitation strategy is defined as a

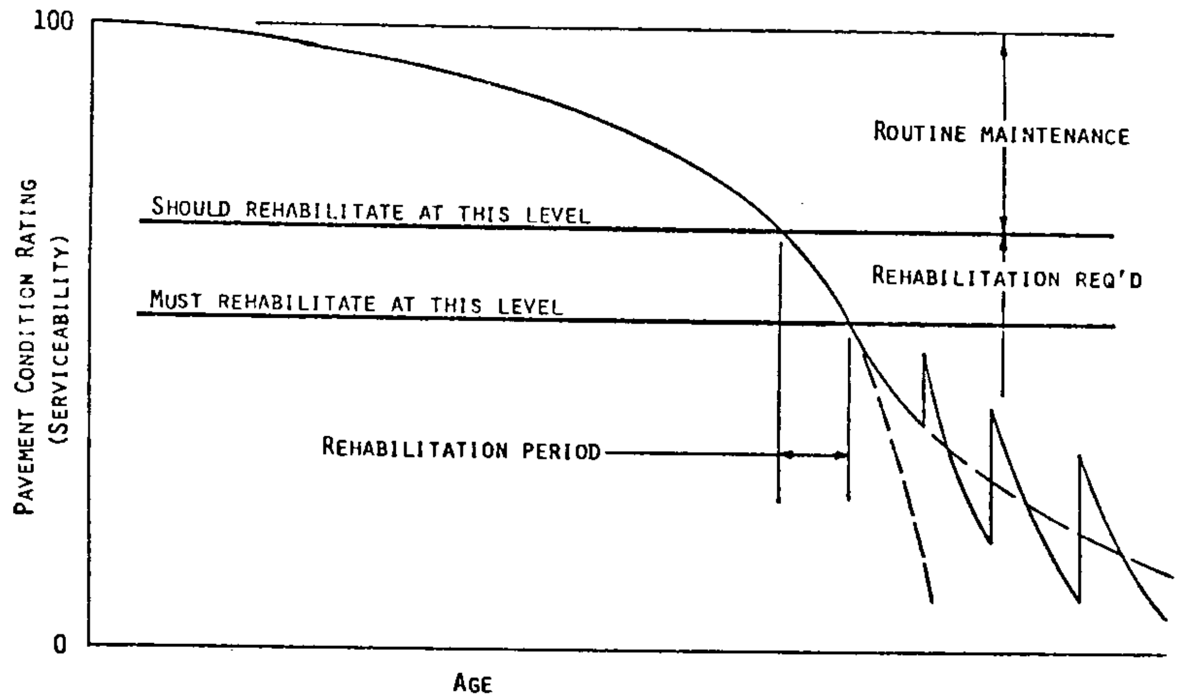


Figure 44. Typical Performance Curve

combination of rehabilitation alternatives designated by type, sequence, and application time. Figures 45a, b, c, and d illustrate this concept with a few examples of strategies.

One of the primary motives for improving our method of managing pavements is to be more cost-effective in providing satisfactory pavement condition. The methods presented here can achieve this by analyzing economically all strategies possible within a set time frame called a consideration period. Basic to the analysis is the stipulation of a minimum level of pavement condition ("must level") to be maintained throughout the consideration period. All costs associated with each strategy can then be totaled and brought back to present worth for comparison with other strategies--the desired strategy being the one with the least total cost. Costs considered in this analysis consist of:

1. Construction costs for each rehabilitation alternative applied.
2. Routine pavement-related maintenance costs (annual).
3. User-incurred costs related to the condition of the pavement.
4. User-incurred costs related to delay during rehabilitation.
5. Salvage value of the pavement at the end of the consideration period.

It is important to note that strategies can be selected on the basis of all these costs, or any combination of them, depending on management's preference.

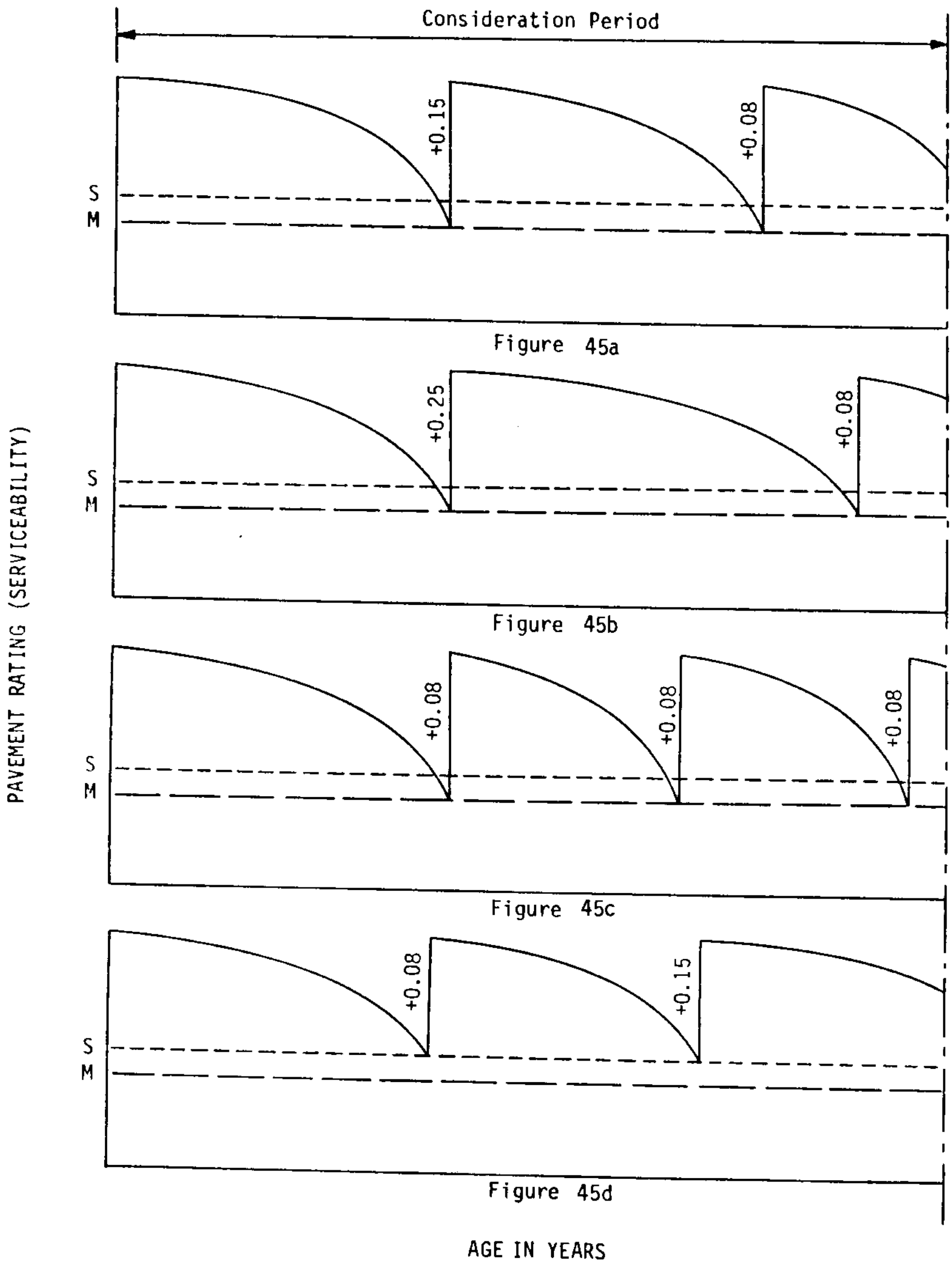


Figure 45. Examples of Rehabilitation Strategies

Figure 46 is a flow chart demonstrating the operations and work flow in the optimizing program. Each box on the flow chart represents a program module (subroutine) which can be easily replaced or modified as new data become available and operating procedures in each of these areas are improved.

Reading the Optimizing Parameters

The first phase of the program represents the means for inputing the parameters used in the optimizing process. In each run of the program, a small data set containing these parameters is read in apart from the project data. As can be seen from the flow chart, this input occurs only once in the process of one run.

In the data processing environment existent within WSDOT at the time this system was developed, CRT remote computer terminals were used for manually editing or inputing data. Because the optimizing parameters do not represent a very large set of data, it is a simple task to manually input this data in the required format. This data set is resident on a direct access system device (disk pack) on a semi-permanent basis. When a variation or change of parameters is desired, the data set is simply edited to reflect the change.

Following is a list of factors contained in the optimizing parameters. Although their uses may not be immediately obvious, they will become apparent in the explanation of other program phases.

Optimizing Parameters

Present Year
Year of Traffic Data
Number of Periods in Consideration Span
Number of Periods in Network Program Span
Length of Periods
Effective Interest Rate
Listing Constant
Should and Must Level Arrays by Functional Class
Traffic Index Intervals for Strategy Array Selection
Strategy Array Selection Matrix
Alternative Array Matrix
Rehabilitation Alternative Parameters
Cost Model Delimiters

Reading Project Data

The second phase of the program is the beginning of a large iterative process and involves the inputing of all data needed to describe and analyze one project. These input records are the product of the interpreting program. A list of the data included on each of these records is as follows:

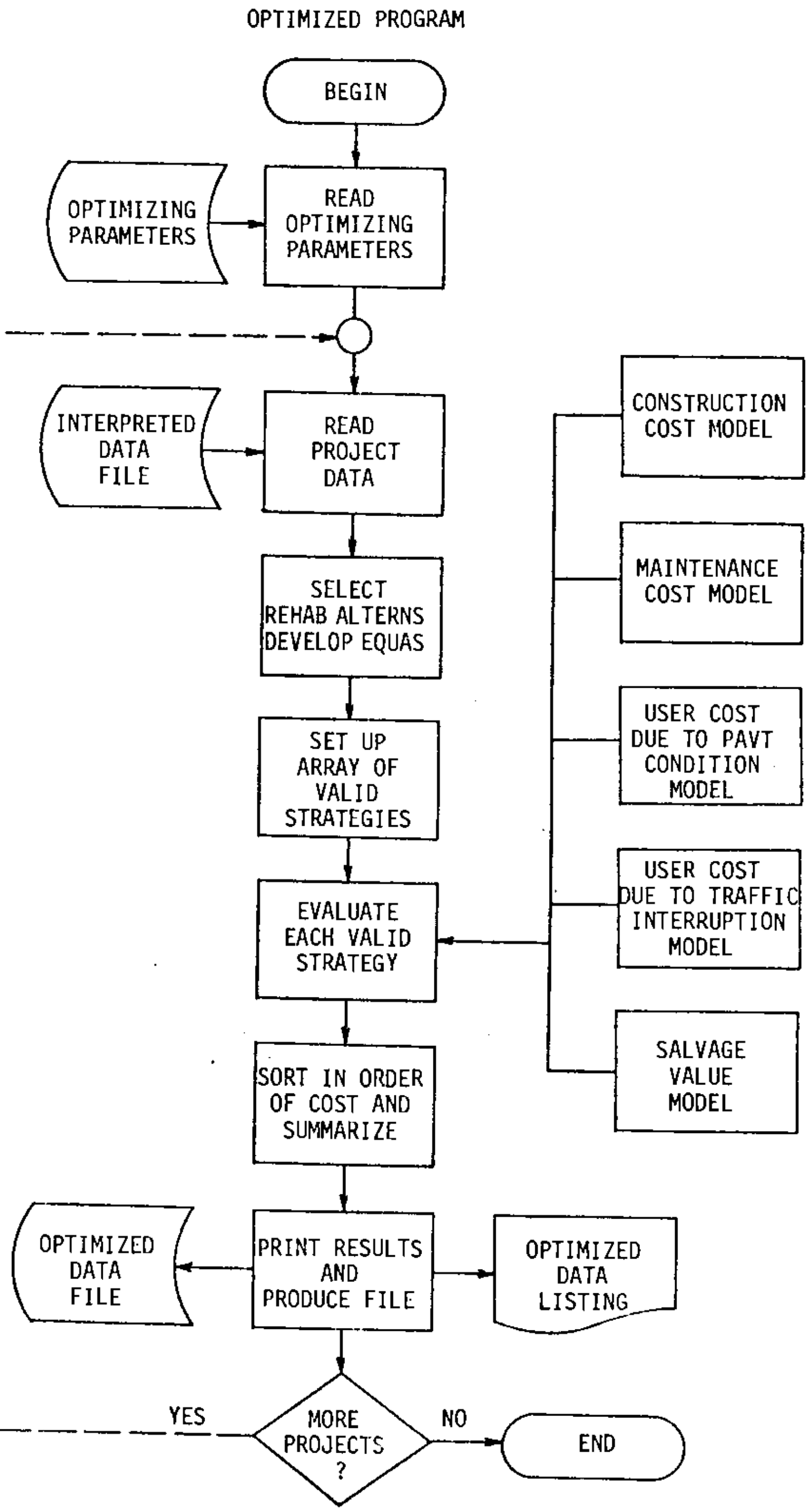


Figure 46. Conceptual Flow Chart of Optimizing Program

Project Input Data

Control Section
Beginning Control Section Milepost
Ending Control Section Milepost
District
State Route Number
Beginning State Route Milepost
Ending State Route Milepost
Length of Project
Urban or Rural
Functional Classification
If highway is divided, which side
Type of Facility
Number of Lanes
Roadway Width
Right Shoulder Width
Left Shoulder Width
Last Contract Number
Contract Type
Surfacing Layer Type
Surfacing Layer Thickness
Month and Year of Completion
Underlying Layers of Surfacing
Average Annual Daily Traffic
Yearly Traffic Growth Rate
Single Unit Truck Percentage
K Factor for Reducing ADT to Design Hour Volume
D Factor for Splitting DHV into Directional DHV
Traffic Index (logarithm of accumulated 5K wheel loads)
Performance Equation Constants
R Squared Value Associated with Performance Equation
Standard Error of Estimate
Projected Ages to Rating Levels of 60, 40, and 20
A Summary of Each Generation of Performance

Selecting Rehabilitation Alternatives and Developing Their Expected Performance Equations

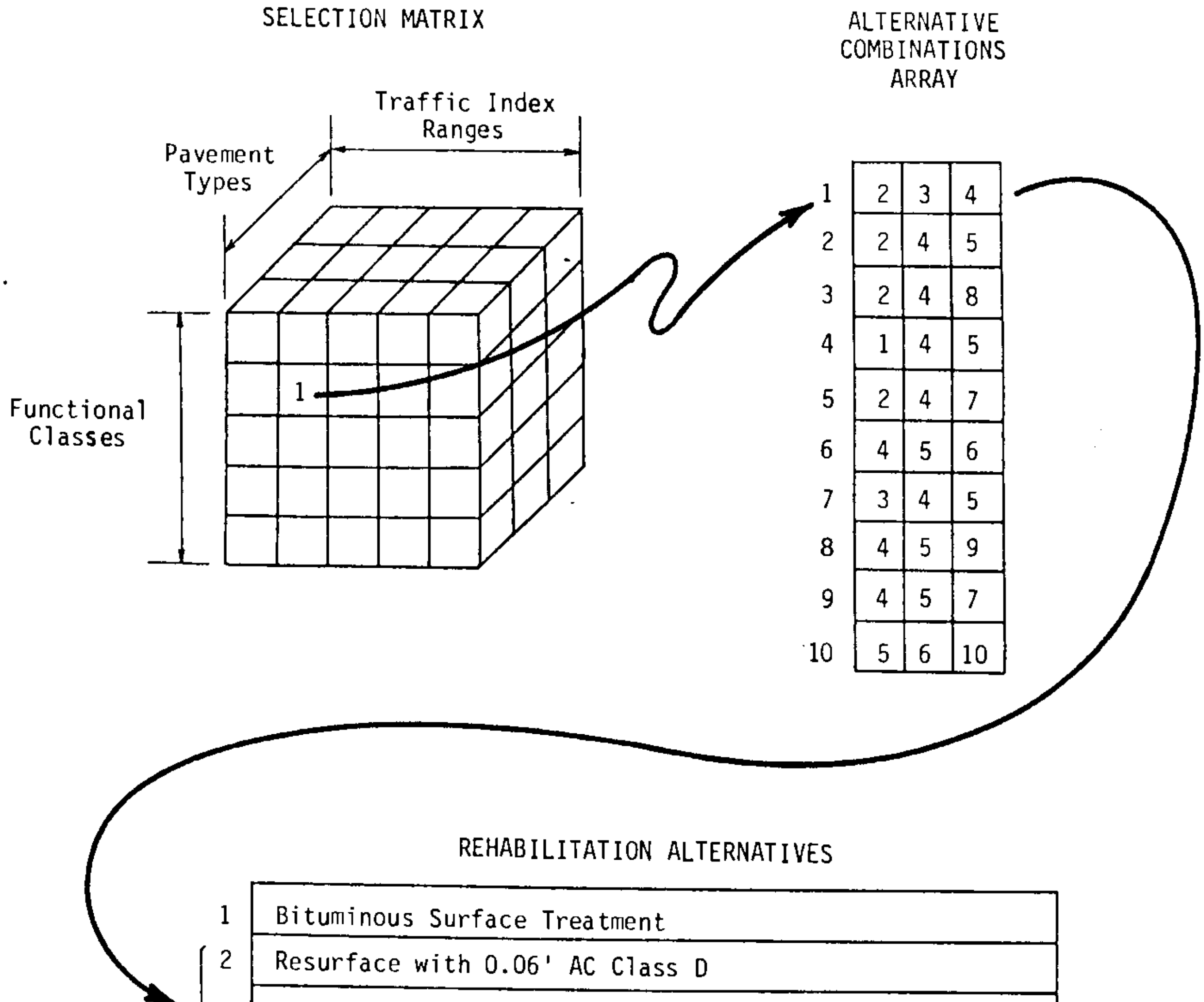
This phase of the program has two purposes:

1. To select a reasonable set of rehabilitation alternatives for each individual project for later evaluation in the program.
2. To develop performance equations for the alternatives chosen so they can be evaluated.

The first task is handled by three basic components:

1. Selection Matrix
2. Array of alternative combinations
3. Array of rehabilitation alternatives

As can be seen in Figure 47, this process begins in the Selection Matrix. Based on the pavement type, functional classification, and traffic index, or



1	2	3	4
2	2	4	5
3	2	4	8
4	1	4	5
5	2	4	7
6	4	5	6
7	3	4	5
8	4	5	9
9	4	5	7
10	5	6	10

REHABILITATION ALTERNATIVES

1	Bituminous Surface Treatment
2	Resurface with 0.06' AC Class D
3	Resurface with 0.08' AC Class G
4	Resurface with 0.15' AC Class B
5	Resurface with 0.25' AC Class B
6	Resurface with 0.35' AC Class B
7	Recycle 0.15'
8	Recycle 0.15' + Overlay 0.06' AC Class D
9	Recycle 0.15' + Overlay 0.15' AC Class B
10	0.35' CSTC + Overlay 0.25' AC Class B

Figure 47. Process for Selecting Rehabilitation Alternatives

T.I. which is the logarithm of accumulated 5K wheel loads over a 10-year period, a particular cell in the matrix is addressed. This cell contains an index number that directs the program to one of many specific sets, or combinations, of rehabilitation alternatives contained in an array. Each set in this array contains three numbers which in turn identify the specific rehabilitation alternatives to be analyzed in the program. Each alternative carries with it certain parameters that will be used to:

- develop its performance equation
- determine its construction cost, and
- determine time of traffic delay during construction.

The use of this mechanism allows the program to initially consider an unlimited number of rehabilitation alternatives and reduces this number to three suitable alternatives for a particular project with certain attributes, namely; pavement type, functional classification, and traffic index.

These criteria were chosen for obvious reasons:

Pavement type - because different pavement types will inherently require different types of rehabilitation.

Functional class - because it is both a measure of the importance of the route (and possibly tolerance of lower level of service) and it is also a rough indicator of overall traffic volume, and

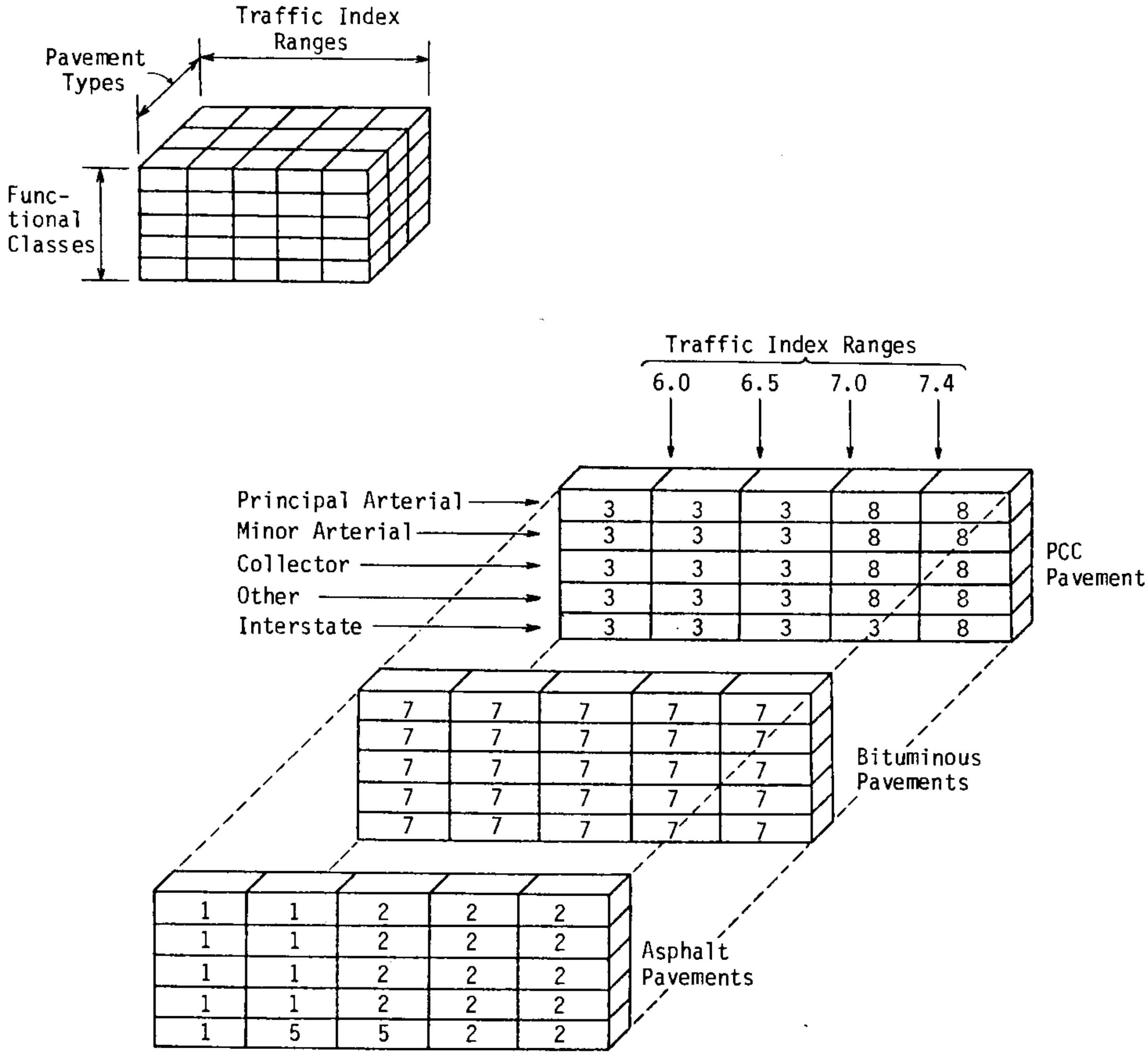
Traffic index - because this is a measure of the loading anticipated on the pavement--a major factor in pavement design.

Figure 48 is a more detailed illustration of the Selection Matrix.

The second task in this program is the development of performance equations for each of the alternatives selected. This process is based on relating the expected performance of the rehabilitation alternative to its average performance when placed on the type of pavement in place on the project, and tempered with how the pavement in place has performed. Because the existing pavement's performance is related to traffic loadings, environmental conditions such as weather and foundation support, and original construction quality, it is assumed the influencing factors for performance of the rehabilitated pavement will not change significantly and future performance will be related to the original pavement's performance.

The form of the equation generated in this phase is identical to that developed for the existing pavement in the Interpreting Program, i.e.,

$$R = C - mA^B$$



SELECTION MATRIX

Figure 48. Selection Matrix

In this equation, R and A represent the dependent and independent variables, rating and age respectively; C is the model constant for the maximum rating which approximates 100; and m and B are the slope coefficient and the degree of curvature exponent respectively which must be determined.

In order to determine the values for m and B in this equation, there are two main considerations:

1. Length of the curve (pavement age)
2. Degree of curvature, or shape of curve

It should be understood that these equations are used to: (1) determine the useful life of each specific rehabilitation alternative; and (2) to provide a datum, or reference line, that can be used for estimating certain categories of cost in economic analysis. Thus, length of curve and degree of curvature are the two basic considerations.

Length of Curve

The method for determining the length of curve for each alternative in this system is based on the age of pavement when its performance curve reaches the MUST level specified in the parameters. This is determined in the program by applying a factor to the projected life of the pavement in place, i.e.,

Age of Alt. at Must = (Age of Exist. Pavt. at Must) x (Factor) or

Life of Alternative = (Projected Life of Pavt. in Place) x (Factor)

These factors, arbitrarily called Equation Factors, are computed with the following formula:

$$\text{Equation Factor} = \frac{\text{Typical Life of Altern. Y Applied on Pavt. Type A}}{\text{Typical Life of Pavement Type A}}$$

As an example, consider that a full depth asphalt pavement in the State of Washington usually has a life expectancy of approximately 12 years. When overlaid with 0.15 ft of asphalt concrete, the pavement will, under normal conditions, last an additional 10 years. An equation factor for a 0.15-ft AC overlay on an existing full depth AC would then be:

$$\text{Equation Factor} = \frac{\text{10 years (0.15-ft AC)}}{\text{12 years (full depth AC)}} = 0.83$$

However, when estimating the life expectancy of a 0.15-ft AC on a specific project with full depth AC, it is noted that the existing pavement has a projected life of only 10 years. The program would then estimate that a 0.15-ft AC overlay would last only 8.3 years and not the average 10 years.

Degree of Curvature

The degree of curvature in the performance equation ($R = C - mA^B$) is controlled by the constant B. In studying a large number of performance curves produced by the interpreting program, it was noted that the degree of curvature is inversely proportional to the life of the pavement, i.e.,

$$B = \frac{K}{A}$$

where K is a constant representing the proportionality.

By studying the general form of the performance equation, it was quickly found that by solving the equation for B the same basic form was obtained.

$$B = \frac{\log\left(\frac{100-R}{m}\right)}{\log A} \qquad \text{or} \qquad B = \frac{\log K}{\log A}$$

$$\text{where:} \quad K = \frac{100-R}{m}$$

Since R in the above equations is actually R_{must}, the MUST level of rating, and A is the age of pavement at the MUST level determined by the equation factor, then B is a function of the slope coefficient m, i.e.,

$$B = f(m) \text{ where } f(m) = \frac{\log\left(\frac{100-R_{must}}{m}\right)}{\log A_{must}}$$

Determining the coefficient constant, m, for the performance equation was the last item needed for developing performance equations for the rehabilitation alternatives. By selecting all performance equations with a coefficient of determination (R^2) equal to or greater than 0.85 for each type of rehabilitation, average values of m were developed for each. Figure 49 is a table of some typical rehabilitation alternatives with their respective equation factors and m values. Figure 50 is an example of a typical family of curves for one alternative type illustrating the relationship between age and degree of curvature as developed with this procedure.

Developing Equations for the Alternatives When the Existing Pavement has been Rehabilitated Previously

The procedure just described was developed for application on pavements that have not been rehabilitated since they were first built. Obviously, if an equation factor was applied to a rehabilitated pavement with a projected performance of very short duration, the expected life of alternatives estimated

TABLE OF TYPICAL REHABILITATION ALTERNATIVES

Description of Alternates	Constr. Cost*	Equation Factors AC	Bit	PCC	"m" Value
Bituminous Surface Treatment	14,300	0.63	1.00	--	8.27407
Resurface with 0.06' AC Class D	23,100	0.69	--	0.30	0.66181
Resurface with 0.08' AC Class G	22,000	0.82	--	--	0.66181
Resurface with 0.15' AC Class B	35,800	0.96	1.51	0.42'	0.22686
Resurface with 0.25' AC Class B	59,600	1.25	1.98	0.55	0.05231
Resurface with 0.35' AC Class B	68,500	1.79	2.82	0.79	0.13558
Recycle 0.15'	45,000	0.69	--	--	0.66181
Recycle 0.15' + 0.06' AC Class D	68,100	0.96	--	--	0.22686
0.35' CSTC + 0.25' AC Class B	68,500	--	--	0.79	0.13558

*Construction Cost = Cost per 12' Lane-Mile

Figure 49. Table of Rehabilitation Alternatives

General Equation Form:

$$\text{Pavement Rating} = 100 - m\ \text{Age}^{\beta}$$

$m = 0.1171875$

Curve	Crit. Age*	Exp. β
1	4	4.50
2	6	3.48
3	8	3.00
4	10	2.71
5	12	2.51
6	14	2.36
7	16	2.25

*Critical Age @ Rating = 40

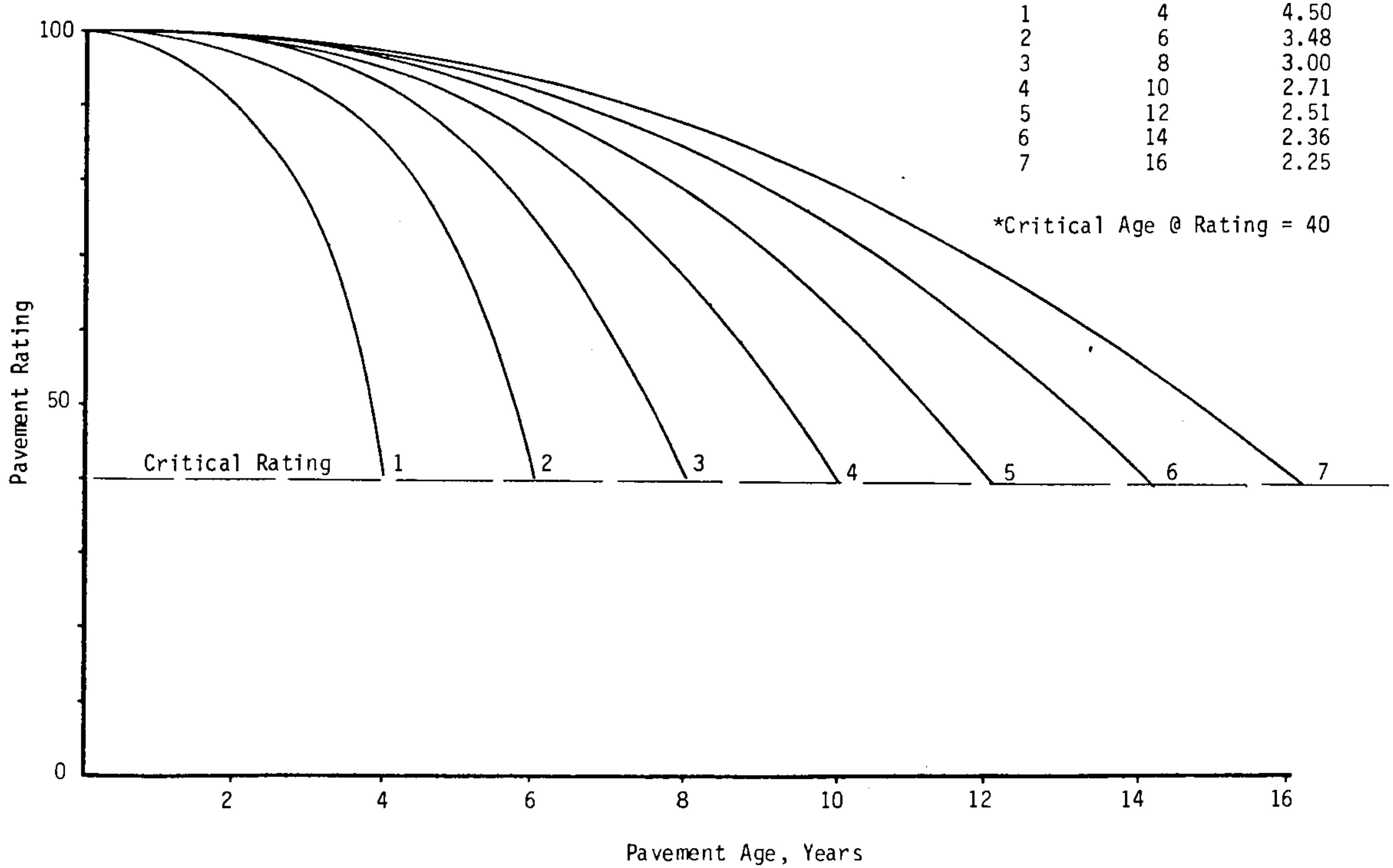


Figure 50. Typical Family of Curves

in this way would not be reasonable. To allow for this, a somewhat inverted procedure is applied to a rehabilitated pavement prior to the above procedure.

Since equation factors relate performance of a rehabilitation type to the life of the original pavement, the type and thickness of rehabilitation presently existing are determined from the project description and used to identify the properly associated equation factor. The projected life of the pavement in place is then divided by this equation factor to estimate the life of original pavement to which the previously described procedure can be applied, i.e.,

$$\text{Estimated Life of Orig. Pavt.} = \frac{\text{Projected Life of Rehabilitated Pavt.}}{\text{Appropriate Equation Factor}}$$

Life of Alternative = (Estimated Life of Orig. Pavt.) x (Factor)

Comment on Method of Developing Equations for Alternatives

It should be noted that the procedures just described are very theoretical. However, this procedure does provide a reasonable means for comparing the predicted performance of rehabilitation alternatives. It is felt that over a period of time and with the acquisition of new data each time the pavements are rated, this process can be verified, or improved, through modification to produce more reasonable estimates. This procedure is simply that--an estimating procedure.

Setting Up the Array of Valid Strategies

This program phase is concerned with generating all strategies possible with the alternatives selected in the preceding phase. In this system, a rehabilitation strategy is defined as a combination of alternatives applied within a specified period (consideration period) identified by type, sequence, and specific application time.

In the preceding phase, three rehabilitation alternatives were selected for consideration on a specific project. In addition to these alternatives, the option of continuing "routine maintenance" is always considered. Each project, then, has four alternatives for analysis in generating and studying strategies for maintaining pavement condition:

Alternative 1: Routine Maintenance - always considered
Alternative 2: Rehabilitation Option 1 }
Alternative 3: Rehabilitation Option 2 } — Selected in Preceding Phase
Alternative 4: Rehabilitation Option 3 }

Since the program considers four possible cycles of application in its analysis, there are 121 combinations of alternatives involving type and sequence as shown in Figure 51.

No.	Alternatives
1	1
2	2
3	3
4	4
5	2-2
6	2-3
7	2-4
8	3-2
9	3-3
10	3-4
11	4-2
12	4-3
13	4-4
14	2-2-2
15	2-2-3
16	2-2-4
17	2-3-2
18	2-3-3
19	2-3-4
20	2-4-2
21	2-4-3
22	2-4-4
23	3-2-2
24	3-2-3
25	3-2-4
26	3-3-2
27	3-3-3
28	3-3-4
29	3-4-2
30	3-4-3
31	3-4-4
32	4-2-2
33	4-2-3
34	4-2-4
35	4-3-2
36	4-3-3
37	4-3-4
38	4-4-2
39	4-4-3
40	4-4-4

No.	Alternatives
41	2-2-2-2
42	2-2-2-3
43	2-2-2-4
44	2-2-3-2
45	2-2-3-3
46	2-2-3-4
47	2-2-4-2
48	2-2-4-3
49	2-2-4-4
50	2-3-2-2
51	2-3-2-3
52	2-3-2-4
53	2-3-3-2
54	2-3-3-3
55	2-3-3-4
56	2-3-4-2
57	2-3-4-3
58	2-3-4-4
59	2-4-2-2
60	2-4-2-3
61	2-4-2-4
62	2-4-3-2
63	2-4-3-3
64	2-4-3-4
65	2-4-4-2
66	2-4-4-3
67	2-4-4-4
68	3-2-2-2
69	3-2-2-3
70	3-2-2-4
71	3-2-3-2
72	3-2-3-3
73	3-2-3-4
74	3-2-4-2
75	3-2-4-3
76	3-2-4-4
77	3-3-2-2
78	3-3-2-3
79	3-3-2-4
80	3-3-3-2
81	3-3-3-3
82	3-3-3-4
83	3-3-4-2
84	3-3-4-3
85	3-3-4-4

No.	Alternatives
86	3-4-2-2
87	3-4-2-3
88	3-4-2-4
89	3-4-3-2
90	3-4-3-3
91	3-4-3-4
92	3-4-4-2
93	3-4-4-3
94	3-4-4-4
95	4-2-2-2
96	4-2-2-3
97	4-2-2-4
98	4-2-3-2
99	4-2-3-3
100	4-2-3-4
101	4-2-4-2
102	4-2-4-3
103	4-2-4-4
104	4-3-2-2
105	4-3-2-3
106	4-3-2-4
107	4-3-3-2
108	4-3-3-3
109	4-3-3-4
110	4-3-4-2
111	4-3-4-3
112	4-3-4-4
113	4-4-2-2
114	4-4-2-3
115	4-4-2-4
116	4-4-3-2
117	4-4-3-3
118	4-4-3-4
119	4-4-4-2
120	4-4-4-3
121	4-4-4-4

Figure 51. Combinations Possible with 3 Alternatives and 4 Application Cycles

In order to determine which strategies to evaluate, each of these combinations is assigned all possible times of application relative to the SHOULD and MUST levels prescribed in the optimizing parameters, and then tested for "validity" within the consideration period.

As an example, consider an analysis of the combination 2-4-3. The performance equation for the existing pavement is evaluated with the SHOULD and MUST rating levels to determine the available time periods for the first rehabilitation. The performance equations for each of the rehabilitation alternatives, 2, 3, and 4, are evaluated in the same way to determine the period of rehabilitation within their own life cycles. Graphically, the results of this preliminary evaluation would look like Figure 52.

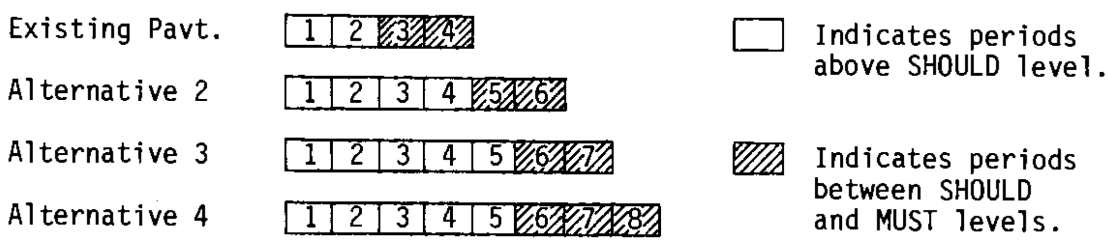


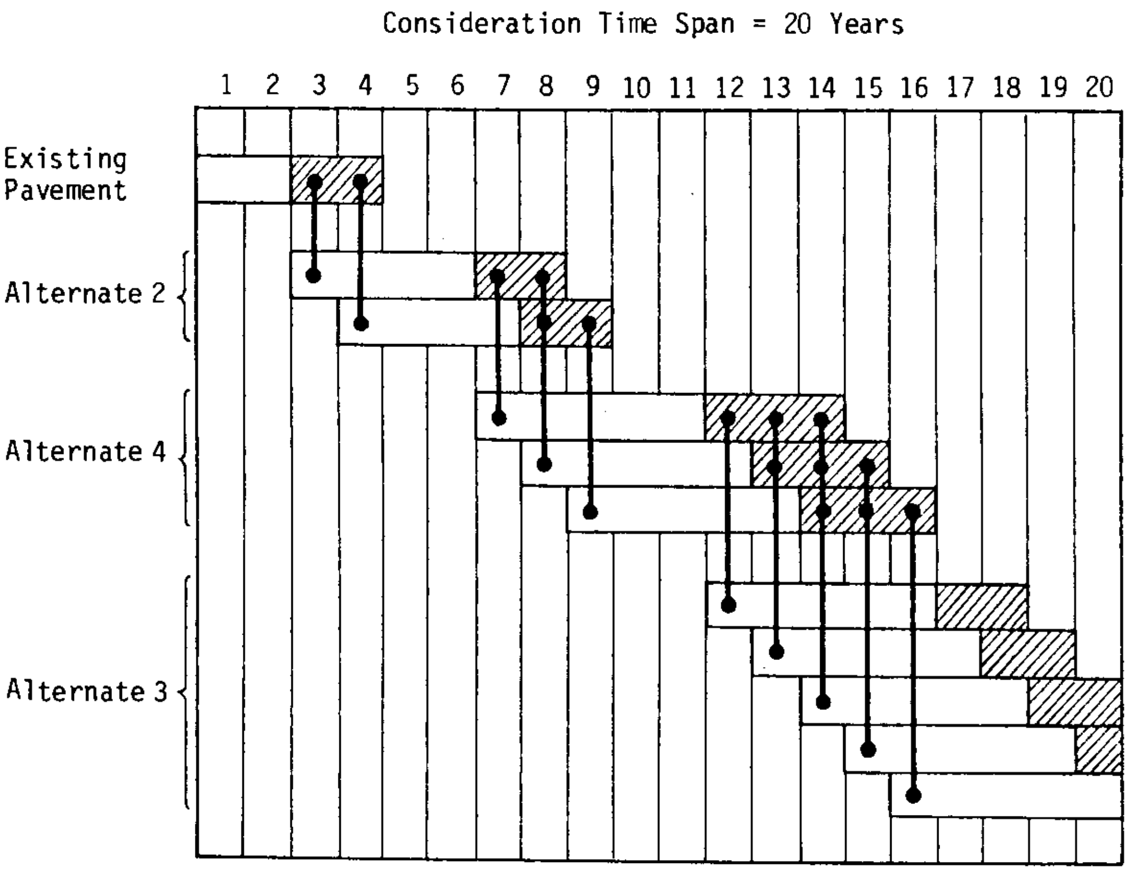
Figure 52. Determining Rehabilitation Timing

Given a specified period of time for evaluation in the economic analysis (consideration period), all possible "strategies" can then be determined. The program logic utilizes the rehabilitation timing determined for the existing pavement and each alternative in an iterative process to produce "valid" application timing. A "valid" selection of application timing is one which would allow rehabilitation to occur only when the pavement rating falls between the SHOULD and MUST level and which would not allow the pavement rating to fall below the MUST level at the end of the consideration period. A strategy would also be considered invalid if the last alternative in a combination is not needed, i.e., the preceding alternative did not fall below the MUST level before the end of the consideration period. Figure 53 is an illustrative example of the logic used to establish valid strategies and their respective timing.

Note that in the example, combination 2-4-3 produces four valid strategies:

1. (2-3)(4-8)(3-15)
2. (2-4)(4-8)(3-15)
3. (2-4)(4-9)(3-15)
4. (2-4)(4-9)(3-16)

Thus, the strategies are defined by stipulating:



Note: (A - P) A = Alternate
P = Period of Application

(2-3) (4-7) (3-12)	Not valid
(2-3) (4-7) (3-13)	Not valid
(2-3) (4-7) (3-14)	Not valid
(2-3) (4-8) (3-13)	Not valid
(2-3) (4-8) (3-14)	Not valid
(2-3) (4-8) (3-15)	Valid
(2-4) (4-8) (3-13)	Not valid
(2-4) (4-8) (3-14)	Not valid
(2-4) (4-8) (3-15)	Valid
(2-4) (4-9) (3-14)	Not valid
(2-4) (4-9) (3-15)	Valid
(2-4) (4-9) (3-16)	Valid

Figure 53. Analysis of Valid Application Timing for Combination (2-4-3)

(A_1-P_1) (A_2-P_2) (A_i-P_i)

where: A is the alternative number

P is the period applied

i is the alternative application cycle (varies from 1 to 4)

and the strategies were developed from the combinations shown in Figure 51.

Discussion of Analysis Boundaries

It should be noted that this program considers 3 rehabilitation alternatives with 4 application cycles, and some discussion is merited on just how these numbers were selected. Much consideration, development, analysis of results, subsequent discussion, and redevelopment went into the determination of these analysis boundaries.

It should be obvious that with 121 combinations of sequence and alternatives available, and a number of different application time periods possible for each combination, there is a significantly large number of strategies that will have to be evaluated for each project. Certainly, no more than this would be reasonable, considering program efficiency and cost of operation.

Figure 54 is an example of the different total numbers of combinations possible when varying the number of rehabilitation alternatives and/or application cycles. These totals were computed using the following formula:

$$C = \sum_{i=0}^{P} A^i$$

where: C = Total number of combinations possible

P = Number of application cycles considered

A = Number of rehabilitation alternatives considered

A - Number of Alternatives	P - Number of Application Cycles: 2	3	4	5
2	7	15	31	63
3	13	40	121	364
4	21	85	341	1365
5	31	156	781	3906

Figure 54. Number of Possible Combinations

The program developed selects three different, but reasonable, alternatives from as large a list as may be desired. Based on experience, three were determined to be adequate. The parameters--Traffic Index, Functional Class, and Pavement Type--perform a function of selection which might be considered as a "narrowing down" process. Thus the program actually "considers" many more alternatives than those used in the final analysis.

The number of application cycles is related to the number of periods in the consideration period. Since the program was originally designed to accommodate up to 30 periods, it required at least four cycles to analyze alternatives with life expectancies of 7 or 8 years when the existing pavement is in immediate need of rehabilitation. Original versions of this program considered only two applications, and it was quickly found that this had shortcomings in comparing alternatives. Over a long consideration period, repetitive applications of a short-lived thin-lift alternative could not be compared to the application of a long-lived thick-lift alternative. Thus, four application cycles were eventually selected.

Evaluating the Valid Strategies

With three reasonable rehabilitation alternatives selected, performance equations developed for each, and all valid rehabilitation strategies identified, the next process in this program is the evaluation of each on the basis of overall total cost. This process involves several cost models, some of which are related to estimated pavement condition, and others that are related only to the chosen action.

There are seven basic cost factors involved in the evaluation of each valid strategy:

1. Construction cost of all rehabilitative action applied within the consideration period.
2. Cost of preparing the pavement immediately prior to each rehabilitation.
3. Salvage value of the pavement at the end of the consideration period.
4. Routine maintenance cost associated with the pavement throughout the consideration period.
5. User-incurred costs due to pavement condition.
6. User-incurred costs due to delay during rehabilitation.
7. Discounting of all estimates to present worth dollars for comparison.

Construction Cost of Each Rehabilitative Action

In order to estimate the construction cost for each rehabilitation alternative, average bid prices for contracts advertised in the preceding year are studied. These costs, which consider only typical projects, include some minor widening, drainage improvement, and normally associated other items such as striping. The total surface area of each project (length x average width) is used to reduce these costs to a cost per 12-ft lane-mile. With typical unit costs developed in this manner for each rehabilitation alternative, an inflation factor must be applied to each in order to estimate present-day costs. These unit costs are input to the program in conjunction with the optimizing parameters. As each alternative is then selected via the Selection Matrix, its unit cost is identified. When each project is read into the program, the physical description including roadway width, shoulder width, and number of lanes is also read. By applying the unit cost of each alternative to the computed surface area (12-ft lane-miles) of a specific project, reasonable and relative costs are generated.

Cost of Pavement Preparation

In rehabilitating different sections of pavement, it was noted that cost for the same treatment may vary widely from one project to another. This variation in cost can be due to contractors' competition, the availability of suitable materials, and differing contract requirements. It can also be attributed to the varying degrees of pavement deterioration which must be rehabilitated. Pavements in very poor condition will require much more preparation than those caught before they get too bad. This preparation cost can account for large differences in the total construction cost of the same alternative when applied to pavements with varying degrees of distress.

During the course of this study it was noted that there were generally three predominant types of preparation applied to asphalt pavement prior to an overlay:

1. Crack sealing
2. Preleveling
3. Pavement removal and replacement

In order to consider the cost of preparation in the economic analysis applied in this program, it was necessary to study the cost of these items as they related to the pavement rating of several recent rehabilitation projects.

The results of that study are shown in Figure 55 which demonstrates the cost of preparation as a function of the condition of the pavement. Also shown in this figure are the relative areas under the curve attributed to the three main components.

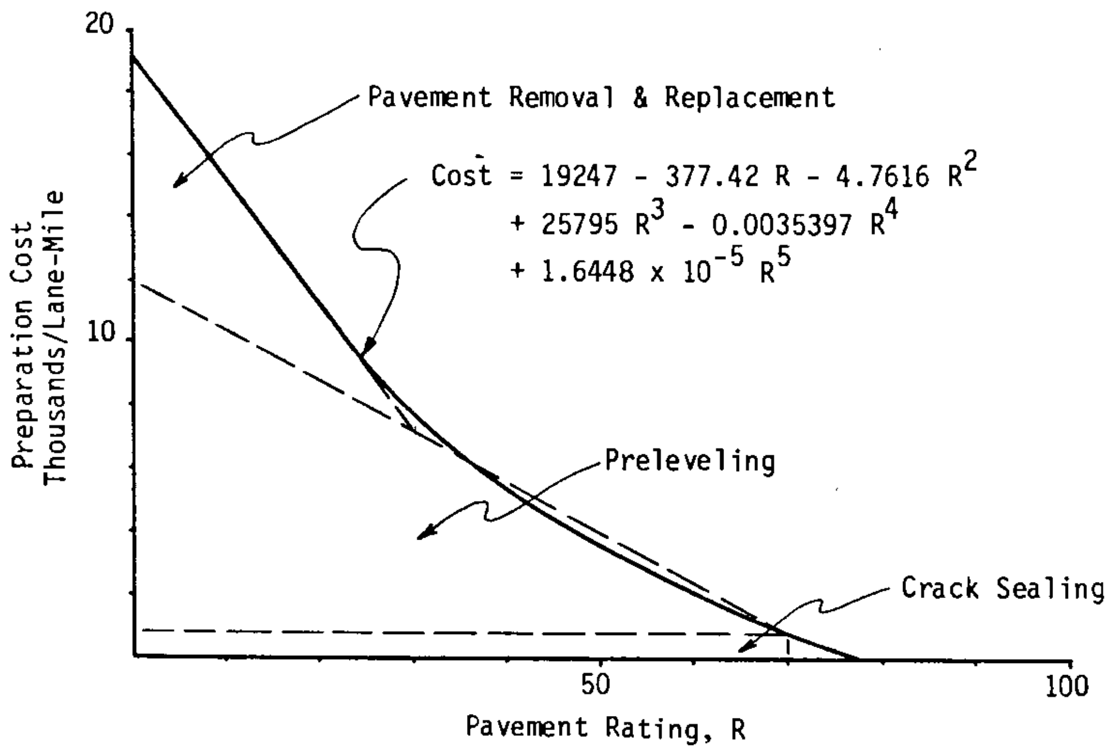


Figure 55. Preparation Cost Model

Salvage Value

In the economic analysis of each strategy, there must be a consideration for the value of the pavement at the end of the consideration period. The term "salvage value" normally conveys a meaning of "worth" at a time late in the useable life of a pavement. The application of salvage value in this analysis is a little different. In order to provide an equitable comparison of rehabilitation strategies, salvage value is used here to associate a dollar amount with the amount of pavement life remaining at the end of the consideration period. This is computed using the following formula:

$$\text{Salvage Value} = \frac{\text{Useable life left in pavement}}{\text{Total expected life of last action}} \times \begin{array}{c}\text{Construction cost}\\ \text{of last action}\end{array}$$

The useable life left in the pavement is the time projected to again reach the MUST level after the end of the consideration period.

Routine Maintenance Cost

Routine maintenance costs have presented a problem to almost every agency attempting to develop a pavement management system. Because sufficient records have not been kept to relate man-hours, equipment-hours, and material costs for pavement maintenance to either specific projects or a defined level of pavement condition, the state of the art in maintenance cost models has not been greatly developed.

The maintenance cost model used in this program is based on a model originally developed in "Economic Analysis of Roadway Occupancy for Freeway Pavement Maintenance and Rehabilitation" by B. C. Buttler, Jr.[8], which uses a logit funtion to relate maintenance costs to pavement age. The model illustrated in that report, however, related maintenance cost to pavement age instead of to pavement condition as was desired for this application.

Even though the logit function was used in Buttler's report to relate pavement maintenance cost to pavement age, it was decided that a sigmoidal curve represented the general relationship of pavement maintenance cost to pavement condition better than other known curve shapes. The general form of this equation is:

$$\text{Cost} = \frac{S}{1 + e^{-f(R)}}$$

where:

Cost = Maintenance Cost

S = Scale factor, or maximum cost level

R = Pavement condition rating

By obtaining typical maintenance costs on several control sections which represented pavements of approximately the same age, a sigmoidal function was calibrated to department costs, and to a typical performance curve relating ratings to age. This function is illustrated in Figure 56.

Note that this function demonstrates three basic phases of maintenance cost related to pavement condition:

1. No maintenance cost when pavement rating is high.
2. Variable maintenance cost in middle ranges of rating.
3. Maximum maintenance cost below a certain rating.

User-Incurred Costs Due to Pavement Condition

As was evident with routine maintenance costs, the topic of users' costs has also presented historic problems to those involved in PMS development. Because so little information in this area was available at the time of development, it was decided to assume a relationship between PSI and the newly developed pavement condition ratings as follows:

PSI	PMS Rating
5	100
4	80
3	60
2	40
1	20

With this assumption, relevant cost information developed by Robley Winfrey[9] was updated to present values and a cost model then assembled for relating user cost, due to pavement condition, to pavement rating. Because user costs differ greatly between passenger vehicles and commercial trucks, vehicle counts for each are projected for each year in the consideration period. As can be seen in Figure 57, the model relates cost per vehicle-mile for each type to pavement condition.

With the length of project, the counts for autos and trucks, and the projected pavement rating for each year, an estimate of user cost can be generated.

$$f(R) = \left[\left(\frac{101.26 - R}{0.99431}\right)^{2/3} - 10\right]\frac{1}{1.18}$$

$$\text{Cost} = \frac{S}{1 + E^{-f(R)}}$$

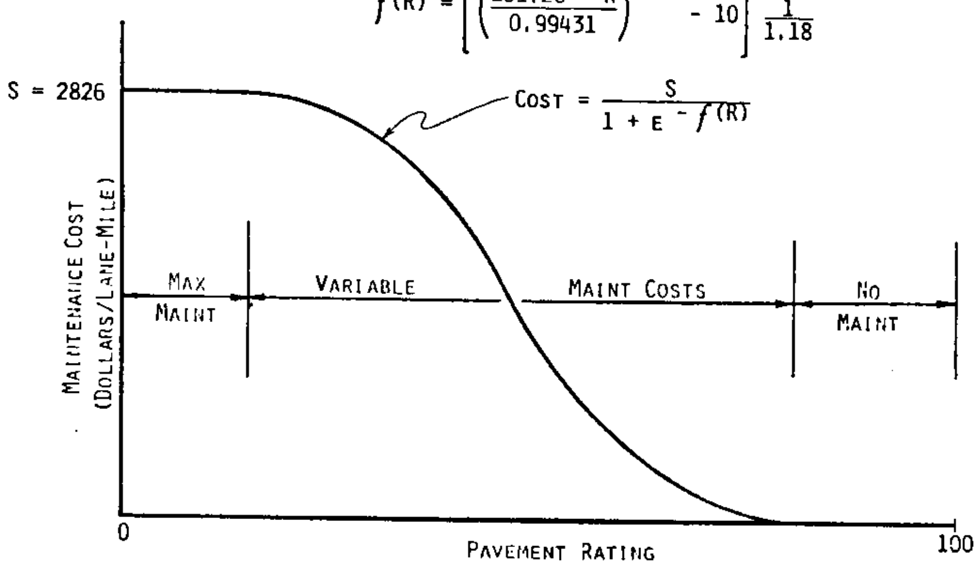


Figure 56. Maintenance Cost Model

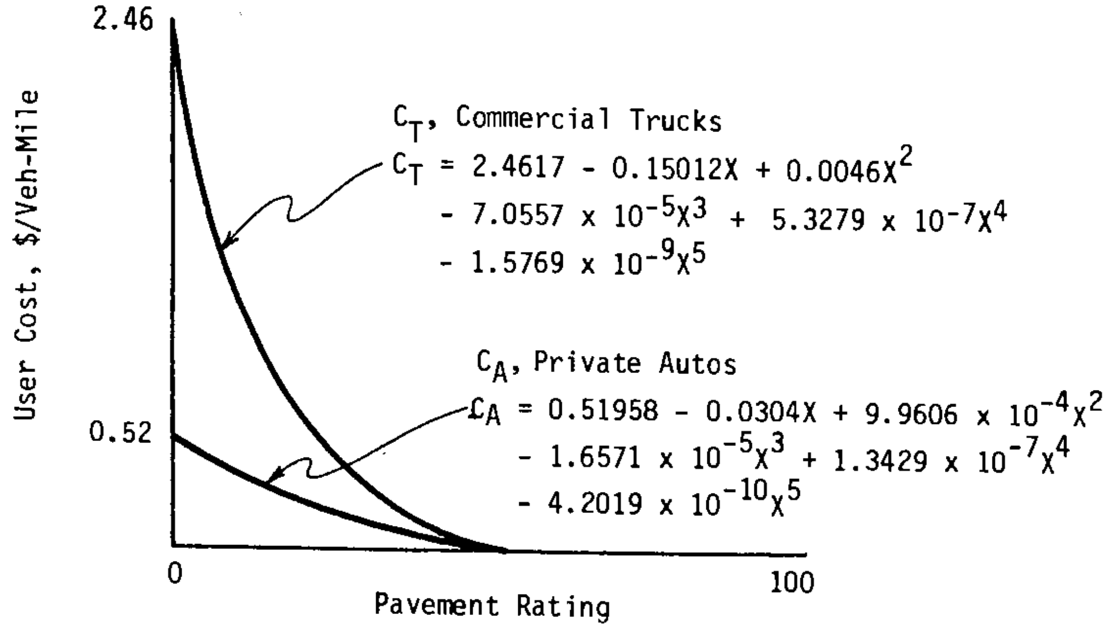


Figure 57. User Cost Function

<u>User-Incurred Cost Due to Traffic Interruption During Construction of Each Alternative</u>

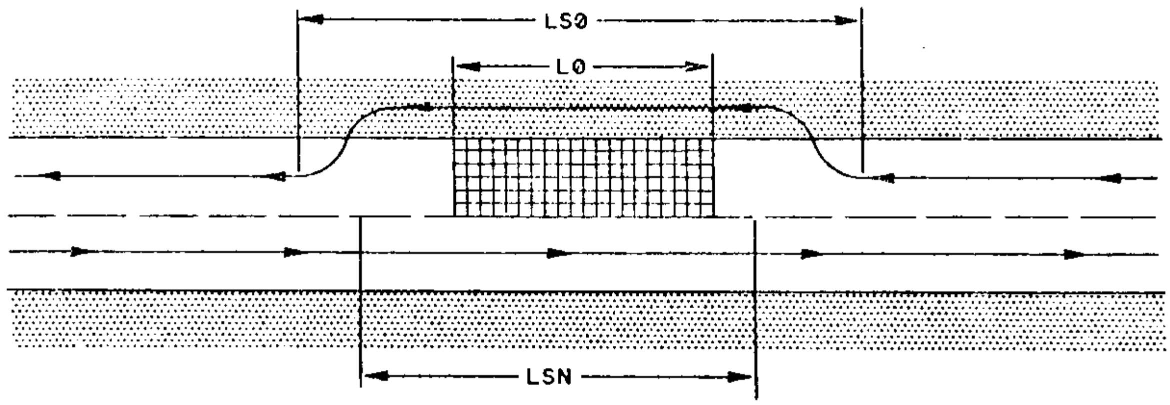
User costs associated with delaying traffic during construction are dependent on the method of handling traffic, the number of lanes, and the volume of traffic. Figures 58 and 59 indicate the possible methods of handling traffic as developed by W. F. McFarland[10]. Methods II and III are the only ones considered in the program because they represent the most common approaches to handling traffic as used by WSDOT.

The general equation for developing these costs is:

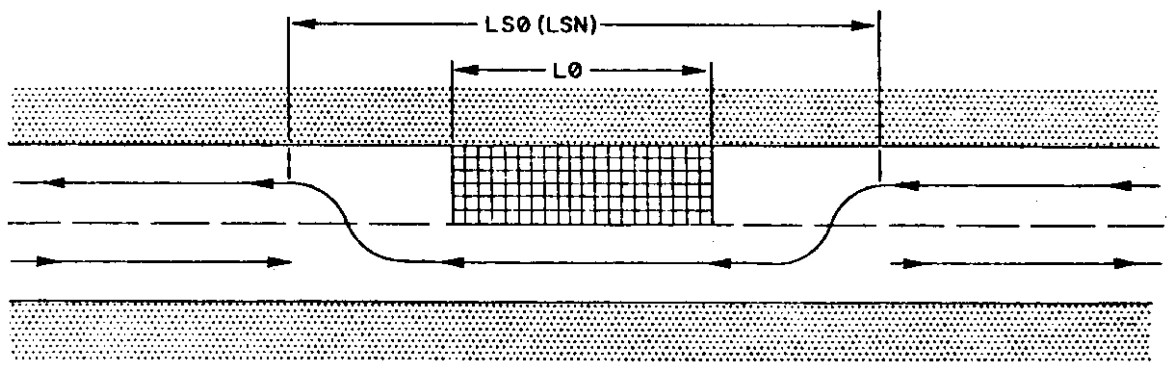
$$UC = (MT)(P)(ADT)[(TP)K_1+(1-TP)K_2]$$

where:
- UC = User Costs due to traffic interruption
- MT = Time required to apply overlay
- P = Average portion of ADT passing through project
- ADT = Average Daily Traffic (one direction only)
- TP = Percentage of trucks in ADT
- K_1 = User Costs per truck-mile
- K_2 = User Costs per vehicle-mile

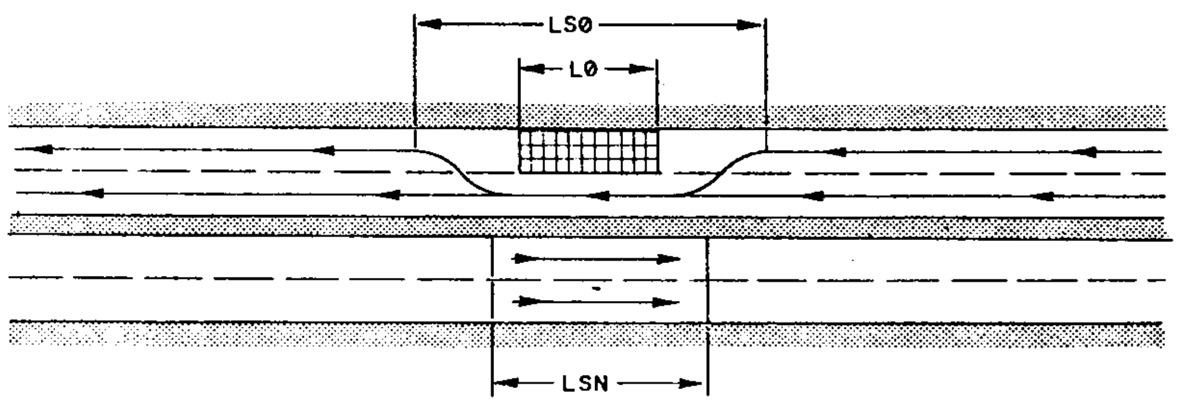
MT is computed based on the depth of overlay at an average rate of 100 tons/hr.



Method I: traffic routed to shoulder.

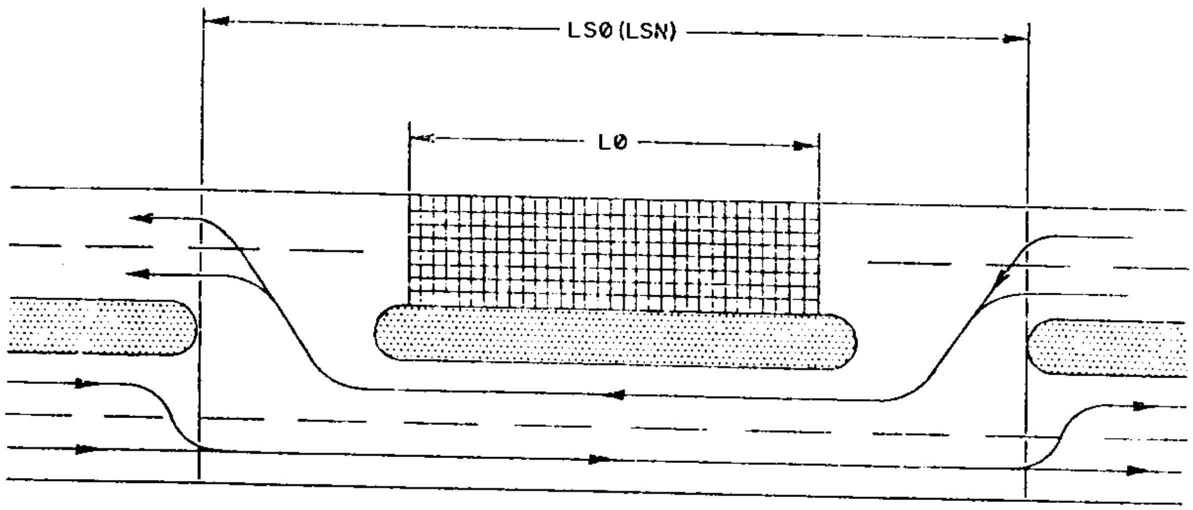


Method II: alternating traffic in one lane.

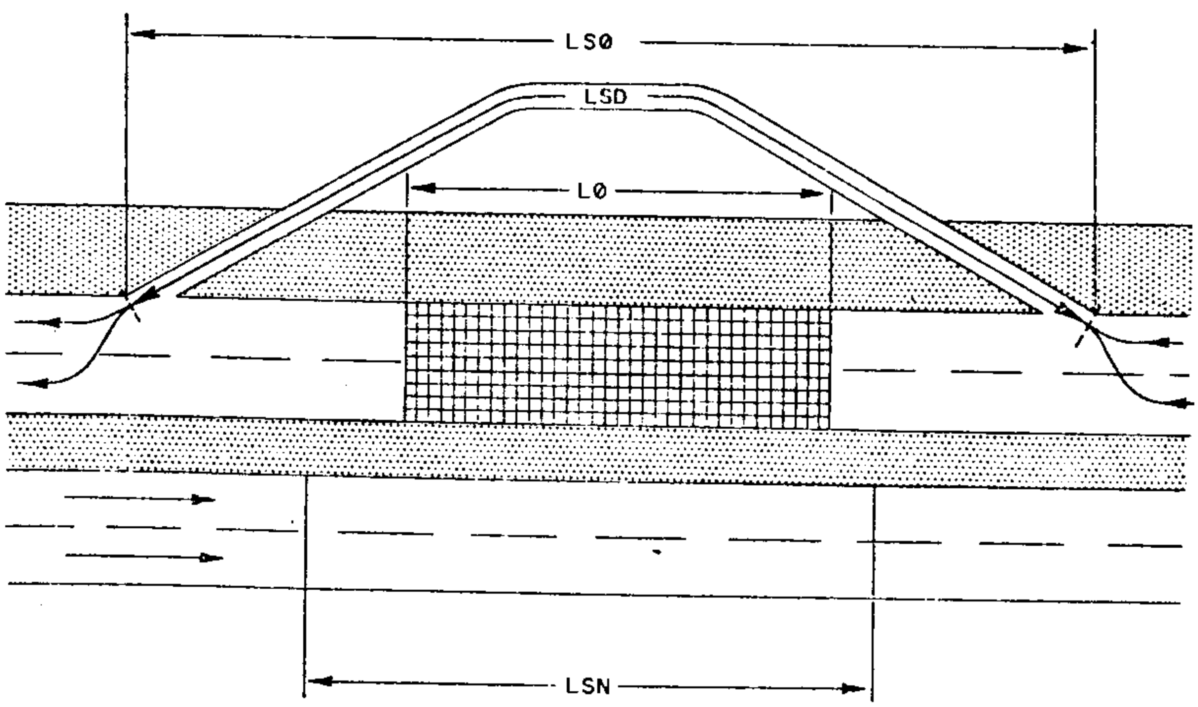


Method III: two lanes merge, nonoverlay
direction not affected.

Figure 58. Traffic Interruption Methods



Method IV: overlay direction traffic routed to nonoverlay lanes.



Method V: overlay direction traffic routed to frontage road or other parallel route.

Figure 59. Traffic Interruption Methods

P is 0.06 for rural areas and 0.055 for urban areas as stated in HRB (1972) "Pavement Rehabilitation--Materials and Techniques," NCHRP Synthesis of Highway Practice 9, 41 p.[11].

ADT is projected to the specific year of construction for each alternative using the growth factors. TP is input with the project description data along with the base year ADT.

K_1 and K_2 are both related to the length of the construction area and the volume of traffic which must be handled. Assuming an affected length of 1.5 miles, and after updating truck and auto data, functions were developed to determine K_1 and K_2 for Method II from the total vehicle miles involved. These functions are illustrated in Figure 60.

K_1 and K_2 were determined to be <u>0.9435</u> and <u>0.1237</u>, respectively, for Method III.

$$K_1 = 1.4559 + 2.8874\times10^{-4}X + 9.5613\times10^{-7}X^2 - 1.8622\times10^{-9}X^3 + 1.4102\times10^{-12}X^4 - 3.2155\times10^{-16}X^5$$

$$K_2 = 0.16275 + 5.4379\times10^{-5}X + 4.8812\times10^{-8}X^2 + 8.5512\times10^{-11}X^3 + 5.7255\times10^{-14}X^4$$

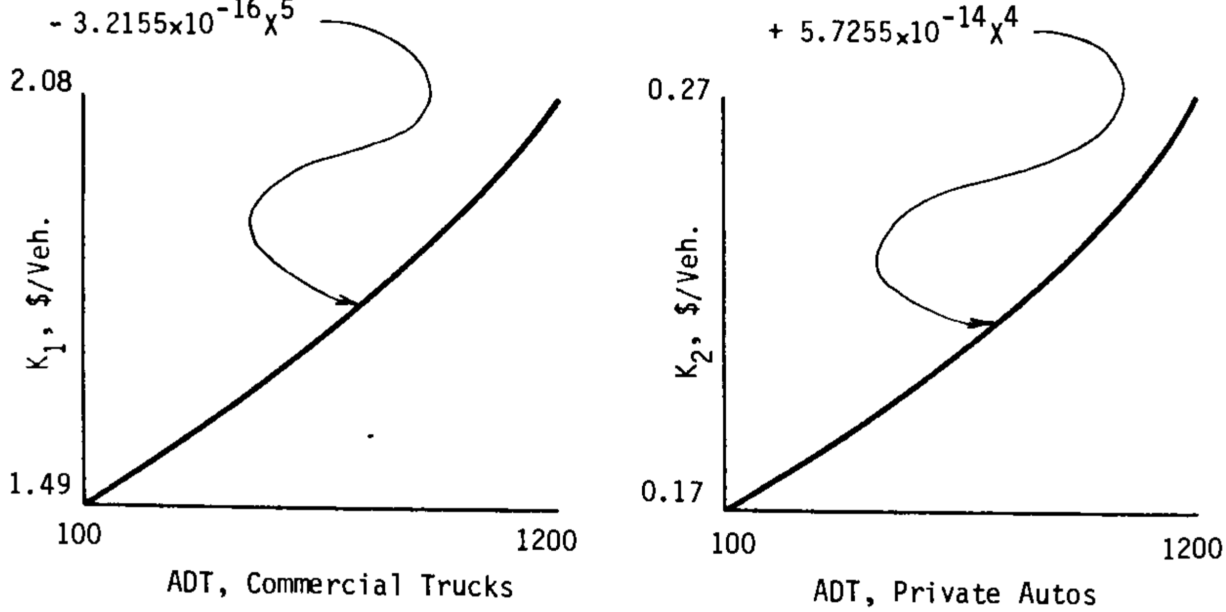


Figure 60. Vehicle Cost Functions for Traffic Interruption

<u>Discounting Costs to Present Worth</u>

Total project costs for each year in the consideration period are estimated according to the models just described. In order to economically gauge the timing, and more specifically the effect of interest rates and inflation on the timing of expenditures, all costs are discounted to present worth prior to summation. This is accomplished by calculating a discount factor for each year according to the formula:

$$DF = \frac{1}{(1 + EI)^N}$$

where: DF = Discount Factor

EI = Effective Interest (interest rate - inflation rate)

N = Number of each consecutive year in the consideration period

These factors are then applied to the total costs estimated for each year.

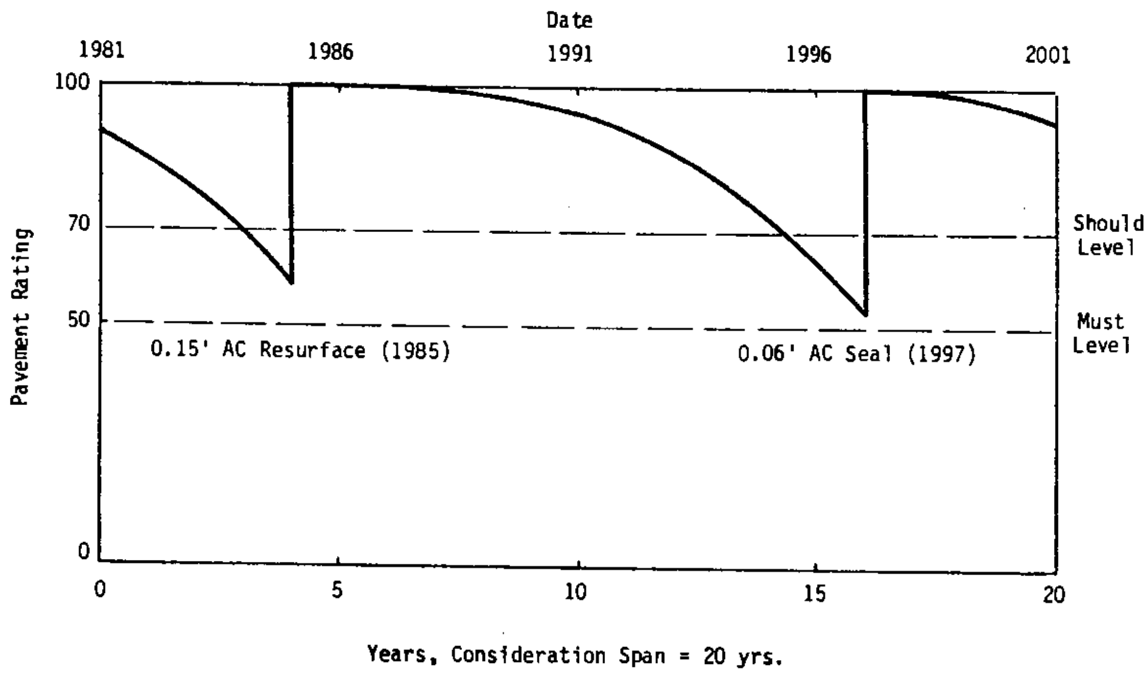
Program Output

Figure 61 is an example of the economic evaluation of one strategy with the tabulation of all costs involved for each year of the consideration span. The top portion of this figure illustrates graphically what type of performance can be expected by resurfacing in 1985 with 0.15-ft AC and again in 1997 with 0.06-ft AC seal. The tabulation in the lower portion lists not only the cost each year per category, but also projected pavement ratings, auto volumes, truck volumes, and the discount factors used to calculate these costs. The information shown at the bottom represents the initial data used to generate the traffic volumes and discount figures.

Figure 62 is an example of the output listing generated by the optimizing program for one project and represents the result of a long evolution of different output formats. To explain this listing, it has been segmented into five blocks of data as shown in Figure 63.

The top portion of this listing, as shown in Figure 64, labeled "Project Description and Performance," is identical to the upper half of the output listing generated by the interpreting program. This was explained in detail in Chapter 3.

The next block of data labeled "Optimizing Parameters" and shown in Figure 65 lists the parameters used in the analysis. The top two statements list the should and must levels and identify the specific year when these rating levels will be attained on the existing pavement. The next statement defines the consideration span in terms of period and explains the length of each period. The provision of changing the length of periods allows for considering two-year periods, or bienniums, for budgeting purposes, or possibly five-year periods when analyzing rigid pavements. The last line of information in this block indicates the effective interest applied in discounting and the equation factors used to develop the performance equations for the alternatives.



	Predicted									
	Pavt Rating	Auto Volume	Truck Volume	Constr Cost	Prep Cost	Traffic Interr. Cost	Maint Cost	User Cost	Total Annual Cost	* Discount Factor
1	84.94	26,683	6,259				1,128	13,971	15,099	0.9615
2	78.48	28,563	6,700				3,723	14,561	18,234	0.9246
3	70.19	30,443	7,141				10,639	15,469	26,108	0.8890
4	59.74	32,323	7,582	387,218	15,974	26,239	0	16,917	446,348	0.8548
5	99.97	34,203	8,023				12	14,903	14,915	0.8219
6	99.78	36,083	8,464				12	15,196	15,208	0.7903
7	99.27	37,963	8,905				15	15,497	15,512	0.7599
8	98.26	39,843	9,346				22	15,816	15,838	0.7307
9	96.61	41,723	9,787				39	16,135	16,174	0.7026
10	94.14	43,603	10,228				81	16,405	16,486	0.6756
11	90.69	45,483	10,669				199	16,571	16,770	0.6496
12	86.11	47,363	11,110				569	16,638	17,207	0.6246
13	80.22	49,243	11,551				1,786	16,732	18,518	0.6006
14	72.87	51,123	11,992				5,207	17,100	22,307	0.5775
15	63.89	53,003	12,433				10,143	17,953	28,096	0.5553
16	53.11	54,883	12,874	156,057	14,970	21,399	0	19,226	211,652	0.5339
17	99.71	56,763	13,315				8	15,851	15,859	0.5134
18	98.63	58,643	13,756				12	15,927	15,939	0.4936
19	96.59	60,523	14,197				26	16,045	16,071	0.4746
20	93.49	62,403	14,638				66	16,101	16,167	0.4564

1980 ADT = 28,300

Trucks = 19%

Growth Rate = 8.2%

Effective Interest = 4%

Subtotal $978,558

Salvage Value -81,219

TOTAL STRATEGY COST = $897,339

*Note: All costs in table have been discounted with listed discount factors.

Figure 61. Tabulation of Cost Evaluation

```
R67730OPT                                                                                                  01/18/82
              BEG   END         BEG  END  PROJ FNC        HWY NUM RDW-RSH-LSH LAST   COMPLT CNT SURFACE BASE
 D  SR  SRMP  SRMP   CS   CSMP CSMP LENG CLS  SIDE TYP LNS   WIDTHS    CONTR  M-YR   TYP TYP-THK TYPE
 *  ***  *****  *****  ****  ****  ****  ****  ***  ****  ***  ***  **********  *****  ******  ***  *******  ****

 4   5  2638  2930  801   560  852  292 R-5   L    3   2   36  10 . 6  08759  9-71    0  40   70  21

                  PERFORMANCE HISTORY                              APPROXIMATE TRAFFIC DATA      PERFORMANCE EQUATION
 ----------------------------------------------------------      --------------------------    --------------------
 YEAR                    73       75       77       79       81      80 ADT              28300     EQUA CONST = 100.46
 AGE                      2        4        6        8       10      GROWTH RATE          6.2%     EQUA COEFF =   -0.00106
 RIDE    RATING        1.00     1.00     1.00     1.00     1.00      SINGLE UNITS           5%     EQUA POWER =   4.00
 STRUCR  RATING       100.0    100.0    100.0     97.4     89.7      COMBINATIONS          14%     R SQUARE   =   0.97184
 CONRD   RATING       100.0     99.9     99.8     97.2     89.5      TRAFFIC INDEX         7.8     STD ERROR  =   0.78
 HIGH    RATING       100.0    100.0     99.9     99.9     99.7      K = 13%          D = 58%      TIME TO 60 = 13.98
 LOW     RATING        99.8     99.8     99.6     94.8     69.9     2 AXLE TRUCKS =   3.3 %      TIME TO 50 = 14.77
 HIGH FRICTION           40       59       49       49       46     3 AXLE TRUCKS =   4.4 %      TIME TO 40 = 15.45
 LOW  FRICTION           40       56       48       48       41     4 AXLE TRUCKS =   1.8 %      TIME TO 30 = 16.06
 AVG  FRICTION           40       58       48       48       43     5 AXLE TRUCKS =   9.4 %      TIME TO 20 = 16.60
 ***********************************************************************************************************************

               SHOULD REHABILITATE AT 70.0 WHICH WILL OCCUR IN 1984
               MUST REHABILITATE AT 50.0 WHICH WILL OCCUR IN 1986
               CONSIDERATION SPAN = 20 PERIODS, EACH PERIOD = 1.0 YEARS
               EFFECTIVE INTEREST RATE =  4.0%   FACTORS :  67.0%  83.0% 100.0%

                                                                                   CONSTRCT COST   MIN LIFE    MAX LIFE
    DESCRIPTION OF THE ALTERNATIVES            PERFORMANCE  EQUATIONS              12' LANE MILE   AT  SHUD    AT  MUST
 -----------------------------------     --------------------------------------    -------------   --------    --------

 ALTERNATE 1 ROUTINE MAINTENANCE         P = 100.46 - 0.00106 P ** 4.00                 0            13.02       14.77
 ALTERNATE 2 OVERLAY  0.06 CLASS D       P = 100.00 - 0.28783 P ** 2.25             23100             7.89        9.90
 ALTERNATE 3 OVERLAY  0.15 CLASS B       P = 100.00 - 0.02713 P ** 3.00             35800            10.34       12.26
 ALTERNATE 4 RECYCLE  + 0.06 CLASS D     P = 100.00 - 0.01551 P ** 3.00             68100            12.46       14.77

                                                                                   NUMB
                             ITEMIZED COSTS                                        POSS          STRATEGY DESCRIPTION
 ************************************************************************          ****      **************************

 ROUT     +    COST OF   +   COST OF   +   USER     -    SALVAGE   =   EXPECTED      80       (ALTERNATIVE - PRD APPLIED)
 MAINT         CONSTR        TRAFFIC       COST          VALUE         TOTAL
 COST          INCL PR       INTERPT                                   COST                     1ST    2ND    3RD    4TH
                                                                                              REHAB  REHAB  REHAB  REHAB

   31930        452691        41189       322760        31555         817015        26        2-85   2-94
   27999        458887        40685       321859        15777         833653        18        2-84   2-93
   33657        574218        47638       323015        81219         897339         9        3-85   2-97
   23976        585276        47069       321377        64975         912723         9        3-84   2-96
   31663        907635        70386       321932       111519        1220317         9        4-85   2-99
   21925        932029        69312       320058        95588        1247736         9        4-84   2-98
```

Figure 62. Optimizing Program Listing

Optimizing Parameters

Project Description and Performance

```
D  SR   BEG    END    CS   BEG  END  PROJ FNC  SIDE HWY NUM ROW-RSH-LSH  LAST  COMPLT CNT SURFACE BASE
        SRMP   SRMP        CSMP CSMP LENG CLS       TYP LNS   WIDTHS     CONTR  M-YR  TYP TYP-THK TYPE
*  ***  *****  *****  **** **** **** **** ***  **** *** *** ***********  ***** ****** *** ******* ****

3   5  13554  13950  2719    0  396   396 U-S   R    3   4  48  10  10  08603  5-70   20  40  33   11

                 PERFORMANCE HISTORY                         APPROXIMATE TRAFFIC DATA     PERFORMANCE EQUATION
---------------------------------------------------------   -------------------------    --------------------
YEAR                71      73      75      77      79        79 ADT           78300      EQUA CONST  =  98.78
AGE                  1       3       5       7       9        GROWTH RATE       5.6%      EQUA COEFF  =  -0.01384
RIDE    RATING    0.99    1.00    1.00    1.00    0.99        SINGLE UNITS        4%      EQUA POWER  =  3.25
STRUCR  RATING   100.0    97.6    93.8    93.8    81.2        COMBINATIONS        6%      R SQUARE    =  0.93744
COMBD   RATING    99.3    97.5    93.5    93.5    80.7        TRAFFIC INDEX      7.9      STD ERROR   =  1.99
HIGH    RATING    99.9   100.0    99.9    99.7    84.9        K = 11%        D = 59%      TIME TO 60  =  11.50
LOW     RATING    97.9    89.7    89.2    84.2    69.8        2 AXLE TRUCKS =  2.7 %      TIME TO 50  =  12.34
HIGH FRICTION       45      45      50      50      52        3 AXLE TRUCKS =  2.5 %      TIME TO 40  =  13.07
LOW  FRICTION       43      43      48      44      49        4 AXLE TRUCKS =  0.3 %      TIME TO 30  =  13.72
AVG  FRICTION       44      44      49      48      50        5 AXLE TRUCKS =  4.0 %      TIME TO 20  =  14.30
***********************************************************************************************************

SHOULD REHABILITATE AT 70.0 WHICH WILL OCCUR IN 1980
MUST REHABILITATE AT 50.0 WHICH WILL OCCUR IN 1982
CONSIDERATION SPAN = 20 PERIODS, EACH PERIOD = 1.0 YEARS
EFFECTIVE INTEREST RATE =  0.0%  FACTORS :  67.0%  83.0% 100.0%

   DESCRIPTION OF THE ALTERNATIVES          PERFORMANCE  EQUATIONS            CONSTRCT COST   MIN LIFE   MAX LIFE
                                                                              12' LANE MILE   AT  SHUD   AT  MUST
-----------------------------------     ------------------------------      -------------   --------   --------
ALTERNATE 1 ROUTINE MAINTENANCE         R =  98.78 - 0.01384 P ** 3.25                  0      10.49      12.34
ALTERNATE 2 OVERLAY  0.06 CLASS D       R = 100.00 - 0.30752 P ** 2.25              23100       7.66       9.61
ALTERNATE 3 OVERLAY  0.15 CLASS B       R = 100.00 - 0.10225 P ** 2.50              35800       9.70      11.90
ALTERNATE 4 RECYCLE  + 0.06 CLASS D     R = 100.00 - 0.01695 P ** 3.00              68100      12.10      14.34

                           ITEMIZED COSTS                                      NUMB
*****************************************************************************  POSS     STRATEGY DESCRIPTION
                                                                               ****  **************************
ROUT    +  COST OF  +  COST OF  +  USER     -  SALVAGE  =  EXPECTED
MAINT      CONSTR      TRAFFIC     COST        VALUE       TOTAL                155   (ALTERNATIVE - PRD APPLIED)
COST       INCL PR     INTERPT                             COST
                                                                                       1ST    2ND    3RD    4TH
                                                                                      REHAB  REHAB  REHAB  REHAB
160135     1633477        0        1321989     435064      2680537               40   2-81   2-89   2-98
201744     1660535        0        1332744     497216      2697827               50   2-82   2-90   2-99
173062     1405090        0        1324666     123127      2779691               29   3-82   2-93
159419     1379032        0        1322639      61563      2798527               18   3-81   2-92
104796     2093552        0        1307378     181594      3324132                9   4-81   2-94
143095     2120610        0        1314792     242125      3338372                9   4-82   2-95
```

Cost Summary

Summary of Strategies

Rehabilitation Alternatives

Figure 63. Division of Optimizing Program Listing

D	SP	BEG SRMP	END SRMP	CS	BEG CSMP	END CSMP	PROJ LENG	FNC CLS	SIDE	HWY TYP	NUM LNS	ROW-RSH-LSH WIDTHS	LAST CONTR	COMPLT M-YR	CNT TYP	SURFACE TYP-THK	BASE TYPE
3	5	13554	13950	2719	0	396	396	U-5	R	3	4	48 10 10	08603	5-70	20	40 33	11

PERFORMANCE HISTORY

	71	73	75	77	79
YEAR	71	73	75	77	79
AGE	1	3	5	7	9
RIDE RATING	0.99	1.00	1.00	1.00	0.99
STRUCR RATING	100.0	97.6	93.8	93.8	81.2
COMBD RATING	99.3	97.5	93.5	93.5	80.7
HIGH RATING	99.9	100.0	99.9	99.7	84.9
LOW RATING	97.9	89.7	89.2	84.2	69.8
HIGH FRICTION	45	45	50	50	52
LOW FRICTION	43	43	48	44	49
AVG FRICTION	44	44	49	48	50

APPROXIMATE TRAFFIC DATA

79 ADT	78300
GROWTH RATE	5.6%
SINGLE UNITS	4%
COMBINATIONS	6%
TRAFFIC INDEX	7.9
K = 11%	D = 59%
2 AXLE TRUCKS =	2.7 %
3 AXLE TRUCKS =	2.5 %
4 AXLE TRUCKS =	0.8 %
5 AXLE TRUCKS =	4.0 %

PERFORMANCE EQUATION

EQUA CONST =	98.78
EQUA COEFF =	-0.01384
EQUA POWER =	3.25
R SQUARE =	0.93744
STD ERROR =	1.99
TIME TO 60 =	11.50
TIME TO 50 =	12.34
TIME TO 40 =	13.07
TIME TO 30 =	13.72
TIME TO 20 =	14.30

Figure 64. Project Description and Performance

```
SHOULD REHABILITATE AT 70.0 WHICH WILL OCCUR IN 1980
MUST REHABILITATE AT 50.0 WHICH WILL OCCUR IN 1982
CONSIDERATION SPAN = 20 PERIODS, EACH PERIOD = 1.0 YEARS
EFFECTIVE INTEREST RATE = 0.0% FACTORS : 67.0% 83.0% 100.0%
```

Figure 65. Parameters Used in Analysis

The third block of data, as shown in Figure 66, describes each of the rehabilitation alternatives and provides a performance equation for each respectively. As was mentioned earlier, the first alternative is always to continue routine maintenance. The performance equation opposite this alternative represents the existing pavement. To the right of the performance equations are the unit construction costs related to each of the alternatives. Note that a zero is shown for the first alternative since no actual construction is performed. The cost for routine maintenance varied with the condition of the pavement and is computed from model as described earlier. The final columns of data in this block are labeled "Minimum life at should" and "Maximum life at must". These figures indicate the number of years expected to elapse to reach the should or the must levels from time of construction. The numbers relating to should and must levels for the routine maintenance alternative indicate the elapsed time from day of construction of the pavement in place to reach the should and must levels.

DESCRIPTION OF THE ALTERNATIVES	PERFORMANCE EQUATIONS	CONSTRCT COST 12' LANE MILE	MIN LIFE AT SHUD	MAX LIFE AT MUST
ALTERNATE 1 ROUTINE MAINTENANCE	R = 98.78 - 0.01384 P ** 3.25	0	10.49	12.34
ALTERNATE 2 OVERLAY 0.06 CLASS D	R = 100.00 - 0.30752 P ** 2.25	23100	7.56	9.61
ALTERNATE 3 OVERLAY 0.15 CLASS B	R = 100.00 - 0.10225 P ** 2.50	35800	9.70	11.90
ALTERNATE 4 RECYCLE • 0.06 CLASS D	R = 100.00 - 0.01695 P ** 3.00	68100	12.10	14.34

Figure 66. Description of Rehabilitation Alternatives

The block of information shown in Figure 67 is a summary of costs accumulated in the consideration span for each category of cost for each of the strategies shown.

ITEMIZED COSTS

ROUT MAINT COST	+	COST OF CONSTR INCL PR	+	COST OF TRAFFIC INTERPT	+	USER COST	-	SALVAGE VALUE	=	EXPECTED TOTAL COST
160135		1633477		0		1321989		435064		2680537
201764		1660535		0		1332744		497216		2697827
173062		1405090		0		1324666		123127		2779691
159419		1378032		0		1322639		61563		2798527
104796		2093552		0		1307378		181594		3324132
143095		2120610		0		1314792		242125		3336372

Figure 67. Summary of Itemized Costs

The final block of information shown in Figure 68 is the summary of strategies. In the early stages of development, the listing generated by the optimizing program showed the top 30 strategies determined by least total cost. A second output format listed all strategies--but this required several pages. The latest form of output "summarizes" the strategies based on the time and type of <u>first</u> rehabilitation action, i.e., several different strategies may all begin with the same alternative in the same time period but differ in types and timing of following actions. Of prime interest to the decision-maker, however, is the first action. For this reason, the strategies were divided into groups based on the time and type of first action. The least expensive strategy in each of these groups is listed in this summary. The column of numbers on the left side of this block indicates the total number of strategies analyzed (possible) and how many strategies were included in each group.

NUMB POSS	STRATEGY DESCRIPTION			
155	(ALTERNATIVE - PRD APPLIED)			
	1ST REHAB	2ND REHAB	3RD REHAB	4TH REHAB
40	2-81	2-89	2-98	
50	2-82	2-90	2-99	
29	3-82	2-93		
18	3-81	2-92		
9	4-81	2-94		
9	4-82	2-95		

Figure 68. Summary of Strategies

An example of how this block of information would be read is as follows:

- There were 155 rehabilitation strategies analyzed for this specific project.
- Forty of these strategies began with an alternative 2 (0.06-ft AC overlay) applied in 1981.
- The most cost-effective strategy in the first group was followed by an alternative 2 in 1989 and again in 1998.

Each successive line is read in the same manner. Note that the least costly strategy is at the top and that costs increase going from top to bottom.

Other Considerations

The optimizing program was developed as an analytical tool. By varying certain parameters, this program can be used to analyze the effects of interest, inflation, user impact, overall timing, etc. The framework of this program considers many different categories of cost. Of these, the routine maintenance cost model, the users' cost model relating to pavement condition, and the users' cost model relating to traffic interruption can all be zeroed for no influence. By zeroing the two user cost models, only those costs related to a highway agency's operating budget would be considered. Many variations in cost modeling can be applied with this program to analyze the economics of rehabilitation alternatives.

It is also important to note that this program has been assembled in a modular fashion. As newer information becomes available, the existing models can be updated or replaced very easily without the necessity of complicated editing in a large computer program.

Chapter 5

NETWORK-LEVEL PROGRAMMING

The last phase in this pavement management system is network-level programming which is based on the optimum rehabilitation strategy, or alternatively one of the others. By aggregating the recommended rehabilitation actions in each year and tracking the performance and cost of all project segments on the network, a schedule of anticipated action, cost, and performance can be tabulated for a future number of years.

The function of network-level programming is to provide the best information possible to decision-makers for:

- Assembling rehabilitation programs
- Establishing effective funding levels, and
- Identifying the time and extent of future needs.

In order to accomplish this, the predicted performance for all segments of highway pavement in the network must be known as well as the most cost-effective or recommended fix, predicted performance of the fix, and estimate of cost for the fix for each of the sections requiring rehabilitation. With these items estimated, system performance levels can be tracked for each year of a rehabilitation program and levels of funding can be satisfactorily estimated.

In this system, network-level programming begins with the combined results of the interpreting phase and the optimizing phase. The interpreting program provides the performance equations needed to forecast pavement performance for all projects--those which require resurfacing as well as those that do not. The optimizing program provides a recommended fix for each project in need of rehabilitation together with estimated construction cost and a performance equation related to how the fix is expected to perform.

The network-level program generates three summaries for each year of a proposed program:

- Action Summary
- Cost Summary
- Rating Distribution Summary

Figure 69 is an example of the Action Summary generated. Since different "should" and "must" levels can be applied for different functional classes of highways, the particular levels used to develop the schedule of action are indicated at the top of the listing. Below that is a summary of all projects programmed for each year specified by route number and inclusive milepost limits, with a description of the action required and the associated cost--both in present dollars and dollars inflated to the respective year. Also shown are the functional classification, length of project, and projected rating at time of intended action.

Figure 70 is an example of the Cost Summary. This summarizes by functional classification the gain in average pavement rating on the system anticipated as a result of funding and constructing all projects itemized on the Action Summary, and indicates the total demand on budget dollars for that year. Three types of dollars are shown on the Cost Summary: present dollars, inflated dollars, and discounted dollars. Inflated dollars indicate the estimated cost at time of construction. Present dollars represent a direct comparison to current-day funding levels, and the discounted dollars are shown to gauge the effect of interest and inflation on the particular time of expenditure.

All costs shown on both the Action Summary and the Cost Summary relate only to construction and preparation costs, since the other costs generated in the optimizing program are not considered in the budget analysis.

The last listing produced in the network program on a yearly basis is the Rating Distribution Summary shown in Figure 71. This listing indicates the number of rating-miles present in pavement condition rating groups before and after completion of all proposed action for each year.

The network-level program is thus a summarizing program which takes into account the performance of existing projects and the recommended time of rehabilitation with a performance equation commensurate to the type of fix for each project requiring rehabilitation.

The flow of network analysis utilizes these three listings for a set number of consecutive years (say six years) to compare different programs. By tabulating directly, without any constraint, the summaries for six years (Figure 72), it is realized that there is an enormous volume of need for rehabilitation within the first few years. This need places a corresponding demand on funding which is neither available nor necessarily desirable. Simply, it may not be possible to fund a program like this, nor would it be good management. A tremendous fluctuation in workload from one year to the next is not desirable from a management standpoint because a fairly consistent work force must be maintained. A shift in timing for some of the projects is required to dampen this fluctuation. The specific projects to be delayed are selected by placing them in a priority order based on their effect on system performance.

The assembling of a balanced rehabilitation program by shifting project timing then becomes constrained by what we are trying to accomplish. There are basically two objectives in building a rehabilitation program:

DISTRICT 3
1981 ACTION SUMMARY

	FC 1	FC 2	FC 3	FC 4	FC 5
	****	****	****	****	****
SHUD	60	60	50	50	70
MUST	40	40	30	30	50

FC	SR	REG SRMP	END SRMP	LENG	CS	REF PTNG	PROPOSED ACTION	DES	PRESENT COST	INFLATED COST
U 1	3	0	6	6	2331	18.6	BITUMINOUS SURF TREATMNT	3	4492	4941
U 1	3	22	368	366	2331	2.3	OVERLAY 0.08 CLASS G	3	286483	315131
U 1	3	24	167	143	2331	23.8	OVERLAY 0.08 CLASS G	3	115485	127033
U 1	3	167	247	80	2331	4.7	OVERLAY 0.15 CLASS B	3	127785	140563
U 1	3	247	0	24	2331	1.0	OVERLAY 0.08 CLASS G	3	35961	39557
R 1	3	368	964	574	2331	20.1	OVERLAY 0.08 CLASS G	3	413835	455218
R 1	3	4796	4800	4	1805	1.0	BITUMINOUS SURF TREATMNT	1	3129	3441
R 1	3	4800	4807	7	1805	1.0	OVERLAY 0.08 CLASS G	1	7004	7704
R 1	3	5103	5166	63	1805	1.0	BITUMINOUS SURF TREATMNT	1	49055	53960
R 1	3	5206	5212	6	1805	1.0	BITUMINOUS SURF TREATMNT	1	4837	5320
R 1	3	5212	5330	118	1805	40.0	OVERLAY 0.08 CLASS G	1	99898	109887
R 1	3	5633	5873	240	1805	1.0	BITUMINOUS SURF TREATMNT	1	203125	223438
R 1	3	5873	5899	26	1805	1.0	OVERLAY 0.08 CLASS G	1	30783	33861
U 5	5	10269	10297	28	3401	49.3	0.35 CSTC + 0.25 AC	2	62900	69189
U 5	5	10297	10405	108	3401	50.0	0.35 CSTC + 0.25 AC	2	242349	266583
U 5	5	10405	10881	476	3407	53.1	0.35 CSTC + 0.25 AC	3	1062938	1169231
U 5	5	10405	10909	504	3407	46.1	0.35 CSTC + 0.25 AC	3	1620622	1782683
U 5	5	10909	10919	10	3407	55.8	0.35 CSTC + 0.25 AC	3	27589	30347
R 5	5	11524	11709	185	2701	50.2	OVERLAY 0.08 CLASS G	3	196931	216623
R 5	5	11709	11901	161	2701	58.1	OVERLAY 0.08 CLASS G	2	159146	175060
R 5	5	11740	11901	161	2701	58.0	OVERLAY 0.08 CLASS G	2	165095	181604
U 5	5	11901	12141	240	2702	36.2	OVERLAY 0.08 CLASS G	2	267052	293757
U 5	5	12419	12464	45	2702	55.5	0.35 CSTC + 0.25 AC	3	154043	169447
U 5	5	12464	12480	16	2718	55.5	0.35 CSTC + 0.25 AC	3	54771	60248
U 5	5	12464	12480	16	2718	41.4	0.35 CSTC + 0.25 AC	3	56402	62042
U 5	5	12480	12959	479	2718	50.8	0.35 CSTC + 0.25 AC	3	1654721	1820192
U 5	5	12480	12959	479	2718	48.5	0.35 CSTC + 0.25 AC	3	1662616	1828876
U 5	5	12959	13158	199	2799	48.5	0.35 CSTC + 0.25 AC	3	690732	759804
U 5	5	12959	13173	214	2799	43.8	0.35 CSTC + 0.25 AC	3	750327	825359
U 5	5	13158	13288	130	2799	55.0	0.35 CSTC + 0.25 AC	3	352651	387915
U 5	5	13173	13288	115	2799	47.4	0.35 CSTC + 0.25 AC	3	400019	440020
U 5	5	13288	13410	122	2799	37.3	0.35 CSTC + 0.25 AC	3	343293	377622
U 5	5	13288	13410	122	2799	45.7	0.35 CSTC + 0.25 AC	3	425980	468577
U 5	5	13410	13554	144	2799	41.9	0.35 CSTC + 0.25 AC	3	619589	681547
R 2	7	2582	2739	157	2710	40.8	OVERLAY 0.08 CLASS G	3	105727	116299
R 2	7	3608	3964	356	2711	33.4	OVERLAY 0.08 CLASS G	2	338531	372363
R 2	7	4578	4723	145	2711	30.1	BITUMINOUS SURF TREATMNT	3	94117	103528

Figure 69. Network Action Summary

'67XXX

DISTRICT 3
1981 COST SUMMARY

04/09/80

	FC 1	FC 2	FC 3	FC 4	FC 5
	****	****	****	****	****
SHUD	60	60	50	50	70
MUST	40	40	30	30	50

FC	RTNG AVG REF ACTN	RTNG AVG AFT ACTN	NUMB PROJ	MILES ACTED ON	TOTAL MILES	% ACTED ON	PRESENT COST	INFLATED COST	DISCOUNTED COST
1	53	90	157	312	644	48 %	30632400	33695545	29454227
2	54	83	104	115	278	41 %	8557393	9413074	8228260
3	36	87	30	82	144	57 %	6888495	7577323	6623550
4	0	0	0	0	0	0 %	0	0	0
5	71	90	21	39	107	36 %	10969766	12066726	10547846
ALL	52	87	312	550	1174	46 %	57048054	62752668	54853883

Figure 70. Network Cost Summary

67XXX

DISTRICT 3
1981 RATING DISTRIBUTION SUMMARY

04/09/80

	FC 1	FC 2	FC 3	FC 4	FC 5
SHUD	60	60	50	50	70
MUST	40	40	30	30	50

LANE MILES IN RATING GROUP BEFORE ACTION

FC	100-91	90-81	80-71	70-61	60-51	50-41	40-31	30-21	20-11	10 -0	AVG RTNG	TOTAL MILES
1	131.4	82.7	43.0	70.9	41.9	21.9	53.3	47.7	22.3	129.2	53.3	644.5
2	27.7	13.7	39.1	45.9	34.1	33.0	45.2	12.7	9.0	17.8	54.2	278.3
3	28.4	1.8	4.3	0.8	3.4	18.8	11.7	6.9	25.1	43.0	36.2	144.2
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	27.1	19.5	14.1	7.2	16.6	19.3	3.6	0.0	0.0	0.0	71.1	107.4
ALL	214.7	117.7	100.5	124.8	96.0	92.9	113.8	67.4	56.5	190.0	53.1	1174.4

LANE MILES IN RATING GROUP AFTER ACTION

FC	100-91	90-81	80-71	70-61	60-51	50-41	40-31	30-21	20-11	10 -0	AVG RTNG	TOTAL MILES
1	444.3	82.7	43.0	41.4	32.6	0.4	0.0	0.0	0.0	0.0	90.8	644.5
2	143.1	13.7	39.1	44.5	34.1	3.7	0.0	0.0	0.0	0.0	83.1	278.3
3	110.7	1.8	4.3	0.8	3.4	18.8	4.5	0.0	0.0	0.0	87.7	144.2
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	66.7	19.5	14.1	7.2	0.0	0.0	0.0	0.0	0.0	0.0	90.1	107.4
ALL	764.9	117.7	100.5	93.9	70.1	22.8	4.5	0.0	0.0	0.0	88.6	1174.4

Figure 71. Network Rating Distribution Summary

1. To identify those projects that can be constructed with available funding--the budget constraint.
2. To identify those projects that must be constructed to attain some minimum acceptable level of pavement condition--the condition-level constraint.

Year	Before	After	Mileage % Aff.	Cost*
1981	53.1	88.6	46	$62,752,668
1982	83.6	87.6	8	11,758,111
1983	83.3	86.4	5	6,624,903
1984	81.4	83.4	4	5,661,168
1985	77.2	81.9	8	14,155,899
1986	75.4	83.1	15	33,893,546
				$134,846,295

6-Yr Avg Rating = 80.4
*All costs are inflated costs

Figure 72. Six-Year Summary of Cost

Budget Constraint

In order to understand how a budget constraint is applied, consider Figure 73. The optimizing program identifies a number of projects scheduled for rehabilitation in each year of the next several years. The projects for the first year are arranged in some priority order. Total estimated cost for the year is accumulated in that order, one project at a time, until the constrained limit for that year is reached. The residual projects are delayed to the following year, and a second iteration of this same process is applied. This process is repeated for the specified number of years in the program and summarized with the network program.

Results of this process are shown in Figures 74 and 75. These summaries were generated by applying budget constraints to the same network and set of projects that were summarized in Figure 72 without constraints. Plotting the average rating for each year provides a graphic representation of the gains and losses expected from implementing each program (Figure 76).

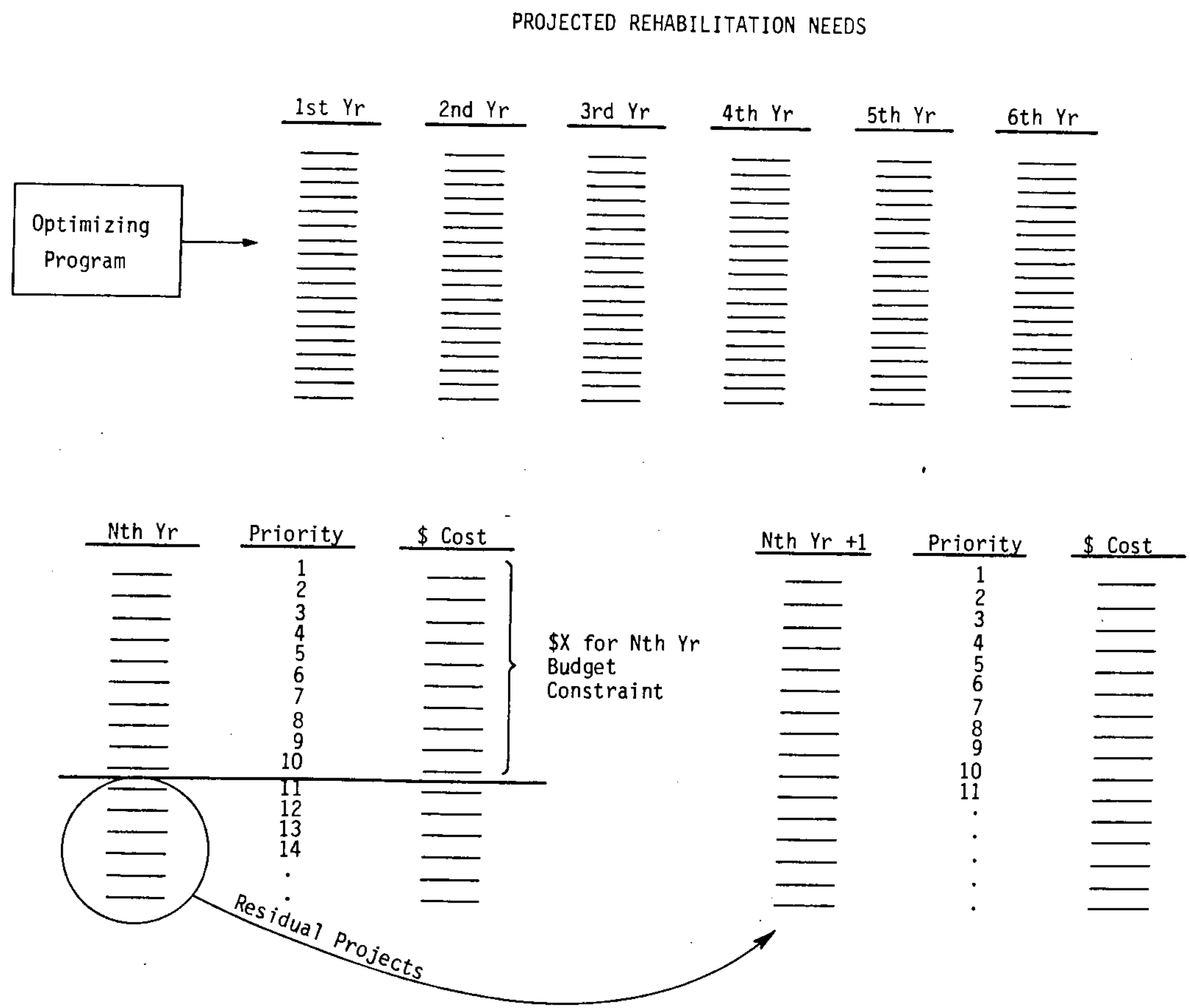


Figure 73. Process of Applying Budget Constraints

Year	Before	After	Mileage % Aff.	Cost
1981	53.1	59.3	7	$9,050,095
1982	52.3	57.4	7	9,048,675
1983	51.2	57.5	7	10,299,085
1984	51.7	56.1	6	10,300,148
1985	50.5	52.8	3	9,449,439
1986	47.4	49.7	4	9,449,286
				$57,596,728

6-Yr Avg Rating = 53.2

Figure 74. Six-Year Summary of Cost with Budget 1

Year	Before	After	Mileage % Aff.	Cost
1981	53.1	62.0	11	$12,349,188
1982	55.4	61.9	8	12,349,691
1983	55.9	63.3	9	14,949,463
1984	57.6	63.4	7	14,949,477
1985	58.0	65.0	9	17,954,686
1986	59.7	64.6	8	17,952,927
				$90,050,432

6-Yr Avg Rating = 60.0

Figure 75. Six-Year Summary of Cost with Budget 2

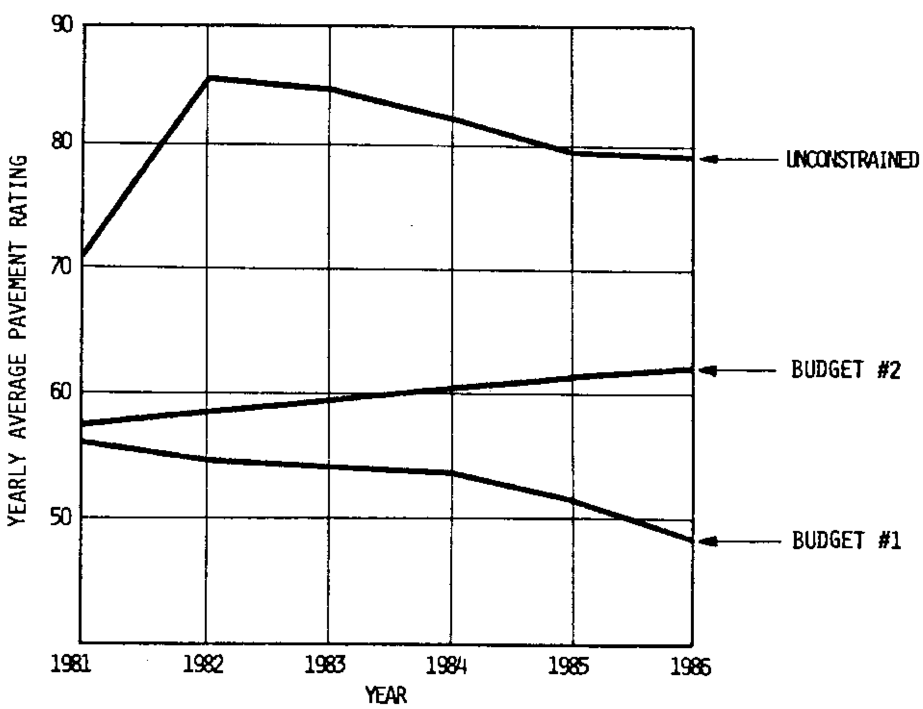


Figure 76. Plot of Six-Year Cost Summaries

Condition-Level Constraint

The approach for applying the condition-level constraint is very similar to the budget constraint. As can be seen in Figure 77, the item accumulated and compared is net gain in average rating. Because the average pavement condition is weighted by miles, the constraint and accumulation figures are both expressed as a product of miles and average rating.

Figure 78 is an illustration that demonstrates how the condition-level constraint was utilized to summarize three future bienniums. The bottom line on the graph indicates a program which maintains the network in its present state. The corresponding bottom line of figures indicates the funding required in each biennium to keep the system where it is. The percentages below the dollar figures indicate how much of the system must be rehabilitated in each biennium to maintain it at its present level. The middle line in the plot represents a modest upgrade in the system over three bienniums, while the top line indicates the unconstrained program. Corresponding dollar amounts and system percentages are shown at the bottom.

Applications of Network Analysis

It should be clearly understood that through multiple applications of constraints and subsequent summarizing with the network level program, many different informative graphs can be generated.

Figure 79 illustrates the resulting average pavement condition on the network that could be expected as a function of available funding in the first year of a program. It was generated by applying various budget constraints. Note that a "no action" program would leave the network average very close to 60, while an unlimited budget would raise the system average to just under 90. Note also that the present network average is indicated together with the level of funding that would be required to maintain it at this level.

Figure 80 is supplemental to Figure 79. In order to gauge the long-term effects of different first-year budgets, a constant budget of $10 million was applied as a constraint to the five remaining years of each program. This was considered to be the best method for comparing the long-term effects of the first-year programs, since the amount of work in any year is affected by the work accomplished in preceding years.

Figure 81 is an example of multiple applications of the condition-level constraint. This figure illustrates the levels of funding required to sustain the various levels of average pavement condition over a six-year period.

K = DESIRED LEVEL OF AVERAGE PAVEMENT CONDITION

T = TOTAL SYSTEM MILEAGE

B = SYSTEM AVERAGE PAVEMENT CONDITION BEFORE PROGRAM ACTION

A = SYSTEM AVERAGE PAVEMENT CONDITION AFTER PROGRAM ACTION

M_N = MILEAGE OF INDIVIDUAL PROJECT

R_N = PRESENT RATING OF INDIVUAL PROJECT

$$\text{NET GAIN IN AVG.} = M_N\ (100-R_N)$$

$$AT = BT + \Sigma\left[M_N\ (100-R_N)\right]$$

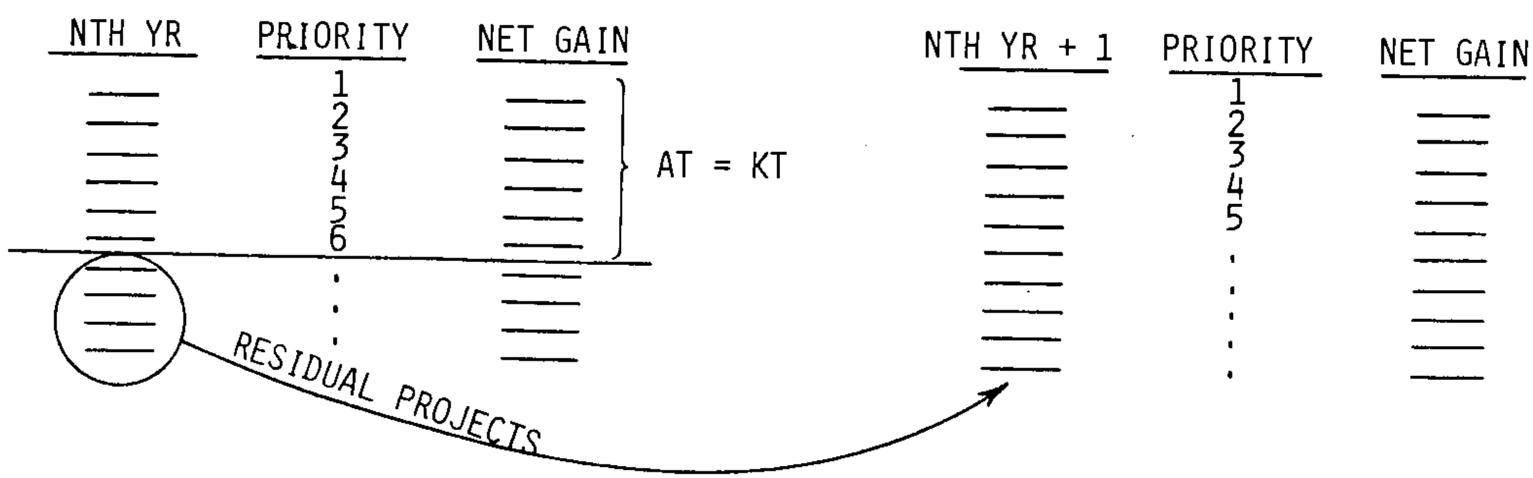
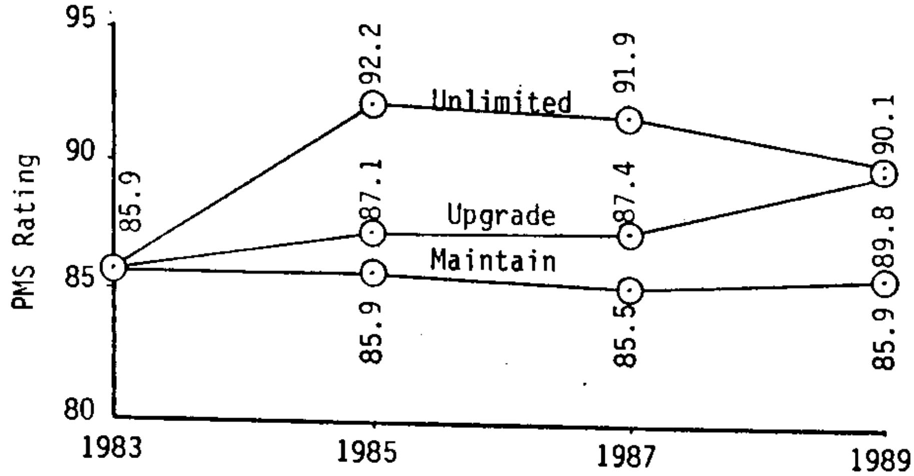


Figure 77. Process of Applying Condition-Level Constraints



Unlimited Budget	36,114,882 (20%)	25,286,924 (13%)	28,367,426 (15%)	← $ in program ← % of system acted on
Upgrade Cond. Level	19,226,745 (10%)	24,439,130 (13%)	42,077,816 (22%)	
Maintain Cond. Level	16,572,007 (8%)	21,205,024 (11%)	32,500,680 (16%)	

Figure 78. Example of Application of Condition-Level Constraint

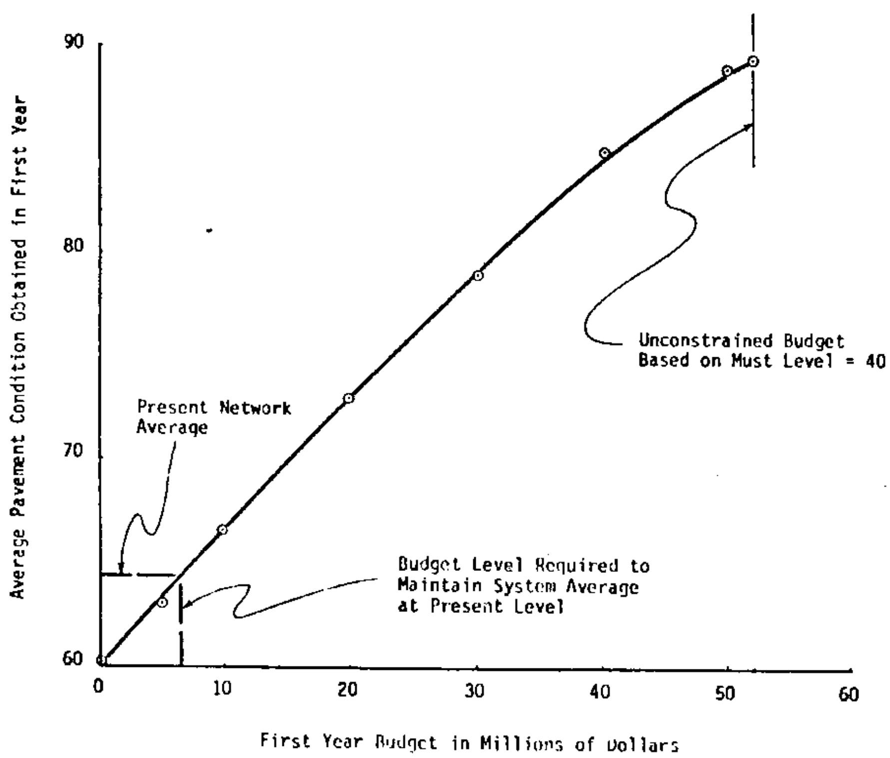


Figure 79. Average Pavement Condition vs. First Year Budget Constraint

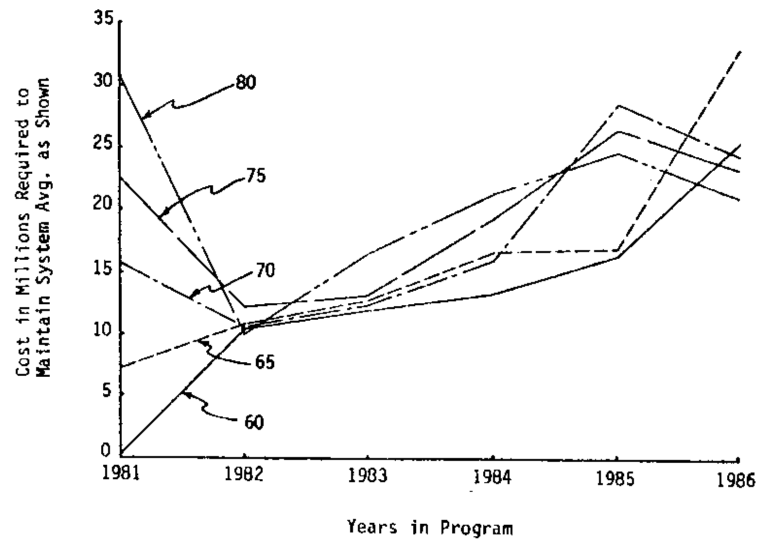


Figure 80. Six-Year Summary of Costs Required to Maintain Minimum Levels of Average Pavement Condition

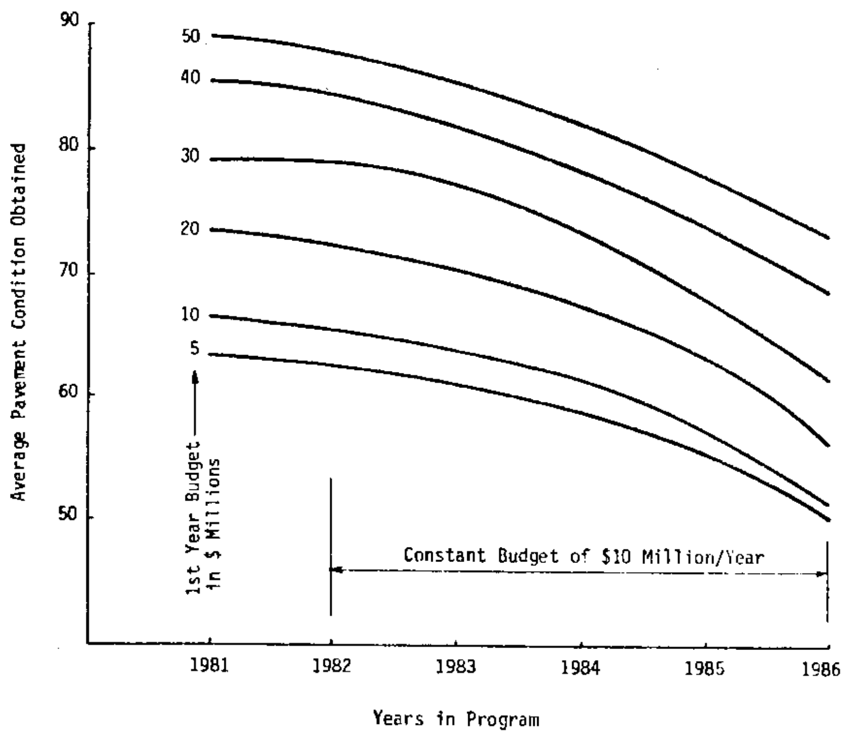


Figure 81. Average Pavement Condition Obtained After First Year Program

Figures 79, 80, and 81 represent examples of network program analysis that are possible through multiple applications of constraints. Another feature of network-level programming lies in the influence of the results from the optimizing program upon which the network analysis is based. Since the "should" and "must" levels applied will have significant bearing on the number of projects needed in each year, the complexion of a rehabilitation program can be altered by changing these parameters.

Figure 82 represents an application of varying the "should" and "must" levels. As would be expected, on an unconstrained program there is a large difference in the average level of pavement condition obtained for the first year which results from varying the "should" and "must" levels. Figure 83 is directly related and indicates the levels of funding required in an unconstrained program resulting from varying the "should" and "must" levels.

It is interesting to note that a different mix of projects is identified by varying the "should" and "must" levels. To summarize the effects on the mix of projects, histograms of mileage were prepared indicating the status of the system prior to any action, and then indicating what portion of each group was acted on by varying the trigger levels.

Figures 84, 85, and 86 represent these different project mixes. In all cases, 100 percent of the mileage below the "must" level is acted on. The difference occurs above the "must" level.

Figure 87 indicates the effects on average pavement condition over a six-year period with unconstrained programs resulting from varying the trigger levels.

Prioritizing Function

It is important to realize that the shift of project timing applied using either constraint requires a prioritizing function. It was stated earlier that projects are prioritized based on their effect on system performance. This can be referred to as the "effect of delay," or how much the delay of a project will affect pavement condition in the following year.

Consider Figure 88. This figure shows the performance curves for two different existing pavement projects. As can be seen, projects 1 and 2 deteriorate at very different rates. The effect of delaying project 1 would have far greater consequences than delaying project 2. By prioritizing projects based on their predicted ratings one year later and applying either constraint, better gains in average pavement condition are achieved.

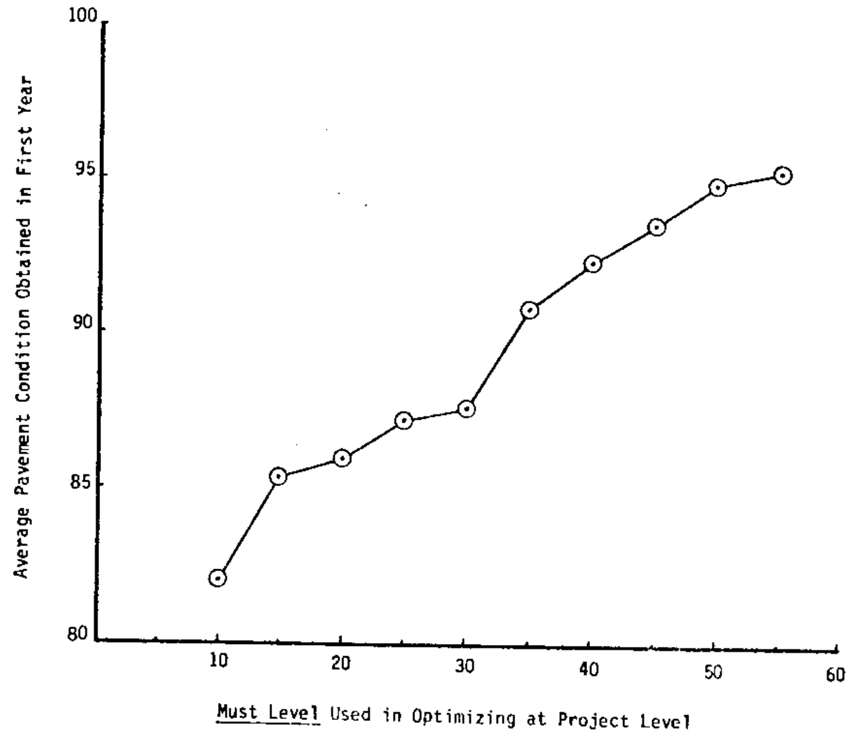


Figure 82. Average Pavement Condition Obtained by Varying the Must Level

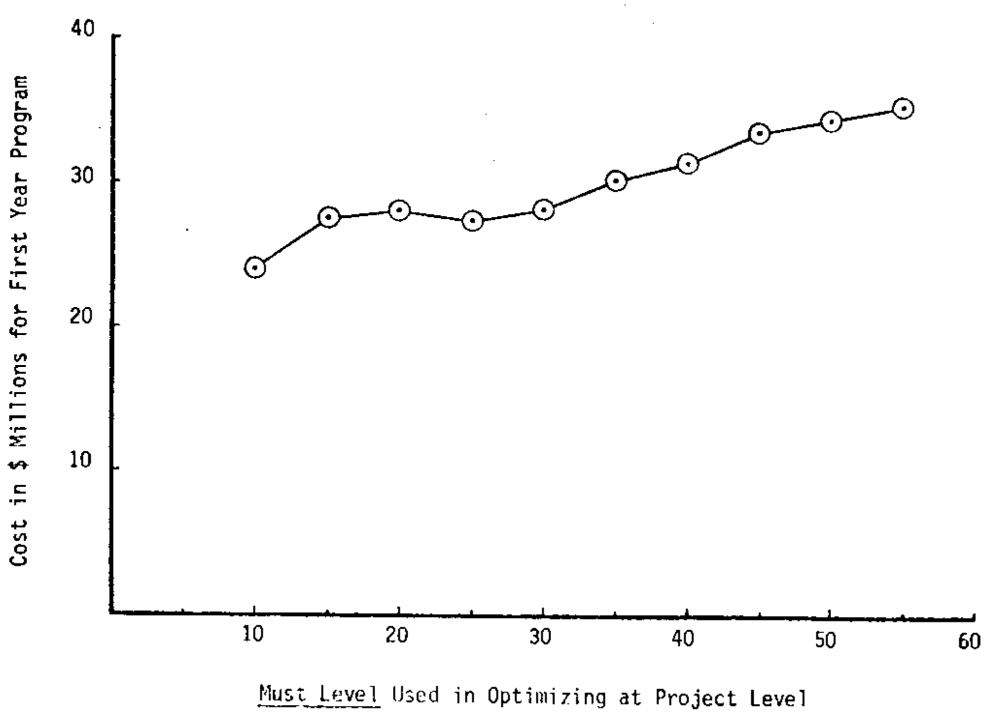


Figure 83. Annual Program Cost Incurred by Varying the Must Level

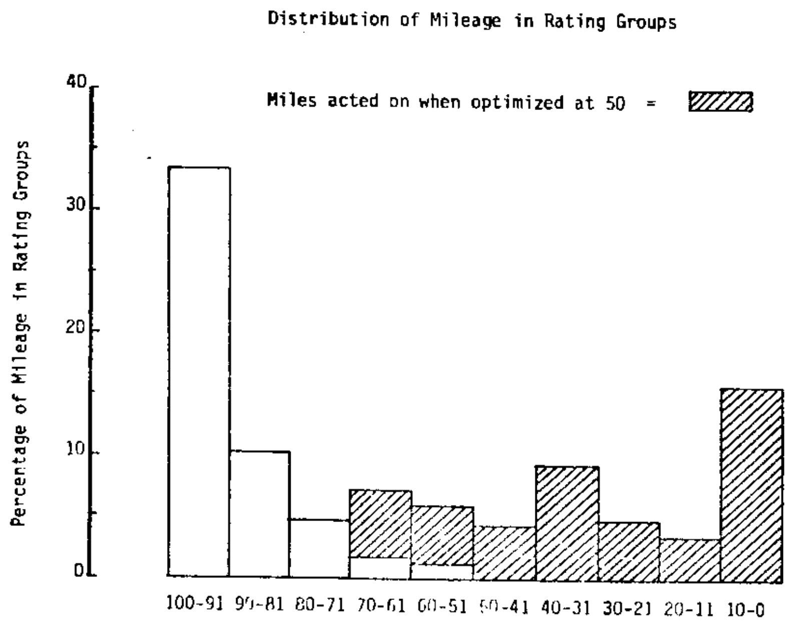


Figure 84. Distribution of Mileage Acted on with Must Level at 50

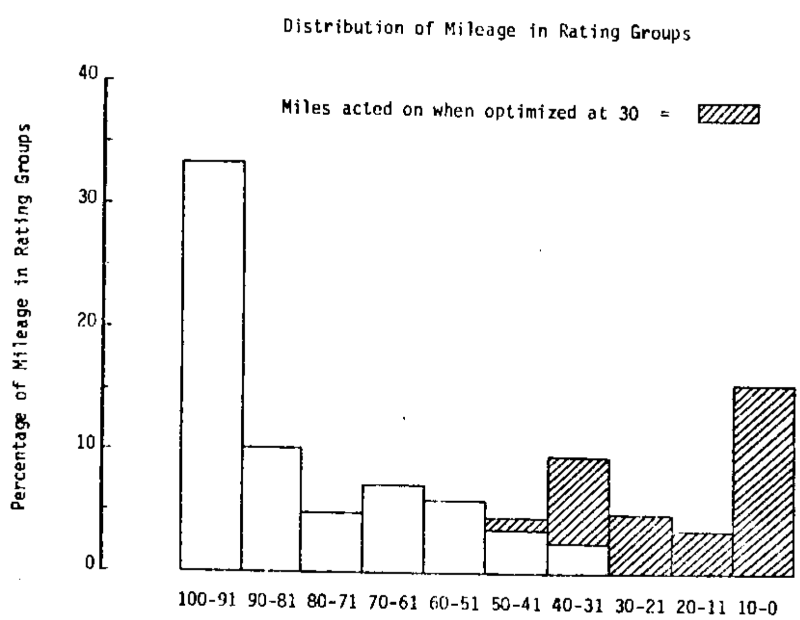


Figure 85. Distribution of Mileage Acted on with Must Level at 30

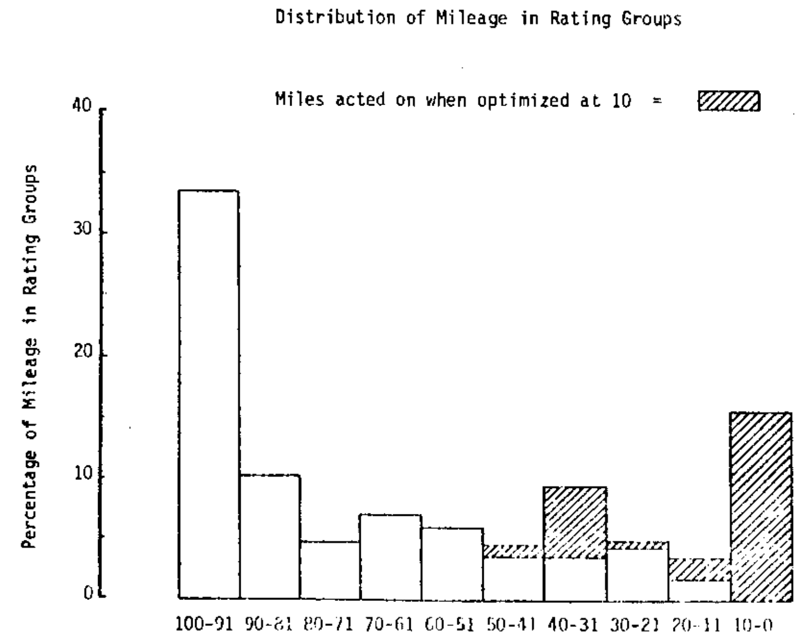


Figure 86. Distribution of Mileage Acted on with Must Level at 10

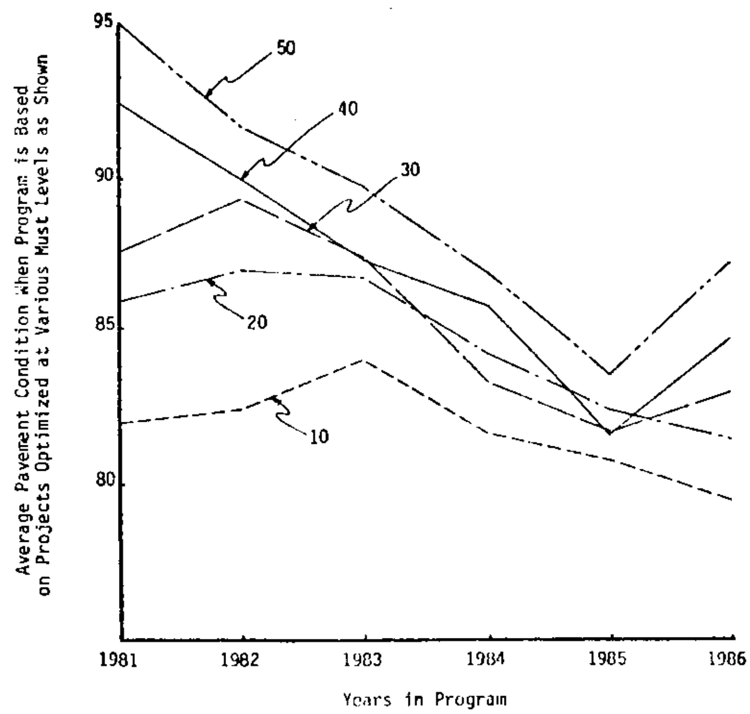


Figure 87. Effects on Average Pavement Condition with Unconstrained Programs Generated at Various Must Levels

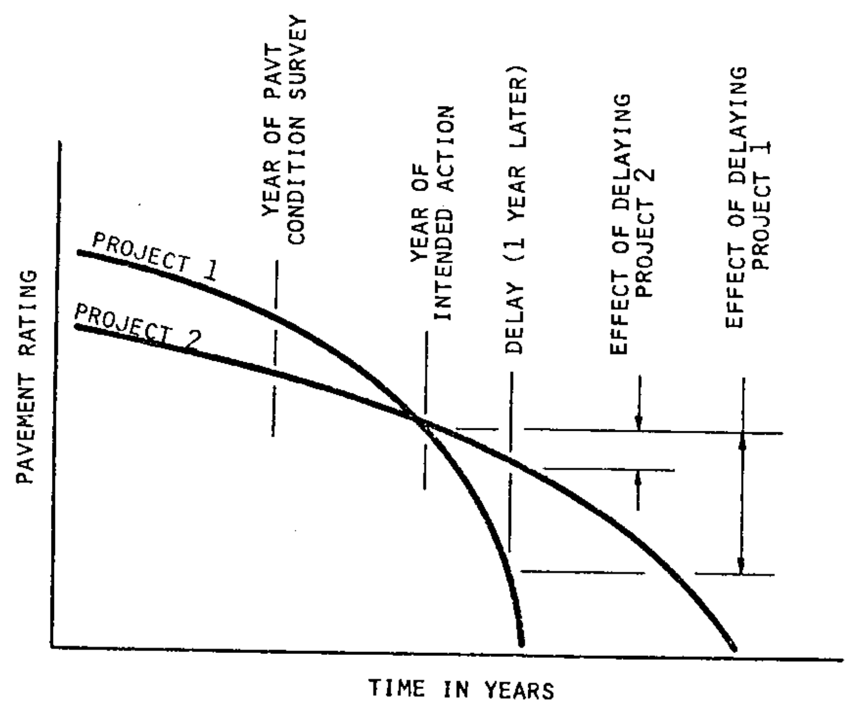


Figure 88. Comparison of Two Different Performance Curves - The Effect of Delay

It should be understood that the "effect of delay" is a useful rule to apply to extract the greatest gains in pavement condition from a rehabilitation program. This approach may not always be the most practical, however. Often the pavements that are in the worst condition are found in the lower classified portion of the system. Highway agencies that prioritize entirely on present pavement condition are often faced with pavements that are not quite bad enough to get into the rehabilitation program, yet they carry a much greater portion of the traffic load than other pavements scheduled for resurfacing. When delayed for a year, these projects will represent a greater impact on serving the public.

There are certainly many factors that could be considered in the prioritizing formula. Among them are:

- Effect of delaying a project on system average
- Average Daily Traffic, a functional need
- Demand on the maintenance budget
- Coordinating with the urgency to rectify other deficiencies such as volume/capacity problems, safety problems, geometric deficiencies
- Administrative priority--a commitment to the public to rectify a problem.

All of these factors should have influence on the priority of placing projects in a program, and they all play a part in the decision process today. By formulating a utility function with these factors weighted to represent management policy, the scope of analyzing the effects of policy is greatly enhanced. However, with a utility function which includes all of these factors, prioritizing might not generate the greatest gains in average pavement condition when applying constraints.

Other Considerations

Because the network program is based on the projects identified by the optimizing program, a new parameter was added to the operation of that program. By defining the length of the network program to be analyzed, all projects that require rehabilitation outside the scope of the network analysis are not optimized (six years was used in all examples). A simple test is applied as the first step in that program to determine whether or not the project will require rehabilitation within the network programming period. The application of this parameter significantly reduces the volume of projects to be analyzed.

Summary of Network Program Analysis

The purpose of this phase is to provide the best information possible to decision-makers for:

- Assembling rehabilitation programs
- Establishing effective funding levels, and
- Identifying the time and extent of future needs.

This is accomplished by aggregating the recommended rehabilitation actions in each year and tracking the performance and cost of all project segments on the network. The network program produces a summary of anticipated action, cost, and performance for each year considered.

The network program can be constrained in two ways:

1. Budget Constraint which limits the amount of work that can be accomplished.
2. Condition-Level Constraint which requires that a minimum level of pavement condition must be obtained with a rehabilitation program.

Application of both constraints requires a prioritizing function. In order to gain optimum results in terms of pavement condition, the rate of deterioration should be used to establish priority.

By plotting the results of the program in terms of funding or average pavement condition for several years, different programs can be compared.

By applying a utility function, which weights other factors of management policy to the prioritizing formula, effects on each program can be gauged.

By varying the "should" and "must" trigger levels in the optimizing program, different projects are identified and a whole new picture can be inspected.

All of these methods constitute what can be accomplished in network program analysis with this pavement management system. With this information available, top-level management will have the factual data they have always desired to identify the benefits and consequences of the alternatives they must face.

Chapter 6

APPLICATION OF THE PMS IN WSDOT

The preceding chapters describing WSDOT's pavement management system may lead to the belief that the computer programs and data files constitute the system, and all one has to do is push a button to generate a rehabilitation program. This definitely is not the case. The computer programs, data files, and information generated only serve to enhance our long-established pavement management practices. The purpose of this chapter is to explain how WSDOT's current pavement management operations will be improved with this system.

The most obvious area of application lies in budgeting and programming rehabilitation projects. In order to understand this application, a knowledge of the current method of identifying and programming projects is required.

Programming and Budget Cycle

The current programming cycle requires a two-year effort and begins in early spring of the odd-numbered calendar years (i.e., every other year). At this time every mile of pavement under state jurisdiction is evaluated with a pavement condition survey. Results of this survey are used in two ways:

1. To report the biennial pavement condition which informs district personnel where the pavement problems are.
2. To establish the pavement condition groups within the Priority Array.

The biennial pavement condition report is published and sent to the districts during the month of August. This report provides mile-by-mile pavement ratings so that bad sections of pavement can be identified and rehabilitation projects can be defined to address them. From this time until the complete construction program is approved, each district utilizes the pavement condition report to help prepare a document called a Project Prospectus for each candidate project. These documents are the building blocks of the construction program and define the project limits, scope of work, and estimate of cost for each project. They also represent an agreement between the district and headquarters as to the definition of a project. Because each project in the ultimate construction program must fulfill the requirements of the Priority Array--i.e., that all projects in a lower group must be addressed before considering projects in a higher group--the Project Prospectus serves as the document that ensures this action is the proper action.

While the pavement condition report identifies bad pavement sections and the Project Prospectus defines the project, the Priority Array effects the order of construction related to first, second, or third biennium.

The Priority Array is developed on a biennial basis in accordance with Washington State law, which requires that consideration be given to the highway's structural condition, capacity and congestion, alignment and geometrics, and accident experience. The Priority Array is based on an engineering analysis of existing conditions at the same point in time and reflects several categories of roadway deficiency--not just pavement condition. Categories of deficiency are arranged in 15 groups as shown below. As can be seen, pavement condition is addressed in groups 2, 6, 12, and 15. Traditionally these groups have been related to the first, second, and third bienniums, and beyond three bienniums respectively.

The separation between groups 2, 6, 12, and 15 is based on an accumulated distribution of mileage related to pavement condition. Traditionally, group 2 has been related to the worst 16 percent of the system in terms of pavement condition, group 6 to the next 16 percent of the system, group 12 to the following 16 percent, and group 15 to the remainder.

<u>Priority Array Groups</u>

1. Bridge Condition
*2. Pavement Condition
3. Hazardous Accident
4. Volume/Capacity
5. Horizontal Curvature
*6. Pavement Condition
7. Bridge Roadway Width
8. Bridges Posted
9. Pavement Width
10. Bridge Clearance
11. Volume/Capacity
*12. Pavement Condition
13. Stopping Sight Distance
14. Roadway Width
*15. Pavement Condition

The Priority Array is transmitted to each district about mid-November. From this point until about mid-April, the districts decide how each identified problem area will be addressed, submit a Project Prospectus for each project to headquarters, and schedule the timing for each phase of the project. Major phases include preliminary engineering, acquisition of right of way, and construction. Depending on the size and complexity of the project, all phases of work may be completed within one biennium or they may extend through as many as three bienniums. Scheduling of each project and phase of work at this stage is also influenced by the availability of funding and manpower. There are basically three categories of funding:

Category A - resurfacing, roadway reconstruction, bridge replacement, safety improvements, etc.

Category B - interstate system improvements financed at the 90/10 matching rate.

Category C - construction on new alignment, or improvements which significantly increase capacity.

Finally, in about mid-April of even-numbered years, all districts must submit their six-year construction programs to headquarters. All district programs are combined into one published document which must be approved at various levels. The Secretary of Transportation approves the program in mid-July; the Transportation Commission approves it in mid-September. Finally, the Legislature meets in January through mid-April and appropriates funding for the first two years of the six-year construction program.

The next step in this process reverts to the districts. After appropriation of funds by the Legislature, each district must review the current status of work in progress, funding carryover from the present biennium, potential overruns, and cash flow. Based on these factors, the district may elect to modify the timing of some projects. Essentially, there are no additions or deletions to the program--only minor adjustments in timing for some projects. From this point on, the program is known as the operating program.

The operating program receives its final approval from the Transportation Commission in mid-September of odd-numbered years. This biennial cycle begins in early spring of the odd-numbered years and culminates 2½ years later in the fall of odd-numbered years.

Application of PMS to Programming and Budget Cycle

One of the biggest problems with the current cycle of programming is the lag time between the pavement condition survey and final approval of the operating program. Approximately 2½ years elapse during which time the condition of pavements can change drastically. It was very obvious from studying the performance curves that every project deteriorates at a different rate. For this reason it is essential that rehabilitation projects are programmed based on their projected ratings instead of ratings at one point in time. In other words, it makes more sense to evaluate the need for rehabilitation on the basis of rating and construction history instead of just one pavement survey.

Another problem with the current methods of programming is the determination of sections that are compared and reported in both the biennial pavement condition report and the Priority Array. These sections, presently known as analysis units, are established to make comparisons on the basis of several categories of deficiency--not just pavements. They are not related to prior contract limits, pavement type, or separating good sections of pavements from poor ones. In order to better distinguish sections of pavement for analysis purposes, prior contract limits as well as current and historical performance should be considered.

Implementation of the pavement management system will address both of these problem areas. Determination of the pavement performance sections will result from a thorough analysis of present and past performance as well as the construction history involved. Once these sections have been established, a performance curve for each will be generated with the interpreting program. These areas will then be reviewed and edited until satisfaction has been obtained for each section. The prioritization of each section will ultimately depend on the rate of deterioration as depicted by these performance curves. Thus, application of the pavement management system will rectify the deficient aspects of WSDOT's current programming scheme.

Although program development will essentially remain the same, implementation of the PMS will provide additional benefits. As the districts assemble their construction programs, each phase of the PMS will be applied to improve the process. The master file listing will help define more precisely the construction limits and demonstrate the nature of distress to be rehabiliated. The performance curves in conjunction with the project optimizing information will be used to help determine the type of fix and construction timing. The network program will be used to fit a program to the funding needs.

There are three primary areas of application for the pavement management system:

1. Provide pavement analysis results to program development section for their use in establishing the Priority Array.
2. Provide pavement performance curves, project optimizing data, and network analysis data to each district for their use in assembling the six-year Legislative Program and two-year Operating Program.
3. Provide detailed information to the District Materials Engineers for their use in designing the most effective rehabilitation alternative for each project.

While these applications represent the primary operations, there are several others:

Provide long-range network analysis data for use in the 12-year Transportation Plan

Each two years the department assembles a long-range (12-year) plan which describes goals, objectives, problems, funding, etc., as a reference document. This is to be used by the Legislature, the Transportation Commission, and department administrators as a basis for decisions and guidance in the long-term planning of the department. One component of this report is an estimate of 2-, 6-, and 12-year pavement rehabilitation needs. Application of the PMS to this task is particularly well-suited. Computer programs and models have been developed not only to project needs, but to match funding levels with specific levels of pavement condition.

Provide PMS data to the Maintenance and Operations Division for their use in the Maintenance Management System

The PMS identifies all sections of pavement on the system needing rehabilitation. Those sections identified but not included in the program because of budget constraints will have to be addressed by the Maintenance Division. With the PMS, a reasonable estimate of maintenance needs and obligations as well as good logistics can be generated.

Monitor system performance

Development of the PMS has provided a means for analyzing the historical pavement rating files. With the PMS, the status of the system can be gauged from many perspectives. Listings can be generated by district, functional class, pavement type, distress category, etc., to indicate miles and percentages in each. The department has a need to be cognizant of trends in pavement performance and distress character from year to year. Information produced by the PMS will be used in many critical areas, particularly pavement design and budgeting. In order to maintain confidence in our decisions, this information must be the best possible. This can only be accomplished through constant improvement and monitoring.

Provide pavement performance data and/or economics data to other department offices on request

Because the PMS is the focal point for deriving most pavement-related information, other department offices will obtain this from the pavement management section in the Materials Laboratory. Offices such as the Public Affairs Office, and those in Planning, Maintenance, and Design require detailed and consistent information relating to our pavements. The PMS will provide accurate and consistent information.

Perform research on pavement performance trends and correlation analysis for improving design formulas and materials specifications

With the performance curves generated in the interpreting phase, it is possible to apply correlation analysis to items such as axle and wheel loads, climate, design formulas, materials specifications, different construction methods, etc. This correlation will be applied to such performance factors as elapsed time to reach a level of rating, degree of curvature of the performance curve, area under the performance curve, etc. Each time the Master File is updated, there are approximately 3000 to 4000 segments of pavement identified, each of which has its own performance curve based primarily on a simple regression fit. This represents an ample data base for analysis purposes. The objective of such analyses is to improve our in-house design formulas, and materials and construction specifications so that our pavements are more cost-effective.

As can be seen from Figure 89, the PMS is central to all other pavement functions. Design, construction, and maintenance need the PMS to improve cost effectiveness. Programming and budgeting need the PMS to establish programs better tailored to the funding available. Planning needs the pavement performance projections from PMS for the 12-year Transportation Plan. And finally, the pavement research area needs the PMS because of its inherent data base and programming facilities. The pavement management system acts as a focal point to all of these activities.

Interactive Version

Because WSDOT has been committed to automated data processing for many years, the department possesses a very complete computer system with remote terminals in each district and virtually every project engineer office. In addition, there are presently 89 remote terminals distributed throughout WSDOT headquarters. With this network of computer terminals, access to PMS files can be accomplished very easily.

During development of this system, an interactive version including some of the basic PMS programs was written to make access to this data faster and easier. Information made available consists of the Master Index, Master File, Interpreted Data, and Optimized Data. Examples of the interactive version are shown in Figures 90, 91, and 92.

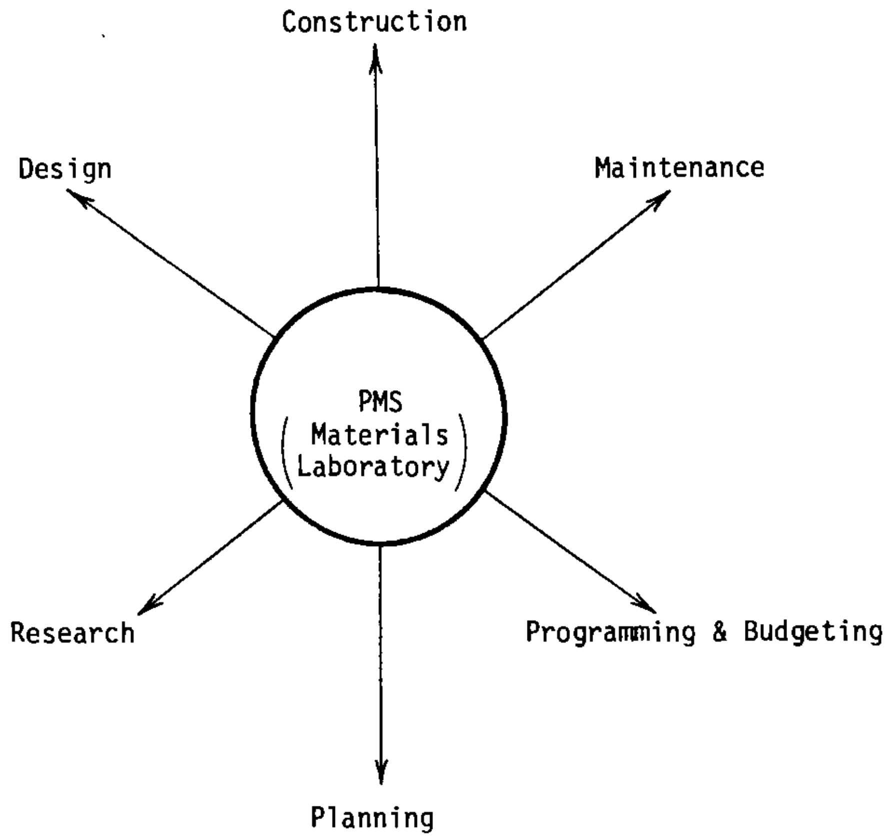


Figure 89. Relationship of PMS to All Pavement Activities

Figure 90 demonstrates how one would identify prior surfacing limits, and then with a subsequent demand obtain a performance summary for one of the identified segments. The top portion is generated with the command LPROJ which is an acronym for list projects. The syntax for the command is:

LPROJ SR(XXX) BEG(XXXXX) END(XXXXX)

This is explained as "List all surfacing project limits on SR XXX between milepost XXXXX and milepost XXXXX". The information listed is a portion of the Master Index between the respective milepost limits.

The lower half of this figure illustrates the retrieval of a performance summary for one of the projects within the aforementioned milepost limits. The command associated syntax is:

PROJ DSN1(XXXXX) SR(XXX) BEG(XXX) END(XXX) SIDE(X)

This is read as "List the project from the specific district output (District 3 is indicated in the example) for the specific project limits and on the specific side". The indication for side is required because project limits and pavement ratings are acquired on both sides for multilane sections and divided highways.

```
LPROJ SR(5) BEG(8500) END(11000)
      R67                                                                                              03/06/80

     CS  BEG  END   D   SR  BEG   END    LENG  FC L HT RDW RSH LSH   CONT# TY S THK M YR BASE  78 ADT GRW SU CM
    **** **** ****  *  *** ***** *****   ****  ** * ** *** *** ***   ***** ** * *** * ** ****  ****** *** ** **

    2104   58  274  4    5  8335  8551    216  U5 L 32  24  10   4   09638  3 6  35 5 75  12    27700  56  6 16
    2104   58  274  4    5  8335  8551    216  U5 R 32  24  10   4   00003  3 6  35 7 76  12    27700  56  6 16
    3401    0  312  3    5  8551  8863    312  R5 L 32  24  10   4   00003  3 6  35 7 76  12    29400  48  6 16
    3401    0  322  3    5  8551  8873    322  R5 R 32  24  10   3   00003  3 6  35 7 76  12    29400  48  6 16
    3401  312 1718  3    5  8863 10269   1406  R5 L 32  24  10   3   07540  3 6  25 4 65  32    32800  54  6 16
    3401  322 1718  3    5  8873 10269   1396  R5 R 32  24  10   4   07540  3 6  25 4 65  32    32800  54  6 16
    3401 1718 1746  3    5 10269 10297     28  U5 L 32  24  10   4   05075  0 7  75 9 56  10    37700  74  6 16
    3401 1746 1854  3    5 10297 10405    108  U5 L 32  24  10   4   05733  0 7  75 7 59  10    37700  74  6 16
    3401 1718 1854  3    5 10269 10405    136  U5 R 32  24  10   4   05733  0 7  75 7 59  10    37200  74  6 16
    3407    0  476  3    5 10405 10881    476  U5 R 32  24  10   4   05733  0 7  75 7 59  10    51500  66  4  9
    3407    0  504  3    5 10405 10909    504  U5 L 33  36  10   8   05733  0 7  75 7 59  10    51500  66  4  9
    3407  504  514  3    5 10909 10919     10  U5 L 32  33  10   4   08360  0 7  67 1 68  21    44500  66  4  9
    3407  476  514  3    5 10881 10919     38  U5 R 33  48  10   6   08360  0 7  67 1 68  21    44500  66  4  9
    3402    0  582  3    5 10919 11501    582  U5 L 33  36  10   6   08360  0 7  67 1 68  21    48800  68  4  9
    3402    0  605  3    5 10919 11524    605  U5 R 33  44  10   6   08360  0 7  67 1 68  21    48800  68  4  9

    NUMBER OF PROJECTS WITHIN MILEPOSTS LIMITS =   15
END CLIST
READY
PROJ DSN1(D3OUT) SR(5) BEG(8863) END(10269) SIDE(L)
    1 R67                                                                                             03/06/80

             BEG   END        BEG  END  PROJ FNC       HWY NUM RDW-RSH-LSH LAST  COMPLT CNT SURFACE BASE
      D  SR  SRMP  SRMP  CS   CSMP CSMP LENG CLS SIDE TYP LNS   WIDTHS     CONTR  M-YR  TYP TYP-THK TYPE
      * *** ***** ***** ****  **** **** **** *** **** *** *** *********** ***** ****** *** ******* ****

      3   5  8863 10269 3401   312 1718 1406 R-5   L    3   2    24  10   3 07540  4-65   3  6   25  32

                PERFORMANCE HISTORY                           APPROXIMATE TRAFFIC DATA   PERFORMANCE EQUATION
    ---------------------------------------------------       ------------------------   --------------------
    YEAR             69     71     73     75     77     79     78 ADT          32800     EQUA CONST =  98.97
    AGE               4      6      8     10     12     14     GROWTH RATE      5.4%     EQUA COEFF =  -0.00029
    RIDE   RATING  1.00   1.00   1.00   1.00   1.00   1.00     SINGLE UNITS       6%     EQUA POWER =  4.00
    STRUCR RATING  96.3   98.7   99.7   94.7   96.2   86.8     COMBINATIONS      16%     R SQUARE   =  0.80543
    COMBD  RATING  96.3   98.2   99.7   94.6   96.0   86.7     TRAFFIC INDEX     8.0     STD ERROR  =  2.19
    HIGH FRICTION    57     54      0     52     59     51     K = 11%       D = 60%     TIME TO 60 = 19.23
    LOW  FRICTION    51     46      0     46     47     45    2AX =  4.0% 3AX =  5.2%    TIME TO 40 = 21.33
    AVG  FRICTION    53     50      0     49     52     48    4AX =  2.1% 5AX = 10.7%    TIME TO 20 = 22.94
    **********************************************************************************************************
```

Figure 90. Interactive PMS Listing Showing Master Index and Performance Summary

```
DO YOU WANT ITEMIZED DEFECT LISTING? (YES OR NO)
YES
1  CS  BEG  END   D   SR  BEG   END   LENG  FC L HT RDW RSH LSH  CONT# TY S THK M YR BASE  78 ADT GRW SU CM
**** **** ****   *   *** ***** *****  ****  ** * ** *** *** ***  ***** ** * *** * ** ****  ****** *** ** **
3401  312 1718   3    5  8863 10269  1406  R5 L 32  24  10   3  07540  3 6  25 4 65 32     32800  54  6 16
```

GEN	SIDE	ECSMP	RUTT WEAR	WAVE SAGS	ALG CRK	RAV FLU	LONG CRK	TRNS CRK	PTCH	BUMPS	BUMP SPEED	ADJ BUMPS	RIDE RATNG	STRUC RATNG	COMBD RATNG
***	****	*****	****	****	***	***	****	****	****	*****	*****	*****	*****	*****	*****
69	L	400	1	11	1N	11	1N	1N	1N	0	0	0	1.00	100	100.0
69	L	500	1	11	1N	11	11	11	1N	0	0	0	1.00	90	90.0
69	L	600	1	11	1N	11	11	11	1N	0	0	0	1.00	90	90.0
69	L	700	1	11	1N	11	1N	1N	1N	0	0	0	1.00	100	100.0
69	L	800	1	11	1N	11	11	1N	1N	0	0	0	1.00	95	95.0
69	L	900	1	11	1N	1N	1N	1N	1N	0	0	0	1.00	100	100.0
69	L	1000	1	11	1N	11	11	1N	1N	0	0	0	1.00	95	95.0
69	L	1100	1	11	1N	11	11	1N	1N	0	0	0	1.00	95	95.0
69	L	1200	1	11	1N	11	11	1N	1N	0	0	0	1.00	95	95.0
69	L	1300	1	11	1N	11	11	1N	1N	0	0	0	1.00	95	95.0
69	L	1400	1	11	1N	11	11	11	1N	0	0	0	1.00	90	90.0
69	L	1500	1	11	1N	11	1N	1N	1N	0	0	0	1.00	100	100.0
69	L	1600	1	11	1N	11	1N	1N	1N	0	0	0	1.00	100	100.0
69	L	1700	1	11	1N	11	1N	1N	1N	0	0	0	1.00	100	100.0
69	L	1718	1	11	1N	11	1N	1N	1N	0	0	0	1.00	100	100.0
71	L	400	1	11	1N	22	11	1N	1N	355	50	408	1.00	95	94.8
71	L	500	1	11	1N	22	11	1N	1N	307	50	325	1.00	95	94.9
71	L	600	1	11	1N	22	1N	1N	1N	237	50	206	1.00	100	99.9
71	L	700	1	11	1N	22	1N	1N	1N	368	50	430	1.00	100	99.8
71	L	800	1	11	1N	22	1N	1N	1N	521	50	691	0.99	100	99.4
71	L	900	1	11	1N	22	1N	1N	1N	464	50	594	1.00	100	99.6
71	L	1000	1	11	1N	22	11	1N	1N	686	50	973	0.99	95	93.9
71	L	1100	1	11	1N	21	11	1N	1N	312	50	334	1.00	95	94.9
71	L	1200	1	11	1N	21	1N	1N	1N	268	50	259	1.00	100	99.9
71	L	1300	1	11	1N	21	1N	1N	1N	288	50	293	1.00	100	99.9
71	L	1400	1	11	1N	21	1N	1N	1N	378	50	447	1.00	100	99.8
71	L	1500	1	11	1N	21	1N	1N	1N	646	50	905	0.99	100	99.0
71	L	1600	1	11	1N	21	1N	1N	1N	577	50	787	0.99	100	99.3
71	L	1700	1	11	1N	21	1N	1N	1N	546	50	734	0.99	100	99.4
71	L	1718	1	11	1N	21	1N	1N	1N	711	50	1016	0.99	100	98.8
73	L	400	1	11	1N	31	1N	1N	1N	348	50	89	1.00	100	100.0
73	L	500	1	11	1N	31	1N	1N	1N	223	50	-10	1.00	100	100.0
73	L	600	1	11	1N	31	1N	1N	1N	104	50	-105	1.00	100	100.0
73	L	700	1	11	1N	31	1N	1N	1N	160	50	-60	1.00	100	100.0
73	L	800	1	12	1N	31	1N	1N	1N	229	50	-5	1.00	100	100.0
73	L	900	1	12	1N	31	1N	1N	1N	266	50	23	1.00	100	100.0
73	L	1000	1	12	1N	31	1N	1N	1N	457	50	176	1.00	100	100.0
73	L	1100	1	12	1N	31	11	1N	1N	247	50	8	1.00	95	95.0
73	L	1200	1	12	1N	31	1N	1N	1N	195	50	-32	1.00	100	100.0
73	L	1300	1	12	1N	31	1N	1N	1N	296	50	47	1.00	100	100.0

Figure 91. Interactive PMS Listing Showing Master File

```
      DO YOU WANT LISTING OF OPTIMUM REHABILITATION STRATEGIES ? (YES OR NO)
YES

                 SHOULD REHABILITATE AT 60.0 WHICH WILL OCCUR IN 1984
                 MUST REHABILITATE AT 40.0 WHICH WILL OCCUR IN 1986
                 CONSIDERATION SPAN = 20 PERIODS, EACH PERIOD = 1.0 YEARS
                 EFFECTIVE INTEREST RATE =  4.0%  FACTORS : 40.0% 70.0%  95.0%

                                                                            CONSTRCT COST   MIN LIFE   MAX LIFE
      DESCRIPTION OF THE ALTERNATIVES          PERFORMANCE  EQUATIONS       12' LANE MILE   AT  SHUD   AT  MUST
   ---------------------------------      ------------------------------    -------------   --------   --------

   ALTERNATE 1 ROUTINE MAINTENANCE        R =  98.97 - 0.00029 P ** 4.00          0          19.15      21.24
   ALTERNATE 2 OVERLAY  0.08 CLASS G      R = 100.00 - 0.39782 P ** 2.25      19100           7.76       9.29
   ALTERNATE 3 OVERLAY  0.15 CLASS B      R = 100.00 - 0.01394 P ** 3.00      35800          14.21      16.26
   ALTERNATE 4 OVERLAY  0.25 CLASS B      R = 100.00 - 0.00558 P ** 3.00      59600          19.28      22.07

                                                                         NUMB
                            ITEMIZED COSTS                               POSS       STRATEGY DESCRIPTION
   *******************************************************************   ****   **************************

   ROUT    +  COST OF  +  COST OF  +  USER    -   SALVAGE  =  EXPECTED    39    (ALTERNATIVE - PRD APPLIED)
   MAINT      CONSTR      TRAFFIC     COST        VALUE       TOTAL
   COST       INCL PR     INTERPT                             COST               1ST    2ND    3RD    4TH
                                                                                REHAB  REHAB  REHAB  REHAB

    278631    1288912      104571    1650741      145141     3177714       4     3-86
    249457    1299717      104492    1637780       93819     3197627       1     3-85
    274220    1246904      205757    1647272      136817     3237336       1     2-85   2-93
    226848    1319783      104240    1636458       45801     3241528       1     3-84
    323826    1238130      204935    1666384      182422     3250853       1     2-86   2-94
    263189    1280900      205504    1652276      146515     3255354       1     2-84   2-93
    246252    2072972      196072    1639490      705485     3449301      12     4-86
    188523    2115139      195924    1619501      651435     3467652       9     4-85
    132921    2167822      195450    1606461      601857     3500797       9     4-84
END CLIST
READY
```

Figure 92. Interactive PMS Listing Showing Cost Analysis

Figure 91 is an example of the option which follows when a project performance summary is requested. By responding "yes" to the question, "Do you want itemized defect listing?" a master file listing is generated. A "no" will skip this output and precipitate the next question as shown in Figure 92. "Do you want a listing of optimum rehabilitation strategies?" With a response of "yes" by the operator, the results of the economic analysis are provided.

This interactive program was developed specifically for individual offices located anywhere in WSDOT to generate PMS data on sections of interest with the quickest response possible.

Future Research

There are many problems to be solved in the area of pavement management. The pavement management system described in this report may not be a "perfect" system; however, it does provide a data base of pavement information to expand on and the necessary tools to help analyze it. Some of the intended areas of research have already been mentioned:

Correlation analysis of performance with:

- geographic areas
- axle loads
- pavement types
- materials and construction specifications
- deflection or pavement strength

Distress trend analysis - a study of the historical progression or regression of specific distress categories.

Other areas of future research may include improvement of each category of cost modeling considered in the project optimizing program, and development of methods to "optimize" at the network level.

One topic of future research and development will be an improvement on the performance curve model. The present equation, $R = C - mA^B$, is reasonably accurate in the upper rating levels, but not in the lower ranges of rating where the curve is almost vertical. For the modeling that is related to the curve in the optimizing program, this is acceptable since the MUST level is always applied at a higher level than the vertical portion. However, for prioritizing projects based on the rate of deterioration, or for the rating distributions calculated in the network programs, a more accurate representation of performance in the lower ranges is necessary. The solution presently contemplated to cure this problem is to develop typical curve "tails" for different categories of pavement types. This concept is illustrated in Figure 93. By studying the performance of pavements only in the low ranges of rating, one or possibly many tails may emerge.

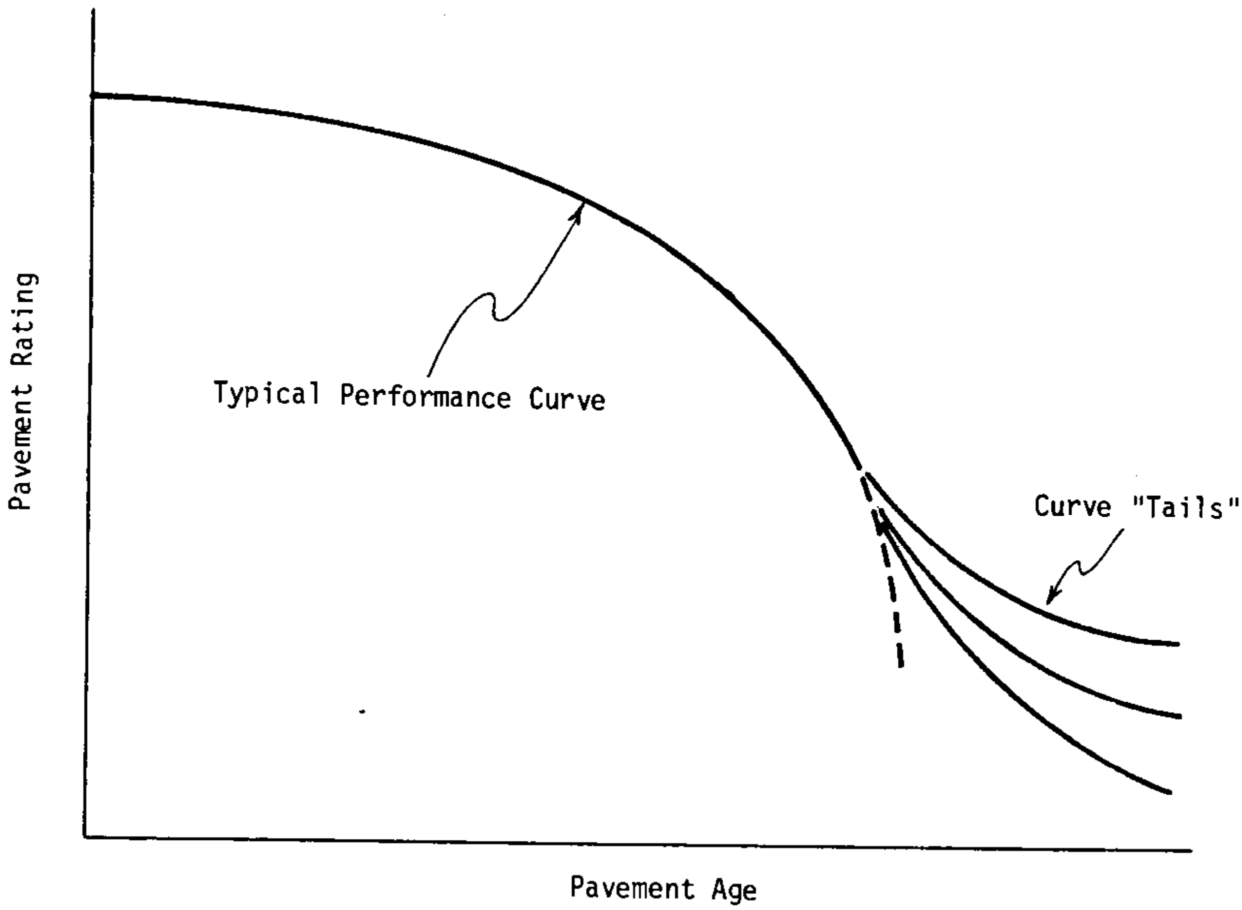


Figure 93. Typical Performance Curve with Curve Tails

Adaptability of the System

It should be noted that the framework of this system could be utilized by any agency that has the two basic constituents for the master file:

1. A construction history file with construction dates, types of surfacing, etc.
2. A pavement rating history file that relates to severity and extent of different distress types.

With this information available, it would be possible to calibrate distress weightings to relate to any combination of distress types and to represent the genesis of pavement deterioration in almost any geographical area. Once performance curves are developed, the mechanics of the rest of this system fall into line.

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APPENDICES

A. Interpreting Source Program

B. Optimizing Source Program

C. Network Source Program

D. Job Control Language and Program Modules for Applying Constraints

E. RATGRP Source Program

APPENDIX A

INTERPRETING SOURCE PROGRAM

```
C
C
C     PROGRAM INTERP
C
C     THIS PROGRAM TRANSLATES THE RAW DISTRESS CODES CONTAINED IN THE
C     MASTER FILE INTO AVERAGE RATINGS FOR EACH PROJECT.  THIS IS
C     ACCOMPLISHED BY APPLYING WEIGHTING VALUES TO THE EXTENT AND
C     SEVERITY OF EACH DISTRESS CATEGORY.  REGRESSION ANALYSIS IS
C     THEN APPLIED TO THE RATINGS TO FIT A PERFORMANCE CURVE.
C
C
C
C
      IMPLICIT INTEGER (A-Z)
C
      COMMON /COMRAT/   AMTRX,   BMTRX,   CMTRX,   PTYP,   STRUCR,
     1                  D1,      D2,      D3A,     D3B,    D4A,
     2                  D4B,     D5A,     D5B,     D6A,    D6B,
     3                  D7A,     D7B,     D8A,     D8B
C
C
      COMMON /COMREG/   RMEAN,     RGEN,      ECONS,    EVAR,    EPOW,    R2,
     1                  NEXP,      EXP,       JK,       LYR,     SE,
     2                  RATHI,     RATLO
C
C
      REAL              RAT(50),   ACUM,        MEAN(10),    RMEAN(10),   R2,
     1                  ECONS,     EVAR,        EXP(20),     EPOW,        TI,
     2                  LIFE60,    LIFE40,      LIFE20,      RF,          ARDR,
     3                  RDR(50),   MRDR(10),    RMRDR(10),   STR(50),     ASTR,
     4                  MSTR(10),  RMSTR(10),                RGRW,        AX2,
     5                  AX3,       AX4,         AX5,         MINR2,       LTI,
     6                  RATIN(50),              LORAT(10),   HIRAT(50),
     7                  RATLO(10),              RATHI(10),   LIFE50, LIFE30,
     8                  DAGE,      AGER,        EC(3,4),     EV(3,4),EP(3,4),
     9                  EPN(4,3,4)
C
      REAL*8            DATE
C
C
      DIMENSION       GEN(10),  AMTRX(3,21),  BMTRX(3,21),  CMTRX(3,21),
     1                RGEN(10), FTMTRX(5,5),  STMTRX(10,3), TIR(4),
     2                RAGE(10), HISK(10),     LOSK(10),     AVSK(10),
     3                RHISK(10),RLOSK(10),    RAVSK(10)
```

```
C
C
C     DEFINE B,L,R AS DATA
C
      DATA B,L,R/'B','L','R'/
C
C
      CALL GETDAT(DATE)
C
C
C     READ INTERPRETING PARAMETERS
C
      DO 3 I = 1,3
      READ (4,401)  (AMTRX(I,J),J=1,21)
  401 FORMAT (21I2)
    3 CONTINUE
      DO 4 I = 1,3
      READ (4,401)  (BMTRX(I,J),J=1,21)
    4 CONTINUE
      DO 5 I = 1,3
      READ (4,401)  (CMTRX(I,J),J=1,21)
    5 CONTINUE
      READ (4,402) NEXP,NOW,TRAFYR,MINR2,WATE
  402 FORMAT (3I2,F3.2,I3)
      READ (4,403)  (EXP(J),J=1,20)
  403 FORMAT (20F4.2)
      DO 6 I=1,3
      READ (4,404)  (EC(I,J),J=1,4)
  404 FORMAT (4(F5.1,5X))
      READ (4,405)  (EV(I,J),J=1,4)
  405 FORMAT (4(F8.5,2X))
      READ (4,406)  (EP(I,J),J=1,4)
  406 FORMAT (1X,4(F4.2,6X))
    6 CONTINUE
C
      DO 8 I = 1,4
      DO 7 J = 1,3
      READ (4,407)  (EPN(I,J,K),K=1,4)
  407 FORMAT (4(F4.2,2X))
    7 CONTINUE
    8 CONTINUE
C
C     INITIALIZE COUNTERS
C
```

```
      RCNT=0
      FIRST=0
      LLEMP=0
      LREMP=0
      II=0
      JJ=0
C
C     BEGIN READING PROJECT DATA
C
  100 READ (5,501,END=998) CSI,      BCMPI,      ECMPI,     SEQI,     DI,
     1                     SRI,      BSMPI,      ESMPI,     LENGI,    URI,
     2                     FCI,      LANEI,      HTI,       NLI,      RWI,
     3                     RSI,      LSI,        SPI,       SNUMI,    CTYPI,
     4                     SURFI,    THKI,       MNTHI,     YRI,      BASEI,
     5                     ADTI,     GRWI,       SUI,       COMBI,    KI,
     6                     KDI,      TI,         GENI,      EMP,      SIDE,
     7                     SPED,     COUNT,      PTYP,      D1,       D2,
     8                     D3A,      D3B,        D4A,       D4B,      D5A,
     9                     D5B,      D6A,        D6B,       D7A,      D7B,
     A                     D8A,      D8B,        HISKI,     LOSKI,    AVSKI,
     B                     CROSS
C
  501 FORMAT (3I4,A3,A1,A3,2I5,I4,A1,I1,A1,2I1,3A2,A1,A4,3I2,A1,2I2,
     1        I6,I3,4I2,F3.1,I2,I4,A1,I2,I5,3A1,6(I1,A1),3I2,I1)
C
      FIRST = FIRST + 1
      IF (FIRST .EQ. 1) GO TO 30
      IF (GENI  .NE. LGEN)  GO TO 20
      IF(ESMPI .NE. LESMP .OR. LANEI .NE. LLANE) GO TO 20
C
C
   30 CALL ARAT
C
C
C     ADJUST COUNT
C
      CALL RIDADJ(GENI,SPED,COUNT,PTYP,ACOUNT)
C
C     COMPUTE RIDE FACTOR
C
      RF = 1.0 - (0.3 * (FLOAT(ACOUNT)/ 5000) ** 2)
      IF (RF .LT. 0.01) RF = 0.01
C
C     COMPUTE LENGTH FOR THIS DEFECT RECORD
```

```
C
      IF (SIDE .EQ. L .AND. LLEMP .GT. 0) GO TO 31
      IF (SIDE .EQ. R .AND. LREMP .GT. 0) GO TO 33
      RLENG = EMP - BCMPI
      GO TO 35
   31 IF (CROSS .GT. 0) GO TO 32
      RLENG = EMP - LLEMP
      IF (EMP .GE. ECMPI) RLENG = ECMPI - LLEMP
      GO TO 35
   32 IF (CROSS .EQ. 1) RLENG = EMP - LLEMP
      IF (CROSS .EQ. 2) RLENG = EMP
      IF (CROSS .EQ. 3) RLENG = ECMPI - LLEMP
      IF (CROSS .EQ. 4) RLENG = ECMPI
      GO TO 35
   33 IF (CROSS .GT. 0) GO TO 34
      RLENG = EMP - LREMP
      IF (EMP .GE. ECMPI) RLENG = ECMPI - LREMP
      GO TO 35
   34 IF (CROSS .EQ. 1) RLENG = EMP - LREMP
      IF (CROSS .EQ. 2) RLENG = EMP
      IF (CROSS .EQ. 3) RLENG = ECMPI - LREMP
      IF (CROSS .EQ. 4) RLENG = ECMPI
      IF (RLENG .LE. 0) RLENG = 50
   35 CLENG = CLENG + RLENG
C
C     MODIFY DISTRESS RATING WITH RIDE FACTOR & RATING LENGTH
C
      II = II + 1
      RATIN(II) = STRUCR * RF
      RAT(II) = STRUCR * RF * RLENG
      RDR(II) = RF * RLENG
      STR(II) = STRUCR * 1.0 * RLENG
C
C     CHANGE ALL ID VARIABLES FROM VARIABLES-IN TO LAST-VARIABLES
C     FOR COMPARISON PURPOSES IN TRIGGERING MEAN COMPUTATIONS,
C     REGRESSION ANALYSIS AND USING PROPER ID IN OUTPUT
C
      LCS   = CSI
      LBCMP = BCMPI
      LECMP = ECMPI
      LSEQ  = SEQI
      LD    = DI
      LSR   = SRI
      LBSMP = BSMPI
```

```
      LESMP = ESMPI
      LLENG = LENGI
      LUR   = URI
      LFC   = FCI
      LHT   = HTI
      LNL   = NLI
      LLANE = LANEI
      LRW   = RWI
      LRS   = RSI
      LLS   = LSI
      LSP   = SPI
      LSNUM = SNUMI
      LCTYP = CTYPI
      LSURF = SURFI
      LTHK  = THKI
      LMNTH = MNTHI
      LYR   = YRI
      LBASE = BASEI
      LGEN  = GENI
      LADT  = ADTI
      LGRW  = GRWI
      LSU   = SUI
      LCOMB = COMBI
      LK    = KI
      LKD   = KDI
      LTT   = TI
C
      IF (HISKI .EQ. 0  .AND. GENI .EQ. LGEN) GO TO 36
      LHISK = HISKI
   36 IF (LOSKI .EQ. 0  .AND. GENI .EQ. LGEN) GO TO 37
      LLOSK = LOSKI
   37 IF (AVSKI .EQ. 0  .AND. GENI .EQ. LGEN) GO TO 38
      LAVSK = AVSKI
C
   38 IF (SIDE .EQ. R .OR. SIDE .EQ. B) LREMP = EMP
      IF (SIDE .EQ. L .OR. SIDE .EQ. B) LLEMP = EMP
      IF (SIDE .EQ. B) SIDE = LANEI
      GO TO 100
C
C     COMPUTE MEAN RATING VALUE FOR EACH GENERATION
C
  998 LAST = I
   20 ACUM=0
      APDR=0
```

```
      ASTR=0
      JJ = JJ + 1
C
      DO 21 N = 1,II
      ACUM = ACUM + RAT(N)
      ARDR = ARDR + RDR(N)
      ASTR = ASTR + STR(N)
      IF (N .EQ. 1) LORAT(JJ) = RATIN(N)
      IF (RATIN(N) .LT. LORAT(JJ)) LORAT(JJ) = RATIN(N)
      IF (N .EQ. 1) HIRAT(JJ) = RATIN(N)
      IF (RATIN(N) .GT. HIRAT(JJ)) HIRAT(JJ) = RATIN(N)
   21 CONTINUE
C
      MEAN(JJ) = ACUM/CLENG
      MRDR(JJ) = ARDR/CLENG
      MSTR(JJ) = ASTR/CLENG
      GEN(JJ) = LGEN
      HISK(JJ) = LHISK
      LOSK(JJ) = LLOSK
      AVSK(JJ) = LAVSK
      CLENG = 0
      LLEMP = 0
      LREMP = 0
      II = 0
      IF (BSMPI .NE. LBSMP .OR. ESMPI .NE. LESMP ) GO TO 10
      IF (LAST .EQ. 1) GO TO 10
      IF (LLANE .NE. LANFI) GO TO 10
      GO TO 30
C
C     SELECT MEAN RATINGS ATTRIBUTED TO MOST RECENT CONTRACT AND
C     PERFORM REGRESSION ANALYSIS
C
   10 AGE= NOW - LYR
      JK = 0
C
      DO 11 I = 1,JJ
      IF (GEN(I) .GE. LYR) GO TO 12
      GO TO 11
   12 JK = JK + 1
      RMEAN(JK) = MEAN(I)
      RMRDR(JK) = MRDR(I)
      RMSTR(JK) = MSTR(I)
      RGEN(JK) = GEN(I)
      RAGE(JK) = GEN(I) - LYR
```

```
      RHISK(JK) = HISK(I)
      RLOSK(JK) = LOSK(I)
      RAVSK(JK) = AVSK(I)
      RATHI(JK) = HIRAT(I)
      RATLO(JK) = LORAT(I)
      IF (RGEN(JK) .GT. LYR) GO TO 11
      RMEAN(JK) = 100.0
      RMSTR(JK) = 100.0
      RATHI(JK) = 100.0
      RATLO(JK) = 100.0
   11 CONTINUE
C
      IF (LYR .LE. NOW) GO TO 15
      JK = 1
      RGEN(JK) = LYR
      RAGE(JK) = 0
      RMEAN(JK) = 100.0
      RMRDR(JK) = 1.00
      RMSTR(JK) = 100.0
      RATHI(JK) = 100.0
      RATLO(JK) = 100.0
      RHISK(JK) = LHISK
      RLOSK(JK) = LLOSK
      RAVSK(JK) = LAVSK
C
   15 JJ = 0
C
C     TEST SECTIONS FOR AGE.
C     IF TOO YOUNG. ASSIGN SYNTHETIC EQUATIONS
C
      IF (JK .GE. 3 .AND. RMEAN(JK) .LE. 95.0) GO TO 300
      IF (LSURF .GE. 20 .AND. LSURF .LT. 30) S = 1
      IF (LSURF .GE. 40) S = 2
      IF (LSURF .EQ. 30) S = 3
      T = 1
      IF (LCTYP .NE. 20) GO TO 210
      T = 2
      IF (LTHK .GE. 10 .AND. LTHK .LT. 20) T = 3
      IF (LTHK .GE. 20) T = 4
  210 ECONS = EC(S,T)
      EVAR = EV(S,T)
      EPOW = EP(S,T)
      R2 = 0
      SE = 0
```

```
      GOOD = 1
      GO TO 400
C
C     CALL THE REGRESSION SUBROUTINE
C
  300 CALL REGR
      GOOD = 2
C
C     TEST THE RESULTS OF THE REGRESSION ANALYSIS FOR POSSIBLE
C     SYNTHESIZING OF EQUATIONS
C
      IF (R2 .GE. MINR2) GO TO 400
C
      ECONS = 100.0
      R2    = 0
      SE    = 0
C
      IF (LSURF .GE. 20 .AND. LSURF .LT. 30) SS = 1
      IF (SSURF .GE. 40 .AND. LCTYP .LT. 20) SS = 2
      IF (LSURF .EQ. 30) SS = 3
      IF (LCTYP .GE. 20 .AND. LCTYP .LT. 30) SS = 4
C
      IF (LTHK .LT. 10) TT = 1
      IF (LTHK .GE. 10 .AND. LTHK .LT. 20) TT = 2
      IF (LTHK .GE. 20) TT = 3
C
      IF (AGE .LT. 8) AA = 1
      IF (AGE .GE. 8 .AND. AGE .LT. 12) AA = 2
      IF (AGE .GE. 12 .AND. AGE .LT. 19) AA = 3
      IF (AGE .GE. 19) AA = 4
C
      EPOW = EPN(SS,TT,AA)
      EVAR = (RMEAN(JK) - 100.0)/(AGE ** EPOW)
      GOOD = 3
C
C     COMPUTE THE LIFE AT RATINGS OF 20, 30, 40, 50, AND 60
C
  400 IF(EVAR .GE. -.00000) EVAR = -.00001
      LIFE60 = ((ECONS - 60.0)/(-1.0 * EVAR)) ** (1.0/EPOW)
      IF (LIFE60 .GT. 99) LIFE60 = 99.99
      LIFE50 = ((ECONS - 50.0)/(-1.0 * EVAR)) ** (1.0/EPOW)
      IF (LIFE50 .GT. 99) LIFE50 = 99.99
      LIFE40 = ((ECONS - 40.0)/(-1.0 * EVAR)) ** (1.0/EPOW)
      IF (LIFE40 .GT. 99) LIFE40 = 99.99
```

```
      LIFE30 = ((ECONS - 30.0)/(-1.0 * EVAR)) ** (1.0/EPOW)
      IF (LIFE30 .GT. 99) LIFE30 = 99.99
      LIFE20 = ((ECONS - 20.0)/(-1.0 * EVAR)) ** (1.0/EPOW)
      IF (LIFE20 .GT. 99) LIFE20 = 99.99
C
C     WRITE OUTPUT
C
      NK = JK + 1
      IF (NK .GT. 10) GO TO 13
C
      DO 13 M = NK,10
      RMEAN(M) = 0
      RGEN(M) = 0
      RAGE(M) = 0
      RMPDR(M) = 0
      RMSTR(M) = 0
      RHISK(M) = 0
      RLOSK(M) = 0
      RAVSK(M) = 0
      RATHI(M) = 0
      RATLO(M) = 0
   13 CONTINUE
C
      WRITE (9,901)  GOOD,   LCS,     LBCMP,    LECMP,  LSEQ,  LD,
     1               LSP,    LBSMP,   LESMP,    LLENG,  LUR,   LFC,
     2               LLANE,  LHT,     LNL,      LRW,    LRS,   LLS,
     3               LSP,    LSNUM,   LCTYP,    LSURF,  LTHK,
     4               LMNTH,  LYR,     LBASE,    LADT,   LGRW,  LSU,
     5               LCOMP,  LK,      LKD,      LTI,    ECONS, EVAR,
     6               EPOW,   R2,      SE,       LIFE60, LIFE40,LIFE20,
     7          WATE, ((RGEN(K),RAGE(K),RMPDR(K),RMSTR(K),RMEAN(K),
     8          RATHI(K), RATLO(K), RHISK(K), RLOSK(K), RAVSK(K)),K=1,6)
C
  901 FORMAT (I1,3I4,A3,A1,A3,2I5,I4,A1,I1,A1,2I1,3A2,A1,A4,3I2,A1,
     1    2I2,I6,I3,4I2,F3.1,F6.2,F9.5,F4.2,F7.5,4F5.2,I3,6(2I2,F5.2,
     2        4F5.1,3I2))
C
C     WRITE DATA TO OUTPUT LISTING
C
      PGRW = LGRW * 0.1
      AX2  = LSU * 0.67
      AX3  = (LSU * 0.33) + (LCOMB * 0.2)
      AX4  = LCOMB * 0.13
      AX5  = LCOMB * 0.67
```

```
   40 RCNT = RCNT + 1
C
      WRITE (6,601) DATE
  601 FORMAT ('1',' R67    ',93X,A8/)
C
   14 WRITE (6,602)
  602 FORMAT (/' ',T14,'BEG    END              BEG  END  PROJ FNC       HWY
     1NUM RDW-RSH-LSH LAST  COMPLT CNT SURFACE BASE'/' ',T7,'D  SR  SRMP
     2  SRMP  CS  SEQ CSMP CSMP LENG CLS SIDE TYP LNS   WIDTHS    CONTR
     3 M-YR  TYP TYP-THK TYPE'/' ',T7,'* *** ***** ***** **** *** **** *
     4*** **** *** **** *** *** ********** ***** ***** *** ******* ***
     5*'/)
C
      WRITE (6,603) LD,LSR,LBSMP,LESMP,LCS,LSEQ,LBCMP,LECMP,LLENG,LUR,
     1             LFC,LLANE,LHT,LNL,LRW,LRS,LLS,LSP,LSNUM,LMNTH,LYR,LCTYP,
     2                  LSURF,LTHK,LBASE
C
  603 FORMAT (' ',T7,A1,1X,A3,2(1X,I5),1X,I4,1X,A3,3(1X,I4),1X,A1,'-',
     1I1,3X,A1,2(3X,I1),2X,3(A2,2X),A1,A4,2X,A1,'-',I2,3X,2(I2,2X),I2,
     2         3X,I2/)
C
      IF (JK .EQ. 6) GO TO 60
      IF (JK .EQ. 5) GO TO 61
      IF (JK .EQ. 4) GO TO 62
      IF (JK .EQ. 3) GO TO 63
      IF (JK .EQ. 2) GO TO 64
C
      WRITE (6,604) RGEN(1),       TRAFYR,    LADT,      ECONS,
     1              RAGE(1),       RGRW,      EVAR,
     2              RMRDR(1),      LSU,       EPOW,
     3              RMSTR(1),      LCOMB,     R2,
     4              RMEAN(1),      LTI,       SE,
     5              RATHI(1),      LK,        LKD,       LIFE60,
     6              RATLO(1),      AX2,       LIFE50,
     7              RHISK(1),      AX3,       LIFE40,
     8              RLOSK(1),      AX4,       LIFE30,
     9              RAVSK(1),      AX5,       GOOD
C
  604 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT
     1A',T89,'PERFORMANCE EQUATION'/' ',
     2    ' -------------------  ----------------------------------   ---
     3------------------   --------------------'/' ',' YEAR',13X,
     4 1(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',
     5 14X,1(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',
```

```
     6 F9.5/' ',' RIDE   RATING ',1(F5.2,2X),T63,'SINGLE UNITS',5X,I2,
     7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',1(F5.1,2X),
     8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE   = ',F8.5/' ',' COMBD
     9 RATING ',1(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.I,T88,'STD ERROR  =
     A ',F5.2/' ',' HIGH   RATING ',1(F5.1,2X),T63,'K = ',I2,'%',6X,'D =
     B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',1(F5.1,
     C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',
     D' HIGH FRICTION',4X,1(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,
     E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,1(I2,5X),T62,'4 AXLE
     FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'
     G,4X,1(I2,5X),T62,'5 AXLE TRUCKS = ',F4.1,' %',T88,'CURVE      = ',
     H 1X,I1/' ',108('*'))
C
      GO TO 65
C
C
   60 WRITE (6,605) (RGEN(K),K=1,6),     TRAFYR,    LADT,     ECONS,
     1                (RAGE(K),K=1,6),     RGPW,      EVAR,
     2                (RMRDR(K),K=1,6),    LSU,       EPOW,
     3                (RMSTR(K),K=1,6),    LCOMB,     R2,
     4                (RMEAN(K),K=1,6),    LTI,       SE,
     5                (RATHI(K),K=1,6),    LK,        LKD,      LIFE60,
     6                (RATLO(K),K=1,6),    AX2,       LIFE50,
     7                (RHISK(K),K=1,6),    AX3,       LIFE40,
     8                (RLOSK(K),K=1,6),    AX4,       LIFE30,
     9                (RAVSK(K),K=1,6),    AX5,       GOOD
C
  605 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT
     1A',T89,'PERFORMANCE EQUATION'/' ',
     2  ' ---------------------------------------------------        ---
     3-------------------    ------------------------'/' ',' YEAR',13X,
     4 6(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',
     5 14X,6(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',
     6 F9.5/' ',' RIDE   RATING ',6(F5.2,2X),T63,'SINGLE UNITS',5X,I2,
     7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',6(F5.1,2X),
     8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE   = ',F8.5/' ',' COMBD
     9 RATING ',6(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR  =
     A ',F5.2/' ',' HIGH   RATING ',6(F5.1,2X),T63,'K = ',I2,'%',6X,'D =
     B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',6(F5.1,
     C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',
     D' HIGH FRICTION',4X,6(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,
     E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,6(I2,5X),T62,'4 AXLE
     FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'
     G,4X,6(I2,5X),T62,'5 AXLE TRUCKS = ',F4.I,' %',T88,'CURVE      = ',
```

```
     H 1X,I1/' ',108('*'))                                              00048500
C                                                                       00048600
      GO TO 65                                                          00048700
C                                                                       00048800
C                                                                       00048900
   61 WRITE (6,606) (RGEN(K),K=1,5),     TRAFYR,   LADT,     ECONS,     00049000
     1              (RAGE(K),K=1,5),     RGRW,     EVAR,                00049100
     2              (RMRDR(K),K=1,5),    LSU,      EPOW,                00049200
     3              (RMSTR(K),K=1,5),    LCOMB,    P2,                  00049300
     4              (RMEAN(K),K=1,5),    LTI,      SE,                  00049400
     5              (RATHI(K),K=1,5),    LK,       LKD,      LIFE60,    00049500
     6              (RATLO(K),K=1,5),    AX2,      LIFE50,              00049600
     7              (RHISK(K),K=1,5),    AX3,      LIFE40,              00049700
     8              (RLOSK(K),K=1,5),    AX4,      LIFE30,              00049800
     9              (RAVSK(K),K=1,5),    AX5,      GOOD                 00049900
C                                                                       00050000
  606 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT00050100
     1A',T89,'PERFORMANCE EQUATION'/' ',                                00050200
     2 ' -----------------------------------------------------------   ---00050300
     3--------------------   ----------------------'/' ',' YEAR',13X,   00050400
     4 5(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',00050500
     5 14X,5(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',  00050600
     6 F9.5/' ',' RIDE   RATING ',5(F5.2,2X),T63,'SINGLE UNITS',5X,I2,  00050700
     7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',5(F5.1,2X),   00050800
     8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE    = ',F8.5/' ',' COMBD 00050900
     9 RATING ',5(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR   =00051000
     A ',F5.2/' ',' HIGH   RATING ',5(F5.1,2X),T63,'K = ',I2,'%',6X,'D =00051100
     B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',5(F5.1,  00051200
     C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',00051300
     D' HIGH FRICTION',4X,5(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,00051400
     E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,5(I2,5X),T62,'4 AXLE 00051500
     FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'00051600
     G,4X,5(I2,5X),T62,'5 AXLE TRUCKS = ',F4.1,' %',T88,'CURVE      = ',00051700
     H 1X,I1/' ',108('*'))                                              00051800
C                                                                       00051900
      GO TO 65                                                          00052000
C                                                                       00052100
C                                                                       00052200
   62 WRITE (6,607) (RGEN(K),K=1,4),     TRAFYR,   LADT,     ECONS,     00052300
     1              (RAGE(K),K=1,4),     RGRW,     EVAR,                00052400
     2              (RMRDR(K),K=1,4),    LSU,      EPOW,                00052500
     3              (RMSTR(K),K=1,4),    LCOMB,    R2,                  00052600
     4              (RMEAN(K),K=1,4),    LTI,      SE,                  00052700
     5              (RATHI(K),K=1,4),    LK,       LKD,      LIFE60,    00052800
```

```
     6                 (RATLO(K),K=1,4),    AX2,       LIFE50,
     7                 (RHISK(K),K=1,4),    AX3,       LIFE40,
     8                 (RLOSK(K),K=1,4),    AX4,       LIFE30,
     9                 (RAVSK(K),K=1,4),    AX5,       GOOD
C
  607 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT
     1A',T89,'PERFORMANCE EQUATION'/' ',
     2    ' -----------------------------------------------------      ---
     3------------------    ----------------------'/' ',' YEAR',13X,
     4 4(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',
     5 14X,4(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',
     6 F9.5/' ',' RIDE   RATING ',4(F5.2,2X),T63,'SINGLE UNITS',5X,I2,
     7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',4(F5.1,2X),
     8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE    = ',F8.5/' ',' COMBD
     9 RATING ',4(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR   =
     A ',F5.2/' ',' HIGH   RATING ',4(F5.1,2X),T63,'K = ',I2,'%',6X,'D =
     B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',4(F5.1,
     C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',
     D' HIGH FRICTION',4X,4(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,
     E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,4(I2,5X),T62,'4 AXLE
     FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'
     G,4X,4(I2,5X),T62,'5 AXLE TRUCKS = ',F4.1,' %',T88,'CURVE       = ',
     H 1X,I1/' ',108('*'))
C
      GO TO 65
C
C
   63 WRITE (6,608) (RGEN(K),K=1,3),      TRAFYR,    LADT,       ECONS,
     1                 (RAGE(K),K=1,3),     RGRW,      EVAR,
     2                 (RMRDR(K),K=1,3),    LSU,       EPOW,
     3                 (RMSTR(K),K=1,3),    LCOMB,     R2,
     4                 (RMEAN(K),K=1,3),    LTI,       SE,
     5                 (RATHI(K),K=1,3),    LK,        LKD,        LIFE60,
     6                 (RATLO(K),K=1,3),    AX2,       LIFE50,
     7                 (RHISK(K),K=1,3),    AX3,       LIFE40,
     8                 (RLOSK(K),K=1,3),    AX4,       LIFE30,
     9                 (RAVSK(K),K=1,3),    AX5,       GOOD
C
  608 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT
     1A',T89,'PERFORMANCE EQUATION'/' ',
     2    ' -----------------------------------------------------      ---
     3------------------    ----------------------'/' ',' YEAR',13X,
     4 3(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',
     5 14X,3(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',
```

```
      6 F9.5/' ',' RIDE   RATING ',3(F5.2,2X),T63,'SINGLE UNITS',5X,I2,    00057300
      7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',3(F5.1,2X),      00057400
      8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE    = ',F8.5/' ',' COMBD 00057500
      9 RATING ',3(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR  =00057600
      A ',F5.2/' ',' HIGH   RATING ',3(F5.1,2X),T63,'K = ',I2,'%',6X,'D =00057700
      B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',3(F5.1,   00057800
      C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',00057900
      D' HIGH FRICTION',4X,3(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,00058000
      E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,3(I2,5X),T62,'4 AXLE 00058100
      FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'00058200
      G,4X,3(I2,5X),T62,'5 AXLE TRUCKS = ',F4.1,' %',T88,'CURVE     = ',00058300
      H 1X,T1/' ',108('*'))                                                00058400
C                                                                          00058500
      GO TO 65                                                             00058600
C                                                                          00058700
C                                                                          00058800
   64 WRITE (6,609) (RGEN(K),K=1,2),     TRAFYR,    LADT,     ECONS,       00058900
     1              (RAGE(K),K=1,2),     RGRW,      EVAR,                  00059000
     2              (RMRDR(K),K=1,2),    LSU,       EPOW,                  00059100
     3              (RMSTR(K),K=1,2),    LCOMB,     R2,                    00059200
     4              (RMEAN(K),K=1,2),    LTI,       SE,                    00059300
     5              (RATHI(K),K=1,2),    LK,        LKD,      LIFE60,      00059400
     6              (RATLO(K),K=1,2),    AX2,       LIFE50,                00059500
     7              (RHISK(K),K=1,2),    AX3,       LIFE40,                00059600
     8              (RLOSK(K),K=1,2),    AX4,       LIFE30,                00059700
     9              (RAVSK(K),K=1,2),    AX5,       GOOD                   00059800
C                                                                          00059900
  609 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT00060000
     1A',T89,'PERFORMANCE EQUATION'/' ',                                   00060100
     2  ' -----------------------------------------------------     ---00060200
     3-------------------   -----------------------'/' ',' YEAR',13X,  00060300
     4 2(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',00060400
     5 14X,2(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',   00060500
     6 F9.5/' ',' RIDE   RATING ',2(F5.2,2X),T63,'SINGLE UNITS',5X,I2,    00060600
     7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',2(F5.1,2X),      00060700
     8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE    = ',F8.5/' ',' COMBD 00060800
     9 RATING ',2(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR  =00060900
     A ',F5.2/' ',' HIGH   RATING ',2(F5.1,2X),T63,'K = ',I2,'%',6X,'D =00061000
     B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',2(F5.1,   00061100
     C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',00061200
     D' HIGH FRICTION',4X,2(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,00061300
     E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,2(I2,5X),T62,'4 AXLE 00061400
     FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'00061500
     G,4X,2(I2,5X),T62,'5 AXLE TRUCKS = ',F4.1,' %',T88,'CURVE     = ',00061600
```

```
     H 1X,I1/' ',108('*'))
C
C
   65 CALL RPLOT
C
C
  375 FCONS = 0
      FVAR  = 0
      FPOW  = 0
      SE    = 0
      R2    = 0
      JK    = 0
C
      IF (LAST .EQ. 1) GO TO 999
      GO TO 30
C
  999 END FILE 9
      STOP
      END
C
C
C
      SUBROUTINE ARAT
C
C     THIS SUBROUTINE USES ALL DEFECT DATA AND MATRICES AMTRX, BMTRX,
C     AND CMTRX, FOR ASPHALT PAVEMENTS, BITUMINOUS PAVEMENTS, AND
C     PCC PAVEMENTS RESPECTIVELY FOR COMPUTING THE STRUCTURAL RATINGS.
C
      IMPLICIT INTEGER (A-Z)
      COMMON /COMRAT/ AMTRX,     BMTRX,     CMTRX,     PTYP,      STRUCR,
     1                D1,        D2,        D3A,       D3B,       D4A,
     2                D4B,       D5A,       D5B,       D6A,       D6B,
     3                D7A,       D7B,       D8A,       D8B
      DATA A,B,C,N,R/'A','B','C','N','R'/
      DIMENSION DEF(8),  COL(8), AMTRX(3,21), BMTRX(3,21), CMTRX(3,21)
C
C
      DEF(1) = D1
      DEF(2) = D2
      DEF(3) = D3B
      DEF(4) = D4B
      DEF(5) = D5B
      DEF(6) = D6B
      DEF(7) = D7B
```

```
      DEF(8) = D8B
      DO 10 I = 1,8
      IF ( DEF(I) .EQ. N .OR. DEF(I) .EQ. R) DEF(I) = 0
      IF ( DEF(I) .EQ. 0) GO TO 10
      DEF(I) = BCDBNV(DEF(I),1)
   10 CONTINUE
      IF (DEF(2) .LT. 0 .OR. DEF(2) .GT. 3) DEF(2) = 0
      COL(1) = 1
      COL(2) = 2
      COL(3) = D3A + 2
      COL(4) = D4A + 5
      COL(5) = D5A + 9
      COL(6) = D6A + 12
      COL(7) = D7A + 15
      COL(8) = D8A + 18
      SCORE = 0
      DO 20 M = 1,8
      IF (DEF(M) .EQ. 0) GO TO 20
      I = DEF(M)
      J = COL(M)
      IF (PTYP .EQ. A) SCORE = SCORE + AMTRX(I,J)
      IF (PTYP .EQ. B) SCORE = SCORE + BMTRX(I,J)
      IF (PTYP .EQ. C) SCORE = SCORE + CMTRX(I,J)
   20 CONTINUE
      STRUCR = 100 - SCORE
      RETURN
      END
C
C
C
      SUBROUTINE RIDADJ(GEN,SPEED,COUNT,PTYPE,ACOUNT)
C
C
C      THIS SUBROUTINE ADJUSTS THE RIDE COUNT TO A COMMON BASE
C      DEPENDING THE GENERATION OF SURVEY, THE VEHICLE USED,
C      AND THE PARTICULAR RIDE METER UTILIZED.
C
C
      IMPLICIT INTEGER (A-Z)
C
C
      REAL CPM,  LCPM50
C
C
```

```
      DATA A,B,C/'A','B','C'/
C
C
      IF (COUNT .FQ. 0) GO TO 100
      IF (GEN .EQ. 69) GO TO 100
      IF (GEN .EQ. 71) GO TO 10
      IF (GEN .GE. 75 .AND. GEN .LE. 79) GO TO 50
      IF (GEN .GE. 81) GO TO 40
C
C
      CPM = (0.4668 * COUNT) + 6.1004
      GO TO 20
C
   10 CPM = COUNT * 1.0
   20 IF (SPEED .EQ. 0) GO TO 30
      IF (SPEED .EQ. 50) GO TO 30
      IF (SPEED .EQ. 40 .AND. (PTYPE .FQ. A .OR. PTYPE .EQ. B))
     1     LCPM50 = (1.1924 * ALOG10(CPM)) - 0.7448
      IF (SPEED .EQ. 30 .AND. (PTYPE .FQ. A .OR. PTYPE .EQ. B))
     1     LCPM50 = (1.1569 * ALOG10(CPM)) - 0.5786
      IF (SPEED .NE. 50 .AND. PTYPE .EQ. C)
     1     LCPM50 = (1.2202 * ALOG10(CPM)) - 0.9093
      CPM = 10 ** LCPM50
   30 ACOUNT = IFIX((CPM/0.585) - 198.8)
      PETURN
C
C
   40 CPM = COUNT * 1.0
      LCPM50 = 1.36641 * (CPM ** .92294)
      ACOUNT = IFIX(LCPM50)
      PETURN
C
C
   50 IF (SPEED .EQ. 50 .OR. SPEED .EQ. 0) GO TO 100
      IF (SPEED .EQ. 45) CPM = (1.09 * COUNT) + 28
      IF (SPEED .EQ. 40) CPM = (1.21 * COUNT) + 63
      IF (SPEED .EQ. 35) CPM = (1.37 * COUNT) + 119
      IF (SPEED .EQ. 30) CPM = (1.53 * COUNT) + 161
      IF (SPEED .EQ. 25) CPM = (1.78 * COUNT) + 180
      ACOUNT = IFIX(CPM)
      RFTURN
C
C
  100 ACOUNT = COUNT
```

```
      RETURN
      END
C
C
C
      SUBROUTINE REGR
C
C     THIS SUBROUTINE PERFORMS LINEAR REGRESSION ANALYSIS USING YEARS
C     AS THE INDEPENDENT VARIABLE AND MEAN RATINGS FOR EACH YEAR AS
C     THE DEPENDENT VARIABLE.  SEVERAL TYPICLE TRANSFORMATIONS ARE
C     APPLIED TO THE INDEPENDENT VARIABLE AND THE BEST FIT EQUATION
C     IS SELECTED BY THE HIGHEST R SQ. VALUE.  THIS SUBROUTINE ALSO
C     COMPUTES THE STANDARD ERROR OF ESTIMATE FOR THE BEST FIT EQUA.
C
      IMPLICIT INTEGER (A-Z)
      COMMON /COMREG/ RMEAN,     RGEN,      ECONS,     EVAR,     EPOW,  R2,
     1                NEXP,      EXP,       JK,        LYR,      SE,
     2                 RATHI,     RATLO
      REAL     ECONS,     EVAR,      EPOW,      R2,     EXP(20),      RSQ,
     1         MEANX,     MEANY,     MXSY,      MYSY,   MXSX,         SXY,
     2         SX2,       SY2,       B,         A,      SEE,          SE,
     3         RMEAN(10),            EX(11),    X(11),  Y(11),        SUMX,
     4         SUMY,                 SUMXY,     SUMX2,  SUMY2
      DIMENSION     RGEN(10)
C
      IF (RGEN(1) .EQ. LYR) GO TO 10
      NUM = JK + 1
      EX(1) = 0.0
      Y(1) = 100.0
      DO 15 I = 2,NUM
      K = I - 1
      EX(I) =(RGEN(K) - LYR) * 1.0
      Y(I) = RMEAN(K)
   15 CONTINUE
      GO TO 20
   10 NUM = JK
      DO 20 I = 1,NUM
      EX(I) =(RGEN(I) - LYR) * 1.0
      Y(I) = RMEAN(I)
   20 CONTINUE
      IF (NUM .EQ. 2) GO TO 30
      PASS = 0
      R2 = 0.0
      DO 30 J = 1,NEXP
```

```
      SUMX  = 0.0
      SUMY  = 0.0
      SUMXY = 0.0
      SUMX2 = 0.0
      SUMY2 = 0.0
      DO 22 I = 1,NUM
      X(I) = EX(I) ** EXP(J)
      SUMX = SUMX + X(I)
      SUMY = SUMY + Y(I)
      SUMXY = SUMXY + (X(I) * Y(I))
      SUMX2 = SUMX2 + (X(I) ** 2)
      SUMY2 = SUMY2 + (Y(I) ** 2)
   22 CONTINUE
      MEANX = SUMX / NUM
      MEANY = SUMY / NUM
      MXSY = MEANX * SUMY
      MYSY = MEANY * SUMY
      MXSX = MEANX * SUMX
      SXY = SUMXY - MXSY
      SX2 = SUMX2 - MXSX
      SY2 = SUMY2 - MYSY
      IF (SXY .EQ. 0 .OR. SX2 .EQ. 0 .OR. SY2 .EQ. 0) GO TO 30
      B = SXY / SX2
      A = MEANY - ( B * MEANX )
      SEE = SQRT (( SY2 - (B * SXY)) / (NUM - 2))
      RSQ = (SXY ** 2) / (SX2 * SY2)
      IF (RSQ .GE. 0.5) GO TO 25
      GO TO 30
   25 PASS = PASS + 1
      IF (PASS .GT. 1) GO TO 26
      R2 = RSQ
      FCONS = A
      EVAR = B
      EPOW = EXP(J)
      SE = SEE
   26 IF (RSQ .LE. R2) GO TO 30
      R2 = RSQ
      FCONS = A
      EVAR = B
      EPOW = EXP(J)
      SE = SEE
   30 CONTINUE
      IF (R2 .GT. 0) GO TO 40
      FCONS = 0
```

```
      EVAR = 0
      EPOW = 0
      SE = 0
   40 RETURN
      END
C
C
C
      SUBROUTINE RPLOT
C
C
C      THIS SUBROUTINE PLOTS A PROJECT SEGMENTS MEAN RATINGS WITH
C      RESPECT TO AGE AND PROVIDES THE MATHEMATICALLY FIT CURVE
C      THE HIGH AND LOW RATINGS FOR EACH AVAILABLE YEAR ARE ALSO
C      PLOTTED
C
C
      IMPLICIT INTEGER (A-Z)
C
      COMMON /COMREG/ RMEAN, RGEN, ECONS, EVAR, EPOW, R2,
     1                NEXP,  EXP,  JK,    LYR,  SE,
     2                RATHI, RATLO
C
      REAL RMEAN(10), ECONS, EVAR, EPOW,  R2,     EXP(20),
     1     SE,        RATHI(10),   RATLO(10),     AAGE,    RVAL
C
      DIMENSION RGEN(10), PLOT(21,92), AGE(21)
C
C
      DATA PLOT/' ','*',17*' ','*',2*' ','*',' ','P','A','V','E','M',
     1'E','N','T',' ','R','A','T','I','N','G',' ','*',2*' ','*',17*' ',
     2'*',43*' ','1',20*' ','0',3*' ','8',3*' ','6',3*' ','4',3*' ',
     3'2',4*' ','0',3*' ','0',3*' ','0',3*' ','0',3*' ','0',3*' ','0',
     421*' ','+',3*'I','+',3*'I','+',3*'I','+',3*'I','+',3*'I','+',
     5128*' ','+',3*'I','+',3*'I','+',3*'I','+',3*'I','+',3*'I','+',
     621*' ','1',3*' ','8',3*' ','6',3*' ','4',3*' ','2',3*' ','0',
     7'0',3*' ','0',3*' ','0',3*' ','0',3*' ','0',4*' ','0',64*' ',
     8'*',' ','+',' ','-',' ','*',' ','.',12*' ','*',20*' ','*',' ',
     9'=',' ','=',' ','=',' ','=',12*' ','*',22*' ','H',' ','L',' ',
     A'M',' ','C',12*' ','N',' ','I',' ','O',' ','E',' ','O',12*' ',
     B'O',' ','G',' ','W',' ','A',' ','M',12*' ','T',' ','H',3*' ',
     C'N',' ','P',12*' ','E',7*' ','U',14*' ','V',' ','V',' ','V',' ',
     D'T','V',11*' ','*',' ','A',' ','A',' ','A',' ','E','A',11*' ',
     E'*',' ','L',' ','L',' ','L',' ','D','L',11*' ','*',' ','U',' ',
```

```
     F'U',' ','U',2*' ','U',11*' ','*',' ','E',' ','E',' ','E',2*' ',
     G'E',9*' '/,PLUS/'+'/,MINUS/'-'/,AST/'*'/,PRD/'.'/,BLK/' '/
      DO 5 I = 1,21
      DO 6 J = 11,71
      PLOT(I,J) = BLK
    6 CONTINUE
    5 CONTINUE
      IF ((RGEN(JK) - LYR) .GT. 20) GO TO 16
      YR = LYR
      DO 15 I = 1,21
      AGE(I) = I - 1
   15 CONTINUE
      GO TO 17
   16 YR = RGEN(JK) - 20
      DO 17 I = 1,21
      AGE(I) = (YR - LYR) + (I - 1)
   17 CONTINUE
      LROW = 1
      AAGE = AGE(1) * 1.0
      DO 10 I = 11,71
      RVAL = ECONS + EVAR * (AAGE ** EPOW)
      IF (RVAL .LT. 0.0) RVAL = 0.0
      VAL = INT(RVAL)
      ROW1 = DETRMN(VAL)
      IF (LROW .EQ. 21) GO TO 18
      PLOT(ROW1,I) = PRD
      LROW =ROW1
   18 AAGE = AAGE + (1.0/3.0)
   10 CONTINUE
      IF (YR .EQ. LYR) PLOT(1,11) = AST
      IF (JK .EQ. 0) GO TO 20
      DO 20 I = 1,JK
      RVAL = RATHI(I)
      IF (RVAL .LT. 0.0) RVAL = 0.0
      VAL = INT(RVAL)
      ROW1 = DETRMN(VAL)
      RVAL = RATLO(I)
      IF (RVAL .LT. 0.0) RVAL = 0.0
      VAL = INT(RVAL)
      ROW2 = DETRMN(VAL)
      RVAL = RMEAN(I)
      IF (RVAL .LT. 0.0) RVAL = 0.0
      VAL = INT(RVAL)
      ROW3 = DETRMN(VAL)
```

```
      COL = ((RGEN(I) - YR) * 3) + 11
      PLOT(ROW1,COL) = PLUS
      PLOT(ROW2,COL) = MINUS
      PLOT(ROW3,COL) = AST
   20 CONTINUE
C
      PYR = YR
      PYR5 = PYR + 5
      PYR10 = PYR + 10
      PYR15 = PYR + 15
      PYR20 = PYR + 20
      AG= AGE(1)
      AG5 = AG + 5
      AG10 = AG + 10
      AG15 = AG + 15
      AG20 = AG + 20
      IF (PYR .GT. 99) PYR = PYR - 100
      IF (PYR5 .GT. 99) PYR5 = PYR5 - 100
      IF (PYR10 .GT. 99) PYR10 = PYR10 - 100
      IF (PYR15 .GT. 99) PYR15 = PYR15 - 100
      IF (PYR20 .GT. 99) PYR20 = PYR20 - 100
      WRITE (6,601)
  601 FORMAT (//' ',T53,'*',5X'*'/' ',T53,'* AGE *'/' ',T53,'*',5X,
     1       '*'//)
      WRITE (6,602) AG,  AG5,  AG10,  AG15,  AG20
  602 FORMAT (' ',T25,5(I2,13X))
      WRITE (6,603)
  603 FORMAT (' ',T25,'+',20('--+'),' ')
C
      DO 100 I = 1,21
      WRITE (6,604) (PLOT(I,J),J=1,92)
  604 FORMAT (' ',T16,92A1)
  100 CONTINUE
C
      WRITE (6,603)
      WRITE (6,602)  PYR,  PYR5,  PYR10,  PYR15,  PYR20
      WRITE (6,605)
  605 FORMAT (//' ',T52,'*',6X,'*'/' ',T52,'* YEAR *'/' ',T52,
     1       '*',6X,'*')
      RETURN
      END
C
C
C
```

```
INTEGER FUNCTION DETRMN(VAL)
INTEGER ROW, VAL
IF (VAL .GE. 96) ROW = 1
IF (VAL .LT. 96 .AND. VAL .GE. 91) ROW = 2
IF (VAL .LT. 91 .AND. VAL .GE. 86) ROW = 3
IF (VAL .LT. 86 .AND. VAL .GE. 81) ROW = 4
IF (VAL .LT. 81 .AND. VAL .GE. 76) ROW = 5
IF (VAL .LT. 76 .AND. VAL .GE. 71) ROW = 6
IF (VAL .LT. 71 .AND. VAL .GE. 66) ROW = 7
IF (VAL .LT. 66 .AND. VAL .GE. 61) ROW = 8
IF (VAL .LT. 61 .AND. VAL .GE. 56) ROW = 9
IF (VAL .LT. 56 .AND. VAL .GE. 51) ROW = 10
IF (VAL .LT. 51 .AND. VAL .GE. 46) ROW = 11
IF (VAL .LT. 46 .AND. VAL .GE. 41) ROW = 12
IF (VAL .LT. 41 .AND. VAL .GE. 36) ROW = 13
IF (VAL .LT. 36 .AND. VAL .GE. 31) ROW = 14
IF (VAL .LT. 31 .AND. VAL .GE. 26) ROW = 15
IF (VAL .LT. 26 .AND. VAL .GE. 21) ROW = 16
IF (VAL .LT. 21 .AND. VAL .GE. 16) ROW = 17
IF (VAL .LT. 16 .AND. VAL .GE. 11) ROW = 18
IF (VAL .LT. 11 .AND. VAL .GE. 6) ROW = 19
IF (VAL .LT. 6 .AND. VAL .GE. 1) ROW = 20
IF (VAL .LT. 1) ROW = 21
DETRMN = ROW
RETURN
END
```

INTERPRETING PARAMETERS

DATA SET

```
000000000020253035000000051530051015101520                    00000100
000000000035404550000000153045101520152025                    00000200
000000000050556065000000304560152025202530                    00000300
000000000020253035000000051530051015101520                    00000400
000000000035404550000000153045101520152025                    00000500
000000000050556065000000304560152025202530                    00000600
 0  0 51020  0  0  0  0 51015  0  0  0 51020  0  0  0         00000700
 0 0102035  0  0  0 0102030  0  0 0102030  0  0  0            00000800
 0 0153050  0  0  0 0153550  0  0 0153040  0  0  0            00000900
158180.75001                                                  00001000
0.500.751.001.251.501.752.002.252.502.753.003.253.503.754.00  00001100
100.0       100.0       100.0       100.0                     00001200
-12.5000    -12.5000    -12.5000    -12.5000                  00001300
 1.50        1.50        1.50        1.50                     00001400
100.0       100.0       100.0       100.0                     00001500
-0.00289    -0.27778    -0.02743    -0.00539                  00001600
 4.00        3.00        3.50        3.75                     00001700
100.0       100.0       100.0       100.0                     00001800
-0.00015    -0.00015    -0.00015    -0.00015                  00001900
 4.00        4.00        4.00        4.00                     00002000
3.00  2.00  1.00  1.00                                        00002100
3.00  2.00  1.00  1.00                                        00002200
3.00  2.00  1.00  1.00                                        00002300
3.00  2.50  1.50  1.50                                        00002400
3.00  2.50  1.50  1.50                                        00002500
3.00  2.50  1.50  1.50                                        00002600
2.00  2.00  3.00  4.00                                        00002700
2.00  2.00  3.00  4.00                                        00002800
2.00  2.00  3.00  4.00                                        00002900
2.00  1.50  1.00  1.00                                        00003000
2.25  1.75  1.25  1.00                                        00003100
2.50  2.00  1.50  1.25                                        00003200
```

APPENDIX B

OPTIMIZING SOURCE PROGRAM

```fortran
C
C     OPTIMIZING PROGRAM (OPTAL)
C
C
C     THIS IS THE MAIN PROGRAM FOR OPTIMIZING FROM I1OUT.DATA
C     IT UTILIZES SUBROUTINES: ROPTPM, WDESCR, RATES, VALSTR,
C                              OPTAL, EVAL, SORT,    WROUT1
C
C
C     IT ALSO UTILIZES HCT.OPT.LIB.DATA(PARMOPT) AS INPUT TO ROPTPM
C
C
      IMPLICIT INTEGER (A-Z)
C
C     SETUP COMMON AREAS BETWEEN MAIN-WROUT1, MAIN-RATES, MAIN-EVAL
C     AND MAIN-ROPTPM
C
C
      COMMON /DESCRP/   CS,         BCSMP,      ECSMP,      DIST,       SR,
     1                  BSRMP,      ESRMP,      LANE,       SP,
     2                  SNUM,       CTYP,       SURF,       THK,        MNTH,
     3                  BASF,       R2,         SE,         TI,         NPRJ,
     4                  GEN(9),     GAGE(9),    RATING(9),HISK(9),      LOSK(9),
     5                  AVGSK(9),   LIFE60,     LIFE40,     LIFE20,     RIDER(9),
     6                  STRUCR(9),              GOOD,       KADT,       DADT,
     7                  RATHI(9),   RATLO(9),   SEQ
C
C
      COMMON /MANVAL/   LENG,       HWYT,       NLANES,     RDW,        RSH,
     1                  LSH,        ADT,        GRW,        SU,         COMB,
     2                  REHAB(3),   FC,         YR,         ECONS,      EVAR,
     3                  FPOW,       UR
C
C
      COMMON /RPMRAT/   NPRDS,         LPRDS,         YEAR,          TRAFYR,
     1                  EFFINT,        SHOULD(5),     MUSTA(5),      DES(10,6),
     2                  CONSTC(10),    EQUAF(10),     MAXRAT(10),    BETA(30),
     3                  TFACT(3),      EXFACT(4),     TIR(4),        OTHK(10),
     4                  MS(10),        AEQ(10),       BEQ(10),       CEQ(10),
     5                  FTMTPX(5,5,3),       RMATRX(10,3),           NETPRD
C
C
```

```
      REAL                      ECONS,   EVAR,    EPOW,    R2,      SE,
     1                          TI,      GRW,     RATING,  LIFE60,  LIFE40,
     2                          TIR,     AEQ,     BEQ,     CEQ,     EQUAF,
     3                          LIFE20,  RIDER,   STRUCR,  MUSTA,   SHOULD,
     4                          TFACT,   FXFACT,  MS,      RATHI,   RATLO
C
C
      CALL ROPTPM (NOPR)
C
      NPC = NPRDS
C
    5 NPRJ = 0
C
  100 READ (5,501,END=999) GOOD,    CS,      RCSMP,   ECSMP,   SEQ,      DIST,
     1                     SR,      BSRMP,   ESRMP,   LENG,    UR,       FC,
     2                     LANE,    HWYT,    NLANES,  RDW,     RSH,
     3                     LSH,     SP,      SNUM,    CTYP,    SURF,
     4                     THK,     MNTH,    YR,      BASE,    ADT,      GRW,
     5                     SU,      COMB,    KADT,    DADT,    TI,     ECONS,
     6                     EVAR,    FPOW,    R2,      SE,      LIFE60,
     7                     LIFE40,  LIFE20,  (GEN(I),GAGE(I),RIDER(I),
     8                     STRUCR(I),RATING(I),RATHI(I),RATLO(I),
     9                     HISK(I),LOSK(I),AVGSK(I),I=1,6)
C
  501 FORMAT (I1,3I4,I3,A1,A3,2I5,I4,A1,I1,A1,2I1,3I2,A1,A4,3I2,A1,
     1        2I2,I6,F3.1,4I2,F3.1,F6.2,F9.5,F4.2,F7.5,4F5.2,3X,
     2        6(2I2,F5.2,4F5.1,3I2))
C
      IF (TI .LT. TIR(1)) J = 1
      IF (TI .GE. TIR(1) .AND. TI .LT. TIR(2)) J = 2
      IF (TI .GE. TIR(2) .AND. TI .LT. TIR(3)) J = 3
      IF (TI .GE. TIR(3) .AND. TI .LT. TIR(4)) J = 4
      IF (TI .GE. TIR(4)) J = 5
      K = 2
      IF (SURF .GE. 40) K = 1
      IF (SURF .GE. 30 .AND. SURF .LT. 40) K = 3
      I = FC
      NUM = FTMTRX(I,J,K)
      DO 10 L = 1,3
      REHAB(L) = RMATRX(NUM,L)
   10 CONTINUE
C
      DO 20 I=1,10
      IF (K .EQ. 1) EQUAF(I) = AEQ(I)
```

```
      IF (K .EQ. 2) EQUAF(I) = BEQ(I)
      IF (K .EQ. 3) EQUAF(I) = CEQ(I)
   20 CONTINUE
C
   40 NPRJ = NPRJ + 1
C
      CALL RATES
C
      CALL VALSTR
C
      CALL OPTAL
C
   50 CALL WROUT1
C
      NPRDS = NPC
C
      GO TO 100
  999 CONTINUE
      END FILE 9
      STOP
      END
C
C
C
      SUBROUTINE ROPTPM (NOPR)
C
C
C     THIS SUBROUTINE READS ALL OPTIMIZING PARAMETERS FOR OPT1
C
C
      IMPLICIT INTEGER (A-Z)
C
C
      COMMON /DESCRP/  CS,        BCSMP,     ECSMP,     DIST,      SR,
     1                 BSRMP,     ESRMP,     LANE,      SP,
     2                 SNUM,      CTYP,      SURF,      THK,       MNTH,
     3                 BASE,      R2,        SE,        TI,        NPRJ,
     4                 GEN(9),    GAGE(9),   RATING(9),HISK(9),    LOSK(9),
     5                 AVGSK(9),  LIFE60,    LIFE40,    LIFE20,    RIDER(9),
     6                 STRUCR(9),            GOOD,      KADT,      DADT,
     7                 RATHI(9),  RATLO(9),  SEQ
C
C
      COMMON /MANVAL/  LENG,      HWYT,      NLANES,    RDW,       RSH,
```

```
     1                LSH,      ADT,       GRW,       SU,        COMB,
     2                REHAB(3), FC,        YR,        ECONS,     EVAR,
     3                EPOW,     UR
C
C
      COMMON /RPMRAT/ NPRDS,       LPRDS,       YEAR,         TRAFYR,
     1                EFFINT,      SHOULD(5),   MUSTA(5),     DES(10,6),
     2                CONSTC(10),  EQUAF(10),   MAXRAT(10),   BETA(30),
     3                TFACT(3),    EXFACT(4),   TIR(4),       OTHK(10),
     4                MS(10),      AEQ(10),     BEQ(10),      CEQ(10),
     5                FTMTRX(5,5,3),            RMATRX(10,3),  NETPRD
C
C
      COMMON /NOCOST/ NOTCOS,      NOMC,        NOPC,       NOUC
C
C
      REAL      TI,       GRW,      RATING,   LIFE60, LIFE40, LIFE20,
     1          RIDER,    STRUCR,   LPRDS,    EFFINT, SHOULD, MUSTA,
     2          BETA,     RATHI,    RATLO,    TFACT,  EXFACT, MS,
     3          OTHK,     TIR,      AEQ,      BEQ,    CEQ,    EQUAF,
     4          MAXRAT,   R2,       SE,       EVAR,   EPOW,   ECONS
C
C
C
C     READ PRESENT YEAR, TRAFFIC YEAR, NUMBER OF PERIODS BEING
C     CONSIDERED, LENGTH OF PERIODS, EFFECTIVE INTEREST, AND CONSTANT
C     IF LISTING THE OPTIMIZING PARAMETERS IS NOT DESIRED.
C
      READ (4,401) YEAR,TRAFYR,NPRDS,NETPRD,LPRDS,EFFINT,NOPR
  401 FORMAT (4I2,F4.2,F4.2,I1)
C
C
C     READ THICKNESS FACTORS FOR DETERMINING EQUATIONS FOR ALTS
C
      READ (4,404) (TFACT(I), I = 1,3)
  404 FORMAT (3(4X,F3.2))
C
C     READ EQUATION FACTORS FOR DETERMINING EQUATIONS FOR ALTS
C     WHEN THE ORIGINAL PAVEMENT HAS BEEN OVERLAYED BEFORE
C
      READ (4,405) (EXFACT(I), I = 1,4)
  405 FORMAT (4(F4.2,3X))
C
```

```
C
C     READ SHOULD AND MUST LEVELS TO BE USED FOR EACH FUNC CLASS
C
C
      READ (4,402) (SHOULD(K),K=1,5)
      READ (4,402) (MUSTA(K),K=1,5)
  402 FORMAT (5F2.0)
C
C
C     READ TI SEGMENT BREAKS
C
C
      READ (4,409) (TIR(I),I=1,4)
  409 FORMAT (4F3.1)
C
C
C     READ FTMTRX WHICH IS FUNCTIONAL CLASS BY TI BY SURFACE TYPE
C
C
      DO 40 K = 1,3
      DO 30 I = 1,5
      READ (4,407) (FTMTRX(I,J,K),J=1,5)
  407 FORMAT (5I1)
   30 CONTINUE
   40 CONTINUE
C
C
C     READ RMATRX WHICH ARE REHABILITATION ALTERNATIVES TO BE SELECTED
C
C
      DO 50 I = 1,9
      READ (4,408) (RMATRX(I,J),J=1,3)
  408 FORMAT (3I1)
   50 CONTINUE
C
C
C     READ REHABILITATION ALTERNATIVE CARDS
C     EACH CARD CONTAINS:
C                                THE DESCRIPTION OF THE ALTERNATIVE
C                                CONSTRUCTION COST PER 12 FT LANE MILE
C                                TRAFFIC INTERRUPTION COST FACTORS
C                                EQUATION FACTOR FOR ALTERNATIVE
C                                CONSTANT SLOPE FACTOR
C
```

```
C
C
      DO 10 I=1,10
      READ (4,403) (DES(I,J),J=1,6),  CONSTC(I),  OTHK(I),
     1                AEQ(I),  BEQ(I),  CEQ(I),  MAXRAT(I),  MS(I)
  403 FORMAT (6A4,I8,F3.2,3F4.2,F6.2,F7.5)
   10 CONTINUE
C
C
      READ (4,406) NOTCOS,NOMC,NOPC,NOUC
  406 FORMAT (4I2)
C
C
C       SETUP BETA FACTORS FOR CONSIDERATION PERIOD
C
C
      DO 20 I=1,NPRDS
      BETA(I) = 1.0 / ((1.0 + EFFINT) ** (I * LPRDS))
   20 CONTINUE
C
C
      RETURN
      END
C
C
C
      SUBROUTINE RATES
C
C
C     THIS SUBROUTINE SETS UP THE EQUATIONS FOR THE ALTERNATIVES
C     AND THEN SETS UP THE ARRAY OF RATINGS FOR EACH PERIOD IN
C     EACH ALTERNATIVE INCLUDING THE ORIGINAL PAVEMENT
C
C
      IMPLICIT INTEGER (A-Z)
C
C
      COMMON /MANVAL/  LENG,       HWYT,      NLANES,    RDW,       RSH,
     1                 LSH,        ADT,       GRW,       SU,        COMB,
     2                 REHAB(3),   FC,        YR,        ECONS,     EVAR,
     3                 EPOW,       UR
C
C
C
```

```
C
      COMMON /RPMRAT/   NPRDS,       LPRDS,       YEAR,        TRAFYR,
     1                  EFFINT,      SHOULD(5),   MUSTA(5),    DES(10,6),
     2                  CONSTC(10),  EQUAF(10),   MAXRAT(10),  BETA(30),
     3                  TFACT(3),    EXFACT(4),   TIR(4),      OTHK(10),
     4                  MS(10),      AEQ(10),     BEQ(10),     CEQ(10),
     5                  FTMTRX(5,5,3),    RMATRX(10,3),        NETPRD
C
C
C
C
      COMMON /RATOUT/   MR(4),     RC(4),     RP(4),       MINL(4),
     1                  SHUD,      MUST,      CRAGE(4),    MAXL(4),
     2                  SHUDP(4),  MUSTP(4),  RATE(4,30),  BSLIFE
C
C
      COMMON /DESCRP/   CS,        BCSMP,     ECSMP,     DIST,      SR,
     1                  BSRMP,     ESRMP,     LANE,      SP,
     2                  SNUM,      CTYP,      SURF,      THK,       MNTH,
     3                  BASE,      R2,        SE,        TI,        NPRJ,
     4                  GEN(9),    GAGE(9),   RATING(9),HISK(9),    LOSK(9),
     5                  AVGSK(9),  LIFE60,    LIFE40,    LIFE20,    RIDER(9),
     6                  STRUCR(9),            GOOD,      KADT,      DADT,
     7                  RATHI(9),  RATLO(9),  SEQ
C
C
      REAL  GRW,       ECONS,     EVAR,      EPOW,      LPRDS,     EFFINT,
     1      SHOULD,    MUSTA,     EQUAF,     MAXRAT,    BETA,      OTHK,
     2      MR,        RC,        RP,        SHUD,      MUST,      CRAGE,
     3      RATE,      FACTOR,    MINL,      MAXL,      RATING,    LIFE60,
     4      LIFE40,    LIFE20,    RIDER,     STRUCR,    CRTIME,    NETTIM,
     5      RATHI,     RATLO,     THIK,      TFACT,     EXFACT,    MS,
     6      MSL,       BSLIFE
C
C
C     SET UP EQUATIONS FOR ALTERNATIVES TO BE CONSIDERED BY EVALUATING
C     EQUATION FOR EXISTING PAVEMENT WITH INPUT CRITICAL LEVEL.
C     THE LIFE OF EACH ALTERNATIVE IS THEN A RATIO OF THE LIFE OF THE
C     EXISTING PAVEMENT.
C
      MR(1) = ECONS
      RC(1) = EVAR * (-1.0)
      RP(1) = EPOW
      K = FC
```

```
      SHUD = SHOULD(K)
      MUST = MUSTA(K)
      CRAGE(1) = ((MR(1) - MUST)/RC(1)) ** (1/RP(1))
      NETTIM = ((YEAR + NETPRD) - YR) * 1.0
      IF (CRAGE(1) .GE. NETTIM) NPRDS = NETPRD
      IF (CRAGE(1) .GE. NETTIM) GO TO 200
      CRTIME = ((YEAR + NPRDS) - YR) * 1.0
      IF (CRAGE(1) .GE. CRTIME) GO TO 200
      IF (CRAGE(1) .GT. 40.0) CRAGE(1) = 40.0
      IF (CRAGE(1) .LT. 4) CRAGE(1) = 4
      BSLIFE = CRAGE(1)
C
      IF (CTYP.GE.20.AND.CTYP.LT.30.AND.SURF.GE.40) GO TO 100
      GO TO 105
C
  100 THIK = THK * .01
      IF (THIK .LE. TFACT(1)) Z = 1
      IF (THIK .GT. TFACT(1) .AND. THK .LE. TFACT(2)) Z = 2
      IF (THIK .GT. TFACT(2) .AND. THK .LE. TFACT(3)) Z = 3
      IF (THIK .GT. TFACT(3)) Z = 4
      BSLIFE = BSLIFE / EXFACT(Z)
C
  105 DO 110 I = 1,3
      M = REHAB(I)
      FACTOR = EQUAF(M)
      MSL = MS(M)
      N = I + 1
      CRAGE(N) = BSLIFE * FACTOR
      RP(N) = (ALOG10((100 - MUST) / MSL)) / ALOG10(CRAGE(N))
      IF (RP(N) .LT. 0.50) RP(N) = 0.50
      IF (RP(N) .GT. 4.00) RP(N) = 4.00
      MR(N) = MAXRAT(M)
      RC(N) = MSL
  110 CONTINUE
C
C     CALCULATE THE RATINGS FOR EACH PERIOD FOR EACH ALTERNATIVE
C     CALCULATE THE SHOULD OVERLAY PERIOD OF EACH ALTERNATE
C     CALCULATE THE MUST OVERLAY PERIOD OF EACH ALTERNATE
C
  120 AGE = YEAR - YR
   90 DO 70 I=1,4
      KSHUD = 0
      KMUST = 0
      DO 80 K = 1,NPRDS
```

```
      IF (I .EQ. 1) GO TO 20
      GO TO 30
   20 RATE(I,K) = MR(I) - RC(I) * ((K+AGE)**RP(I))
      IF (RATE(I,K) .LT. 0) RATE(I,K)=0.0
      GO TO 40
   30 RATE(I,K) = MR(I) - RC(I) * (K**RP(I))
      IF (RATE(I,K) .LT. 0) RATE(I,K)=0.0
   40 IF (KSHUD .EQ. 1) GO TO 50
      IF (RATE(I,K) .LT. SHUD) KSHUD=1
      IF (KSHUD .EQ. 1) SHUDP(I) = K-1
      IF (SHUDP(I) .EQ. 0) SHUDP(I)=1
   50 IF (KMUST .EQ. 1) GO TO 80
      IF (RATE(I,K) .LT. MUST) KMUST=1
      IF (KMUST .EQ. 1) MUSTP(I) = K-1
      IF (MUSTP(I) .EQ. 0) MUSTP(I)=1
      IF (K .EQ. NPRDS .AND. KSHUD .EQ. 0) SHUDP(I)= NPRDS
      IF (K .EQ. NPRDS .AND. KMUST .EQ. 0) MUSTP(I)= NPRDS
   80 CONTINUE
   70 CONTINUE
C
C
C     CALCULATE THE MINIMUM LIFE EXPECTANCY AND MAXIMUM LIFE
C     EXPECTANCY FOR THE EXISTING PAVEMENT AND EACH OF THE REHAB
C     ALTERNATIVES, BASED ON THE SHOULD AD MUST LEVELS
C
      DO 95 I = 1,4
      MINL(I) = ((MR(I) - SHUD) / RC(I)) ** (1 / RP(I))
      MAXL(I) = ((MR(I) - MUST) / RC(I)) ** (1 / RP(I))
      IF (MINL(I) .GT. 99.0) MINL(I) = 99.0
      IF (MAXL(I) .GT. 99.0) MAXL(I) = 99.0
   95 CONTINUE
C
C
      RETURN
  200 AGE = YEAR - YR
      RSLIFE = CRAGE(1)
      SHUDP(1) = 30
      MUSTP(1) = 30
      MINL(1) = ((MR(1) - SHUD) / RC(1)) ** (1/RP(1))
      MAXL(1) = ((MR(1) - MUST) / RC(1)) ** (1/RP(1))
      IF (MINL(1) .GT. 99.0) MINL(1) = 99.0
      IF (MAXL(1) .GT. 99.0) MAXL(1) = 99.0
      DO 210 I = 1,30
      RATE(1,I) = MR(1) - RC(1) * ((I + AGE) ** RP(1))
```

```
  210 CONTINUE
      DO 220 I = 2,4
      MR(I) = MR(1)
      RC(I) = RC(1)
      RP(I) = RP(1)
      MINL(I) = MINL(1)
      MAXL(I) = MAXL(1)
      CRAGE(I) = CRAGE(1)
      SHUDP(I)= SHUDP(1)
      MUSTP(I) = MUSTP(1)
      DO 230 J = 1,30
      RATE(I,J) = RATE(1,J)
  230 CONTINUE
  220 CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE VALSTR
C
C
C
C
C     THIS SUBROUTINE SELECTS ALL VALID STRATEGIES BASED ON SHOULD
C     AND MUST PERIODS COMPUTED FOR THE EXISTING PAVEMENT AND EACH
C     REHABILITATION ALTERNATIVE.
C
      IMPLICIT INTEGER (A-Z)
C
C
      COMMON /STROPT/  PRD1(2000), PRD2(2000), PRD3(2000), PRD4(2000),
     1                 ALT1(2000), ALT2(2000), ALT3(2000), ALT4(2000)
C
C
C
C
      COMMON /RPMRAT/  NPRDS,       LPRDS,       YEAR,        TRAFYR,
     1                 EFFINT,      SHOULD(5),   MUSTA(5),    DES(10,6),
     2                 CONSTC(10),  EQUAF(10),   MAXRAT(10),  BETA(30),
     3                 TFACT(3),    EXFACT(4),   TIR(4),      OTHK(10),
     4                 MS(10),      AEQ(10),     REQ(10),     CEQ(10),
     5                 FTMTRX(5,5,3),    RMATRX(10,3),        NETPRD
```

```
C
C
C
C
      COMMON /RATOUT/  MR(4),      RC(4),      RP(4),        MINL(4),
     1                 SHUD,       MUST,       CRAGE(4),     MAXL(4),
     2                 SHUDP(4),   MUSTP(4),   RATE(4,30),   BSLIFE
C
C
C
C
      COMMON /STROUT/  ST
C
C
C
C
      REAL  SHUD,      MUST,      LPRDS,     EFFINT,    SHOULD,    MUSTA,
     1      EQUAF,     MAXRAT,    BETA,      OTHK,      MR,        RC,
     2      RP,        CRAGE,     RATE,      TFACT,     EXFACT,    MS
C
C
      DO 10 K=1,2000
      ALT1(K) = 0
      ALT2(K) = 0
      ALT3(K) = 0
      ALT4(K) = 0
      PRD1(K) = 0
      PRD2(K) = 0
      PRD3(K) = 0
      PRD4(K) = 0
   10 CONTINUE
C
C     SELECT ALL VALID STRATEGIES
C
C
C     SELECT ALL POSSIBLE 2 COMBINATION STRATEGIES
C
      ST = 0
      N1=SHUDP(1)
      N2=MUSTP(1)
      TOPRD=MUSTP(1)
      IF (TOPRD .GE. NPRDS) GO TO   20
      GO TO   21
   20 ST = 1
```

```
      ALT1(ST)=1
      GO TO 50
21    DO    22 I1=2,4
      IF  (MUSTP(1)+MUSTP(I1).GE.NPRDS)  GO TO    23
      GO TO    22
23    DO    24 K=N1,N2
      IF  (K+MUSTP(I1).LT.NPRDS)  GO TO    24
      ST = ST + 1
      ALT1(ST)=I1
      PRD1(ST)=K
24    CONTINUE
22    CONTINUE
      DO    25 I2=2,4
      DO    26 J2=2,4
      IF  (MUSTP(1)+MUSTP(I2)+MUSTP(J2).GE.NPRDS)  GO TO    27
      GO TO    26
27    DO    28 K=N1,N2
      IF  (K+MUSTP(I2)+MUSTP(J2).LT.NPRDS)  GO TO    28
      N3=SHUDP(I2)
      N4=MUSTP(I2)
      DO    29 L=N3,N4
      IF  (K+L+MUSTP(J2).LT.NPRDS)  GO TO    29
      IF  (K+L  .GE.  NPRDS)  GO TO    29
      ST = ST + 1
      ALT1(ST)=I2
      ALT2(ST)=J2
      PRD1(ST)=K
      PRD2(ST)=K+L
29    CONTINUE
28    CONTINUE
26    CONTINUE
25    CONTINUE
C
C     SELECT ALL POSSIBLE 3 COMBINATION STRATEGIES
C
      DO    30 I3=2,4
      DO    31 J3=2,4
      DO    32 K3=2,4
      IF  (MUSTP(1)+MUSTP(I3)+MUSTP(J3)+MUSTP(K3).GE.NPRDS)  GO TO    33
      GO TO    32
33    DO    34 K=N1,N2
      IF  (K+MUSTP(I3)+MUSTP(J3)+MUSTP(K3).LT.NPRDS)  GO TO    34
      N5=SHUDP(I3)
      N6=MUSTP(I3)
```

```
      DO    35 L=N5,N6
      IF  (K+L+MUSTP(J3)+MUSTP(K3).LT.NPRDS)  GO TO    35
      N7=SHUDP(J3)
      N8=MUSTP(J3)
      DO    36 M=N7,N8
      IF  (K+L+M+MUSTP(K3).LT.NPRDS)  GO TO    36
      IF  (K+L+M  .GE. NPRDS)  GO TO    36
      ST = ST + 1
      ALT1(ST)=I3
      ALT2(ST)=J3
      ALT3(ST)=K3
      PRD1(ST)=K
      PRD2(ST)=K+L
      PRD3(ST)=K+L+M
   36 CONTINUE
   35 CONTINUE
   34 CONTINUE
   32 CONTINUE
   31 CONTINUE
   30 CONTINUE
C
C     SELECT ALL POSSIBLE 4 COMBINATION STRATEGIES
C
      DO    37 I4=2,4
      DO    38 J4=2,4
      DO    39 K4=2,4
      DO    40 L4=2,4
      IF  (MUSTP(1)+MUSTP(I4)+MUSTP(J4)+MUSTP(K4)+MUSTP(L4).GE.NPRDS)
     1GO TO    41
      GO TO    40
   41 DO    42 K=N1,N2
      IF  (K+MUSTP(I4)+MUSTP(J4)+MUSTP(K4)+MUSTP(L4).LT.NPRDS)  GO TO    42
      N9=SHUDP(I4)
      N10=MUSTP(I4)
      DO    43 L=N9,N10
      IF  (K+L+MUSTP(J4)+MUSTP(K4)+MUSTP(L4).LT.NPRDS)  GO TO    43
      N11=SHUDP(J4)
      N12=MUSTP(J4)
      DO    44 M=N11,N12
      IF  (K+L+M+MUSTP(K4)+MUSTP(L4).LT.NPRDS)  GO TO    44
      N13=SHUDP(K4)
      N14=MUSTP(K4)
      DO    45 N=N13,N14
      IF  (K+L+M+N+MUSTP(L4).LT.NPRDS)  GO TO    45
```

```
      IF (K+L+M+N .GE. NPRDS) GO TO   45
      ST = ST + 1
      ALT1(ST)=I4
      ALT2(ST)=J4
      ALT3(ST)=K4
      ALT4(ST)=L4
      PRD1(ST)=K
      PRD2(ST)=K+L
      PRD3(ST)=K+L+M
      PRD4(ST)=K+L+M+N
   45 CONTINUE
   44 CONTINUE
   43 CONTINUE
   42 CONTINUE
   40 CONTINUE
   39 CONTINUE
   38 CONTINUE
   37 CONTINUE
   50 RETURN
      END
C
C
C
C
C
C
      SUBROUTINE OPTAL
C
C
C     THIS SUBROUTINE WHEN USED IN AN OPTIMIZING MAIN PROGRAM
C     PRODUCES THE TOP 30 STRATEGIES BASED ON TOTAL COST.
C     IT USES SUBROUTINES EVAL AND SORTAL
C
C
      IMPLICIT INTEGER (A-Z)
C
C
      COMMON /OPTVAL/  MU1,      MU2,      MU3,      MU4,
     1                 NU1,      NU2,      NU3,      NU4,
     2                 MC,       CCOS,     TCOS,     UC,
     3                 SAL,      TOT
C
C
C
```

```
C
      COMMON /OPTOUT/  A1(40),    A2(40),    A3(40),    A4(40),
     1                 P1(40),    P2(40),    P3(40),    P4(40),
     2                 MCOST(40),CCOST(40),TICOST(40),UCOST(40),
     3                 SALV(40), TOTAL(40),TST(40),   DIFST
C
C
C
C
      COMMON /STROPT/  PRD1(2000), PRD2(2000), PRD3(2000), PRD4(2000),
     1                 ALT1(2000), ALT2(2000), ALT3(2000), ALT4(2000)
C
C
C
C
      COMMON /STROUT/  ST
C
C
C
C
      EVALUATE ALL STRATEGIES
C
      DO 30 L=1,40
      TST(L)=0
      A1(L) = 0
      A2(L) = 0
      A3(L) = 0
      A4(L) = 0
      P1(L) = 0
      P2(L) = 0
      P3(L) = 0
      P4(L) = 0
   30 CONTINUE
      I = 0
      DIFST = 0
      IF (ST .EQ. 1) GO TO 50
      DO 10 K=1,ST
      MU1=PRD1(K)
      MU2=PRD2(K)
      MU3=PRD3(K)
      MU4=PRD4(K)
      NU1=ALT1(K)
      NU2=ALT2(K)
      NU3=ALT3(K)
      NU4=ALT4(K)
```

```
C
C
      CALL EVAL
C
C
      IF (K .GT. 1) GO TO 12
   11 I = I + 1
      MCOST(I)=MC
      CCOST(I)=CCOS
      TICOST(I)=TCOS
      UCOST(I)=UC
      SALV(I)=SAL
      TOTAL(I)=TOT
      A1(I)=NU1
      A2(I)=NU2
      A3(I)=NU3
      A4(I)=NU4
      P1(I)=MU1
      P2(I)=MU2
      P3(I)=MU3
      P4(I)=MU4
      TST(I)=TST(I) + 1
      GO TO 10
   12 DO 20 J=1,I
      IF (NU1 .EQ. A1(J) .AND. MU1 .EQ. P1(J)) GO TO 13
   20 CONTINUE
      GO TO 11
   13 IF (TOT .LT. TOTAL(J)) GO TO 14
      TST(J)=TST(J) + 1
      GO TO 10
   14 MCOST(J)=MC
      CCOST(J)=CCOS
      TICOST(J)=TCOS
      UCOST(J)=UC
      SALV(J)=SAL
      TOTAL(J)=TOT
      A1(J)=NU1
      A2(J)=NU2
      A3(J)=NU3
      A4(J)=NU4
      P1(J)=MU1
      P2(J)=MU2
      P3(J)=MU3
      P4(J)=MU4
```

```
      TST(J)=TST(J) + 1
   10 CONTINUE
      DIFST = I
C
C
C     SORT ALL DIFFERENT STRATEGIES IN ORDER OF INCREASING TOTAL COST
C
C
C
      CALL SORT
C
C
      RETURN
C
C
   50 MU1=PRD1(1)
      MU2=PRD2(1)
      MU3=PRD3(1)
      MU4=PRD4(1)
      NU1=ALT1(1)
      NU2=ALT2(1)
      NU3=ALT3(1)
      NU4=ALT4(1)
C
C
      CALL EVAL
C
C
      MCOST(1)=MC
      CCOST(1)=CCOS
      TICOST(1)=TCOS
      UCOST(1)=UC
      SALV(1)=SAL
      TOTAL(1)=TOT
      A1(1)=NU1
      A2(1)=NU2
      A3(1)=NU3
      A4(1)=NU4
      P1(1)=MU1
      P2(1)=MU2
      P3(1)=MU3
      P4(1)=MU4
      TST(1)= 1
      DIFST = 1
```

```
      RETURN
      END
C
C
C
      SUBROUTINE EVAL
C
C
C
C     THIS SUBROUTINE EVALUATES TOTAL STRATEGY COST BY APPLYING EACH
C     COST MODEL TO EACH PERIOD OF THE STRATEGY.  THE TOTAL STRATEGY
C     COST IS THE SUM OF THE COSTS FOR EACH PERIOD
C
C
      IMPLICIT INTEGER (A-Z)
C
C
      COMMON /RATOUT/  MR(4),     RC(4),     RP(4),       MINL(4),
     1                 SHUD,      MUST,      CRAGE(4),    MAXL(4),
     2                 SHUDP(4),  MUSTP(4),  RATE(4,30),  BSLIFE
C
C
C
C
      COMMON /OPTVAL/  MU1,       MU2,       MU3,       MU4,
     1                 NU1,       NU2,       NU3,       NU4,
     2                 MCI,       CCOSI,     TCOSI,     UCI,
     3                 SALI,      TOT
C
C
C
C
      COMMON /MANVAL/  LENG,      HWYT,      NLANES,    RDW,       RSH,
     1                 LSH,       ADT,       GRW,       SU,        COMB,
     2                 REHAB(3),  FC,        YR,        ECONS,     EVAR,
     3                 EPOW,      UR
C
C
C
C
      COMMON /RPMRAT/  NPRDS,       LPRDS,       YEAR,          TRAFYR,
     1                 EFFINT,      SHOULD(5),   MUSTA(5),      DES(10,6),
     2                 CONSTC(10),  EQUAF(10),   MAXRAT(10),    BETA(30),
```

```
     3                 TFACT(3),    EXFACT(4),  TIR(4),      OTHK(10),
     4                 MS(10),      AEQ(10),    BEQ(10),     CEQ(10),
     5                 FTMTRX(5,5,3),     RMATRX(10,3),      NETPRD
C
C
C
C
      COMMON /STROUT/  ST
C
C
C
      COMMON /NOCOST/  NOTCOS,     NOMC,       NOPC,      NOUC
C
C
C
      REAL   RTNG(30), RATE,     MC,       MSURF,    MCOS,     MAXM,
     1       MCOF,     MEXP,     BETA,     CC(4),    SURF,     CC1,
     2       CC2,      CC3,      CC4,      MPRP,     PCOF,     PEXP,
     3       CCOS,     OTHK,     VMI,      TIC1,     TIC2,
     4       TIC3,     TIC4,     TCOS,     UC,       TRKP,     UCOS,
     5       MTRC,     TCOF,     TEXP,     MVEH,     VCOF,     VEXP,
     6       TK1,      TK2,      TK3,      TK4,      GRW,      ECONS,
     7       EVAR,     EPOW,     LPRDS,    EFFINT,   SHOULD,   MUSTA,
     8       EQUAF,    MAXRAT,   SAL,      MR,       RC,       RP,
     9       SHUD,     MUST,     CRAGE,    AGE1,     AGE2,     AGE3,
     A       AGE4,     AGE5,     RP1,      RP2,      RP3,      RP4,
     B       RP5,      RP6,      LENGTH,   PADT,     DEPTH,    PCOST,
     C       MCOST,    UCOST,    TICOST,   MINL,     MAXL,     MCST,
     D       TFACT,    EXFACT,   MS
C
C
C
C       USING THE ALTERNATIVE AND PERIOD NUMBERS THAT CONSTITUTE EACH
C       STRATEGY, ESTABLISH THE ARRAY OF RATINGS FOR THE STRATEGY.
C
      PD=0
      IF (NU1 .EQ. 1) GO TO 20
      DO 10 I=1,MU1
      PD=PD+1
      RTNG(PD)=RATE(I,I)
   10 CONTINUE
      IF (MU2 .EQ. 0) GO TO 22
      GAP=MU2-MU1
      DO 11 I=1,GAP
```

```
      PD=PD+1
      RTNG(PD)=RATE(NU1,I)
   11 CONTINUE
      IF (MU3 .EQ. 0) GO TO 24
      GAP=MU3-MU2
      DO 12 I=1,GAP
      PD=PD+1
      RTNG(PD)=RATE(NU2,I)
   12 CONTINUE
      IF (MU4 .EQ. 0) GO TO 26
      GAP=MU4-MU3
      DO 13 I=1,GAP
      PD=PD+1
      RTNG(PD)=RATE(NU3,I)
   13 CONTINUE
      GAP=NPRDS-MU4
      DO 14 I=1,GAP
      PD=PD+1
      RTNG(PD)=RATE(NU4,I)
   14 CONTINUE
      GO TO 30
   20 DO 21 I=1,NPRDS
      PD=PD+1
      RTNG(PD)=RATE(1,I)
   21 CONTINUE
      GO TO 30
   22 GAP=NPRDS-MU1
      DO 23 I=1,GAP
      PD=PD+1
      RTNG(PD)=RATE(NU1,I)
   23 CONTINUE
      GO TO 30
   24 GAP=NPRDS-MU2
      DO 25 I=1,GAP
      PD=PD+1
      RTNG(PD)=RATE(NU2,I)
   25 CONTINUE
      GO TO 30
   26 GAP=NPRDS-MU3
      DO 27 I=1,GAP
      PD=PD+1
      RTNG(PD)=RATE(NU3,I)
   27 CONTINUE
C
```

```
C
C     COMPUTE THE ROUTINE MAINTENANCE COSTS FOR EACH PERIOD OF THE
C     STRATEGY AS DETERMINED BY THE RATING FOR EACH PERIOD
C
   30 MC=0
      MSURF = LENG * .01 * (FLOAT(RDW)/12)
      DO 32 I=1,NPRDS
      MCST = (MCOST(RTNG(I)))
      MCOS = MSURF * MCST * BETA(I)
      MC=MC+MCOS
   32 CONTINUE
C
C     COMPUTE THE TOTAL CONSTRUCTION COST INCLUDING THE PREP COST
C
      CC(1) = 0
      DO 60 I=1,3
      M = REHAB(I)
      N = I + 1
      CC(N) = FLOAT(CONSTC(M))
   60 CONTINUE
      SURF = (LENG * .01) * (FLOAT(RDW + RSH + LSH)/12)
      IF (NOPC .EQ. 1) MSURF = 0
      IF (NU1 .EQ. 1) GO TO 33
      CC1=((CC(NU1) * SURF) + MSURF * PCOST(RTNG(MU1))) * BETA(MU1)
      IF (MU2 .EQ. 0) GO TO 34
      CC2=((CC(NU2) * SURF) + MSURF * PCOST(RTNG(MU2))) * BETA(MU2)
      IF (MU3 .EQ. 0) GO TO 35
      CC3=((CC(NU3) * SURF) + MSURF * PCOST(RTNG(MU3))) * BETA(MU3)
      IF (MU4 .EQ. 0) GO TO 36
      CC4=((CC(NU4) * SURF) + MSURF * PCOST(RTNG(MU4))) * BETA(MU4)
      CCOS=CC1+CC2+CC3+CC4
      GO TO 37
   33 CCOS=0
      GO TO 37
   34 CCOS=CC1
      GO TO 37
   35 CCOS=CC1+CC2
      GO TO 37
   36 CCOS=CC1+CC2+CC3
   37 CONTINUE
C
C     COMPUTE THE USER COSTS DUE TO TRAFFIC INTERRUPTION DURRING
C     APPLICATION OF THE OVERLAY
C
      TRKP = (SU + COMB) * .01
```

```
      LENGTH = LENG * .01
      WIDTH = RDW + RSH + LSH
      IF (NU1 .EQ. 1) GO TO 38
      PADT = ADT * (1.0 + (GRW * MU1 * .01))
      DEPTH = OTHK(NU1)
      TIC1 = BETA(MU1) * TICOST(PADT,TRKP,LENGTH,WIDTH,
     1                         DEPTH,NLANES,HWYT,UR)
      IF (MU2 .EQ. 0) GO TO 39
      PADT = ADT * (1.0 + (GRW * MU2 * .01))
      DEPTH = OTHK(NU2)
      TIC2 = BETA(MU2) * TICOST(PADT,TRKP,LENGTH,WIDTH,
     1                         DEPTH,NLANES,HWYT,UR)
      IF (MU3 .EQ. 0) GO TO 40
      PADT = ADT * (1.0 + (GRW * MU3 * .01))
      DEPTH = OTHK(NU3)
      TIC3 = BETA(MU3) * TICOST(PADT,TRKP,LENGTH,WIDTH,
     1                         DEPTH,NLANES,HWYT,UR)
      IF (MU4 .EQ. 0) GO TO 41
      PADT = ADT * (1.0 + (GRW * MU4 * .01))
      DEPTH = OTHK(NU4)
      TIC4 = BETA(MU4) * TICOST(PADT,TRKP,LENGTH,WIDTH,
     1                         DEPTH,NLANES,HWYT,UR)
      TCOS=TIC1+TIC2+TIC3+TIC4
      GO TO 42
   38 TCOS=0
      GO TO 42
   39 TCOS=TIC1
      GO TO 42
   40 TCOS=TIC1+TIC2
      GO TO 42
   41 TCOS=TIC1+TIC2+TIC3
   42 CONTINUE
C
C     COMPUTE THE USER COSTS ASSOCIATED WITH EACH STRATEGY
C
      UC=0
      VMI=(ADT * LENG)*.01
      DO 43 I=1,NPRDS
      UCOS = (UCOST(RTNG(I),TRKP,VMI)) * BETA(I) * (1.0+(GRW* I * .01))
      UC=UC+UCOS
   43 CONTINUE
C
C     COMPUTE THE SALVAGE VALUE AT THE END OF THE CONSIDERATION PERIOD
C
```

```
      IF (MU4 .GT. 0) GO TO 44
      GO TO 45
   44 TK1=FLOAT(MUSTP(NU4)-(NPRDS-MU4))/FLOAT(MUSTP(NU4))
      SAL=(CC4*TK1)*BETA(NPRDS-MU4)
      GO TO 51
   45 IF (MU3 .GT. 0) GO TO 46
      GO TO 47
   46 TK2=FLOAT(MUSTP(NU3)-(NPRDS-MU3))/FLOAT(MUSTP(NU3))
      SAL=(CC3*TK2)*BETA(NPRDS-MU3)
      GO TO 51
   47 IF (MU2 .GT. 0) GO TO 48
      GO TO 49
   48 TK3=FLOAT(MUSTP(NU2)-(NPRDS-MU2))/FLOAT(MUSTP(NU2))
      SAL=(CC2*TK3)*BETA(NPRDS-MU2)
      GO TO 51
   49 IF (NU1 .GT. 1) GO TO 50
      SAL=0
      GO TO 51
   50 TK4=FLOAT(MUSTP(NU1)-(NPRDS-MU1))/FLOAT(MUSTP(NU1))
      SAL=(CC1*TK4)*BETA(NPRDS-MU1)
   51 MCI = IFIX(MC)
      CCOSI = IFIX(CCOS)
      TCOSI = IFIX(TCOS)
      UCI = IFIX(UC)
      SALI = IFIX(SAL)
      IF (NOTCOS .EQ. 1) TCOSI=0
      IF (NOMC .EQ. 1) MCI=0
      IF (NOUC .EQ. 1) UCI=0
      TOT = MCI + CCOSI + TCOSI + UCI - SALI
      RETURN
      END
C
C
C
      REAL FUNCTION MCOST(X)
C
C
C     THIS FUNCTION COMPUTES THE MAINTENANCE COST PER
C     LANE MILE AS RELATED TO THE CONDITION OF THE
C     PAVEMENT
C
C
      REAL MCOST
C
```

```
C
      A = ((101.26 - X) / 0.99431) ** 0.666667
C
      FX = (10 - A) / 1.18
C
      MCOST = 2826 / (1 + (2.718281828 ** (EX)))
C
C
      RETURN
      END
C
C
C
      REAL FUNCTION PCOST(RTNG)
C
C
C     THIS FUNCTION COMPUTES THE COST OF PREPARING THE
C     PAVEMENT SURFACE PRIOR TO AN OVERLAY.  THIS COST
C     VARIES WITH THE CONDITION OF THE PAVEMENT AND
C     IS RELATED TO CRACK SEALING, PRE-LEVELING, AND
C     PAVEMENT REMOVAL.
C
C
      PRATE = RTNG
      IF (PRATE .GT. 75.0) PRATE = 75.0
      IF (PRATE .LT. 1.0) PRATE = 1.0
      PCOST = 19247 - (377.42 * PRATE) - (4.7616 * (PRATE**2))
     1      + (0.25795 * (PRATE**3)) - (0.0035397 * (PRATE**4))
     2      + (1.6448E-5 * (PRATE**5))
C
C
      RETURN
      END
C
C
C
      REAL FUNCTION UCOST(RTNG,TRKP,VMI)
C
C
C
C     THIS FUNCTION COMPUTES THE USER COST DUE TO
C     THE CONDITION OF THE ROADWAY.  IT IS DIVIDED INTO TWO
C     AREAS:  COSTS ASSOCIATED WITH AUTOS, AND COSTS ASSOCIATED
C     WITH COMMERCIAL TRUCKS.
C
```

```
C
      REAL  K1,  K2
C
C
      K1 = 2.4617 - (0.15012 * RTNG) + (0.0046009 * (RTNG**2))
     1   - (7.0557E-5 * (RTNG**3)) + (5.3279E-7 * (RTNG**4))
     2   - (1.5769E-9 * (RTNG**5))
C
C
      K2 = 0.51958 - (0.030408 * RTNG) + (9.9606E-4 * (RTNG**2))
     1   - (1.6571E-5 * (RTNG**3)) + (1.3429E-7 * (RTNG**4))
     2   - (4.2019E-10 * (RTNG**5))
C
C
      UCOST = VMI * ((TRKP * K1) + ((1 - TRKP) * K2))
C
C
      RETURN
      END
C
C
C
      REAL FUNCTION TICOST(ADT,TRKP,LENGTH,WIDTH,
     1                     DEPTH,NLANES,HWYT,UR)
C
C
C     THIS FUNCTION COMPUTES THE TRAFFIC INTERRUPTION COSTS
C     INCURRED BY THE USER DURING THE APPLICATION OF A
C     REHABILITATION OVERLAY.  IT USES THE FOLLOWING
C     EQUATION TO COMPUTE TI-COST.
C
C     COST = MT * P * ADT * ((TRKP * K1) + ((1 - TRKP) * K2))
C
C     WHERE:  MT = TIME REQUIRED TO APPLY OVERLAY IN HRS / L-MILE
C             P = PERCENTAGE OF VEH PASSING THROUGH PROJECT
C             ADT = AVERAGE DAILY TRAFFIC
C             TRKP = PERCENTAGE OF TRUCKS
C
C     MAINTENANCE TIME, MT, IS COMPUTED FROM THE FOLLOWING
C     EQUATION:
C
C     MT = 4.01 * LANE-WIDTH(FT) * LENGTH(MI) * DEPTH(FT)
C
C     P = 0.06 IF RURAL, 0.055 IF URBAN
```

```
C
C
      REAL   MT,   K,   K1,   K2,  LENGTH
C
      INTEGER    HWYT, UR,   WIDTH
C
      DATA  U,R/'U','R'/
C
      TICOST = 0.0
C
      MT = 4.01 * LENGTH * WIDTH * DEPTH
C
      P = 0.060
      IF (UR .EQ. U) P = 0.055
C
      RADT = ADT * 1.0
      IF (HWYT .EQ. 0 .OR. HWYT .EQ. 2) RADT = ADT * 0.5
      IF (HWYT .EQ. 0 .AND. NLANES .EQ. 2) GO TO 20
      IF (NLANES .GT. 2) GO TO 10
C
      K1 = 0.9435
      K2 = 0.1237
      GO TO 30
   20 E=2.718281828
      IF (HWYT .EQ. 0 .AND. RADT .GT. 10000.0) RADT = 10000.0
      K=RADT*.003
      P01=0.5*((1-(E**(-K)))**2)
      T1=1+(E**(2*K))
      T2=(E**K)-K-1
      R1=(E**(2*K))-(E**K)+1
      D01=(T1*T2)/(2*RADT*R1*P01)
      IF (D01 .GT. 0.25) D01=0.25
      C02=D01*14.04
      K1=2*((P01*(0.98334+C02))+((1-P01)*0.73104))
      C02=D01*2.88
      K2=2*((P01*(0.1097+C02))+((1-P01)*0.082))
C
   30 TICOST = MT * P * RADT * ((TRKP * K1) + ((1 - TRKP) * K2))
C
   10 RETURN
      END
C
C
C
```

```
      SUBROUTINE SORT
C
C
C
C     THIS SUBROUTINE SORTS ALL STRATEGIES IN ORDER OF INCREASING
C     TOTAL COST WITH ONLY THE TOP STRATEGY FOR EACH DIFFERENT APPL
C
C
C
      IMPLICIT INTEGER (A-Z)
C
C
      COMMON /OPTOUT/  A1(40),     A2(40),     A3(40),      A4(40),
     1                 P1(40),     P2(40),     P3(40),      P4(40),
     2                 MCOST(40),  CCOST(40),  TICOST(40),  UCOST(40),
     3                 SALV(40),   TOTAL(40),  TST(40),     DIFST
C
C
      COMMON /STROUT/  ST
C
C
C
C
      OL = DIFST - 1
      DO 10 I=1,OL
      JJ=DIFST-I
      DO 20 KK=1,JJ
      IF (TOTAL(KK).GT.TOTAL(KK+1)) GO TO 30
      GO TO 20
   30 M1=A1(KK+1)
      M2=A2(KK+1)
      M3=A3(KK+1)
      M4=A4(KK+1)
      M5=P1(KK+1)
      M6=P2(KK+1)
      M7=P3(KK+1)
      M8=P4(KK+1)
      Z1=MCOST(KK+1)
      Z2=CCOST(KK+1)
      Z3=TICOST(KK+1)
      Z4=UCOST(KK+1)
      Z5=SALV(KK+1)
      Z6=TOTAL(KK+1)
      A1(KK+1)=A1(KK)
```

```
      A2(KK+1)=A2(KK)
      A3(KK+1)=A3(KK)
      A4(KK+1)=A4(KK)
      P1(KK+1)=P1(KK)
      P2(KK+1)=P2(KK)
      P3(KK+1)=P3(KK)
      P4(KK+1)=P4(KK)
      MCOST(KK+1)=MCOST(KK)
      CCOST(KK+1)=CCOST(KK)
      TICOST(KK+1)=TICOST(KK)
      UCOST(KK+1)=UCOST(KK)
      SALV(KK+1)=SALV(KK)
      TOTAL(KK+1)=TOTAL(KK)
      A1(KK)=M1
      A2(KK)=M2
      A3(KK)=M3
      A4(KK)=M4
      P1(KK)=M5
      P2(KK)=M6
      P3(KK)=M7
      P4(KK)=M8
      MCOST(KK)=Z1
      CCOST(KK)=Z2
      TICOST(KK)=Z3
      UCOST(KK)=Z4
      SALV(KK)=Z5
      TOTAL(KK)=Z6
   20 CONTINUE
   10 CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE WROUT1
C
C
C     THIS SUBROUTINE WRITES THE OUTPUT FOR THE OPTIMIZING PROGRAM
C     ON SMALL (11") PAPER
C
      IMPLICIT INTEGER (A-Z)
C
C
      COMMON /OPTOUT/  A1(40),     A2(40),     A3(40),     A4(40),
```

```
     1                   P1(40),       P2(40),        P3(40),        P4(40),
     2                   MCOST(40),    CCOST(40),     TICOST(40),    UCOST(40),
     3                   SALV(40),     TOTAL(40),     TST(40),       DIFST
C
C
C
C
      COMMON /DESCRP/    CS,           BCSMP,         ECSMP,         DIST,        SR,
     1                   BSRMP,        ESRMP,         LANE,          SP,
     2                   SNUM,         CTYP,          SURF,          THK,         MNTH,
     3                   BASE,         R2,            SE,            TI,          NPRJ,
     4                   GEN(9),       GAGE(9),       RATING(9),     HISK(9),     LOSK(9),
     5                   AVGSK(9),     LIFE60,        LIFE40,        LIFE20,      RIDER(9),
     6                   STRUCR(9),                   GOOD,          KADT,        DADT,
     7                   RATHI(9),     RATLO(9),      SEQ
C
C
C
C
      COMMON /MANVAL/    LENG,         HWYT,          NLANES,        RDW,         RSH,
     1                   LSH,          ADT,           GRW,           SU,          COMB,
     2                   REHAB(3),     FC,            YR,            ECONS,       EVAR,
     3                   EPOW,         UR
C
C
C
C
      COMMON /RATOUT/    MR(4),        RC(4),         RP(4),         MINL(4),
     1                   SHUD,         MUST,          CRAGE(4),      MAXL(4),
     2                   SHUDP(4),     MUSTP(4),      RATE(4,30),    BSLIFE
C
C
C
C
      COMMON /RPMRAT/    NPRDS,        LPRDS,         YEAR,          TRAFYR,
     1                   EFFINT,       SHOULD(5),     MUSTA(5),      DES(10,6),
     2                   CONSTC(10),   EQUAF(10),     MAXRAT(10),    BETA(30),
     3                   TFACT(3),     EXFACT(4),     TIR(4),        OTHK(10),
     4                   MS(10),       AEQ(10),       BEQ(10),       CEQ(10),
     5                   FTMTRX(5,5,3),      RMATRX(10,3),           NETPRD
C
C
C
C
```

```
      COMMON /STROUT/  ST
C
C
      REAL  R2,       SE,       TI,       GRW,      ECONS,    EVAR,
     1      EPOW,     MR,       RC,       RP,       SHUD,     MUST,
     2      CRAGE,    LPRDS,    EFFINT,   SHOULD,   MUSTA,    EQUAF,
     3      MAXRAT,   BETA,     OTHK,     RATE,     MINL,     MAXL,
     4      DECMNL,   DECMXL,   PRAT,     RATING,   LIFE60,   LIFE40,
     5      LIFE20,   AX2,      AX3,      AX4,      AX5,
     6      RIDER,    STRUCR,   EFINTP,   EQF1,     EQF2,     EQF3,
     7      RATHI,    RATLO,    LIFE50,   LIFE30,   TFACT,    EXFACT,
     8      MS
C
      REAL*8  DATE
C
      DIMENSION          DESC(3,6)
C
C
C
C     START WRITING PROJECT TEXT
C
      CALL GETDAT(DATE)
      WRITE (6,601) DATE
  601 FORMAT ('1',' R67730OPT',T101,A8)
      WRITE (6,602)
  602 FORMAT (/' ',T16,'BEG   END          BEG  END  PROJ FNC         HWY NUM
     1RDW-RSH-LSH LAST  COMPLT CNT SURFACE BASE'/' ',T9,'D  SR  SRMP  SR
     2MP  CS  CSMP CSMP LENG CLS SIDE TYP LNS   WIDTHS    CONTR  M-YR  T
     3YP TYP-THK TYPE'/' ',T9,'* *** ***** ***** **** **** **** **** ***
     4 **** *** *** *********** ***** ****** *** ******* ****'/)
      WRITE (6,603) DIST,SR,BSRMP,ESRMP,CS,RCSMP,ECSMP,LENG,UR,FC,LANE,
     1              HWYT,NLANES,RDW,RSH,LSH,SP,SNUM,MNTH,YR,CTYP,SURF,
     2              THK,BASE
      AX2 = SU * .67
      AX3 = (SU * .33) + (COMB * .20)
      AX4 = COMB * .13
      AX5 = COMB * .67
  603 FORMAT (' ',T9,A1,1X,A3,2(1X,I5),4(1X,I4),1X,A1,'-',I1,3X,A1,
     1       2(3X,I1),2X,3(I2,2X),A1,A4,2X,A1,'-',I2,3X,I2,2X,I2,2X,I2,
     2       2X,I2//)
      LIFE60 = ((ECONS - 60.0)/(-1.0 * EVAR)) ** (1.0/EPOW)
      IF (LIFE60 .GT. 99) LIFE60 = 99.99
      LIFE50 = ((ECONS - 50.0)/(-1.0 * EVAR)) ** (1.0/EPOW)
      IF (LIFE50 .GT. 99) LIFE50 = 99.99
```

```
      LIFE40 = ((ECONS - 40.0)/(-1.0 * EVAR)) ** (1.0/EPOW)
      IF (LIFE40 .GT. 99) LIFE40 = 99.99
      LIFE30 = ((ECONS - 30.0)/(-1.0 * EVAR)) ** (1.0/EPOW)
      IF (LIFE30 .GT. 99) LIFE30 = 99.99
      LIFE20 = ((ECONS - 20.0)/(-1.0 * EVAR)) ** (1.0/EPOW)
      IF (LIFE20 .GT. 99) LIFE20 = 99.99
      IF (GEN(7) .GT. 0) GO TO 59
      IF (GEN(6) .GT. 0) GO TO 60
      IF (GEN(5) .GT. 0) GO TO 61
      IF (GEN(4) .GT. 0) GO TO 62
      IF (GEN(3) .GT. 0) GO TO 63
      IF (GEN(2) .GT. 0) GO TO 64
      WRITE (6,604) GEN(1),       TRAFYR,    ADT,       ECONS,
     1              GAGE(1),      GRW,       EVAR,
     2              RIDER(1),     SU,        EPOW,
     3              STRUCR(1),    COMB,      R2,
     4              RATING(1),    TI,        SE,
     5              RATHI(1),     KADT,      DADT,      LIFE60,
     6              RATLO(1),     AX2,       LIFE50,
     7              HISK(1),      AX3,       LIFE40,
     8              LOSK(1),      AX4,       LIFE30,
     9              AVGSK(1),     AX5,       LIFE20
  604 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT
     1A',T89,'PERFORMANCE EQUATION'/' ',
     2 ' -----------------------------------------------------        ---
     3------------------  -------------------------'/' ',' YEAR',13X,
     4 1(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',
     5 14X,1(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',
     6 F9.5/' ',' RIDE   RATING ',1(F5.2,2X),T63,'SINGLE UNITS',5X,I2,
     7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',1(F5.1,2X),
     8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE    = ',F8.5/' ',' COMBD
     9 RATING ',1(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR  =
     A ',F5.2/' ',' HIGH   RATING ',1(F5.1,2X),T63,'K = ',I2,'%',6X,'D =
     B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',1(F5.1,
     C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',
     D' HIGH FRICTION',4X,1(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,
     E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,1(I2,5X),T62,'4 AXLE
     FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'
     G,4X,1(I2,5X),T62,'5 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 20 = ',
     H F5.2/' ',108('*'))
      JK = 1
      GO TO 65
   59 WRITE (6,610) (GEN(K),K=1,7),     TRAFYR,   ADT,     ECONS,
     1              (GAGE(K),K=1,7),    GRW,      EVAR,
```

```
     2              (RIDER(K),K=1,7),    SU,        EPOW,                     00136500
     3              (STRUCR(K),K=1,7),   COMB,      R2,                       00136600
     4              (RATING(K),K=1,7),   TI,        SE,                       00136700
     5              (RATHI(K),K=1,7),    KADT,      DADT,     LIFE60,         00136800
     6              (RATLO(K),K=1,7),    AX2,       LIFE50,                   00136900
     7              (HISK(K),K=1,7),     AX3,       LIFE40,                   00137000
     8              (LOSK(K),K=1,7),     AX4,       LIFE30,                   00137100
     9              (AVGSK(K),K=1,7),    AX5,       LIFE20                    00137200
 610 FORMAT (' ',T22,'PERFORMANCE HISTORY',T62,'APPROXIMATE TRAFFIC DAT00137300
    1A',T89,'PERFORMANCE EQUATION'/' ',                                     00137400
    2 ' --------------------------------------------------------   --00137500
    3-------------------  ---------------------'/' ',' YEAR',13X,  00137600
    4 7(I2,4X),T64,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',00137700
    5 14X,7(I2,4X),T64,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',  00137800
    6 F9.5/' ',' RIDE   RATING ',7(F5.2,1X),T64,'SINGLE UNITS',5X,I2,  00137900
    7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',7(F5.1,1X),   00138000
    8T64,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE    = ',F8.5/' ',' COMBD 00138100
    9 RATING ',7(F5.1,1X),T64,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR  =00138200
    A ',F5.2/' ',' HIGH   RATING ',7(F5.1,1X),T64,'K = ',I2,'%',6X,'D =00138300
    B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',7(F5.1,  00138400
    C1X),T63,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',00138500
    D' HIGH FRICTION',4X,7(I2,4X),T63,'3 AXLE TRUCKS = ',F4.1,' %',T88,00138600
    E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,7(I2,4X),T63,'4 AXLE 00138700
    FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'00138800
    G,4X,7(I2,4X),T63,'5 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 20 = ',00138900
    H F5.2/' ',108('*'))                                                    00139000
     GO TO 65                                                               00139100
  60 WRITE (6,605)  (GEN(K),K=1,6),     TRAFYR,   ADT,      ECONS,          00139200
    1               (GAGE(K),K=1,6),    GRW,      EVAR,                     00139300
    2               (RIDER(K),K=1,6),   SU,       EPOW,                     00139400
    3               (STRUCR(K),K=1,6),  COMB,     R2,                       00139500
    4               (RATING(K),K=1,6),  TI,       SE,                       00139600
    5               (RATHI(K),K=1,6),   KADT,     DADT,     LIFE60,         00139700
    6               (RATLO(K),K=1,6),   AX2,      LIFE50,                   00139800
    7               (HISK(K),K=1,6),    AX3,      LIFE40,                   00139900
    8               (LOSK(K),K=1,6),    AX4,      LIFE30,                   00140000
    9               (AVGSK(K),K=1,6),   AX5,      LIFE20                    00140100
 605 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT00140200
    1A',T89,'PERFORMANCE EQUATION'/' ',                                     00140300
    2 ' ---------------------------------------------------   ---00140400
    3-------------------  ---------------------'/' ',' YEAR',13X,  00140500
    4 6(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',00140600
    5 14X,6(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',  00140700
    6 F9.5/' ',' RIDE   RATING ',6(F5.2,2X),T63,'SINGLE UNITS',5X,I2,  00140800
```

```
7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',6(F5.1,2X),    00140900
8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE    = ',F8.5/' ',' COMBD 00141000
9 RATING ',6(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR   =00141100
A ',F5.2/' ',' HIGH   RATING ',6(F5.1,2X),T63,'K = ',I2,'%',6X,'D =00141200
B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',6(F5.1,  00141300
C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',00141400
D' HIGH FRICTION',4X,6(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,00141500
E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,6(I2,5X),T62,'4 AXLE 00141600
FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'00141700
G,4X,6(I2,5X),T62,'5 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 20 = ',00141800
H F5.2/' ',108('*'))                                                 00141900
  JK = 6                                                              00142000
  GO TO 65                                                            00142100
61 WRITE (6,606)  (GEN(K),K=1,5),      TRAFYR,   ADT,     ECONS,      00142200
 1                (GAGE(K),K=1,5),     GRW,      EVAR,                00142300
 2                (RIDER(K),K=1,5),    SU,       EPOW,                00142400
 3                (STRUCR(K),K=1,5),   COMB,     R2,                  00142500
 4                (RATING(K),K=1,5),   TI,       SE,                  00142600
 5                (RATHI(K),K=1,5),    KADT,     DADT,    LIFE60,     00142700
 6                (RATLO(K),K=1,5),    AX2,      LIFE50,              00142800
 7                (HISK(K),K=1,5),     AX3,      LIFE40,              00142900
 8                (LOSK(K),K=1,5),     AX4,      LIFE30,              00143000
 9                (AVGSK(K),K=1,5),    AX5,      LIFE20               00143100
606 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT00143200
 1A',T89,'PERFORMANCE EQUATION'/' ',                                  00143300
 2   ' -------------------------------------------------          ---00143400
 3-------------------   ---------------------------'/' ',' YEAR',13X, 00143500
 4 5(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',00143600
 5 14X,5(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',   00143700
 6 F9.5/' ',' RIDE   RATING ',5(F5.2,2X),T63,'SINGLE UNITS',5X,I2,   00143800
 7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',5(F5.1,2X),   00143900
 8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE    = ',F8.5/' ',' COMBD 00144000
 9 RATING ',5(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR  =00144100
 A ',F5.2/' ',' HIGH   RATING ',5(F5.1,2X),T63,'K = ',I2,'%',6X,'D =00144200
 B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',5(F5.1,  00144300
 C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',00144400
 D' HIGH FRICTION',4X,5(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,00144500
 E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,5(I2,5X),T62,'4 AXLE 00144600
 FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'00144700
 G,4X,5(I2,5X),T62,'5 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 20 = ',00144800
 H F5.2/' ',108('*'))                                                00144900
  JK = 5                                                              00145000
  GO TO 65                                                            00145100
62 WRITE (6,607) (GEN(K),K=1,4),     TRAFYR,  ADT,     ECONS,         00145200
```

```
     1              (GAGE(K),K=1,4),    GRW,      EVAR,                          00145300
     2              (RIDER(K),K=1,4),   SU,       EPOW,                          00145400
     3              (STRUCR(K),K=1,4),  COMB,     R2,                            00145500
     4              (RATING(K),K=1,4),  TI,       SF,                            00145600
     5              (RATHI(K),K=1,4),   KADT,     DADT,    LIFE60,               00145700
     6              (RATLO(K),K=1,4),   AX2,      LIFE50,                        00145800
     7              (HISK(K),K=1,4),    AX3,      LIFE40,                        00145900
     8              (LOSK(K),K=1,4),    AX4,      LIFE30,                        00146000
     9              (AVGSK(K),K=1,4),   AX5,      LIFE20                         00146100
 607 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT00146200
    1A',T89,'PERFORMANCE EQUATION'/' ',                                       00146300
    2  ' ----------------------------------------------------------      ---00146400
    3-------------------   ----------------------'/' ',' YEAR',13X,  00146500
    4 4(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',00146600
    5 14X,4(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',  00146700
    6 F9.5/' ',' RIDE    RATING ',4(F5.2,2X),T63,'SINGLE UNITS',5X,I2,  00146800
    7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',4(F5.1,2X),   00146900
    8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE    = ',F8.5/' ',' COMBD 00147000
    9 RATING ',4(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR  =00147100
    A ',F5.2/' ',' HIGH   RATING ',4(F5.1,2X),T63,'K = ',I2,'%',6X,'D =00147200
    B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',4(F5.1,  00147300
    C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',00147400
    D' HIGH FRICTION',4X,4(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,00147500
    E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,4(I2,5X),T62,'4 AXLE 00147600
    FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'00147700
    G,4X,4(I2,5X),T62,'5 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 20 = ',00147800
    H F5.2/' ',108('*'))                                                 00147900
      JK = 4                                                             00148000
      GO TO 65                                                           00148100
  63 WRITE (6,608)  (GEN(K),K=1,3),     TRAFYR,   ADT,     ECONS,        00148200
     1              (GAGE(K),K=1,3),    GRW,      EVAR,                  00148300
     2              (RIDER(K),K=1,3),   SU,       EPOW,                  00148400
     3              (STRUCR(K),K=1,3),  COMB,     R2,                    00148500
     4              (RATING(K),K=1,3),  TI,       SE,                    00148600
     5              (RATHI(K),K=1,3),   KADT,     DADT,    LIFE60,       00148700
     6              (RATLO(K),K=1,3),   AX2,      LIFE50,                00148800
     7              (HISK(K),K=1,3),    AX3,      LIFE40,                00148900
     8              (LOSK(K),K=1,3),    AX4,      LIFE30,                00149000
     9              (AVGSK(K),K=1,3),   AX5,      LIFE20                 00149100
 608 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT00149200
    1A',T89,'PERFORMANCE EQUATION'/' ',                                       00149300
    2  ' ----------------------------------------------------------      ---00149400
    3-------------------   ----------------------'/' ',' YEAR',13X,  00149500
    4 3(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',00149600
```

```
5 14X,3(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',
6 F9.5/' ',' RIDE   RATING ',3(F5.2,2X),T63,'SINGLE UNITS',5X,I2,
7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',3(F5.1,2X),
8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE    = ',F8.5/' ',' COMBD
9 RATING ',3(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR   =
A ',F5.2/' ',' HIGH   RATING ',3(F5.1,2X),T63,'K = ',I2,'%',6X,'D =
B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',3(F5.1,
C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',
D' HIGH FRICTION',4X,3(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,
E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,3(I2,5X),T62,'4 AXLE
FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'
G,4X,3(I2,5X),T62,'5 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 20 = ',
H F5.2/' ',108('*'))
  JK = 3
  GO TO 65
64 WRITE (6,609)  (GEN(K),K=1,2),    TRAFYR,  ADT,     ECONS,
 1                (GAGE(K),K=1,2),   GRW,     EVAR,
 2                (RIDER(K),K=1,2),  SU,      EPOW,
 3                (STRUCR(K),K=1,2), COMB,    R2,
 4                (RATING(K),K=1,2), TI,      SE,
 5                (RATHI(K),K=1,2),  KADT,    DADT,    LIFE60,
 6                (RATLO(K),K=1,2),  AX2,     LIFE50,
 7                (HISK(K),K=1,2),   AX3,     LIFE40,
 8                (LOSK(K),K=1,2),   AX4,     LIFE30,
 9                (AVGSK(K),K=1,2),  AX5,     LIFE20
609 FORMAT (' ',T18,'PERFORMANCE HISTORY',T61,'APPROXIMATE TRAFFIC DAT
 1A',T89,'PERFORMANCE EQUATION'/' ',
 2 ' ---------------------------------------------------   ---
 3--------------------    ----------------------'/' ',' YEAR',13X,
 4 2(I2,5X),T63,I2,' ADT',8X,I6,T88,'EQUA CONST = ',F6.2/' ',' AGE',
 5 14X,2(I2,5X),T63,'GROWTH RATE',4X,F4.1,'%',T88,'EQUA COEFF = ',
 6 F9.5/' ',' RIDE   RATING ',2(F5.2,2X),T63,'SINGLE UNITS',5X,I2,
 7 '%',T88,'EQUA POWER = ',F5.2/' ',' STRUCR RATING ',2(F5.1,2X),
 8T63,'COMBINATIONS',5X,I2,'%',T88,'R SQUARE    = ',F8.5/' ',' COMBD
 9 RATING ',2(F5.1,2X),T63,'TRAFFIC INDEX',4X,F3.1,T88,'STD ERROR   =
 A ',F5.2/' ',' HIGH   RATING ',2(F5.1,2X),T63,'K = ',I2,'%',6X,'D =
 B ',I2,'%',T88,'TIME TO 60 = ',F5.2/' ',' LOW    RATING ',2(F5.1,
 C2X),T62,'2 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 50 = ',F5.2/' ',
 D' HIGH FRICTION',4X,2(I2,5X),T62,'3 AXLE TRUCKS = ',F4.1,' %',T88,
 E'TIME TO 40 = ',F5.2/' ',' LOW  FRICTION',4X,2(I2,5X),T62,'4 AXLE
 FTRUCKS = ',F4.1,' %',T88,'TIME TO 30 = ',F5.2/' ',' AVG  FRICTION'
 G,4X,2(I2,5X),T62,'5 AXLE TRUCKS = ',F4.1,' %',T88,'TIME TO 20 = ',
 H F5.2/' ',108('*'))
65 IF (GOOD .EQ. 0) MINL(1) = LIFE60
```

```
      IF (GOOD .EQ. 0) MAXL(1) = LIFE40
      DECMNL=MINL(1) - INT(MINL(1))
      DECMXL=MAXL(1) - INT(MAXL(1))
      IF (DECMNL .GT. .5) GO TO 100
      MNL = INT(MINL(1))
      GO TO 105
  100 MNL = INT(MINL(1)) + 1
  105 IF (DECMXL .GT. .5) GO TO 110
      MXL = INT(MAXL(1))
      GO TO 115
  110 MXL = INT(MAXL(1)) + 1
  115 SYEAR = YR + MNL + 1900
      MYEAR = YR + MXL + 1900
      EFINTP = EFFINT * 100
      EQF1 = EQUAF(REHAB(1)) * 100
      EQF2 = EQUAF(REHAB(2)) * 100
      EQF3 = EQUAF(REHAB(3)) * 100
      WRITE (6,611) SHUD,SYEAR,MUST,MYFAR,NPRDS,LPRDS,EFINTP,
     1              EQF1,EQF2,EQF3
  611 FORMAT (/' ',15X,'SHOULD REHABILITATE AT ',F4.1,' WHICH WILL OCCUR
     2 IN ',I4/' ',15X,'MUST REHABILITATE AT ',F4.1,' WHICH WILL OCCUR I
     3N ',I4/' ',15X,'CONSIDERATION SPAN = ',I2,' PERIODS, EACH PERIOD =
     4 ',F3.1,' YEARS'/' ',15X,'EFFECTIVE INTEREST RATE = ',F4.1,'%  FAC
     5TORS : ',F5.1,'% ',F5.1,'% ',F5.1,'%')
      WRITE (6,612)
  612 FORMAT (//' ',T75,'CONSTRCT COST   MIN LIFE   MAX LIFE'/' ',T6,'DE
     1SCRIPTION OF THE ALTERNATIVES           PERFORMANCE  EQUATIONS
     2 12'' LANE MILE    AT   SHUD    AT  MUST'/' ',' --------------------
     3--------------  ----------------------------   -------------
     4 --------   ---------'/)
      IF (A1(1) .GT. 1) GO TO 70
      I = 1
      M = 10
      WRITE (6,613) I,DES(M,1),DES(M,2),DES(M,3),DES(M,4),DES(M,5),
     1              DES(M,6),MR(I),RC(I),RP(I),CONSTC(M),MINL(I),MAXL(I)
      GO TO 15
   70 DO 10 I=1,4
      IF (I .EQ. 1) GO TO 11
      M = REHAB(I-1)
      GO TO 12
   11 M = 10
   12 WRITE (6,613) I,DES(M,1),DES(M,2),DES(M,3),DES(M,4),DES(M,5),
     1              DES(M,6),MR(I),RC(I),RP(I),CONSTC(M),MINL(I),MAXL(I)
  613 FORMAT (' ',' ALTERNATE ',I1,1X,6A4,3X,'R = ',F6.2,1X,'-',F8.5,
```

```
     1        1X,'P ** ',F4.2,5X,I8,8X,F5.2,6X,F5.2)
  10 CONTINUE
  15 WRITE (6,614) ST
 614 FORMAT (//' ',T75,'NUMB'/' ',T29,'ITEMIZED COSTS',T75,'POSS',7X,
    1'STRATEGY DESCRIPTION'/' ',' ************************************
    2******************************     ****    ************************
    3****'//' ',' ROUT      +    COST OF   +  COST OF   +  USER    -     SALVA
    4GE   =  EXPECTED      ',I4,'     (ALTERNATIVE - PRD APPLIED)'/' ',' MA
    5INT         CONSTR          TRAFFIC        COST          VALUE          TOTAL'/'
    6 ',' COST            INCL PR          INTERPT',T63,'COST',T84,'1ST      2ND
    7  3RD       4TH'/' ',T83,'REHAB  REHAB  REHAB  REHAB'/)
      DO 50 I=1,DIFST
      P1(I) = P1(I) + YEAR
      IF (P1(I) .GE. 100) P1(I) = P1(I) - 100
      IF (A2(I) .EQ. 0) GO TO 49
      P2(I) = P2(I) + YEAR
      IF (P2(I) .GE. 100) P2(I) = P2(I) - 100
      IF (A3(I) .EQ. 0) GO TO 49
      P3(I) = P3(I) + YEAR
      IF (P3(I) .GE. 100) P3(I) = P3(I) - 100
      IF (A4(I) .EQ. 0) GO TO 49
      P4(I) = P4(I) + YEAR
      IF (P4(I) .GE. 100) P4(I) = P4(I) - 100
  49  IF (A2(I).EQ.0.AND.A3(I).EQ.0.AND.A4(I).EQ.0) GO TO 51
      IF (A3(I).EQ.0.AND.A4(I).EQ.0) GO TO 52
      IF (A4(I).EQ.0) GO TO 53
C
C     WRITE 4 COMBINATION STRATEGIES
C
      WRITE (6,615) MCOST(I),CCOST(I),TICOST(I),UCOST(I),SALV(I),
     1              TOTAL(I),TST(I),A1(I),P1(I),A2(I),P2(I),A3(I),P3(I),
     2              A4(I),P4(I)
 615  FORMAT(' ',1X,5(I7,5X),I8,4X,I4,5X,4(I1,'-',I2,3X))
      GO TO 50
C
C     WRITE 1 COMBINATION STRATEGIES
C
  51  WRITE (6,616) MCOST(I),CCOST(I),TICOST(I),UCOST(I),SALV(I),
     1              TOTAL(I),TST(I),A1(I),P1(I)
 616  FORMAT (' ',1X,5(I7,5X),I8,4X,I4,5X,I1,'-',I2)
      GO TO 50
C
C     WRITE 2 COMBINATION STRATEGIES
C
```

```
   52 WRITE (6,617) MCOST(I),CCOST(I),TICOST(I),UCOST(I),SALV(I),
     1              TOTAL(I),TST(I),A1(I),P1(I),A2(I),P2(I)
  617 FORMAT(' ',1X,5(I7,5X),I8,4X,I4,5X,2(I1,'-',I2,3X))
      GO TO 50
C
C     WRITE 3 COMBINATION STRATEGIES
C
   53 WRITE (6,618) MCOST(I),CCOST(I),TICOST(I),UCOST(I),SALV(I),
     1              TOTAL(I),TST(I),A1(I),P1(I),A2(I),P2(I),A3(I),P3(I)
  618 FORMAT(' ',1X,5(I7,5X),I8,4X,I4,5X,3(I1,'-',I2,3X))
   50 CONTINUE
C
      DO 71 M = 1,3
      I = REHAB(M)
      DESC(M,1) = DES(I,1)
      DESC(M,2) = DES(I,2)
      DESC(M,3) = DES(I,3)
      DESC(M,4) = DES(I,4)
      DESC(M,5) = DES(I,5)
      DESC(M,6) = DES(I,6)
   71 CONTINUE
C
      WRITE (9,901)          GOOD,   CS,     SEQ ,   DIST,   SR,
     1                       BSRMP,  ESRMP,  LENG,   UR,     FC,
     2                       LANE,   HWYT,   NLANES, RDW,    RSH,
     3                       LSH,    SP,     SNUM,   CTYP,   SURF,
     4                       THK,    MNTH,   YR,     (MR(I),
     5                       RC(I),  RP(I),I=1,4),   (CONSTC(REHAB(K)),
     6                       K=1,3), (DESC(K,1),DESC(K,2),DESC(K,3),
     7                       DESC(K,4),DESC(K,5),DESC(K,6),K=1,3),
     8                       A1(1),  P1(1),  A2(1),  P2(1),  A3(1),
     9                       P3(1),  A4(1),  P4(1)
C
  901 FORMAT (I1,I4,A3,A1,A3,2I5,I4,A1,I1,A1,2I1,3I2,A1,A4,3I2,A1,
     1          I2,4(F6.2,F9.5,F4.2),3I6,3(6A4),4(I1,I2),11X)
C
  998 RETURN
      END
```

OPTIMIZING PARAMETERS

DATA SET

```
82802012 1000.041                                                    00000100
     .08      .15      .25                                           00000200
0.63     0.82     0.96     1.25                                      00000300
5050404060                                                           00000400
4040303050                                                           00000500
6.06.57.07.4                                                         00000600
77777                                                                00000700
77777                                                                00000800
77777                                                                00000900
77777                                                                00001000
99993                                                                00001100
44444                                                                00001200
44444                                                                00001300
44444                                                                00001400
44444                                                                00001500
44444                                                                00001600
88886                                                                00001700
88886                                                                00001800
88886                                                                00001900
88886                                                                00002000
66666                                                                00002100
234                                                                  00002200
245                                                                  00002300
248                                                                  00002400
145                                                                  00002500
247                                                                  00002600
456                                                                  00002700
345                                                                  00002800
459                                                                  00002900
457                                                                  00003000
BITUMINOUS SURF TREATMNT   14300 06 063 100     100008.27404         00003100
OVERLAY  0.06 CLASS D      22800 06 083     030 100000.66181         00003200
OVERLAY  0.08 CLASS G      23500 08 050          95000.66181         00003300
OVERLAY  0.15 CLASS B      35800 15 083 150 032 100000.22686         00003400
OVERLAY  0.25 CLASS B      57800 25 100 200 040 100000.05231         00003500
OVERLAY  0.35 CLASS B      68500 35 140 283 048 100000.13558         00003600
RECYCLE  0.15              35800 15 090         100000.66181         00003700
RECYCLE  + 0.06 CLASS D    44100 21 100         100000.13558         00003800
0.35 CSTC + 0.25 AC        68500 60         079 100000.13558         00003900
ROUTINE MAINTENANCE                                                  00004000
 2 2 2 2                                                             00004100
```

APPENDIX C

NETWORK SOURCE PROGRAM

```
C
C
      PROGRAM NETWORK
C
C
      IMPLICIT INTEGER (A-Z)
C
C
      REAL*8    GETDAT,  DATE
C
C
      REAL     EQCONS(4),      EQVAR(4),       EQPOW(4),     EQ1,    EQ2,    EQ3,
     1         RATEH,          RATEA,          RTXLNG,       SUMRBL,         SUMRAL,
     2         RDBS(6,12),     RDAS(6,12),     PCOST,        TI,     GRTH,   KOST,
     3         RDB(7,7,6,12),  TCOST,          RDA(7,7,6,12),        KOST2,  KOST3,
     4         SUMRLB(6,6,5),  EI,             SUMRLA(6,6,5),        TOP,    SUM1,
     5         PREP,           CCOST,          INFL,         LENGR,  SURF,   MSURF,
     6         KOST4,          DRAT,           ENGCST,       RATEW
C
C
      DIMENSION        CSUM(7,7,6,9),      ALTCST(3),      TCOST(2),
     1                 DESCR(3,6),         CSUMS(6,8),
     2                 ALT(4),             AYEAR(4),       DES(6),
     3                 LINES(66),          SHUD(5),        MUST(5)
C
C
      DATA     RDBS,RDAS/72*0.0,72*0.0/,RDB,RDA/3528*0.0,3528*0.0/
      DATA     SUMRLB,SUMRLA/180*0.0,180*0.0/,LINES/66*0/
C
C     READ PARAMETERS:      YEAR = PRESENT YEAR  (I4)
C                           INFL = INFLATION RATE  (F4.2)
C                           STAT = BYPASS CONSTANT  (I1)
C                        SHUD(5) = SHUD LEVELS ASSOC WITH FC   (5I2)
C                        MUST(5) = MUST LEVELS ASSOC WITH FC   (5I2)
C
C
      READ (4,401) YEAR, INFL,  STAT, EI, ENGCST
  401 FORMAT (I4,1X,F4.2,1X,I1,2(1X,F4.2))
      READ (4,402)  (SHUD(I),I=1,5)
      READ (4,402)  (MUST(I),I=1,5)
  402 FORMAT (5(I2,1X))
C
C
```

```
      CALL GETDAT(DATE)
C
C     OPEN DATA SETS IN PROPER SEQUENCE FOR YEARLY ACTIVITY SUMMARIES
C
C
      DO 5 DIST = 1,6
      DO 6 YR = 1,6
      UNIT = (DIST * 10) + YR
      YER = YEAR + YR
      WRITE (UNIT,602) DIST,   DATE,     YER,
     1                (SHUD(I),I=1,5),      (MUST(I),I=1,5)
  602 FORMAT (/' ','R67XXX',T52,'DISTRICT ',I1,T102,A8/' ',T47,I4,
     1T52,'ACTION SUMMARY'///' ',T43,'FC 1     FC 2     FC 3     FC 4',
     2T71,'FC 5'/' ',T43,5('****',3X)/' ',T36,'SHUD',4X,5(I2,5X)/' ',
     3T36,'MUST',4X,5(I2,5X)/)
    6 CONTINUE
    5 CONTINUE
C
C
C     READ PROJECT RECORDS
C
C
  100 READ (5,501,END=999) DESIG,     CS,          SEQ,
     1                     DIST,      SR,          BSRMP,     ESRMP,
     2                     LENG,      UR,          FC,        LANE,
     3                     HWTYP,     NUML,        RDW,       RSH,
     4                     LSH,       PREF,        CONTR,     CTYP,
     5                     SURF,      THK,         MNTH,      CYEAR,
     8                     (EQCONS(I),EQVAR(I),EQPOW(I),I=1,4),
     9                     (ALTCST(I),I=1,3),   (DESCR(1,I),I=1,6),
     A                     (DESCR(2,I),I=1,6),   (DESCR(3,I),I=1,6),
     B                     (ALT(I),   AYEAR(I),  I=1,4)
C
  501 FORMAT (I1,I4,A3,I1,I3,2I5,I4,A1,I1,A1,2I1,3I2,A1,A4,I2,I2,I2,
     1            A1,I2,4(F6.2,F9.5,F4.2),3I6,3(6A4),4(I1,I2))
C
C
C     ACCUMULATE IN BASIC ARRAYS WITH PROCESSING FOR EACH PROJECT
C
C
      CONYR = CYEAR + 1900
      APPYR = CONYR
      LENGR = LENG * .01
```

```
      EQ1 = EQCONS(I)
      EQ2 = EQVAR(I)
      EQ3 = EQPOW(I)
      DO 10 YR = 1,6
      AGE = (YEAR + YR) - CONYR
      IF (APPYR .NE. CONYR) AGE = (YEAR + YR) - APPYR
      RATEB = EQ1 - (EQ2 * (AGE ** EQ3))
      RATEW = RATEB
      IF (RATEB .LE. -99.9) RATEB = -99.9
      IF (RATEB .GT. 100.0) RATEB = 100.0
      IF (RATEW .LE. 0.0) RATEW = 0.01
      RATEA = RATEB
      GR = 1
      DO 20 J = 1,10
      IF (RATEW .LE. (110.0 - (J * 10.0)) .AND.
     1    RATEW .GT. (100.0 - (J * 10.0))) GR = J
   20 CONTINUE
      RDB(YR,DIST,FC,GR) = RDB(YR,DIST,FC,GR) + LENGR
      RDB(YR,DIST,FC,12) = RDB(YR,DIST,FC,12) + LENGR
      RTXLNG = RATEB * LENGR
      SUMRLB(YR,DIST,FC) = SUMRLB(YR,DIST,FC) + RTXLNG
      IF (RDB(YR,DIST,FC,12) .EQ. 0.0) GO TO 21
      RDB(YR,DIST,FC,11) = SUMRLB(YR,DIST,FC) / RDB(YR,DIST,FC,12)
   21 L = 0
      Z = (YEAR + YR) - 1900
      DO 25 J=1,4
      IF (Z .EQ. AYEAR(J)) L = J
   25 CONTINUE
      IF (L .EQ. 0) GO TO 30
C
C
      K = ALT(L)
      EQ1 = EQCONS(K)
      EQ2 = EQVAR(K)
      EQ3 = EQPOW(K)
      APPYR = AYEAR(L) + 1900
      RATEA = 100.0
      CSUM(YR,DIST,FC,3) = CSUM(YR,DIST,FC,3) + 1
      CSUM(YR,DIST,FC,4) = CSUM(YR,DIST,FC,4) + LENG
      PREP = PCOST(RATEB)
      CCOST = FLOAT(ALTCST(K-1))
      SURF = LENGR * (FLOAT(RDW + RSH + LSH) / 12)
      MSURF = LENGR * (FLOAT(RDW) / 12)
      KOST3 = ((SURF * CCOST) + (MSURF * PREP)) * (1.0 + ENGCST)
```

```
      COST = IFIX(KOST3)
      KOST2 = COST * (1.0 + INFL) ** YR
      ICOST = IFIX(KOST2)
      KOST4 = KOST3 * ( 1.0 / ((1.0 + EI) ** YR))
      EICOST = IFIX(KOST4)
      CSUM(YR,DIST,FC,7) = CSUM(YR,DIST,FC,7) + COST
      CSUM(YR,DIST,FC,8) = CSUM(YR,DIST,FC,8) + ICOST
      CSUM(YR,DIST,FC,9) = CSUM(YR,DIST,FC,9) + EICOST
      IF (K .EQ. 2) M = 1
      IF (K .EQ. 3) M = 2
      IF (K .EQ. 4) M = 3
      DO 24 I = 1,6
      DES(I) = DESCR(M,I)
   24 CONTINUE
      YER = YEAR + YR
      UNIT = (DIST * 10) + YR
      IF (LINES(UNIT) .EQ. 0) GO TO 26
      GO TO 27
   26 WRITE (UNIT,615)
  615 FORMAT (' ',T17,'BEG',T25,'END',T54,'BEF',T91,'PRESENT',T101,'INFL
     1ATED'/' ',T5,'FC        SR       SRMP      SRMP      LENG     CS      SIDE',
     2T54,'RTNG          PROPOSED     ACTION             COST          COST'/
     3' ',T4,'----    ---    -----    -----    ----    ----   ----    ----',
     4T62,'------------------------      --------    --------'/)
      LINES(UNIT) = LINES(UNIT) + 13
   27 LINES(UNIT)= LINES(UNIT) + 1
      IF (LINES(UNIT) .GT. 50) GO TO 28
      GO TO 29
   28 WRITE (UNIT,616)
  616 FORMAT ('1',// T17,'BEG',T25,'END',T54,'BEF',T91,'PRESENT',T101,'I
     1NFLATED'/' ',T5,'FC       SR       SRMP      SRMP      LENG     CS      SIDE',
     2T54,'RTNG          PROPOSED     ACTION             COST          COST'/
     3' ',T4,'----    ---    -----    -----    ----    ----   ----    ----',
     4T62,'------------------------      --------    --------'/)
      LINES(UNIT) = 4
   29 WRITE (UNIT,601) UR, FC, SR, BSRMP, ESRMP, LENG, CS, LANE, RATEW,
     1                 (DES(I),I=1,6), COST, ICOST
  601 FORMAT (' ',2X,A1,2X,I1,3X,I3,2(3X,I5),2(3X,I4),5X,A1,4X,F4.1,
     1         4X,6A4,4X,2(I8,3X))
C
C
   30 CONTINUE
      RTXLNG = RATEA * LENGR
      SUMPLA(YR,DIST,FC) = SUMRLA(YR,DIST,FC) + RTXLNG
```

```
      CSUM(YR,DIST,FC,1) = IFIX(RDB(YR,DIST,FC,11))
      IF (RDB(YR,DIST,FC,12) .EQ. 0.0) GO TO 22
      CSUM(YR,DIST,FC,2) = IFIX(SUMRLA(YR,DIST,FC) / RDB(YR,DIST,FC,12))
   22 CSUM(YR,DIST,FC,5) = CSUM(YR,DIST,FC,5) + LENG
      IF (CSUM(YR,DIST,FC,5) .EQ. 0) GO TO 31
      TOP = FLOAT(CSUM(YR,DIST,FC,4))
      SUM1 = (TOP / CSUM(YR,DIST,FC,5)) * 100.0
      CSUM(YR,DIST,FC,6) = IFIX(SUM1)
C
      GR = 1
      IF (RATEA .LE. 0.0) GR = 10
   31 DO 40 J=1,10
      IF (RATEA .LE. (110.0 - (J * 10.0)) .AND.
     1    RATEA .GT. (100.0 - (J * 10.0))) GR = J
   40 CONTINUE
      RDA(YR,DIST,FC,GR) = RDA(YR,DIST,FC,GR) + LENGR
      RDA(YR,DIST,FC,12) = RDA(YR,DIST,FC,12) + LENGR
      IF (RDA(YR,DIST,FC,12) .EQ. 0.0) GO TO 10
      RDA(YR,DIST,FC,11) = SUMRLA(YR,DIST,FC) / RDA(YR,DIST,FC,12)
   10 CONTINUE
      GO TO 100
C
C
C     BUILD TOTALS FOR DISTRICT SUMMARIES
C
C
  999 CONTINUE
      DO 110 YR = 1,6
      DO 120 DIST = 1,6
      SUMRBL = 0
      SUMRAL = 0
      DO 130 FC = 1,5
      CSUM(YR,DIST,6,3) = CSUM(YR,DIST,6,3) + CSUM(YR,DIST,FC,3)
      CSUM(YR,DIST,6,4) = CSUM(YR,DIST,6,4) + CSUM(YR,DIST,FC,4)
      CSUM(YR,DIST,6,5) = CSUM(YR,DIST,6,5) + CSUM(YR,DIST,FC,5)
      CSUM(YR,DIST,6,7) = CSUM(YR,DIST,6,7) + CSUM(YR,DIST,FC,7)
      CSUM(YR,DIST,6,8) = CSUM(YR,DIST,6,8) + CSUM(YR,DIST,FC,8)
      CSUM(YR,DIST,6,9) = CSUM(YR,DIST,6,9) + CSUM(YR,DIST,FC,9)
      SUMRBL = SUMRBL + (CSUM(YR,DIST,FC,1) * CSUM(YR,DIST,FC,5) * 1.0)
      SUMRAL = SUMRAL + (CSUM(YR,DIST,FC,2) * CSUM(YR,DIST,FC,5) * 1.0)
  130 CONTINUE
      IF (CSUM(YR,DIST,6,5) .EQ. 0) GO TO 131
      DO 107 FC = 1,6
      CSUM(YR,DIST,FC,4) = IFIX(CSUM(YR,DIST,FC,4) * .01)
```

```
      CSUM(YR,DIST,FC,5) = IFIX(CSUM(YR,DIST,FC,5) * .01)
  107 CONTINUE
      TOP = FLOAT(CSUM(YR,DIST,6,4))
      SUM1 = (TOP / CSUM(YR,DIST,6,5)) * 100.0
      CSUM(YR,DIST,6,6) = IFIX(SUM1)
  131 SUMRBL = 0
      SUMRAL = 0
      DO 140 FC = 1,5
      DO 150 N = 1,10
      RDB(YR,DIST,6,N) = RDB(YR,DIST,6,N) + RDB(YR,DIST,FC,N)
      RDA(YR,DIST,6,N) = RDA(YR,DIST,6,N) + RDA(YR,DIST,FC,N)
  150 CONTINUE
      SUMRBL = SUMRBL + RDB(YR,DIST,FC,11) * RDB(YR,DIST,FC,12)
      SUMRAL = SUMRAL + RDA(YR,DIST,FC,11) * RDA(YR,DIST,FC,12)
      RDB(YR,DIST,6,12) = RDB(YR,DIST,6,12) + RDB(YR,DIST,FC,12)
      RDA(YR,DIST,6,12) = RDA(YR,DIST,6,12) + RDA(YR,DIST,FC,12)
  140 CONTINUE
      IF (RDB(YR,DIST,6,12) .EQ. 0.0) GO TO 120
      RDB(YR,DIST,6,11) = SUMRBL / RDB(YR,DIST,6,12)
      RDA(YR,DIST,6,11) = SUMRAL / RDB(YR,DIST,6,12)
      CSUM(YR,DIST,6,1) = IFIX(RDB(YR,DIST,6,11))
      CSUM(YR,DIST,6,2) = IFIX(RDA(YR,DIST,6,11))
  120 CONTINUE
  110 CONTINUE
C
C
C     WRITE DISTRICT COST SUMMARIES
C
C
      DO 300 DIST = 1,6
      DO 310 YR = 1,6
      UNIT = (DIST * 10) + YR
      YER = YEAR + YR
      WRITE (UNIT,604) DIST,DATE,YER,(SHUD(I),I=1,5),(MUST(I),I=1,5)
  604 FORMAT ('1',//' R67XXX',T52,'DISTRICT ',I1,T102,A8/' ',T48,I4,
     1T53,'COST SUMMARY'///' ',T43,'FC 1    FC 2    FC 3    FC 4    FC 5'/
     2' ',T43,5('****',3X)/' ',T36,'SHUD',4X,5(I2,5X)/' ',T36,'MUST',
     34X,5(I2,5X)///)
      WRITE (UNIT,605)
  605 FORMAT (' ',T11,'RTNG AVG   RTNG AVG   NUMB',T42,'MILES',
     1T53,'TOTAL',T66,'%',T76,'PRESENT      INFLATED     DISCOUNTED'/' ',
     2T5,'FC     BEF ACTN   AFT ACTN   PROJ   ACTED ON      MILES',
     3T62,'ACTED ON',T77,'COST',T90,'COST',T103,'COST'/' ',T4,'----',
     4T11,'--------   --------   ----   --------   --------   --------'
```

```
     5T74,'----------    ----------    ----------'/)
      DO 320 FC = 1,5
      WRITE (UNIT,606) FC, (CSUM(YR,DIST,FC,J),J = 1,9)
  606 FORMAT (' ',T6,I1,T14,I2,T25,I2,T33,I4,T42,I4,T53,I4,T63,I3,
     11X,'%',T74,I10,3X,I10,3X,I10/)
  320 CONTINUE
      WRITE (UNIT,607) (CSUM(YR,DIST,6,J),J = 1,9)
  607 FORMAT (' ',T4,'----   --------   --------   ----   --------',
     1T51,'--------   --------   ----------   ----------',
     2T100,'----------'//' ',T5,'ALL',T14,I2,T25,I2,T33,I4,T42,I4,
     3T53,I4,T63,I3,1X,'%',T74,I10,3X,I10,3X,I10)
C
C
C     WRITE RATING DISTRIBUTION SUMMARIES FOR DISTRICTS
C
C
      WRITE (UNIT,608) DIST,DATE,YER,(SHUD(I),I=1,5),(MUST(I),I=1,5)
  608 FORMAT ('1',//' R67XXX',T52,'DISTRICT ',I1,T102,A8/' ',T41,I4,
     1T46,'RATING DISTRIBUTION SUMMARY'///' ',T43,'FC 1   FC 2   FC 3',
     2T64,'FC 4   FC 5'/' ',T43,5('****',3X)/' ',T36,'SHUD',4X,
     35(I2,5X)/' ',T36,'MUST',4X,5(I2,5X)///)
      WRITE (UNIT,609)
  609 FORMAT (' ',T36,'LANE MILES IN RATING GROUP BEFORE ACTION'/' ',
     1T63,'******',T89,'AVG      TOTAL')
      WRITE (UNIT,610)
  610 FORMAT (' ',T9,'FC',T16,'100-91  90-81  80-71  70-61  60-51',
     1T52,'50-41  40-31  30-21  20-11  10 -0    RTNG    MILES'/' ',
     2T8,'----     ------',2X,9('------',2X),2X,'----    ------'/)
      DO 330 FC = 1,5
      WRITE (UNIT,611) FC,  (RDB(YR,DIST,FC,J),J=1,12)
  611 FORMAT (' ',T10,I1,T16,10(F6.1,1X),2X,F5.1,4X,F6.1/)
  330 CONTINUE
      WRITE (UNIT,612)
  612 FORMAT (' ',T8,'----     ------',2X,9('-----',2X),2X,'----',
     1T97,'------'/)
      WRITE (UNIT,613) (RDB(YR,DIST,6,J),J=1,12)
  613 FORMAT (' ',T9,'ALL',4X,10(F6.1,1X),2X,F5.1,4X,F6.1////)
      WRITE (UNIT,614)
  614 FORMAT (' ',T36,'LANE MILES IN RATING GROUP AFTER ACTION'/' ',
     1T63,'******',T89,'AVG     TOTAL')
      WRITE (UNIT,610)
      DO 340 FC = 1,5
      WRITE (UNIT,611) FC, (RDA(YR,DIST,FC,J),J=1,12)
  340 CONTINUE
```

```
      WRITE (UNIT,612)
      WRITE (UNIT,613) (RDA(YR,DIST,6,J),J=1,12)
  310 CONTINUE
      UNIT = (DIST * 10) + 7
      WRITE (UNIT,617) DIST, DATE
  617 FORMAT ('1',//' R67XXX',T52,'DISTRICT ',I1,T102,A8/' ',
     1T42,'RATING AND COST YEARLY SUMMARY'////' ',T40,'RATING',T55,
     2 'RATING',T70,'MILEAGE'/' ',T25,'YEAR',T40,'BEFORE',T55,
     3 'AFTER',T71,'% AFF.',T87,'COST'/' ',T25,'----',T40,'------',
     4 T55,'-----',T70,'-------',T87,'----')
      SUMRBL = 0
      SUMRAL = 0
      DO 350 YR = 1,6
      YER = YEAR + YR
      CSUM(7,DIST,6,8) = CSUM(7,DIST,6,8) + CSUM(YR,DIST,6,8)
      SUMRBL = SUMRBL + RDB(YR,DIST,6,11) * RDB(YR,DIST,6,12)
      SUMRAL = SUMRAL + RDA(YR,DIST,6,11) * RDA(YR,DIST,6,12)
      RDB(7,DIST,6,12) = RDB(7,DIST,6,12) + RDB(YR,DIST,6,12)
      RDA(7,DIST,6,12) = RDA(7,DIST,6,12) + RDA(YR,DIST,6,12)
      WRITE (UNIT,618) YER, RDB(YR,DIST,6,11), RDA(YR,DIST,6,11),
     1                 CSUM(YR,DIST,6,6), CSUM(YR,DIST,6,8)
  618 FORMAT (//' ',T25,I4,T41,F5.1,T56,F5.1,T73,I2,' %',T83,'$',I10)
  350 CONTINUE
      IF (RDB(7,DIST,6,12) .EQ. 0.0) GO TO 300
      RDB(7,DIST,6,11) = SUMRBL / RDB(7,DIST,6,12)
      RDA(7,DIST,6,11) = SUMRAL / RDA(7,DIST,6,12)
      DRAT = (RDB(7,DIST,6,11) + RDA(7,DIST,6,11)) / 2.0
      WRITE (UNIT,619)          CSUM(7,DIST,6,8), DRAT
  619 FORMAT (' ',T84,'----------'//' ',T83,'$',I10/' ',T25,'6-YR AVG RA
     1TING  = ',F5.1)
  300 CONTINUE
C
C
C     WRITE STATEWIDE SUMMARIES
C
C
      IF (STAT .EQ. 1) GO TO 1000
C
C
C     BUILD TOTALS FOR STATEWIDE SUMMARIES
C
C
      DO 710 YR = 1,6
      DO 720 FC = 1,6
```

```
      SUMRBL = 0
      SUMRAL = 0
      DO 730 DIST = 1,6
      CSUM(YR,7,FC,3) = CSUM(YR,7,FC,3) + CSUM(YR,DIST,FC,3)
      CSUM(YR,7,FC,4) = CSUM(YR,7,FC,4) + CSUM(YR,DIST,FC,4)
      CSUM(YR,7,FC,5) = CSUM(YR,7,FC,5) + CSUM(YR,DIST,FC,5)
      CSUM(YR,7,FC,7) = CSUM(YR,7,FC,7) + CSUM(YR,DIST,FC,7)
      CSUM(YR,7,FC,8) = CSUM(YR,7,FC,8) + CSUM(YR,DIST,FC,8)
      CSUM(YR,7,FC,9) = CSUM(YR,7,FC,9) + CSUM(YR,DIST,FC,9)
      SUMRBL = SUMRBL + (CSUM(YR,DIST,FC,1) * CSUM(YR,DIST,FC,5) * 1.0)
      SUMRAL = SUMRAL + (CSUM(YR,DIST,FC,2) * CSUM(YR,DIST,FC,5) * 1.0)
  730 CONTINUE
      IF (CSUM(YR,7,FC,5) .EQ. 0) GO TO 731
      TOP = FLOAT(CSUM(YR,7,FC,4))
      SUM1 = (TOP / CSUM(YR,7,FC,5)) * 100.0
      CSUM(YR,7,FC,6) = IFIX(SUM1)
  731 SUMRBL = 0
      SUMRAL = 0
      DO 740 DIST = 1,6
      DO 750 N = 1,10
      RDB(YR,7,FC,N) = RDB(YR,7,FC,N) + RDB(YR,DIST,FC,N)
      RDA(YR,7,FC,N) = RDA(YR,7,FC,N) + RDA(YR,DIST,FC,N)
  750 CONTINUE
      SUMRBL = SUMRBL + RDB(YR,DIST,FC,11) * RDB(YR,DIST,FC,12)
      SUMRAL = SUMRAL + RDA(YR,DIST,FC,11) * RDA(YR,DIST,FC,12)
      RDB(YR,7,FC,12) = RDB(YR,7,FC,12) + RDB(YR,DIST,FC,12)
      RDA(YR,7,FC,12) = RDA(YR,7,FC,12) + RDA(YR,DIST,FC,12)
  740 CONTINUE
      IF (RDB(YR,7,FC,12) .EQ. 0.0) GO TO 720
      RDB(YR,7,FC,11) = SUMRBL / RDB(YR,7,FC,12)
      RDA(YR,7,FC,11) = SUMRAL / RDB(YR,7,FC,12)
      CSUM(YR,7,FC,1) = IFIX(RDB(YR,7,FC,11))
      CSUM(YR,7,FC,2) = IFIX(RDA(YR,7,FC,11))
  720 CONTINUE
  710 CONTINUE
C
C
C     WRITE STATEWIDE COST SUMMARIES
C
C
      DO 800 YR = 1,6
      UNIT = (7 * 10) + YR
      YER = YEAR + YR
      WRITE (UNIT,620)      DATE,YER,(SHUD(I),I=1,5),(MUST(I),I=1,5)
```

```
620 FORMAT ('1',//' R67XXX',T52,'STATEWIDE    ',T102,A8/' ',T48,I4,
   1T53,'COST SUMMARY'/' ',T43,'BY FUNCTIONAL CLASSIFICATION'///' ',
   2                        T43,'FC 1    FC 2    FC 3    FC 4    FC 5'/
   3' ',T43,5('*****',3X)/' ',T36,'SHUD',4X,5(I2,5X)/' ',T36,'MUST',
   44X,5(I2,5X)///)
    WRITE (UNIT,605)
    DO 820 FC = 1,5
    WRITE (UNIT,606) FC, (CSUM(YR,7,FC,J),J = 1,9)
820 CONTINUE
    WRITE (UNIT,607) (CSUM(YR,7,6,J),J = 1,9)
C
C
C     WRITE RATING DISTRIBUTION SUMMARIES FOR STATEWIDE
C
C
    WRITE (UNIT,621)       DATE,YER,(SHUD(I),I=1,5),(MUST(I),I=1,5)
621 FORMAT ('1',//' R67XXX',T52,'STATEWIDE    ',T102,A8/' ',T41,I4,
   1T46,'RATING DISTRIBUTION SUMMARY'/' ',T43,'BY FUNCTIONAL CLASSIFIC
   2ATION'///' ',T43,'FC 1    FC 2    FC 3',
   3T64,'FC 4    FC 5'/' ',T43,5('*****',3X)/' ',T36,'SHUD',4X,
   45(I2,5X)/' ',T36,'MUST',4X,5(I2,5X)///)
    WRITE (UNIT,609)
    WRITE (UNIT,610)
    DO 830 FC = 1,5
    WRITE (UNIT,611) FC,  (RDB(YR,7,FC,J),J=1,12)
830 CONTINUE
    WRITE (UNIT,612)
    WRITE (UNIT,613) (RDB(YR,7,6,J),J=1,12)
    WRITE (UNIT,614)
    WRITE (UNIT,610)
    DO 840 FC = 1,5
    WRITE (UNIT,611) FC, (RDA(YR,7,FC,J),J=1,12)
840 CONTINUE
    WRITE (UNIT,612)
    WRITE (UNIT,613) (RDA(YR,7,6,J),J=1,12)
    WRITE (UNIT,622)       DATE,YER,(SHUD(I),I=1,5),(MUST(I),I=1,5)
622 FORMAT ('1',//' R67XXX',T52,'STATEWIDE    ',T102,A8/' ',T48,I4,
   1T53,'COST SUMMARY'/' ',T51,'BY DISTRICT'///' ',
   2                        T43,'FC 1    FC 2    FC 3    FC 4    FC 5'/
   3' ',T43,5('*****',3X)/' ',T36,'SHUD',4X,5(I2,5X)/' ',T36,'MUST',
   44X,5(I2,5X)///)
    WRITE (UNIT,623)
623 FORMAT (' ',T11,'RTNG AVG    RTNG AVG    NUMB',T42,'MILES',
   1T53,'TOTAL',T66,'%',T76,'PRESENT      INFLATED     DISCOUNTED'/' ',
```

```
     2T4,'DIST    REF ACTN    AFT ACTN    PROJ   ACTED ON      MILES',
     3T62,'ACTED ON',T77,'COST',T90,'COST',T103,'COST'/' ',T4,'----',
     4T11,'--------   --------   ----   --------   --------   --------',
     5T74,'----------   ----------   ----------'/)
      DO 850 DIST = 1,6
      WRITE (UNIT,606) DIST, (CSUM(YR,DIST,6,J),J = 1,9)
  850 CONTINUE
      WRITE (UNIT,607) (CSUM(YR,7,6,J),J = 1,9)
      WRITE (UNIT,624)       DATE,YER,(SHUD(I),I=1,5),(MUST(I),I=1,5)
  624 FORMAT ('1','R67XXX',T52,'STATEWIDE    ',T102,A8/' ',T41,I4,
     1T46,'RATING DISTRIBUTION SUMMARY'/' ',T51,'BY DISTRICT'//' ',
     2T43,'FC 1    FC 2    FC 3',
     3T64,'FC 4    FC 5'/' ',T43,5('####',3X)/' ',T36,'SHUD',4X,
     45(I2,5X)/' ',T36,'MUST',4X,5(I2,5X)//)
      WRITE (UNIT,609)
      WRITE (UNIT,625)
  625 FORMAT (' ',T8,'DIST',T16,'100-91  90-81  80-71  70-61  60-51',
     1T52,'50-41  40-31  30-21  20-11  10 -0    RTNG    MILES'/' ',
     2T8,'----    ------',2X,9('-----',2X),2X,'----    ------'/)
      DO 860 DIST = 1,6
      WRITE (UNIT,611) DIST,  (RDB(YR,DIST,6,J),J=1,12)
  860 CONTINUE
      WRITE (UNIT,612)
      WRITE (UNIT,626) (RDB(YR,7,6,J),J=1,12)
  626 FORMAT (' ',T9,'ALL',4X,10(F6.1,1X),2X,F5.1,4X,F6.1//)
      WRITE (UNIT,614)
      WRITE (UNIT,625)
      DO 870 DIST = 1,6
      WRITE (UNIT,611) DIST, (RDA(YR,DIST,6,J),J=1,12)
  870 CONTINUE
      WRITE (UNIT,612)
      WRITE (UNIT,626) (RDA(YR,7,6,J),J=1,12)
  800 CONTINUE
      UNIT = UNIT + 1
      WRITE (UNIT,627) DATE
  627 FORMAT ('1',//' R67XXX',T52,'STATEWIDE    ',T102,A8/' ',
     1T42,'RATING AND COST YEARLY SUMMARY'////' ',T40,'RATING',T55,
     2 'RATING',T70,'MILEAGE'/' ',T25,'YEAR',T40,'BEFORE',T55,
     3 'AFTER',T71,'% AFF.',T87,'COST'/' ',T25,'----',T40,'------',
     4 T55,'------',T70,'-------',T87,'----')
      SUMRBL = 0
      SUMRAL = 0
      DO 880 YR = 1,6
      YER = YEAR + YR
```

```
      CSUM(7,7,6,8) = CSUM(7,7,6,8) + CSUM(YR,7,6,8)
      SUMRBL = SUMRBL + RDB(YR,7,6,11) * RDB(YR,7,6,12)
      SUMRAL = SUMRAL + RDA(YR,7,6,11) * RDA(YR,7,6,12)
      RDB(7,7,6,12) = RDB(7,7,6,12) + RDB(YR,7,6,12)
      RDA(7,7,6,12) = RDA(7,7,6,12) + RDA(YR,7,6,12)
      WRITE (UNIT,618) YER, RDB(YR,7,6,11), RDA(YR,7,6,11),
     1                 CSUM(YR,7,6,6), CSUM(YR,7,6,8)
  880 CONTINUE
      IF (RDE(7,7,6,12) .EQ. 0.0) GO TO 1000
      RDB(7,7,6,11) = SUMRBL / RDB(7,7,6,12)
      RDA(7,7,6,11) = SUMRAL / RDA(7,7,6,12)
      DRAT = (RDB(7,7,6,11) + RDA(7,7,6,11)) / 2.0
      WRITE (UNIT,619)       CSUM(7,7,6,8), DRAT
 1000 CONTINUE
      STOP
      END
```

APPENDIX D

JOB CONTROL LANGUAGE AND PROGRAM MODULES FOR APPLYING CONSTRAINTS

```
//*THIS JOB CONTROL LANGUAGE IS SET UP TO RUN THE 'PMS' NETWORK
//*PROGRAM AND BUDGET CONSTRAINT PROGRAMS IN SEQUENCE. PASSING
//*ALONG ANY PROJECTS NOT ACTED ON IN THE SCHEDULED YEAR TO THE
//*FOLLOWING YEAR, REPRIORITIZING AND REBUDGETING THROUGHOUT THE
//*BUDGET PERIOD. ---   BY DENNIS CRIMMINS FEB 1980
//STEP1    EXEC PGM=BUDG1
//STEPLIB DD DSN=HCT.LOAD.LIB,DISP=SHR
//FT05F001 DD DSN=MATLS.PERM.C346610.D10PT6,DISP=SHR
//          DD DSN=MATLS.PERM.C346610.D20PT6,DISP=SHR
//          DD DSN=MATLS.PERM.C346610.D30PT6,DISP=SHR
//          DD DSN=MATLS.PERM.C346610.D40PT6,DISP=SHR
//          DD DSN=MATLS.PERM.C346610.D50PT6,DISP=SHR
//          DD DSN=MATLS.PERM.C346610.D60PT6,DISP=SHR
//FT06F001 DD SYSOUT=A
//FT10F001 DD DSN=&&TEMP1A,DISP=(,PASS),UNIT=WORK,
//          SPACE=(TRK,(5,5),RLSE),
//          DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT11F001 DD DSN=&&TEMP1B,DISP=(,PASS),UNIT=WORK,
//          SPACE=(TRK,(5,5),RLSE),
//          DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT12F001 DD DSN=&&TEMP1C,DISP=(,PASS),UNIT=WORK,
//          SPACE=(TRK,(5,5),RLSE),
//          DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT13F001 DD DSN=&&TEMP1D,DISP=(,PASS),UNIT=WORK,
//          SPACE=(TRK,(5,5),RLSE),
//          DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT14F001 DD DSN=&&TEMP1E,DISP=(,PASS),UNIT=WORK,
//          SPACE=(TRK,(5,5),RLSE),
//          DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT15F001 DD DSN=&&TEMP1F,DISP=(,PASS),UNIT=WORK,
//          SPACE=(TRK,(5,5),RLSE),
//          DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT16F001 DD DSN=&&TEMP1G,DISP=(,PASS),UNIT=WORK,
//          SPACE=(TRK,(5,5),RLSE),
//          DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT04F001 DD *
80
/*
//STEP2    EXEC PGM=IEBRC000,REGION=76K
//SYSOUT    DD  SYSOUT=A
//SORTIN    DD  DSN=*.STEP1.FT11F001,DISP=(OLD,DELETE),UNIT=WORK
//SORTOUT   DD  DSN=&&TEMP2A,UNIT=WORK,DISP=(,PASS),
//          SPACE=(TRK,(5,5),RLSE),
//           DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
```

```
//SORTWK01  DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK02  DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK03  DD UNIT=WORK,SPACE=(TRK,(100,10))
//SYSIN  DD  *
  SORT FIELDS=(230,8,BI,A)
/*
//STEP3 EXEC PGM=BUDG2
//STEPLIB DD DSN=HCT.LOAD.LIB,DISP=SHR
//FT05F001 DD DSN=*.STEP2.SORTOUT,UNIT=WORK,DISP=(OLD,DELETE)
//FT06F001 DD SYSOUT=A
//FT08F001 DD DSN=&&TEMP3A,UNIT=WORK,DISP=(,PASS),
//            SPACE=(TRK,(5,5),RLSE),
//             DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT09F001 DD DSN=&&TEMP3B,UNIT=WORK,DISP=(,PASS),
//            SPACE=(TRK,(5,5),RLSE),
//            DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT04F001  DD *
81 80 0.13 0.17
0012600000
/*
//STEP4   EXEC PGM=IERRC000,REGION=76K
//SYSOUT   DD  SYSOUT=A
//SORTIN   DD  DSN=*.STEP3.FT09F001,DISP=(OLD,DELETE),UNIT=WORK
//         DD  DSN=*.STEP1.FT12F001,DISP=(OLD,DELETE),UNIT=WORK
//SORTOUT  DD  DSN=&&TEMP4,UNIT=WORK,DISP=(,PASS),
//            SPACE=(TRK,(5,5),RLSE),
//             DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//SORTWK01  DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK02  DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK03  DD UNIT=WORK,SPACE=(TRK,(100,10))
//SYSIN  DD  *
  SORT FIELDS=(230,8,BI,A)
/*
//STEP5 EXEC PGM=BUDG2
//STEPLIB DD DSN=HCT.LOAD.LIB,DISP=SHR
//FT05F001 DD DSN=*.STEP4.SORTOUT,UNIT=WORK,DISP=(OLD,DELETE)
//FT06F001 DD SYSOUT=A
//FT08F001 DD DSN=&&TEMP5A,UNIT=WORK,DISP=(,PASS),
//            SPACE=(TRK,(5,5),RLSE),
//             DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT09F001 DD DSN=&&TEMP5B,UNIT=WORK,DISP=(,PASS),
//            SPACE=(TRK,(5,5),RLSE),
//            DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT04F001  DD *
```

```
82 80 0.13 0.17
0012600000
/*
//STEP6    EXEC PGM=IERRC000,REGION=76K
//SYSOUT    DD   SYSOUT=A
//SORTIN    DD   DSN=*.STEP5.FT09F001,DISP=(OLD,DELETE),UNIT=WORK
//          DD   DSN=*.STEP1.FT13F001,DISP=(OLD,DELETE),UNIT=WORK
//SORTOUT   DD   DSN=&&TEMP6,UNIT=WORK,DISP=(,PASS),
//          SPACE=(TRK,(5,5),RLSE),
//           DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//SORTWK01   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK02   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK03   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SYSIN  DD  *
  SORT FIELDS=(230,8,BI,A)
/*
//STEP7 EXEC PGM=BUDG2
//STEPLIB DD DSN=HCT.LOAD.LIB,DISP=SHR
//FT05F001 DD DSN=*.STEP6.SORTOUT,UNIT=WORK,DISP=(OLD,DELETE)
//FT06F001 DD SYSOUT=A
//FT08F001 DD DSN=&&TEMP7A,UNIT=WORK,DISP=(,PASS),
//          SPACE=(TRK,(5,5),RLSE),
//           DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT09F001 DD DSN=&&TEMP7B,UNIT=WORK,DISP=(,PASS),
//          SPACE=(TRK,(5,5),RLSE),
//          DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT04F001  DD *
83 80 0.13 0.17
0020085000
/*
//STEP8    EXEC PGM=IERRC000,REGION=76K
//SYSOUT    DD   SYSOUT=A
//SORTIN    DD   DSN=*.STEP7.FT09F001,DISP=(OLD,DELETE),UNIT=WORK
//          DD   DSN=*.STEP1.FT14F001,DISP=(OLD,DELETE),UNIT=WORK
//SORTOUT   DD   DSN=&&TEMP8A,UNIT=WORK,DISP=(,PASS),
//          SPACE=(TRK,(5,5),RLSE),
//           DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//SORTWK01   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK02   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK03   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SYSIN  DD  *
  SORT FIELDS=(230,8,BI,A)
/*
//STEP9 EXEC PGM=BUDG2
```

```
//STEPLIB DD DSN=HCT.LOAD.LIB,DISP=SHR
//FT05F001 DD DSN=*.STEP8.SORTOUT,UNIT=WORK,DISP=(OLD,DELETE)
//FT06F001 DD SYSOUT=A
//FT08F001 DD DSN=&&TEMP9A,UNIT=WORK,DISP=(,PASS),
//            SPACE=(TRK,(5,5),RLSE),
//             DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT09F001 DD DSN=&&TEMP9B,UNIT=WORK,DISP=(,PASS),
//            SPACE=(TRK,(5,5),RLSE),
//            DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT04F001  DD *
84 80 0.13 0.17
0020085000
/*
//STEP10  EXEC PGM=IERRCOOO,REGION=76K
//SYSOUT    DD   SYSOUT=A
//SORTIN    DD   DSN=*.STEP9.FT09F001,DISP=(OLD,DELETE),UNIT=WORK
//          DD   DSN=*.STEP1.FT15F001,DISP=(OLD,DELETE),UNIT=WORK
//SORTOUT   DD   DSN=&&TEMP10,UNIT=WORK,DISP=(,PASS),
//          SPACE=(TRK,(5,5),RLSE),
//           DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//SORTWK01  DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK02  DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK03  DD UNIT=WORK,SPACE=(TRK,(100,10))
//SYSIN   DD  *
 SORT FIELDS=(230,8,BI,A)
/*
//STEP11 EXEC PGM=BUDG2
//STEPLIB DD DSN=HCT.LOAD.LIB,DISP=SHR
//FT05F001 DD DSN=*.STEP10.SORTOUT,UNIT=WORK,DISP=(OLD,DELETE)
//FT06F001 DD SYSOUT=A
//FT08F001 DD DSN=&&TEMP11A,UNIT=WORK,DISP=(,PASS),
//            SPACE=(TRK,(5,5),RLSE),
//             DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT09F001 DD DSN=&&TEMP11B,UNIT=WORK,DISP=(,PASS),
//            SPACE=(TRK,(5,5),RLSE),
//            DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT04F001  DD *
85 80 0.13 0.17
0020115000
/*
//STEP12  EXEC PGM=IERRCOOO,REGION=76K
//SYSOUT    DD   SYSOUT=A
//SORTIN    DD   DSN=*.STEP11.FT09F001,DISP=(OLD,DELETE),UNIT=WORK
//          DD   DSN=*.STEP1.FT16F001,DISP=(OLD,DELETE),UNIT=WORK
```

```
//SORTOUT   DD   DSN=&&TEMP12,UNIT=WORK,DISP=(,PASS),
//             SPACE=(TRK,(5,5),RLSE),
//              DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//SORTWK01   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK02   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK03   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SYSIN  DD  *
  SORT FIELDS=(230,8,BI,A)
/*
//STEP13 EXEC PGM=BUDG2
//STEPLIB DD DSN=HCT.LOAD.LIB,DISP=SHR
//FT05F001 DD DSN=*.STEP12.SORTOUT,UNIT=WORK,DISP=(OLD,DELETE)
//FT06F001 DD SYSOUT=A
//FT08F001 DD DSN=&&TEMP13A,UNIT=WORK,DISP=(,PASS),
//             SPACE=(TRK,(5,5),RLSE),
//              DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT09F001 DD DSN=&&TEMP13B,UNIT=WORK,DISP=(,PASS),
//             SPACE=(TRK,(5,5),RLSE),
//             DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//FT04F001  DD *
86 80 0.13 0.17
0020115000
/*
//STEP14     EXEC PGM=IERRC000,REGION=76K
//SYSOUT     DD   SYSOUT=A
//SORTIN     DD   DSN=*.STEP1.FT10F001,DISP=(OLD,DELETE),UNIT=WORK
//           DD   DSN=*.STEP3.FT08F001,DISP=(OLD,DELETE),UNIT=WORK
//           DD   DSN=*.STEP5.FT08F001,DISP=(OLD,DELETE),UNIT=WORK
//           DD   DSN=*.STEP7.FT08F001,DISP=(OLD,DELETE),UNIT=WORK
//           DD   DSN=*.STEP9.FT08F001,DISP=(OLD,DELETE),UNIT=WORK
//           DD   DSN=*.STEP11.FT08F001,DISP=(OLD,DELETE),UNIT=WORK
//           DD   DSN=*.STEP13.FT08F001,DISP=(OLD,DELETE),UNIT=WORK
//           DD   DSN=*.STEP13.FT09F001,DISP=(OLD,DELETE),UNIT=WORK
//SORTOUT DD DSN=MATLS.NET81.VERS1,UNIT=SYSDA,DISP=(,CATLG),
//             SPACE=(TRK,(30,30),RLSE),
//              DCB=(RECFM=FB,LRECL=240,BLKSIZE=6000)
//SORTWK01   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK02   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SORTWK03   DD UNIT=WORK,SPACE=(TRK,(100,10))
//SYSIN  DD  *
  SORT FIELDS=(219,2,BI,A,230,8,BI,A,10,3,BI,A,13,5,BI,A)
/*
//STEP15  EXEC PGM=NETWORK
//STEPLIB  DD DSN=HCT.LOAD.LIB,DISP=SHR
```

```
//FT05F001 DD DSN=MAILS.NET81.VERS1,DISP=SHR                                       00022100
//FT06F001  DD SYSOUT=A                                                            00022200
//FT04F001  DD *                                                                   00022300
1980 0.13 0 0.04 0.17                                                              00022400
50 40 40 40 60                                                                     00022500
40 30 30 30 50                                                                     00022600
                        BASE BUDGET FOR 1982-87 PROGRAM                            00022700
/*                                                                                 00022800
//FT11F001  DD SYSOUT=A,DCB=RECFM=UA                                               00022900
//FT12F001  DD SYSOUT=A,DCB=RECFM=UA                                               00023000
//FT13F001  DD SYSOUT=A,DCB=RECFM=UA                                               00023100
//FT14F001  DD SYSOUT=A,DCB=RECFM=UA                                               00023200
//FT15F001  DD SYSOUT=A,DCB=RECFM=UA                                               00023300
//FT16F001  DD SYSOUT=A,DCB=RECFM=UA                                               00023400
//FT17F001  DD SYSOUT=A,DCB=RECFM=UA                                               00023500
//FT21F001  DD SYSOUT=A,DCB=RECFM=UA                                               00023600
//FT22F001  DD SYSOUT=A,DCB=RECFM=UA                                               00023700
//FT23F001  DD SYSOUT=A,DCB=RECFM=UA                                               00023800
//FT24F001  DD SYSOUT=A,DCB=RECFM=UA                                               00023900
//FT25F001  DD SYSOUT=A,DCB=RECFM=UA                                               00024000
//FT26F001  DD SYSOUT=A,DCB=RECFM=UA                                               00024100
//FT27F001  DD SYSOUT=A,DCB=RECFM=UA                                               00024200
//FT31F001  DD SYSOUT=A,DCB=RECFM=UA                                               00024300
//FT32F001  DD SYSOUT=A,DCB=RECFM=UA                                               00024400
//FT33F001  DD SYSOUT=A,DCB=RECFM=UA                                               00024500
//FT34F001  DD SYSOUT=A,DCB=RECFM=UA                                               00024600
//FT35F001  DD SYSOUT=A,DCB=RECFM=UA                                               00024700
//FT36F001  DD SYSOUT=A,DCB=RECFM=UA                                               00024800
//FT37F001  DD SYSOUT=A,DCB=RECFM=UA                                               00024900
//FT41F001  DD SYSOUT=A,DCB=RECFM=UA                                               00025000
//FT42F001  DD SYSOUT=A,DCB=RECFM=UA                                               00025100
//FT43F001  DD SYSOUT=A,DCB=RECFM=UA                                               00025200
//FT44F001  DD SYSOUT=A,DCB=RECFM=UA                                               00025300
//FT45F001  DD SYSOUT=A,DCB=RECFM=UA                                               00025400
//FT46F001  DD SYSOUT=A,DCB=RECFM=UA                                               00025500
//FT47F001  DD SYSOUT=A,DCB=RECFM=UA                                               00025600
//FT51F001  DD SYSOUT=A,DCB=RECFM=UA                                               00025700
//FT52F001  DD SYSOUT=A,DCB=RECFM=UA                                               00025800
//FT53F001  DD SYSOUT=A,DCB=RECFM=UA                                               00025900
//FT54F001  DD SYSOUT=A,DCB=RECFM=UA                                               00026000
//FT55F001  DD SYSOUT=A,DCB=RECFM=UA                                               00026100
//FT56F001  DD SYSOUT=A,DCB=RECFM=UA                                               00026200
//FT57F001  DD SYSOUT=A,DCB=RECFM=UA                                               00026300
//FT61F001  DD SYSOUT=A,DCB=RECFM=UA                                               00026400
```

```
//FT62F001  DD SYSOUT=A,DCB=RECFM=UA
//FT63F001  DD SYSOUT=A,DCB=RECFM=UA
//FT64F001  DD SYSOUT=A,DCB=RECFM=UA
//FT65F001  DD SYSOUT=A,DCB=RECFM=UA
//FT66F001  DD SYSOUT=A,DCB=RECFM=UA
//FT67F001  DD SYSOUT=A,DCB=RECFM=UA
//FT71F001  DD SYSOUT=A,DCB=RECFM=UA
//FT72F001  DD SYSOUT=A,DCB=RECFM=UA
//FT73F001  DD SYSOUT=A,DCB=RECFM=UA
//FT74F001  DD SYSOUT=A,DCB=RECFM=UA
//FT75F001  DD SYSOUT=A,DCB=RECFM=UA
//FT76F001  DD SYSOUT=A,DCB=RECFM=UA
//FT77F001  DD SYSOUT=A,DCB=RECFM=UA
/*
```

SOURCE PROGRAM FOR BUDG 1

```
C     PROGRAM BUDG1
C
C     1ST PROGRAM MODULE TO BE USED IN JOB STREAM FOR
C     BALANCING 6 YEAR CONSTRUCTION PROGRAM
C
      IMPLICIT INTEGFR (A-Z)
C
      DIMENSION    ALPHA(35), ALT(4), APPYR(4)
C
      REAL  ECONS(4), EVAR(4),  EXP(4),  PI,  RTNG, EQ1, EG2, EQ3
C
      READ (4,401) YEAR
  401 FORMAT (I2)
C
  100 READ (5,501,END=999) (ALPHA(J),J=1,6),LENG,R,FC,(ALPHA(J),J=7,12),
     1       YR, (ECONS(J), EVAR(J), EXP(J),J=1,4), (ALPHA(J),J=13,35),
     2       (ALT(J), APPYR(J),J=1,4)
C
  501 FORMAT (5A4, A2, I4, A1, I1, 5A4, A1, I2, 4(F6.2, F9.5, F4.2),
     1        22A4, A2, 4(I1, I2))
C
      X = 0
      AGE = APPYR(1) - YEAR
      IF (APPYR(1) .LE. YFAR) X = 1
      EQ1 = ECONS(1)
      EQ2 = EVAR(1)
      EQ3 = EXP(1)
      IF (X .NE. 0) EQ1 = ECONS(ALT(1))
      IF (X .NE. 0) EQ2 = EVAR(ALT(1))
      IF (X .NE. 0) EQ3 = EXP(ALT(1))
      IF (X .NE. 0) AGE = APPYR(2) - APPYR(1)
      IF (X .NE. 0 .AND .APPYR(2) .LT. APPYR(1)) AGE = AGE + 100
      IF (AGE .GT. 40) AGE = 40
      RTNG= EQ1 - (EQ2 * (AGE + 1) ** EQ3)
      IF (RTNG .LT. -99.9) RTNG = -99.9
      PI = RTNG + 100.0
C
      UNIT = 10
C
      Z = 1
      IF (APPYR(1) .LE. YEAR .AND. ALT(1) .GT. 1) Z = 2
      00 150 I = 1,6
      IF ((YEAR + I) .EQ. APPYR(Z)) UNIT = UNIT + I
  150 CONTINUE
```

```
C
      WRITE (UNIT,502)      (ALPHA(J),J=1,6),LENG,R,FC,(ALPHA(J),J=7,12),
     1        YR,(ECONS(J), EVAR(J), EXP(J),J=1,4),(ALPHA(J),J=13,35),
     2        (ALT(J),APPYR(J),J=1,4), PI
C
  502 FORMAT (5A4, A2, I4, A1, I1, 5A4, A1, I2, 4(F6.2, F9.5, F4.2),
     1          22A4,A2,4(I1,I2), F8.1, 3X)
C
      GO TO 100
C
  999 CONTINUE
      DO 200 I = 10,16
      END FILE I
  200 CONTINUE
      STOP
      END
```

SOURCE PROGRAM FOR BUDG 2

```
C     PROGRAM BUDG2
C
C     2ND PROGRAM MODULE TO BE USED IN JOB STREAM FOR
C     BALANCING 6 YEAR CONSTRUCTION PROGRAM
C
      IMPLICIT INTEGER (A-Z)
C
      REAL    CONS(4), COEFF(4), EXP(4), COST,  PCOST,  RTNG,   PI,   EI,
     1        SURF,    BUDGET,   TOTAL,  PREP,  MSURF,  CONST,  COEF, EX,
     2        INFL, ENGCST
C
      DIMENSION  ALPHA(37),  ACOST(3),  ALT(4),  APPYR(4)
C
C
      TOTAL = 0.0
C
      READ (4,401) BUDGET, YEAR, NOW, FI, ENGCST
  401 FORMAT (F10.0,1X,I2,1X,I2,2(1X,F4.2))
C
  100 READ (5,501,END=999) (ALPHA(J),J=1,6), LENGTH, DUMY1, DUMY2, RDW,
     1                     PSH, LSH, (ALPHA(J),J=7,9),  YR,
     2                     (CONS(I), COEFF(I), EXP(I),I=1,4),
     3                     (ACOST(J),J=1,3), (ALPHA(J),J=10,27),
     4                     (ALT(J), APPYR(J),J=1,4), PI
C
  501 FORMAT(5A4, A2, I4, A4, A1, 3I2, 3A4, I2, 4(F6.2, F9.5,
     1       F4.2), 3I6, 18A4, 4(I1,I2), F8.1, 3X)
C
C
      AK = 0
      DO 10 I = 1,4
      IF (APPYR(I) .NE. YEAR) GO TO 10
      AK = I
      APPLIC = I
      AYEAR = APPYR(I)
      ALTNT = ALT(I)
      KJ = 1
      IF (I .GT. 1) KJ = ALT(APPLIC - 1)
      CONST = CONS(KJ)
      COFF = COEFF(KJ)
      FX = FXP(KJ)
   10 CONTINUE
C
C
```

```
      IF (AK .EQ. 0) GO TO 998
C
C
      AGE = AYEAR - YR
      IF (APPLIC .GT. 1) AGE = AYEAR - APPYR(APPLIC - 1)
      RTNG = CONST - (COEF * AGE ** EX)
      IF (RTNG .LT. 0.0) RTNG = 0.0
      SURF = (LENGTH * .01) * (FLOAT(RDW + RSH + LSH) / 12)
      MSURF = (LENGTH * .01) * (FLOAT(PDW) / 12)
C
      K = ALTNT - 1
C
      PREP = PCOST(RTNG)
C
      INFL = (1.0 + EI) ** (AYEAR - NOW)
      COST = ((ACOST(K)*SURF) + (MSURF*PREP))*INFL* (1.0+ENGCST)
C
      TOTAL = TOTAL + COST
      IF (TOTAL .GT. BUDGET) GO TO 900
C
C
      AGAIN = 0
      NAPPL = APPLIC + 1
      IF (NAPPL .EQ. 5) GO TO 30
      NEXT = AYEAR + 1
      FINAL = NOW + 6
      IF (NEXT .EQ. FINAL) GO TO 35
      DO 30 J = NEXT,FINAL
      GO TO 36
   35 J = NEXT
   36 IF (APPYR(NAPPL) .EQ. J) AGAIN = 1
   30 CONTINUE
C
C
      IF (AGAIN .EQ. 1) GO TO 800
C
C
      WRITE (5,601)          (ALPHA(J),J=1,6), LENGTH, DUMY1, DUMY2, RDW,
     1                       RSH, LSH, (ALPHA(J),J=7,9),  YR,
     2                       (CONS(I), COEFF(I), EXP(I),I=1,4),
     3                       (ACOST(J),J=1,3), (ALPHA(J),J=10,27),
     4                       (ALT(J), APPYR(J),J=1,4), PI
C
C
```

```
      GO TO 100
C
C
  800 AGE = APPYR(NAPPL) - AYEAR
      ALTNT = ALT(NAPPL - 1)
      CONST = CONS(ALTNT)
      COEF = COEFF(ALTNT)
      EX = EXP(ALTNT)
      GO TO 910
C
C
  900 TOTAL = TOTAL - COST
      AYEAR = AYEAR + 1
      AGE = AYEAR - YR
      IF (APPLIC .GT. 1) AGE = AYEAR - APPYR(APPLIC - 1)
      IF (APPLIC .EQ. 4) GO TO 910
      DO 40 I = APPLIC,4
      IF (ALT(I) .EQ. 0) GO TO 40
      APPYR(I) = APPYR(I) + 1
      IF (APPYR(I) .GE. 100) APPYR(I) = APPYR(I) - 100
   40 CONTINUE
  910 RTNG = CONST - (COEF * (AGE + 1) ** EX)
      IF (RTNG .LT. -99.9) RTNG = -99.9
      PI = RTNG + 100.0
C
C
  998 WRITE (9,501)         (ALPHA(J),J=1,6), LENGTH, DUMY1, DUMY2, RDW,
     1                      RSH, LSH, (ALPHA(J),J=7,9),  YR,
     2                      (CONS(I), COEFF(I), EXP(I),I=1,4),
     3                      (ACOST(J),J=1,3), (ALPHA(J),J=10,27),
     4                      (ALT(J), APPYR(J),J=1,4), PI
C
C
      GO TO 100
C
C
  999 CONTINUE
      END FILE 8
      END FILE 9
      STOP
      END
```

SOURCE PROGRAM FOR BUDG A

```
C     PROGRAM BUDGA
C
C     1ST PROGRAM MODULE TO BE USED IN JOB STREAM FOR
C     BALANCING 6 YEAR CONSTRUCTION PROGRAM BY AVG RATING
C
      IMPLICIT INTEGER (A-Z)
C
      REAL  CONS(4), COEFF(4), EXP(4), TOTRT, RTNG,   PI,  LENGR
C
      DIMENSION  ALPHA(38),  ACOST(3),  ALT(4),  APPYR(4)
C
C
      TOTAL = 0.0
      TOTRT = 0.0
      TOTMI = 0
C
C
      READ (4,401) YEAR,     AYR
  401 FORMAT (I2,1X,I2)
C
  100 READ (5,501,END=999) (ALPHA(J),J=1,6), LENGTH, DUMY1, DUMY2, RDW,
     1                     RSH, LSH, (ALPHA(J),J=7,9), YR,
     2                     (CONS(I), COEFF(I), EXP(I),I=1,4),
     3                     (ACOST(J),J=1,3), (ALPHA(J),J=10,27),
     4                     (ALT(J), APPYR(J),J=1,4)
C
  501 FORMAT(5A4, A2, I4, A4, A1, 3I2, 3A4, I2, 4(F6.2, F9.5,
     1        F4.2), 3I6, 18A4, 4(I1,I2))
C
C
      K = 1
      IF (APPYR(1) .LT. AYR .AND. ALT(1) .GT. 1) K = ALT(1)
      IF (APPYR(2) .LT. AYR .AND. APPYR(2) .GT. YEAR) K = ALT(2)
      AGE = AYR - YR
      IF (APPYR(1).LT.AYR.AND.ALT(1).GT.1) AGE=AYR-APPYR(1)
      IF (APPYR(2).LT.AYR.AND.APPYR(2).GT.YEAR) AGE=AYR-APPYR(2)
      IF (AGE .LT. 0)   AGE = 0
      RTNG = CONS(K) - (COEFF(K) * AGE ** EXP(K))
      IF (RTNG .LT. -99.9) RTNG = -99.9
      IF (RTNG .GT. 100.0) RTNG = 100.0
      PI = RTNG + 100.0
C
C
      LENGR = LENGTH * .01
```

```
      TOTMI = TOTMI + LENGTH
      TOTRT = TOTRT + (LENGR * RTNG)
      K = 0
      DO 10 I = 1,4
      IF (AYR .NE. APPYR(I)) GO TO 10
      K = I
   10 CONTINUE
      IF (K .GT. 0) GO TO 30
      WRITE (8,502)          (ALPHA(J),J=1,6), LENGTH, DUMY1, DUMY2, RDW,
     1                       RSH, LSH, (ALPHA(J),J=7,9), YR,
     2                       (CONS(I), COEFF(I), EXP(I),I=1,4),
     3                       (ACOST(J),J=1,3), (ALPHA(J),J=10,27),
     4                       (ALT(J), APPYR(J),J=1,4),  PI
C
  502 FORMAT(5A4, A2, I4, A4, A1, 3I2, 3A4, I2, 4(F6.2, F9.5,
     1        F4.2), 3I6, 18A4, 4(I1,I2), F8.0)
C
C
      GO TO 100
C
C
   30 KJ = 1
      IF (K .GT. 1) KJ = ALT(K - 1)
      AGE = AYR - YR
      IF (K .GT. 1) AGE = AYR - APPYR(K - 1)
      RTNG = CONS(KJ) - (COEFF(KJ) * (AGE + 1) ** EXP(KJ))
      IF (RTNG .LT. -99.9) RTNG = -99.9
      PI = RTNG + 100.0
      WRITE (9,502)          (ALPHA(J),J=1,6), LENGTH, DUMY1, DUMY2, RDW,
     1                       RSH, LSH, (ALPHA(J),J=7,9), YR,
     2                       (CONS(I), COEFF(I), EXP(I),I=1,4),
     3                       (ACOST(J),J=1,3), (ALPHA(J),J=10,27),
     4                       (ALT(J), APPYR(J),J=1,4),  PI
C
C
      GO TO 100
C
C
  999 WRITE (10,503)  TOTMI, TOTRT
  503 FORMAT (I8,F12.1)
      END FILE 8
      END FILE 9
      END FILE 10
      STOP
```

00008900

END

SOURCE PROGRAM FOR BUDG B

```
C     PROGRAM BUDGR
C
C     2ND PROGRAM MODULE TO BE USED IN JOB STREAM FOR
C     BALANCING 6 YEAR CONSTRUCTION PROGRAM BY AVG RATING
C     BY DENNIS CRIMMINS          NOV 1980
C
      IMPLICIT INTEGER (A-Z)
C
      REAL  CONS(4), COEFF(4), EXP(4), RTNG,  OLDRT,  PI,   LENGR,
     1      CONST,   COEF,     EX,     NEWRT, TOTAL,  TOTRT
C
      DIMENSION  ALPHA(38),  ACOST(3),  ALT(4),  APPYR(4)
C
C
      TOTAL  = 0
      LAST   = 0
C
      READ (4,401) NOW, YEAR, FRAT
  401 FORMAT (I2,1X,I2,1X,I2)
C
C
      READ (7,701) TOTMI, TOTRT
  701 FORMAT (I8,F12.1)
C
      NEWRT = (TOTMI * FRAT * 0.01) - TOTRT
C
  100 READ (5,501,END=999)  (ALPHA(J),J=1,6), LENGTH, DUMY1, DUMY2, RDW,
     1                      RSH, LSH, (ALPHA(J),J=7,9), YR,
     2                      (CONS(I), COEFF(I), EXP(I),I=1,4),
     3                      (ACOST(J),J=1,3), (ALPHA(J),J=10,27),
     4                      (ALT(J), APPYR(J),J=1,4), PI
C
  501 FORMAT(5A4, A2, I4, A4, A1, 3I2, 3A4, I2, 4(F6.2, F9.5,
     1          F4.2), 3I6, 18A4, 4(I1,I2), F8.0)
C
C
      AK = 0
      LENGR = LENGTH * 0.01
      DO 10 I = 1,4
      IF (APPYR(I) .NE. YEAR) GO TO 10
      AK = 1
      APPLIC = I
      AYEAR = APPYR(I)
      ALTINT = ALT(I)
```

```
      KJ = 1
      IF (I .GT. 1) KJ = ALT(APPLIC - 1)
      CONST = CONS(KJ)
      COEF = COEFF(KJ)
      EX = EXP(KJ)
   10 CONTINUE
C
C
      IF (AK .EQ. 0) GO TO 998
C
C
C
      IF (LAST .EQ. 1) GO TO 900
      AGE = YEAR - YR
      IF (APPLIC .GT. 1) AGE = YEAR - APPYR(APPLIC - 1)
      RTNG = (CONST - (COEF * (AGE ** EX)))
      IF (RTNG .LT. -99.9) RTNG = -99.9
      OLDRT = LENGR * RTNG
      TOTAL = TOTAL - OLDRT + (100.0 * LENGR)
      IF (TOTAL .GT. NEWRT) LAST = 1
C
C
      AGAIN = 0
      NAPPL = APPLIC + 1
      IF (NAPPL .EQ. 5) GO TO 30
      NEXT = AYEAR + 1
      FINAL = NOW + 6
      IF (NEXT .EQ. FINAL) GO TO 35
      DO 30 J = NEXT,FINAL
      GO TO 36
   35 J = NEXT
   36 IF (APPYR(NAPPL) .EQ. J) AGAIN = 1
   30 CONTINUE
C
C
      IF (AGAIN .EQ. 1) GO TO 800
C
C
      GO TO 998
C
C
  800 AGE = APPYR(NAPPL) - AYEAR
      ALTNT = ALT(NAPPL - 1)
      CONST = CONS(ALTNT)
```

```
      COEF = COEFF(ALTNT)
      EX = EXP(ALTNT)
      GO TO 910
C
C
  900 AYEAR = AYEAR + 1
      AGE = AYEAR - YR
      IF (APPLIC .GT. 1) AGE = AYEAR - APPYR(APPLIC - 1)
      IF (APPLIC .EQ. 4) GO TO 910
      DO 40 I = APPLIC,4
      IF (ALT(I) .EQ. 0) GO TO 40
      APPYR(I) = APPYR(I) + 1
      IF (APPYR(I) .GE. 100) APPYR(I) = APPYR(I) - 100
   40 CONTINUE
  910 PTNG = CONST - (COEF * (AGE + 1) ** EX)
      IF (RTNG .LT. -99.9) RTNG = -99.9
      IF (RTNG .GT. 100.0) PTNG = 100.0
      PI = RTNG + 100.0
C
C
  998 WRITE (9,501)          (ALPHA(J),J=1,6), LENGTH, DUMY1, DUMY2, RDW,
     1                       RSH, LSH, (ALPHA(J),J=7,9), YR,
     2                       (CONS(I), COEFF(I), EXP(I),I=1,4),
     3                       (ACOST(J),J=1,3), (ALPHA(J),J=10,27),
     4                       (ALT(J), APPYR(J),J=1,4), PI
C
C
      GO TO 100
C
C
  999 CONTINUE
      END FILE 9
      STOP
      END
```

APPENDIX E

SOURCE PROGRAM FOR RATGRP

```
C        PROGRAM  RATGRP        BY DMC 7-81
C
C        THIS PROGRAM PRODUCES DISTRIBUTIONS OF MILEAGES BY DISTRICT
C        AND STATEWIDE OF STRUCTURAL RATINGS AND BUMPCOUNTS FOR EVALUATION
C        IN THE PAVEMENT MANAGEMENT SYSTEM.
C
C
         IMPLICIT INTEGER (A-Z)
C
C
         COMMON /COMRAT/   AMTRX,  BMTRX,  CMTRX,  PTYPE, STRUCR,
        1                  D1,     D2,     D3A,    D3B,   D4A,
        2                  D4B,    D5A,    D5B,    D6A,   D6B,
        3                  D7A,    D7B,    D8A,    D8B
C
C
         REAL P2,            FXP(20),        LENG,           COMBR,
        1     AMILES(7,6,10),BMILES(7,6,10),CMILES(7,6,10),ACNTMI(7,6,10),
        2     BCNTMI(7,6,10),CCNTMI(7,6,10),ACOMBM(7,6,10),BCOMBM(7,6,10),
        3     CCOMBM(7,6,10),ACCUM(7,6),     BCCUM(7,6),     CCCUM(7,6),
        4     ACLCUM(7,6),   BCLCUM(7,6),    CCLCUM(7,6),    DACAVG(7,6),
        5     DBCAVG(7,6),   DCCAVG(7,6),    DACUM(7,6),     DBCUM(7,6),
        6     DCCUM(7,6),    DACNTC(7,6),    DBCNTC(7,6),    DCCNTC(7,6),
        7     DALCUM(7,6),   DBLCUM(7,6),    DCLCUM(7,6),    DACMIL(7,6),
        8     DBCMIL(7,6),   DCCMIL(7,6),    DAVG(7,6),      DCTAV(7,6),
        9     DCOAVG(7,6),   DLCUM(7,6),     DCNTC(7,6),     DCMIL(7,6),
        A     DAAVG(7,6),    DBAVG(7,6),     DCAVG(7,6),     DACTAV(7,6),
        B     DBCTAV(7,6),   DCCTAV(7,6),    RF,             CLCUM(7,6),
        C     CCUM(7,6),     DCUM(7,6),      COMBM(7,6,10),  MILES(7,6,10),
        D     CNTMI(7,6,10), MDB(7,6,3,8,14),                TOP,
        E     PERC(7,6,3,8,13)
C
         REAL*8   GETDAT,  DATE
C
         DIMENSION          AMTRX(3,21),  BMTRX(3,21),  CMTRX(3,21),
        1                   DEF(8),       DEFA(8),       DEFB(8)
C
C        READ INTERPRETING PARAMETERS
C
         READ (4,402) GENER
     402 FORMAT (I2)
         DO 3 I = 1,3
         READ (4,401) (AMTRX(I,J),J=1,21)
     401 FORMAT (21I2)
```

```
    3 CONTINUE
      DO 4 I = 1,3
      READ (4,401)  (BMTRX(I,J),J=1,21)
    4 CONTINUE
      DO 5 I = 1,3
      READ (4,401)  (CMTRX(I,J),J=1,21)
    5 CONTINUE
C
C     CALL THE SUBROUTINE THAT LISTS THE INTERPRETING PARAMETERS
C
      CALL LPARM
C
      CALL GETDAT(DATE)
C
C     INITIALIZE
C
      DATA   A,B,C,L,R,N,F/'A','B','C','L','R','N','F'/
      DATA   AMILES,BMILES,CMILES/1260*0.0/
      DATA   DAAVG,DBAVG,DCAVG/126*0.0/
      DATA   DACUM,DBCUM,DCCUM/126*0.0/
      DATA   DALCUM,DBLCUM,DCLCUM/126*0.0/
      DATA   LCS,LRMP,LLMP,LBMP/4*0/
      DATA   ACNTMI,BCNTMI,CCNTMI,DACTAV,DBCTAV,DCCTAV/1386*0.0/
      DATA   DACNTC,DBCNTC,DCCNTC,DACMIL,DBCMIL,DCCMIL/252*0.0/
      DATA   ACOMBM,BCOMBM,CCOMBM/1260*0.0/
      DATA   ACCUM,BCCUM,CCCUM,ACLCUM,BCLCUM,CCLCUM/252*0.0/
      DATA   DACAVG,DBCAVG,DCCAVG/126*0.0/
      DATA   COMBM,MILES,CNTMI,CLCUM,CCUM,DCUM/1386*0.0/
      DATA   DLCUM,DCNTC,DCMIL,DCOAVG,DAVG,DCTAV/252*0.0/
      DATA   MDB/14112*0.0/,PERC/13104*0.0/
C
C     READ EACH PAVEMENT RATING CARD ONE AT A TIME
C
  100 READ (5,501,END=999)  DIST,SR,FC,CS,CSMP,PTYPE,SIDE,D1,D2,D3A,D3B,
     1            D4A,D4B,D5A,D5B,D6A,D6B,D7A,D7B,D8A,D8B,SP,BUMP
  501 FORMAT (2X,I1,3X,I3,I1,2I4,3X,2A1,6X,2A1,6(I1,A1),I2,I5)
      IF (DIST .EQ. 7) DIST = 1
C
C     COMPUTE THE RATING SEGMENT LENGTH
C
      IF (CS .EQ. LCS) GO TO 10
      LRMP = 0
      LLMP = 0
      LBMP = 0
```

```
   10 LCS = CS
      IF (SIDE .EQ. L  .OR. SIDE .EQ. B) GO TO 20
      LENG = FLOAT(CSMP - LRMP) * 0.01
      LRMP = CSMP
      GO TO 35
   20 IF (SIDE .EQ. B) GO TO 30
      LENG = FLOAT(CSMP - LLMP) * 0.01
      LLMP = CSMP
      GO TO 35
   30 LBMP = LRMP
      IF (LLMP .GT. LRMP) LBMP = LLMP
      LENG = FLOAT(CSMP - LBMP) * 0.01
      LBMP = CSMP
      LRMP = CSMP
      LLMP = CSMP
C
C     CALL THE SUBROUTINE THAT COMPUTES THE STRUCTURAL RATING
C
   35 CALL ARAT
C
      CALL RIDADJ(GENER,SP,BUMP,PTYPE,COUNT)
      RF = 1.0 - (0.3 * (FLOAT(COUNT)/5000) ** 2)
      COMBR = STRUCR * RF
C
C
      DEFA(1) = 0
      DEFA(2) = 0
      DEFA(3) = D3A
      DEFA(4) = D4A
      DEFA(5) = D5A
      DEFA(6) = D6A
      DEFA(7) = D7A
      DEFA(8) = D8A
      DEFB(1) = D1
      DEFB(2) = D2
      DEFB(3) = D3B
      DEFB(4) = D4B
      DEFB(5) = D5B
      DEFB(6) = D6B
      DEFB(7) = D7B
      DEFB(8) = D8B
      DO 200 I = 1,8
      IF (DEFB(I) .EQ. N.OR.DEFB(I).EQ.F.OR.DEFB(I).EQ.R) DEFB(I) = 0
      IF (DEFB(I) .EQ. 0) GO TO 200
```

```
      DEFB(I) = BCDBNV(DEFB(I),1)
  200 CONTINUE
      DO 210 I = 1,8
      IF  (DEFA(I) .LE. 1) DEF(I) = DEFB(I) + 1
      IF  (DEFA(I) .EQ. 2) DEF(I) = DEFB(I) + 4
      IF  (DEFA(I) .EQ. 3) DEF(I) = DEFB(I) + 7
      IF  (DEFA(I) .EQ. 4) DEF(I) = DEFB(I) + 10
  210 CONTINUE
      IF  (PTYPE .EQ. A) PAVE = 1
      IF  (PTYPE .EQ. B) PAVE = 2
      IF  (PTYPE .EQ. C) PAVE = 3
      DO 220 CAT = 1,8
      GR = DEF(CAT)
      MDB(DIST,FC,PAVE,CAT,GR) = MDB(DIST,FC,PAVE,CAT,GR) + LENG
      MDB(DIST,FC,PAVE,CAT,14) = MDB(DIST,FC,PAVE,CAT,14) + LENG
      MDB(DIST,6,PAVE,CAT,GR) = MDB(DIST,6,PAVE,CAT,GR) + LENG
      MDB(DIST,6,PAVE,CAT,14) = MDB(DIST,6,PAVE,CAT,14) + LENG
      MDB(7,FC,PAVE,CAT,GR) = MDB(7,FC,PAVE,CAT,GR) + LENG
      MDB(7,FC,PAVE,CAT,14) = MDB(7,FC,PAVE,CAT,14) + LENG
      MDB(7,6,PAVE,CAT,GR) = MDB(7,6,PAVE,CAT,GR) + LENG
      MDB(7,6,PAVE,CAT,14) = MDB(7,6,PAVE,CAT,14) + LENG
  220 CONTINUE
C
C
C     BRANCH FOR SEGREGATING THE PAVEMENT TYPES
C
      IF  (PTYPE .EQ. C) GO TO 80
      IF  (PTYPE .EQ. B) GO TO 40
C
C     ASSIGN MILEAGE TO STRUCTURAL RATING GROUPS FOR ASPHALT PAVTS
C
      IF  (STRUCR .LE. 100 .AND. STRUCR .GT. 90) GROUP = 1
      IF  (STRUCR .LE. 90 .AND. STRUCR .GT. 80) GROUP = 2
      IF  (STRUCR .LE. 80 .AND. STRUCR .GT. 70) GROUP = 3
      IF  (STRUCR .LE. 70 .AND. STRUCR .GT. 60) GROUP = 4
      IF  (STRUCR .LE. 60 .AND. STRUCR .GT. 50) GROUP = 5
      IF  (STRUCR .LE. 50 .AND. STRUCR .GT. 40) GROUP = 6
      IF  (STRUCR .LE. 40 .AND. STRUCR .GT. 30) GROUP = 7
      IF  (STRUCR .LE. 30 .AND. STRUCR .GT. 20) GROUP = 8
      IF  (STRUCR .LE. 20 .AND. STRUCR .GT. 10) GROUP = 9
      IF  (STRUCR .LE. 10) GROUP = 10
C
C     SETUP ACCUMULATIONS TO BE USED FOR COMPUTING AVERAGES AFTER
C     ALL PAVEMENT RATING CARDS HAVE BEEN READ
```

```
C
      AMILES(DIST,FC,GROUP) = AMILES(DIST,FC,GROUP) + LENG
      AMILES(DIST,6,GROUP) = AMILES(DIST,6,GROUP) + LENG
      AMILES(7,6,GROUP) = AMILES(7,6,GROUP) + LENG
      AMILES(7,FC,GROUP) = AMILES(7,FC,GROUP) + LENG
      DACUM(DIST,FC) = DACUM(DIST,FC)+ (STRUCR * LENG)
      DALCUM(DIST,FC) = DALCUM(DIST,FC) + LENG
      DACUM(DIST,6) = DACUM(DIST,6)+ (STRUCR * LENG)
      DACUM(7,6) = DACUM(7,6)+ (STRUCR * LENG)
      DACUM(7,FC) = DACUM(7,FC)+ (STRUCR * LENG)
      DALCUM(DIST,6) = DALCUM(DIST,6) + LENG
      DALCUM(7,6) = DALCUM(7,6) + LENG
      DALCUM(7,FC) = DALCUM(7,FC) + LENG
      IF (COMBR .LE. 100.0 .AND. COMBR .GT. 90.0) GROUP = 1
      IF (COMBR .LE. 90.0 .AND. COMBR .GT. 80.0) GROUP = 2
      IF (COMBR .LE. 80.0 .AND. COMBR .GT. 70.0) GROUP = 3
      IF (COMBR .LE. 70.0 .AND. COMBR .GT. 60.0) GROUP = 4
      IF (COMBR .LE. 60.0 .AND. COMBR .GT. 50.0) GROUP = 5
      IF (COMBR .LE. 50.0 .AND. COMBR .GT. 40.0) GROUP = 6
      IF (COMBR .LE. 40.0 .AND. COMBR .GT. 30.0) GROUP = 7
      IF (COMBR .LE. 30.0 .AND. COMBR .GT. 20.0) GROUP = 8
      IF (COMBR .LE. 20.0 .AND. COMBR .GT. 10.0) GROUP = 9
      IF (COMBR .LE. 10.0) GROUP = 10
C
C     SETUP ACCUMULATIONS TO BE USED FOR COMPUTING AVERAGES AFTER
C     ALL PAVEMENT RATING CARDS HAVE BEEN READ
C
      ACOMBM(DIST,FC,GROUP) = ACOMBM(DIST,FC,GROUP) + LENG
      ACOMBM(DIST,6,GROUP) = ACOMBM(DIST,6,GROUP) + LENG
      ACOMBM(7,6,GROUP) = ACOMBM(7,6,GROUP) + LENG
      ACOMBM(7,FC,GROUP) = ACOMBM(7,FC,GROUP) + LENG
      ACCUM(DIST,FC) = ACCUM(DIST,FC)+ (COMBR * LENG)
      ACLCUM(DIST,FC) = ACLCUM(DIST,FC) + LENG
      ACCUM(DIST,6) = ACCUM(DIST,6)+ (COMBR * LENG)
      ACLCUM(DIST,6) = ACLCUM(DIST,6) + LENG
      ACCUM(7,6) = ACCUM(7,6)+ (COMBR * LENG)
      ACLCUM(7,6) = ACLCUM(7,6) + LENG
      ACCUM(7,FC) = ACCUM(7,FC)+ (COMBR * LENG)
      ACLCUM(7,FC) = ACLCUM(7,FC) + LENG
      IF (PUMP .EQ. 0) GO TO 100
C
C     ASSIGN MILEAGE TO CPM GROUPS FOR ASPHALT PAVTS
C
      IF (COUNT .GE. 10000 ) GROUP = 10
```

```
      IF (COUNT .LT. 10000 .AND. COUNT .GE. 7500) GROUP = 9
      IF (COUNT .LT. 7500 .AND. COUNT .GE. 5000) GROUP = 8
      IF (COUNT .LT. 5000 .AND. COUNT .GE. 4000) GROUP = 7
      IF (COUNT .LT. 4000 .AND. COUNT .GE. 3000) GROUP = 6
      IF (COUNT .LT. 3000 .AND. COUNT .GE. 2000) GROUP = 5
      IF (COUNT .LT. 2000 .AND. COUNT .GE. 1500) GROUP = 4
      IF (COUNT .LT. 1500 .AND. COUNT .GE. 1000) GROUP = 3
      IF (COUNT .LT. 1000 .AND. COUNT .GE. 500)  GROUP = 2
      IF (COUNT .LT. 500)  GROUP = 1
C
C     SETUP ACCUMLATIONS TO BE USED FOR COMPUTING AVERAGES AFTER
C     ALL PAVEMENT RATING CARDS HAVE BEEN READ
C
      ACNTMI(DIST,FC,GROUP) = ACNTMI(DIST,FC,GROUP) + LENG
      ACNTMI(DIST,6,GROUP) = ACNTMI(DIST,6,GROUP) + LENG
      ACNTMI(7,6,GROUP) = ACNTMI(7,6,GROUP) + LENG
      ACNTMI(7,FC,GROUP) = ACNTMI(7,FC,GROUP) + LENG
      DACNTC(DIST,FC) = DACNTC(DIST,FC) + (COUNT * LENG)
      DACMIL(DIST,FC) = DACMIL(DIST,FC) + LENG
      DACNTC(DIST,6) = DACNTC(DIST,6) + (COUNT * LENG)
      DACMIL(DIST,6) = DACMIL(DIST,6) + LENG
      DACNTC(7,6) = DACNTC(7,6) + (COUNT * LENG)
      DACMIL(7,6) = DACMIL(7,6) + LENG
      DACNTC(7,FC) = DACNTC(7,FC) + (COUNT * LENG)
      DACMIL(7,FC) = DACMIL(7,FC) + LENG
C
C     WRITE PAVEMENT TYPE, STRUCTURAL RATING, AND BUMP COUNT TO A
C     PAIRED DATA SET TO BE USED IN OTHER ANALYSIS
C
C
      GO TO 100
C
C     ASSIGN MILEAGE TO STRUCTURAL RATING GROUPS FOR BITUMINOUS PAVTS
C
   40 IF (STRUCR .LE. 100 .AND. STRUCR .GT. 90) GROUP = 1
      IF (STRUCR .LE. 90 .AND. STRUCR .GT. 80) GROUP = 2
      IF (STRUCR .LE. 80 .AND. STRUCR .GT. 70) GROUP = 3
      IF (STRUCR .LE. 70 .AND. STRUCR .GT. 60) GROUP = 4
      IF (STRUCR .LE. 60 .AND. STRUCR .GT. 50) GROUP = 5
      IF (STRUCR .LE. 50 .AND. STRUCR .GT. 40) GROUP = 6
      IF (STRUCR .LE. 40 .AND. STRUCR .GT. 30) GROUP = 7
      IF (STRUCR .LE. 30 .AND. STRUCR .GT. 20) GROUP = 8
      IF (STRUCR .LE. 20 .AND. STRUCR .GT. 10) GROUP = 9
      IF (STRUCR .LE. 10) GROUP = 10
```

```
C
C     SETUP ACCUMULATIONS TO BE USED FOR COMPUTING AVERAGES AFTER
C     ALL PAVEMENT RATING CARDS HAVE BEEN READ
C
      BMILES(DIST,FC,GROUP) = BMILES(DIST,FC,GROUP) + LENG
      BMILES(DIST,6,GROUP) = BMILES(DIST,6,GROUP) + LENG
      BMILES(7,6,GROUP) = BMILES(7,6,GROUP) + LENG
      BMILES(7,FC,GROUP) = BMILES(7,FC,GROUP) + LENG
      DBCUM(DIST,FC) = DBCUM(DIST,FC) + (STRUCR * LENG)
      DBLCUM(DIST,FC) = DBLCUM(DIST,FC) + LENG
      DBCUM(DIST,6) = DBCUM(DIST,6) + (STRUCR * LENG)
      DBCUM(7,6) = DBCUM(7,6) + (STRUCR * LENG)
      DBCUM(7,FC) = DBCUM(7,FC) + (STRUCR * LENG)
      DBLCUM(DIST,6) = DBLCUM(DIST,6) + LENG
      DBLCUM(7,6) = DBLCUM(7,6) + LENG
      DBLCUM(7,FC) = DBLCUM(7,FC) + LENG
      IF (COMBR .LE. 100.0 .AND. COMBR .GT. 90.0) GROUP = 1
      IF (COMBR .LE. 90.0 .AND. COMBR .GT. 80.0) GROUP = 2
      IF (COMBR .LE. 80.0 .AND. COMBR .GT. 70.0) GROUP = 3
      IF (COMBR .LE. 70.0 .AND. COMBR .GT. 60.0) GROUP = 4
      IF (COMBR .LE. 60.0 .AND. COMBR .GT. 50.0) GROUP = 5
      IF (COMBR .LE. 50.0 .AND. COMBR .GT. 40.0) GROUP = 6
      IF (COMBR .LE. 40.0 .AND. COMBR .GT. 30.0) GROUP = 7
      IF (COMBR .LE. 30.0 .AND. COMBR .GT. 20.0) GROUP = 8
      IF (COMBR .LE. 20.0 .AND. COMBR .GT. 10.0) GROUP = 9
      IF (COMBR .LE. 10.0) GROUP = 10
C
C     SETUP ACCUMULATIONS TO BE USED FOR COMPUTING AVERAGES AFTER
C     ALL PAVEMENT RATING CARDS HAVE BEEN READ
C
      BCOMBM(DIST,FC,GROUP) = BCOMBM(DIST,FC,GROUP) + LENG
      BCOMBM(DIST,6,GROUP) = BCOMBM(DIST,6,GROUP) + LENG
      BCOMBM(7,6,GROUP) = BCOMBM(7,6,GROUP) + LENG
      BCOMBM(7,FC,GROUP) = BCOMBM(7,FC,GROUP) + LENG
      BCCUM(DIST,FC) = BCCUM(DIST,FC) + (COMBR * LENG)
      BCLCUM(DIST,FC) = BCLCUM(DIST,FC) + LENG
      BCCUM(DIST,6) = BCCUM(DIST,6) + (COMBR * LENG)
      BCCUM(7,6) = BCCUM(7,6) + (COMBR * LENG)
      BCCUM(7,FC) = BCCUM(7,FC) + (COMBR * LENG)
      BCLCUM(DIST,6) = BCLCUM(DIST,6) + LENG
      BCLCUM(7,6) = BCLCUM(7,6) + LENG
      BCLCUM(7,FC) = BCLCUM(7,FC) + LENG
      IF (BUMP .EQ. 0) GO TO 100
C
```

```
C     ASSIGN MILEAGE TO CPM GROUPS FOR BITUMINOUS PAVTS
C
      IF (COUNT .GE. 10000 ) GROUP = 10
      IF (COUNT .LT. 10000 .AND. COUNT .GE. 7500) GROUP = 9
      IF (COUNT .LT. 7500 .AND. COUNT .GE. 5000) GROUP = 8
      IF (COUNT .LT. 5000 .AND. COUNT .GE. 4000) GROUP = 7
      IF (COUNT .LT. 4000 .AND. COUNT .GE. 3000) GROUP = 6
      IF (COUNT .LT. 3000 .AND. COUNT .GE. 2000) GROUP = 5
      IF (COUNT .LT. 2000 .AND. COUNT .GE. 1500) GROUP = 4
      IF (COUNT .LT. 1500 .AND. COUNT .GE. 1000) GROUP = 3
      IF (COUNT .LT. 1000 .AND. COUNT .GE. 500)  GROUP = 2
      IF (COUNT .LT. 500)  GROUP = 1
C
C     SETUP ACCUMULATIONS TO BE USED FOR COMPUTING AVERAGES AFTER
C     ALL PAVEMENT RATING CARDS HAVE BEEN READ
C
      BCNTMI(DIST,FC,GROUP) = BCNTMI(DIST,FC,GROUP) + LENG
      BCNTMI(DIST,6,GROUP) = BCNTMI(DIST,6,GROUP) + LENG
      BCNTMI(7,6,GROUP) = BCNTMI(7,6,GROUP) + LENG
      BCNTMI(7,FC,GROUP) = BCNTMI(7,FC,GROUP) + LENG
      DBCNTC(DIST,FC) = DBCNTC(DIST,FC) + (COUNT * LENG)
      DBCMIL(DIST,FC) = DBCMIL(DIST,FC) + LENG
      DBCNTC(DIST,6) = DBCNTC(DIST,6) + (COUNT * LENG)
      DBCNTC(7,6) = DBCNTC(7,6) + (COUNT * LENG)
      DBCNTC(7,FC) = DBCNTC(7,FC) + (COUNT * LENG)
      DBCMIL(DIST,6) = DBCMIL(DIST,6) + LENG
      DBCMIL(7,6) = DBCMIL(7,6) + LENG
      DBCMIL(7,FC) = DBCMIL(7,FC) + LENG
C
C     WRITE PAVEMENT TYPE,STRUCTURAL RATING, AND BUMP COUNT TO A
C     PAIRED DATA SET TO BE USED IN OTHER ANALYSIS
C
      GO TO 100
C
C     ASSIGN MILEAGE TO STRUCTURAL RATING GROUPS FOR PCC PAVTS
C
   80 IF (STRUCR .LE. 100 .AND. STRUCR .GT. 90) GROUP = 1
      IF (STRUCR .LE. 90 .AND. STRUCR .GT. 80) GROUP = 2
      IF (STRUCR .LE. 80 .AND. STRUCR .GT. 70) GROUP = 3
      IF (STRUCR .LE. 70 .AND. STRUCR .GT. 60) GROUP = 4
      IF (STRUCR .LE. 60 .AND. STRUCR .GT. 50) GROUP = 5
      IF (STRUCR .LE. 50 .AND. STRUCR .GT. 40) GROUP = 6
      IF (STRUCR .LE. 40 .AND. STRUCR .GT. 30) GROUP = 7
      IF (STRUCR .LE. 30 .AND. STRUCR .GT. 20) GROUP = 8
```

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      IF (STRUCR .LE. 20 .AND. STRUCR .GT. 10) GROUP = 9
      IF (STRUCR .LE. 10) GROUP = 10
C
C     SETUP ACCUMLATIONS TO BE USED FOR COMPUTING AVERGES AFTER
C     ALL PAVEMENT RATING CARDS HAVE BEEN READ
C
      CMILES(DIST,FC,GROUP) = CMILES(DIST,FC,GROUP) + LENG
      CMILES(DIST,6,GROUP) = CMILES(DIST,6,GROUP) + LENG
      CMILES(7,6,GROUP) = CMILES(7,6,GROUP) + LENG
      CMILES(7,FC,GROUP) = CMILES(7,FC,GROUP) + LENG
      DCCUM(DIST,FC) = DCCUM(DIST,FC)+ (STRUCR * LENG)
      DCLCUM(DIST,FC) = DCLCUM(DIST,FC) + LENG
      DCCUM(DIST,6) = DCCUM(DIST,6)+ (STRUCR * LENG)
      DCCUM(7,6) = DCCUM(7,6)+ (STRUCR * LENG)
      DCCUM(7,FC) = DCCUM(7,FC)+ (STRUCR * LENG)
      DCLCUM(DIST,6) = DCLCUM(DIST,6) + LENG
      DCLCUM(7,6) = DCLCUM(7,6) + LENG
      DCLCUM(7,FC) = DCLCUM(7,FC) + LENG
      IF (COMBR .LE. 100.0 .AND. COMBR .GT. 90.0) GROUP = 1
      IF (COMBR .LE. 90.0 .AND. COMBR .GT. 80.0) GROUP = 2
      IF (COMBR .LE. 80.0 .AND. COMBR .GT. 70.0) GROUP = 3
      IF (COMBR .LE. 70.0 .AND. COMBR .GT. 60.0) GROUP = 4
      IF (COMBR .LE. 60.0 .AND. COMBR .GT. 50.0) GROUP = 5
      IF (COMBR .LE. 50.0 .AND. COMBR .GT. 40.0) GROUP = 6
      IF (COMBR .LE. 40.0 .AND. COMBR .GT. 30.0) GROUP = 7
      IF (COMBR .LE. 30.0 .AND. COMBR .GT. 20.0) GROUP = 8
      IF (COMBR .LE. 20.0 .AND. COMBR .GT. 10.0) GROUP = 9
      IF (COMBR .LE. 10.0) GROUP = 10
C
C     SETUP ACCUMLATIONS TO BE USED FOR COMPUTING AVERGES AFTER
C     ALL PAVEMENT RATING CARDS HAVE BEEN READ
C
      CCOMBM(DIST,FC,GROUP) = CCOMBM(DIST,FC,GROUP) + LENG
      CCOMBM(DIST,6,GROUP) = CCOMBM(DIST,6,GROUP) + LENG
      CCOMBM(7,6,GROUP) = CCOMBM(7,6,GROUP) + LENG
      CCOMBM(7,FC,GROUP) = CCOMBM(7,FC,GROUP) + LENG
      CCCUM(DIST,FC) = CCCUM(DIST,FC)+ (COMBR * LENG)
      CCLCUM(DIST,FC) = CCLCUM(DIST,FC) + LENG
      CCCUM(DIST,6) = CCCUM(DIST,6)+ (COMBR * LENG)
      CCCUM(7,6) = CCCUM(7,6)+ (COMBR * LENG)
      CCCUM(7,FC) = CCCUM(7,FC)+ (COMBR * LENG)
      CCLCUM(DIST,6) = CCLCUM(DIST,6) + LENG
      CCLCUM(7,6) = CCLCUM(7,6) + LENG
      CCLCUM(7,FC) = CCLCUM(7,FC) + LENG
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```
      IF (BUMP .EQ. 0) GO TO 100
C
C     ASSIGN MILEAGE TO CPM GROUPS FOR PCC PAVEMENTS
C
      IF (COUNT .GE. 10000 ) GROUP = 10
      IF (COUNT .LT. 10000 .AND. COUNT .GE. 7500) GROUP = 9
      IF (COUNT .LT. 7500 .AND. COUNT .GE. 5000) GROUP = 8
      IF (COUNT .LT. 5000 .AND. COUNT .GE. 4000) GROUP = 7
      IF (COUNT .LT. 4000 .AND. COUNT .GE. 3000) GROUP = 6
      IF (COUNT .LT. 3000 .AND. COUNT .GE. 2000) GROUP = 5
      IF (COUNT .LT. 2000 .AND. COUNT .GE. 1500) GROUP = 4
      IF (COUNT .LT. 1500 .AND. COUNT .GE. 1000) GROUP = 3
      IF (COUNT .LT. 1000 .AND. COUNT .GE. 500)  GROUP = 2
      IF (COUNT .LT. 500)  GROUP = 1
C
C     SETUP ACCUMULATIONS TO BE USED FOR COMPUTING AVERAGES AFTER
C     ALL PAVEMENT RATING CARDS HAVE BEEN READ
C
      CCNTMI(DIST,FC,GROUP) = CCNTMI(DIST,FC,GROUP) + LENG
      CCNTMI(DIST,6,GROUP) = CCNTMI(DIST,6,GROUP) + LENG
      CCNTMI(7,6,GROUP) = CCNTMI(7,6,GROUP) + LENG
      CCNTMI(7,FC,GROUP) = CCNTMI(7,FC,GROUP) + LENG
      DCCNTC(DIST,FC) = DCCNTC(DIST,FC) + (COUNT * LENG)
      DCCMIL(DIST,FC) = DCCMIL(DIST,FC) + LENG
      DCCNTC(DIST,6) = DCCNTC(DIST,6) + (COUNT * LENG)
      DCCNTC(7,6) = DCCNTC(7,6) + (COUNT * LENG)
      DCCNTC(7,FC) = DCCNTC(7,FC) + (COUNT * LENG)
      DCCMIL(DIST,6) = DCCMIL(DIST,6) + LENG
      DCCMIL(7,6) = DCCMIL(7,6) + LENG
      DCCMIL(7,FC) = DCCMIL(7,FC) + LENG
C
C
      GO TO 100
C
C
C     COMPUTE ALL AVERAGES
C
  999 DO 61 I = 1,7
      DO 60 J = 1,6
      IF (ACLCUM(I,J) .EQ. 0 .OR. ACCUM(I,J) .EQ. 0) GO TO 44
      DACAVG(I,J) = ACCUM(I,J) / ACLCUM(I,J)
   44 IF (BCLCUM(I,J) .EQ. 0 .OR. BCCUM(I,J) .EQ. 0) GO TO 45
      DBCAVG(I,J) = BCCUM(I,J) / BCLCUM(I,J)
   45 IF (CCLCUM(I,J) .EQ. 0 .OR. CCCUM(I,J) .EQ. 0) GO TO 46
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      DCCAVG(I,J) = CCCUM(I,J) / CCLCUM(I,J)
   46 IF (DALCUM(I,J) .EQ. 0 .OR. DACUM(I,J) .EQ. 0) GO TO 47
      DAAVG(I,J) = DACUM(I,J) / DALCUM(I,J)
   47 IF (DBLCUM(I,J) .EQ. 0 .OR. DBCUM(I,J) .EQ. 0) GO TO 48
      DBAVG(I,J) = DBCUM(I,J) / DBLCUM(I,J)
   48 IF (DCLCUM(I,J) .EQ. 0 .OR. DCCUM(I,J) .EQ. 0) GO TO 49
      DCAVG(I,J) = DCCUM(I,J) / DCLCUM(I,J)
   49 IF (DACMIL(I,J) .EQ. 0 .OR. DACNTC(I,J) .EQ. 0) GO TO 50
      DACTAV(I,J) = DACNTC(I,J) / DACMIL(I,J)
   50 IF (DBCMIL(I,J) .EQ. 0 .OR. DBCNTC(I,J) .EQ. 0) GO TO 51
      DBCTAV(I,J) = DBCNTC(I,J) / DBCMIL(I,J)
   51 IF (DCCMIL(I,J) .EQ. 0 .OR. DCCNTC(I,J) .EQ. 0) GO TO 60
      DCCTAV(I,J) = DCCNTC(I,J) / DCCMIL(I,J)
   60 CONTINUE
   61 CONTINUE
      DO 74 I = 1,7
      DO 73 J = 1,6
      DO 70 K = 1,10
      COMBM(I,J,K) = ACOMBM(I,J,K) + BCOMBM(I,J,K) + CCOMBM(I,J,K)
      MILES(I,J,K) = AMILES(I,J,K) + BMILES(I,J,K) + CMILES(I,J,K)
      CNTMI(I,J,K) = ACNTMI(I,J,K) + BCNTMI(I,J,K) + CCNTMI(I,J,K)
   70 CONTINUE
      CLCUM(I,J) = ACLCUM(I,J) + BCLCUM(I,J) + CCLCUM(I,J)
      CCUM(I,J)  = ACCUM(I,J) + BCCUM(I,J) + CCCUM(I,J)
      DCUM(I,J)  = DACUM(I,J) + DBCUM(I,J) + DCCUM(I,J)
      DLCUM(I,J) = DALCUM(I,J) + DBLCUM(I,J) + DCLCUM(I,J)
      DCNTC(I,J) = DACNTC(I,J) + DBCNTC(I,J) + DCCNTC(I,J)
      DCMIL(I,J) = DACMIL(I,J) + DBCMIL(I,J) + DCCMIL(I,J)
      IF (CLCUM(I,J) .EQ. 0 .OR. CCUM(I,J) .EQ. 0) GO TO 71
      DCOAVG(I,J) = CCUM(I,J) / CLCUM(I,J)
   71 IF (DLCUM(I,J) .EQ. 0 .OR. DCUM(I,J) .EQ. 0) GO TO 72
      DAVG(I,J) = DCUM(I,J) / DLCUM(I,J)
   72 IF (DCNTC(I,J) .EQ. 0 .OR. DCMIL(I,J) .EQ. 0) GO TO 73
      DCTAV(I,J) = DCNTC(I,J) / DCMIL(I,J)
   73 CONTINUE
   74 CONTINUE
C
C     WRITE SUMMARIES OF DISTRIBUTIONS FOR ASPHALT PAVEMENTS
C
      DO 230 DIST = 1,7
      DO 240 PAVE = 1,3
      DO 250 CAT = 1,8
      DO 260 FC = 1,6
      TOP = MDB(DIST,FC,PAVE,CAT,14)
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      DO 270 GR = 1,13
      IF (TOP .EQ. 0.0) GO TO 270
      PERC(DIST,FC,PAVE,CAT,GR) = (MDB(DIST,FC,PAVE,CAT,GR)/TOP) * 100.0
  270 CONTINUE
  260 CONTINUE
  250 CONTINUE
  240 CONTINUE
  230 CONTINUE
      DO 280 DIST = 1,7
      UNIT = DIST + 20
      IF (DIST .EQ. 7) GO TO 150
      WRITE (UNIT,601) DIST, GENER
  601 FORMAT ('1'/' ',26X,'DISTRICT ',I1,3X,I2,1X,'DEFECT RATING SUMMARY
     1 FOR ASPHALT PAVTS')
      GO TO 151
  150 WRITE (UNIT,590) GENER
  590 FORMAT ('1'/' ',26X,'STATEWIDE',4X,I2,1X,'DEFECT RATING SUMMARY FO
     1R ASPHALT PAVTS')
  151 WRITE (UNIT,602)
  602 FORMAT       (//' ',2X,' FC     100-91    90-81     80-71     71-60    6
     10-51     50-41     40-31     30-21     20-11     10-0      AVG'/' ',
     2'  ****  *******  *******  *******  *******  *******  *******  ***
     3****  *******  *******  *******    *****'/)
      WRITE (UNIT,603)    (AMILES(DIST,1,J),J=1,10),DAAVG(DIST,1)
  603 FORMAT (' ',3X,' 1 ',2X,10(F7.1,2X),1X,F5.1/)
      WRITE (UNIT,604)    (AMILES(DIST,2,J),J=1,10),DAAVG(DIST,2)
  604 FORMAT (' ',3X,' 2 ',2X,10(F7.1,2X),1X,F5.1/)
      WRITE (UNIT,605)    (AMILES(DIST,3,J),J=1,10),DAAVG(DIST,3)
  605 FORMAT (' ',3X,' 3 ',2X,10(F7.1,2X),1X,F5.1/)
      WRITE (UNIT,606)    (AMILES(DIST,4,J),J=1,10),DAAVG(DIST,4)
  606 FORMAT (' ',3X,' 4 ',2X,10(F7.1,2X),1X,F5.1/)
      WRITE (UNIT,607)    (AMILES(DIST,5,J),J=1,10),DAAVG(DIST,5)
  607 FORMAT (' ',3X,' 5 ',2X,10(F7.1,2X),1X,F5.1/)
      WRITE (UNIT,608)    (AMILES(DIST,6,J),J=1,10),DAAVG(DIST,6)
  608 FORMAT (' ',1X,'TOTAL',2X,10(F7.1,2X),1X,F5.1)
      WRITE (UNIT,609)
  609 FORMAT (///' ',37X,'BUMP COUNT SUMMARY FOR ASPHALT PAVTS')
      WRITE (UNIT,610)
  610 FORMAT (//' ',2X,' FC    LT 500    .5K-1K  1K-1.5K  1.5K-2K    2K-3K
     1    3K-4K     4K-5K    5K-7.5K  7.5-10K    GT 10K     AVG'/' ',2X,'***
     2*  *******   *******   *******  *******   *******  *******  *******
     3*******  *******  *******   ******'/)
      WRITE (UNIT,611)    (ACNTMI(DIST,1,J),J=1,10),DACTAV(DIST,1)
  611 FORMAT (' ',3X,' 1 ',2X,10(F7.1,2X),1X,F6.1/)
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      WRITE (UNIT,612)    (ACNTMI(DIST,2,J),J=1,10),DACTAV(DIST,2)
  612 FORMAT (' ',3X,' 2 ',2X,10(F7.1,2X),1X,F6.1/)
      WRITE (UNIT,613)    (ACNTMI(DIST,3,J),J=1,10),DACTAV(DIST,3)
  613 FORMAT (' ',3X,' 3 ',2X,10(F7.1,2X),1X,F6.1/)
      WRITE (UNIT,614)    (ACNTMI(DIST,4,J),J=1,10),DACTAV(DIST,4)
  614 FORMAT (' ',3X,' 4 ',2X,10(F7.1,2X),1X,F6.1/)
      WRITE (UNIT,615)    (ACNTMI(DIST,5,J),J=1,10),DACTAV(DIST,5)
  615 FORMAT (' ',3X,' 5 ',2X,10(F7.1,2X),1X,F6.1/)
      WRITE (UNIT,616)    (ACNTMI(DIST,6,J),J=1,10),DACTAV(DIST,6)
  616 FORMAT (' ',1X,'TOTAL',2X,10(F7.1,2X),1X,F6.1/)
      WRITE (UNIT,617)
  617 FORMAT (//' ',34X,'COMBINED RATING SUMMARY FOR ASPHALT PAVTS')
      WRITE (UNIT,602)
      WRITE (UNIT,603)    (ACOMBM(DIST,1,J),J=1,10),DACAVG(DIST,1)
      WRITE (UNIT,604)    (ACOMBM(DIST,2,J),J=1,10),DACAVG(DIST,2)
      WRITE (UNIT,605)    (ACOMBM(DIST,3,J),J=1,10),DACAVG(DIST,3)
      WRITE (UNIT,606)    (ACOMBM(DIST,4,J),J=1,10),DACAVG(DIST,4)
      WRITE (UNIT,607)    (ACOMBM(DIST,5,J),J=1,10),DACAVG(DIST,5)
      WRITE (UNIT,608)    (ACOMBM(DIST,6,J),J=1,10),DACAVG(DIST,6)
C
C     WRITE SUMMARIES OF DISTRIBUTIONS FOR BITUMINOUS PAVEMENTS
C
      IF (DIST .EQ. 7) GO TO 152
      WRITE (UNIT,618) DIST, GENER
  618 FORMAT ('1'/' ',25X,'DISTRICT ',I1,3X,I2,1X,'DEFECT RATING SUMMARY
     1 FOR BITUMINOUS PAVTS')
      GO TO 153
  152 WRITE (UNIT,591) GENER
  591 FORMAT ('1'/' ',25X,'STATEWIDE',4X,I2,1X,'DEFECT RATING SUMMARY FO
     1R BITUMINOUS PAVTS')
  153 WRITE (UNIT,602)
      WRITE (UNIT,603)    (BMILES(DIST,1,J),J=1,10),DBAVG(DIST,1)
      WRITE (UNIT,604)    (BMILES(DIST,2,J),J=1,10),DBAVG(DIST,2)
      WRITE (UNIT,605)    (BMILES(DIST,3,J),J=1,10),DBAVG(DIST,3)
      WRITE (UNIT,606)    (BMILES(DIST,4,J),J=1,10),DBAVG(DIST,4)
      WRITE (UNIT,607)    (BMILES(DIST,5,J),J=1,10),DBAVG(DIST,5)
      WRITE (UNIT,608)    (BMILES(DIST,6,J),J=1,10),DBAVG(DIST,6)
      WRITE (UNIT,619)
  619 FORMAT (///' ',35X,'BUMP COUNT SUMMARY FOR BITUMINOUS PAVTS')
      WRITE (UNIT,610)
      WRITE (UNIT,611)    (BCNTMI(DIST,1,J),J=1,10),DBCTAV(DIST,1)
      WRITE (UNIT,612)    (BCNTMI(DIST,2,J),J=1,10),DBCTAV(DIST,2)
      WRITE (UNIT,613)    (BCNTMI(DIST,3,J),J=1,10),DBCTAV(DIST,3)
      WRITE (UNIT,614)    (BCNTMI(DIST,4,J),J=1,10),DBCTAV(DIST,4)
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      WRITE (UNIT,615)    (BCNTMI(DIST,5,J),J=1,10),DBCTAV(DIST,5)
      WRITE (UNIT,616)    (BCNTMI(DIST,6,J),J=1,10),DBCTAV(DIST,6)
      WRITE (UNIT,620)
  620 FORMAT (//' ',33X,'COMBINED RATING SUMMARY FOR BITUMINOUS PAVTS')
      WRITE (UNIT,602)
      WRITE (UNIT,603)    (BCOMBM(DIST,1,J),J=1,10),DBCAVG(DIST,1)
      WRITE (UNIT,604)    (BCOMBM(DIST,2,J),J=1,10),DBCAVG(DIST,2)
      WRITE (UNIT,605)    (BCOMBM(DIST,3,J),J=1,10),DBCAVG(DIST,3)
      WRITE (UNIT,606)    (BCOMBM(DIST,4,J),J=1,10),DBCAVG(DIST,4)
      WRITE (UNIT,607)    (BCOMBM(DIST,5,J),J=1,10),DBCAVG(DIST,5)
      WRITE (UNIT,608)    (BCOMBM(DIST,6,J),J=1,10),DBCAVG(DIST,6)
C
C     WRITE SUMMARIES OF DISTRIBUTIONS FOR PCC PAVEMENTS
C
      IF (DIST .EQ. 7) GO TO 154
      WRITE (UNIT,621)   DIST, GENER
  621 FORMAT ('1'/' ',29X,'DISTRICT ',I1,3X,I2,' DEFECT RATING SUMMARY F
     1OR PCC PAVTS')
      GO TO 155
  154 WRITE (UNIT,592) GENER
  592 FORMAT ('1'/' ',29X,'STATEWIDE',4X,I2,1X,'DEFECT RATING SUMMARY FO
     1R PCC PAVTS')
  155 WRITE (UNIT,602)
      WRITE (UNIT,603)    (CMILES(DIST,1,J),J=1,10),DCAVG(DIST,1)
      WRITE (UNIT,604)    (CMILES(DIST,2,J),J=1,10),DCAVG(DIST,2)
      WRITE (UNIT,605)    (CMILES(DIST,3,J),J=1,10),DCAVG(DIST,3)
      WRITE (UNIT,606)    (CMILES(DIST,4,J),J=1,10),DCAVG(DIST,4)
      WRITE (UNIT,607)    (CMILES(DIST,5,J),J=1,10),DCAVG(DIST,5)
      WRITE (UNIT,608)    (CMILES(DIST,6,J),J=1,10),DCAVG(DIST,6)
      WRITE (UNIT,622)
  622 FORMAT (///' ',39X,'BUMP COUNT SUMMARY FOR PCC PAVTS')
      WRITE (UNIT,610)
      WRITE (UNIT,611)    (CCNTMI(DIST,1,J),J=1,10),DCCTAV(DIST,1)
      WRITE (UNIT,612)    (CCNTMI(DIST,2,J),J=1,10),DCCTAV(DIST,2)
      WRITE (UNIT,613)    (CCNTMI(DIST,3,J),J=1,10),DCCTAV(DIST,3)
      WRITE (UNIT,614)    (CCNTMI(DIST,4,J),J=1,10),DCCTAV(DIST,4)
      WRITE (UNIT,615)    (CCNTMI(DIST,5,J),J=1,10),DCCTAV(DIST,5)
      WRITE (UNIT,616)    (CCNTMI(DIST,6,J),J=1,10),DCCTAV(DIST,6)
      WRITE (UNIT,623)
  623 FORMAT (//' ',36X,'COMBINED RATING SUMMARY FOR PCC PAVTS')
      WRITE (UNIT,602)
      WRITE (UNIT,603)    (CCOMBM(DIST,1,J),J=1,10),DCCAVG(DIST,1)
      WRITE (UNIT,604)    (CCOMBM(DIST,2,J),J=1,10),DCCAVG(DIST,2)
      WRITE (UNIT,605)    (CCOMBM(DIST,3,J),J=1,10),DCCAVG(DIST,3)
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      WRITE (UNIT,606)   (CCOMBM(DIST,4,J),J=1,10),DCCAVG(DIST,4)
      WRITE (UNIT,607)   (CCOMBM(DIST,5,J),J=1,10),DCCAVG(DIST,5)
      WRITE (UNIT,608)   (CCOMBM(DIST,6,J),J=1,10),DCCAVG(DIST,6)
C
C     WRITE SUMMARIES OF DISTRIBUTIONS FOR PCC PAVEMENTS
C
      IF (DIST .EQ. 7) GO TO 156
      WRITE (UNIT,624)  DIST, GENER
  624 FORMAT ('1'/' ',29X,'DISTRICT ',I1,3X,I2,' DEFECT RATING SUMMARY F
     1OR ALL PAVTS')
      GO TO 157
  156 WRITE (UNIT,593) GENER
  593 FORMAT ('1'/' ',29X,'STATEWIDE',4X,I2,1X,'DEFECT RATING SUMMARY FO
     1R ALL PAVTS')
  157 WRITE (UNIT,602)
      WRITE (UNIT,603)   (MILES(DIST,1,J),J=1,10),DAVG(DIST,1)
      WRITE (UNIT,604)   (MILES(DIST,2,J),J=1,10),DAVG(DIST,2)
      WRITE (UNIT,605)   (MILES(DIST,3,J),J=1,10),DAVG(DIST,3)
      WRITE (UNIT,606)   (MILES(DIST,4,J),J=1,10),DAVG(DIST,4)
      WRITE (UNIT,607)   (MILES(DIST,5,J),J=1,10),DAVG(DIST,5)
      WRITE (UNIT,608)   (MILES(DIST,6,J),J=1,10),DAVG(DIST,6)
      WRITE (UNIT,625)
  625 FORMAT (///' ',39X,'BUMP COUNT SUMMARY FOR ALL PAVTS')
      WRITE (UNIT,610)
      WRITE (UNIT,611)   (CNTMI(DIST,1,J),J=1,10),DCTAV(DIST,1)
      WRITE (UNIT,612)   (CNTMI(DIST,2,J),J=1,10),DCTAV(DIST,2)
      WRITE (UNIT,613)   (CNTMI(DIST,3,J),J=1,10),DCTAV(DIST,3)
      WRITE (UNIT,614)   (CNTMI(DIST,4,J),J=1,10),DCTAV(DIST,4)
      WRITE (UNIT,615)   (CNTMI(DIST,5,J),J=1,10),DCTAV(DIST,5)
      WRITE (UNIT,616)   (CNTMI(DIST,6,J),J=1,10),DCTAV(DIST,6)
      WRITE (UNIT,626)
  626 FORMAT (//' ',36X,'COMBINED RATING SUMMARY FOR ALL PAVTS')
      WRITE (UNIT,602)
      WRITE (UNIT,603)   (COMBM(DIST,1,J),J=1,10),DCOAVG(DIST,1)
      WRITE (UNIT,604)   (COMBM(DIST,2,J),J=1,10),DCOAVG(DIST,2)
      WRITE (UNIT,605)   (COMBM(DIST,3,J),J=1,10),DCOAVG(DIST,3)
      WRITE (UNIT,606)   (COMBM(DIST,4,J),J=1,10),DCOAVG(DIST,4)
      WRITE (UNIT,607)   (COMBM(DIST,5,J),J=1,10),DCOAVG(DIST,5)
      WRITE (UNIT,608)   (COMBM(DIST,6,J),J=1,10),DCOAVG(DIST,6)
C
C
      DO 290 PAVE = 1,3
      DO 300 CAT = 1,8
      IF (PAVE .EQ. 3) GO TO 350
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      IF (CAT .EQ. 2) GO TO 300
      IF (PAVE .EQ. 2) GO TO 310
      IF (DIST .EQ. 7) GO TO 305
      WRITE (UNIT,628) DIST, DATE, GENER
628   FORMAT ('1',//,2X,'R67750',T52,'DISTRICT ',I1,T102,A8/'0',
     1        T37,I2,' PAVEMENT CONDITION DEFICIENCY SUMMARY'/'0',T44,
     2        'ASPHALT CONCRETE PAVEMENT'/)
      GO TO 320
305   WRITE (UNIT,629) DATE, GENER
629   FORMAT ('1',//,2X,'R67750',T52,'STATEWIDE',T102,A8/'0',
     1        T37,I2,' PAVEMENT CONDITION DEFICIENCY SUMMARY'/'0',T44,
     2        'ASPHALT CONCRETE PAVEMENT'/)
      GO TO 320
310   IF (DIST .EQ. 7) GO TO 315
      WRITE (UNIT,630) DIST, DATE, GENER
630   FORMAT ('1',//,2X,'R67750',T52,'DISTRICT ',I1,T102,A8/'0',
     1        T37,I2,' PAVEMENT CONDITION DEFICIENCY SUMMARY'/'0',T47,
     2        'BITUMINOUS PAVEMENT'/)
      GO TO 320
315   WRITE (UNIT,631) DATE, GENER
631   FORMAT ('1',//,2X,'R67750',T52,'STATEWIDE',T102,A8/'0',
     1        T37,I2,' PAVEMENT CONDITION DEFICIENCY SUMMARY'/'0',T47,
     2        'BITUMINOUS PAVEMENT'/)
320   IF (CAT .EQ. 8) GO TO 341
      IF (CAT .EQ. 7) GO TO 339
      IF (CAT .EQ. 6) GO TO 337
      IF (CAT .EQ. 5) GO TO 335
      IF (CAT .EQ. 4) GO TO 333
      IF (CAT .EQ. 3) GO TO 331
      WRITE (UNIT,632)
632   FORMAT ('0',T44,'RUTTING AND PAVEMENT WEAR'/'0',
     1     '  FUNCTIONAL     NONE',T28,'1/4 - 1/2 INCH',T52,
     2     '1/2 - 3/4 INCH',T76,'OVER 3/4 INCH',T101,
     3     'TOTAL'/' ',' CLASS',T26,3('THROUGHOUT SECTION',6X)//)
      DO 330 FC = 1,5
      WRITE (UNIT,633) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,4),
     1       MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,4)
633   FORMAT ('0',5X,I1/' ','   MILES',T16,F5.0,T32,F6.0,T57,F6.0,
     1          T80,F6.0,T100,F6.0/' ','   PERCENT',T17,F4.0,T34,F4.0,
     2          T59,F4.0,T82,F4.0//)
330   CONTINUE
      WRITE (UNIT,634)   (MDB(DIST,6,PAVE,CAT,J),J=1,4),
     1       MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,4)
634   FORMAT ('0','  TOTAL'/' ','   MILES',T16,F5.0,T32,F6.0,T57,F6.0,
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     1        T80,F6.0,T100,F6.0/' ',' PERCENT',T17,F4.0,T34,F4.0,
     2        T59,F4.0,T82,F4.0//)
      GO TO 300
331   WRITE (UNIT,635)
635   FORMAT ('0',T41,'CORRUGATIONS, WAVES, SAGS, HUMPS'/'0',
     1      ' FUNCTIONAL   NONE',T25,'1/8-2 IN CHANGE/10FT',5X,
     2      '2-4 IN CHANGE/10FT     OVER 4 IN CHANGE/10FT',T101,
     3      'TOTAL'/' ',' CLASS',T25,3('1-25  26-75  OVER 75',4X)//)
      DO 332 FC = 1,5
      WRITE (UNIT,636) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,10)
636   FORMAT ('0',5X,I1/' ',' MILES',T16,F5.0,3(4X,F5.0,2X,F5.0,
     1        3X,F5.0),T100,F6.0/' ',' PERCENT',T17,F4.0,3(5X,F4.0,
     2        3X,F4.0,4X,F4.0)//)
332   CONTINUE
      WRITE (UNIT,637)  (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
637   FORMAT ('0',' TOTAL'/' ',' MILES',T16,F5.0,3(4X,F5.0,2X,F5.0,
     1        3X,F5.0),T100,F6.0/' ',' PERCENT',T17,F4.0,3(5X,F4.0,
     2        3X,F4.0,4X,F4.0)//)
      GO TO 300
333   WRITE (UNIT,638)
638   FORMAT ('0',T48,'ALLIGATOR CRACKING'/'0',' FUNCTIONAL   NONE',
     1    T27,'1-24 PERCENT       25-49 PERCENT       50-74 PERCENT',
     2    6X,'75-100 PERCENT',T103,'TOTAL'/' ',' CLASS',T26,
     3    4('WHFEL TRACK/STA',4X)/' ',T25,4('H-LINE SPAL  PUMP',2X)//)
      DO 334 FC = 1,5
      WRITE (UNIT,639) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,13),
     1      MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,13)
639   FORMAT ('0',5X,I1/' ',' MILES',T16,F5.0,T25,4(3(F5.0,1X),1X),
     1  T102,F6.0/' ',' PERCENT',T17,F4.0,T26,4(3(F4.0,2X),1X)//)
334   CONTINUE
      WRITE (UNIT,640) (MDB(DIST,6,PAVE,CAT,J),J=1,14),
     1                 (PERC(DIST,6,PAVE,CAT,J),J=1,13)
640   FORMAT ('0',' TOTAL'/' ',' MILES',T16,F5.0,T25,4(3(F5.0,1X),
     1    1X),T102,F6.0/' ',' PERCENT',T17,F4.0,T26,4(3(F4.0,2X),1X))
      GO TO 300
335   WRITE (UNIT,641)
641   FORMAT ('0',T47,'RAVELING AND FLUSHING'/'0',
     1      ' FUNCTIONAL   NONE',T30,'LOCALIZED',T53,
     2      'WHEEL PATHS',T77,'ENTIRE LANE',T101,
     3      'TOTAL'/' ',' CLASS',T25,3('SLIGHT MODER. SEVERE',4X)//)
      DO 336 FC = 1,5
      WRITE (UNIT,636) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,10),
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     1      MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,10)
 336 CONTINUE
     WRITE (UNIT,637)  (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
     GO TO 300
 337 WRITE (UNIT,642)
 642 FORMAT ('0',T46,'LONGITUDINAL CRACKING'/'0',
     1      '  FUNCTIONAL   NONE',T26,'LESS THAN 1/4 INCH',T52,
     2      'OVER 1/4 INCH',T78,'SPALLED',T101,
     3      'TOTAL'/' ',' CLASS',T27,3('LINEAL FT/STATION',7X)/' ',
     4      T25,3('1-99  100-199   200+',4X)//)
     DO 338 FC = 1,5
     WRITE (UNIT,636) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,10)
 338 CONTINUE
     WRITE (UNIT,637)  (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
     GO TO 300
 339 WRITE (UNIT,643)
 643 FORMAT ('0',T47,'TRANSVERSE CRACKING'/'0',
     1      '  FUNCTIONAL   NONE',T29,3('NO./STATION',13X),T101,
     3      'TOTAL'/' ',' CLASS',T25,3(' 1-4    5-9    10 +',5X)//)
     DO 340 FC = 1,5
     WRITE (UNIT,636) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,10)
 340 CONTINUE
     WRITE (UNIT,637)  (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
     GO TO 300
 341 WRITE (UNIT,644)
 644 FORMAT ('0',T52,'PATCHING'/'0',
     1      '  FUNCTIONAL   NONE',T26,'0.10-0.50 IN THICK',5X,
     2      '0.50 - 1.0 IN THICK        OVER 1.0 IN THICK',T101,
     3      'TOTAL'/' ',' CLASS',T27,3('PCT AREA/STATION',8X)/' ',
     4      T25,3(' 1-5   6-25   OVER25',4X)//)
     DO 342 FC = 1,5
     WRITE (UNIT,636) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,10)
 342 CONTINUE
     WRITE (UNIT,637)  (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
     GO TO 300
 350 IF (DIST .EQ. 7) GO TO 345
     WRITE (UNIT,645) DIST, DATE, GENER
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645 FORMAT ('1',//,2X,'R67750',T52,'DISTRICT ',I1,T102,A8/'0',
   1        T37,I2,' PAVEMENT CONDITION DEFICIENCY SUMMARY'/'0',T44,
   2        'PORTLAND CEMENT CONCRETE'/)
    GO TO 346
345 WRITE (UNIT,646) DATE, GENER
646 FORMAT ('1',//,2X,'R67750',T52,'STATEWIDE',T102,A8/'0',
   1        T37,I2,' PAVEMENT CONDITION DEFICIENCY SUMMARY'/'0',T44,
   2        'PORTLAND CEMENT CONCRETE'/)
346 IF (CAT .EQ. 8) GO TO 364
    IF (CAT .EQ. 7) GO TO 362
    IF (CAT .EQ. 6) GO TO 360
    IF (CAT .EQ. 5) GO TO 358
    IF (CAT .EQ. 4) GO TO 356
    IF (CAT .EQ. 3) GO TO 354
    IF (CAT .EQ. 2) GO TO 352
    WRITE (UNIT,632)
    DO 351 FC = 1,5
    WRITE (UNIT,633) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,4),
   1       MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,4)
351 CONTINUE
    WRITE (UNIT,634)   (MDB(DIST,6,PAVE,CAT,J),J=1,4),
   1       MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,4)
    GO TO 300
352 WRITE (UNIT,647)
647 FORMAT ('0',T53,'BLOWUPS'/'0',
   1       '  FUNCTIONAL   NONE',T30,'1 PER MILE',T53,
   2       '2-3 PER MILE  ',T75,'OVER 3 PER MILE',T101,
   3       'TOTAL'//)
    DO 353 FC = 1,5
    WRITE (UNIT,633) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,4),
   1       MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,4)
353 CONTINUE
    WRITE (UNIT,634)   (MDB(DIST,6,PAVE,CAT,J),J=1,4),
   1       MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,4)
    GO TO 300
354 WRITE (UNIT,648)
648 FORMAT ('0',T53,'CRACKING'/'0',
   1       '  FUNCTIONAL   NONE',T29,'1 - 25 PERCENT',T52,
   2       '26 - 50 PERCENT',T76,'OVER 50 PERCENT',T101,
   3       'TOTAL'/' ',' CLASS',T27,3('UNITS PANEL LENGTH',6X)/' ',
   4       T27,3('1-2    3-4    OVER 4',6X)//)
    DO 355 FC = 1,5
    WRITE (UNIT,636) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,10),
   1       MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,10)
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```
355 CONTINUE
    WRITE (UNIT,637)   (MDB(DIST,6,PAVE,CAT,J),J=1,10),
   1     MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
    GO TO 300
356 WRITE (UNIT,649)
649 FORMAT ('0',T34,'RAVELING, DISINTEGRATION, POP OUT, SCALING'/'0',
   1    '  FUNCTIONAL    NONE',T28,'1 - 25 PERCENT',T51,
   2    '26 - 75 PERCENT',T75,'OVER 75 PERCENT',T101,
   3    'TOTAL'/' ',' CLASS',T25,3('SLIGHT MODER. SEVERE',4X)//)
    DO 357 FC = 1,5
    WRITE (UNIT,636) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,10),
   1     MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,10)
357 CONTINUE
    WRITE (UNIT,637)   (MDB(DIST,6,PAVE,CAT,J),J=1,10),
   1     MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
    GO TO 300
358 WRITE (UNIT,650)
650 FORMAT ('0',T50,'JOINT SPALLING'/'0',
   1    '  FUNCTIONAL    NONE',T28,'1 - 15 PERCENT',T51,
   2    '16 - 50 PERCENT',T75,'OVER 50 PERCENT',T101,
   3    'TOTAL'/' ',' CLASS',T27,3('WIDTH IN INCHES',9X)/' ',
   4    T25,3('1/4-1   1-3   3 PLUS',4X)//)
    DO 359 FC = 1,5
    WRITE (UNIT,636) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,10),
   1     MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,10)
359 CONTINUE
    WRITE (UNIT,637)   (MDB(DIST,6,PAVE,CAT,J),J=1,10),
   1     MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
    GO TO 300
360 WRITE (UNIT,651)
651 FORMAT ('0',T49,'PUMPING, BLOWING'/'0',
   1    '  FUNCTIONAL    NONE',T28,'0 - 15 PERCENT',T51,
   2    '16 - 35 PERCENT',T75,'OVER 35 PERCENT',T101,
   3    'TOTAL'/' ',' CLASS',T27,3('PCT PANEL LENGTH',8X)/' ',
   4    T25,3('1 - 9  10-50  OVER50',4X)//)
    DO 361 FC = 1,5
    WRITE (UNIT,636) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,10),
   1     MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,10)
361 CONTINUE
    WRITE (UNIT,637)   (MDB(DIST,6,PAVE,CAT,J),J=1,10),
   1     MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
    GO TO 300
362 WRITE (UNIT,652)
652 FORMAT ('0',T37,'FAULTING, CURLING, WARPING, SETTLEMENT'/'0',
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     1     '  FUNCTIONAL    NONE',T28,'1 - 15 PERCENT',T51,
     2     '16 - 35 PERCENT',T75,'OVER 75 PERCENT',T101,'TOTAL'/' ',
     3     '  CLASS',T32,3('INCHES',18X)/' ',T25,
     4        3('1/8-1/4 1/4-1/2  1/2+',3X)//)
      DO 363 FC = 1,5
      WRITE (UNIT,636) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,10),
     1     MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,10)
  363 CONTINUE
      WRITE (UNIT,637)   (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1     MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
      GO TO 300
  364 WRITE (UNIT,653)
  653 FORMAT ('0',T52,'PATCHING'/'0',' FUNCTIONAL   NONE',T28,
     1     '1 - 5 PERCENT',T52,'6 - 25 PERCENT',T75,'OVER 25 PERCENT',
     2     T101,'TOTAL'/' ',' CLASS',T28,3('PCT AREA/PANEL',10X)/' ',
     3     T25,3(' 1-5    6-20    OVER20',4X)//)
      DO 365 FC = 1,5
      WRITE (UNIT,636) FC, (MDB(DIST,FC,PAVE,CAT,J),J=1,10),
     1     MDB(DIST,FC,PAVE,CAT,14), (PERC(DIST,FC,PAVE,CAT,J),J=1,10)
  365 CONTINUE
      WRITE (UNIT,637)   (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1     MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
  300 CONTINUE
  290 CONTINUE
  280 CONTINUE
C
C
C
C
      WRITE (UNIT,690) GENER
  690 FORMAT ('1',26X,'STATEWIDE',4X,I2,1X,'DEFECT RATING SUMMARY FOR AS
     1PHALT PAVTS')
      WRITE (UNIT,702)
  702 FORMAT      (/' ',2X,'DIST    100-91    90-81    80-71    70-61    60
     1-51    50-41    40-31    30-21    20-11    10-0        AVG'/' ',
     2'  ****  *******  *******  *******  *******  *******  *******  ***
     3****  *******  *******  *******    *****'/)
      WRITE (UNIT,603)    (AMILES(1,6,J),J=1,10),DAAVG(1,6)
      WRITE (UNIT,604)    (AMILES(2,6,J),J=1,10),DAAVG(2,6)
      WRITE (UNIT,605)    (AMILES(3,6,J),J=1,10),DAAVG(3,6)
      WRITE (UNIT,606)    (AMILES(4,6,J),J=1,10),DAAVG(4,6)
      WRITE (UNIT,607)    (AMILES(5,6,J),J=1,10),DAAVG(5,6)
      WRITE (UNIT,707)    (AMILES(6,6,J),J=1,10),DAAVG(6,6)
  707 FORMAT (' ',3X,' 6 ',2X,10(F7.1,2X),1X,F5.1/)
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      WRITE (UNIT,608)    (AMILES(7,6,J),J=1,10),DAAVG(7,6)
      WRITE (UNIT,709)
  709 FORMAT (/' ',37X,'BUMP COUNT SUMMARY FOR ASPHALT PAVTS')
      WRITE (UNIT,710)
  710 FORMAT  (/' ',2X,'DIST   LT 500    .5K-1K  1K-1.5K  1.5K-2K   2K-3K
     1   3K-4K    4K-5K   5K-7.5K  7.5-10K   GT 10K    AVG'/' ',2X,'***
     2*  *******  *******  *******  *******  *******  *******  *******
     3*******  *******  *******   ******'/)
      WRITE (UNIT,611)    (ACNTMI(1,6,J),J=1,10),DACTAV(1,6)
      WRITE (UNIT,612)    (ACNTMI(2,6,J),J=1,10),DACTAV(2,6)
      WRITE (UNIT,613)    (ACNTMI(3,6,J),J=1,10),DACTAV(3,6)
      WRITE (UNIT,614)    (ACNTMI(4,6,J),J=1,10),DACTAV(4,6)
      WRITE (UNIT,615)    (ACNTMI(5,6,J),J=1,10),DACTAV(5,6)
      WRITE (UNIT,715)    (ACNTMI(6,6,J),J=1,10),DACTAV(6,6)
  715 FORMAT (' ',3X,' 6 ',2X,10(F7.1,2X),1X,F6.1/)
      WRITE (UNIT,616)    (ACNTMI(7,6,J),J=1,10),DACTAV(7,6)
      WRITE (UNIT,717)
  717 FORMAT   (/' ',34X,'COMBINED RATING SUMMARY FOR ASPHALT PAVTS')
      WRITE (UNIT,702)
      WRITE (UNIT,603)    (ACOMBM(1,6,J),J=1,10),DACAVG(1,6)
      WRITE (UNIT,604)    (ACOMBM(2,6,J),J=1,10),DACAVG(2,6)
      WRITE (UNIT,605)    (ACOMBM(3,6,J),J=1,10),DACAVG(3,6)
      WRITE (UNIT,606)    (ACOMBM(4,6,J),J=1,10),DACAVG(4,6)
      WRITE (UNIT,607)    (ACOMBM(5,6,J),J=1,10),DACAVG(5,6)
      WRITE (UNIT,707)    (ACOMBM(6,6,J),J=1,10),DACAVG(6,6)
      WRITE (UNIT,608)    (ACOMBM(7,6,J),J=1,10),DACAVG(7,6)
C
C     WRITE SUMMARIES OF DISTRIBUTIONS FOR BITUMINOUS PAVEMENTS
C
      WRITE (UNIT,691) GENER
  691 FORMAT      ('1',25X,'STATEWIDE',4X,I2,1X,'DEFECT RATING SUMMARY FO
     4R BITUMINOUS PAVTS')
      WRITE (UNIT,702)
      WRITE (UNIT,603)    (BMILES(1,6,J),J=1,10),DBAVG(1,6)
      WRITE (UNIT,604)    (BMILES(2,6,J),J=1,10),DBAVG(2,6)
      WRITE (UNIT,605)    (BMILES(3,6,J),J=1,10),DBAVG(3,6)
      WRITE (UNIT,606)    (BMILES(4,6,J),J=1,10),DBAVG(4,6)
      WRITE (UNIT,607)    (BMILES(5,6,J),J=1,10),DBAVG(5,6)
      WRITE (UNIT,707)    (BMILES(6,6,J),J=1,10),DBAVG(6,6)
      WRITE (UNIT,608)    (BMILES(7,6,J),J=1,10),DBAVG(7,6)
      WRITE (UNIT,719)
  719 FORMAT    (/' ',35X,'BUMP COUNT SUMMARY FOR BITUMINOUS PAVTS')
      WRITE (UNIT,710)
      WRITE (UNIT,611)    (BCNTMI(1,6,J),J=1,10),DBCTAV(1,6)
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      WRITE (UNIT,612)     (BCNTMI(2,6,J),J=1,10),DBCTAV(2,6)
      WRITE (UNIT,613)     (BCNTMI(3,6,J),J=1,10),DBCTAV(3,6)
      WRITE (UNIT,614)     (BCNTMI(4,6,J),J=1,10),DBCTAV(4,6)
      WRITE (UNIT,615)     (BCNTMI(5,6,J),J=1,10),DBCTAV(5,6)
      WRITE (UNIT,715)     (BCNTMI(6,6,J),J=1,10),DBCTAV(6,6)
      WRITE (UNIT,616)     (BCNTMI(7,6,J),J=1,10),DBCTAV(7,6)
      WRITE (UNIT,720)
  720 FORMAT  (/' ',33X,'COMBINED RATING SUMMARY FOR BITUMINOUS PAVTS')
      WRITE (UNIT,702)
      WRITE (UNIT,603)     (BCOMBM(1,6,J),J=1,10),DBCAVG(1,6)
      WRITE (UNIT,604)     (BCOMBM(2,6,J),J=1,10),DBCAVG(2,6)
      WRITE (UNIT,605)     (BCOMBM(3,6,J),J=1,10),DBCAVG(3,6)
      WRITE (UNIT,606)     (BCOMBM(4,6,J),J=1,10),DBCAVG(4,6)
      WRITE (UNIT,607)     (BCOMBM(5,6,J),J=1,10),DBCAVG(5,6)
      WRITE (UNIT,707)     (BCOMBM(6,6,J),J=1,10),DBCAVG(6,6)
      WRITE (UNIT,608)     (BCOMBM(7,6,J),J=1,10),DBCAVG(7,6)
C
C     WRITE SUMMARIES OF DISTRIBUTIONS FOR PCC PAVEMENTS
C
      WRITE (UNIT,692) GENER
  692 FORMAT      ('1',29X,'STATEWIDE',4X,I2,1X,'DEFECT RATING SUMMARY FO
     4R PCC PAVTS')
      WRITE (UNIT,702)
      WRITE (UNIT,603)     (CMILES(1,6,J),J=1,10),DCAVG(1,6)
      WRITE (UNIT,604)     (CMILES(2,6,J),J=1,10),DCAVG(2,6)
      WRITE (UNIT,605)     (CMILES(3,6,J),J=1,10),DCAVG(3,6)
      WRITE (UNIT,606)     (CMILES(4,6,J),J=1,10),DCAVG(4,6)
      WRITE (UNIT,607)     (CMILES(5,6,J),J=1,10),DCAVG(5,6)
      WRITE (UNIT,707)     (CMILES(6,6,J),J=1,10),DCAVG(6,6)
      WRITE (UNIT,608)     (CMILES(7,6,J),J=1,10),DCAVG(7,6)
      WRITE (UNIT,722)
  722 FORMAT     (/' ',39X,'BUMP COUNT SUMMARY FOR PCC PAVTS')
      WRITE (UNIT,710)
      WRITE (UNIT,611)     (CCNTMI(1,6,J),J=1,10),DCCTAV(1,6)
      WRITE (UNIT,612)     (CCNTMI(2,6,J),J=1,10),DCCTAV(2,6)
      WRITE (UNIT,613)     (CCNTMI(3,6,J),J=1,10),DCCTAV(3,6)
      WRITE (UNIT,614)     (CCNTMI(4,6,J),J=1,10),DCCTAV(4,6)
      WRITE (UNIT,615)     (CCNTMI(5,6,J),J=1,10),DCCTAV(5,6)
      WRITE (UNIT,715)     (CCNTMI(6,6,J),J=1,10),DCCTAV(6,6)
      WRITE (UNIT,616)     (CCNTMI(7,6,J),J=1,10),DCCTAV(7,6)
      WRITE (UNIT,723)
  723 FORMAT  (/' ',36X,'COMBINED RATING SUMMARY FOR PCC PAVTS')
      WRITE (UNIT,702)
      WRITE (UNIT,603)     (CCOMBM(1,6,J),J=1,10),DCCAVG(1,6)
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      WRITE (UNIT,604)    (CCOMBM(2,6,J),J=1,10),DCCAVG(2,6)
      WRITE (UNIT,605)    (CCOMBM(3,6,J),J=1,10),DCCAVG(3,6)
      WRITE (UNIT,606)    (CCOMBM(4,6,J),J=1,10),DCCAVG(4,6)
      WRITE (UNIT,607)    (CCOMBM(5,6,J),J=1,10),DCCAVG(5,6)
      WRITE (UNIT,707)    (CCOMBM(6,6,J),J=1,10),DCCAVG(6,6)
      WRITE (UNIT,608)    (CCOMBM(7,6,J),J=1,10),DCCAVG(7,6)
C
C     WRITE SUMMARIES OF DISTRIBUTIONS FOR PCC PAVEMENTS
C
      WRITE (UNIT,693) GENER
  693 FORMAT      ('1',29X,'STATEWIDE',4X,I2,1X,'DEFECT RATING SUMMARY FO
     4R ALL PAVTS')
      WRITE (UNIT,702)
      WRITE (UNIT,603)    (MILES(1,6,J),J=1,10),DAVG(1,6)
      WRITE (UNIT,604)    (MILES(2,6,J),J=1,10),DAVG(2,6)
      WRITE (UNIT,605)    (MILES(3,6,J),J=1,10),DAVG(3,6)
      WRITE (UNIT,606)    (MILES(4,6,J),J=1,10),DAVG(4,6)
      WRITE (UNIT,607)    (MILES(5,6,J),J=1,10),DAVG(5,6)
      WRITE (UNIT,707)    (MILES(6,6,J),J=1,10),DAVG(6,6)
      WRITE (UNIT,608)    (MILES(7,6,J),J=1,10),DAVG(7,6)
      WRITE (UNIT,725)
  725 FORMAT    (/' ',39X,'BUMP COUNT SUMMARY FOR ALL PAVTS')
      WRITE (UNIT,710)
      WRITE (UNIT,611)    (CNTMI(1,6,J),J=1,10),DCTAV(1,6)
      WRITE (UNIT,612)    (CNTMI(2,6,J),J=1,10),DCTAV(2,6)
      WRITE (UNIT,613)    (CNTMI(3,6,J),J=1,10),DCTAV(3,6)
      WRITE (UNIT,614)    (CNTMI(4,6,J),J=1,10),DCTAV(4,6)
      WRITE (UNIT,615)    (CNTMI(5,6,J),J=1,10),DCTAV(5,6)
      WRITE (UNIT,715)    (CNTMI(6,5,J),J=1,10),DCTAV(6,6)
      WRITE (UNIT,616)    (CNTMI(7,6,J),J=1,10),DCTAV(7,6)
      WRITE (UNIT,726)
  726 FORMAT  (/' ',36X,'COMBINED RATING SUMMARY FOR ALL PAVTS')
      WRITE (UNIT,702)
      WRITE (UNIT,603)    (COMBM(1,6,J),J=1,10),DCOAVG(1,6)
      WRITE (UNIT,604)    (COMBM(2,6,J),J=1,10),DCOAVG(2,6)
      WRITE (UNIT,605)    (COMBM(3,6,J),J=1,10),DCOAVG(3,6)
      WRITE (UNIT,606)    (COMBM(4,6,J),J=1,10),DCOAVG(4,6)
      WRITE (UNIT,607)    (COMBM(5,6,J),J=1,10),DCOAVG(5,6)
      WRITE (UNIT,707)    (MILES(6,6,J),J=1,10),DCOAVG(6,6)
      WRITE (UNIT,608)    (COMBM(7,6,J),J=1,10),DCOAVG(7,6)
C
C
      DO 390 PAVE = 1,3
      DO 400 CAT = 1,8
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      IF (PAVE .EQ. 3) GO TO 450
      IF (CAT .EQ. 2) GO TO 400
      IF (PAVE .EQ. 2) GO TO 410
      WRITE (UNIT,629) DATE, GENER
      GO TO 420
  410 WRITE (UNIT,631) DATE, GENER
  420 IF (CAT .EQ. 8) GO TO 441
      IF (CAT .EQ. 7) GO TO 439
      IF (CAT .EQ. 6) GO TO 437
      IF (CAT .EQ. 5) GO TO 435
      IF (CAT .EQ. 4) GO TO 433
      IF (CAT .EQ. 3) GO TO 431
      WRITE (UNIT,732)
  732 FORMAT ('0',T44,'RUTTING AND PAVEMENT WEAR'/'0',
     1     '  DISTRICT       NONE',T28,'1/4 - 1/2 INCH',T52,
     2     '1/2 - 3/4 INCH',T76,'OVER 3/4 INCH',T101,
     3     'TOTAL'/' ',T26,3('THROUGHOUT SECTION',6X)//)
      DO 430 DIST = 1,6
      WRITE (UNIT,633) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,4),
     1       MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,4)
  430 CONTINUE
      WRITE (UNIT,634)   (MDB(7,6,PAVE,CAT,J),J=1,4),
     1       MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,4)
      GO TO 400
  431 WRITE (UNIT,735)
  735 FORMAT ('0',T41,'CORRUGATIONS, WAVES, SAGS, HUMPS'/'0',
     1     '  DISTRICT       NONE',T25,'1/8-2 IN CHANGE/10FT',5X,
     2     '2-4 IN CHANGE/10FT       OVER 4 IN CHANGE/10FT',T101,
     3     'TOTAL'/' ',T25,3('1-25  26-75  OVER 75',4X)//)
      DO 432 DIST = 1,6
      WRITE (UNIT,636) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1       MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
  432 CONTINUE
      WRITE (UNIT,637)   (MDB(7,6,PAVE,CAT,J),J=1,10),
     1       MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,10)
      GO TO 400
  433 WRITE (UNIT,738)
  738 FORMAT ('0',T48,'ALLIGATOR CRACKING'/'0','  DISTRICT       NONE',
     1     T27,'1-24 PERCENT        25-49 PERCENT       50-74 PERCENT',
     2     6X,'75-100 PERCENT',T103,'TOTAL'/' ',T26,
     3     4('WHEEL TRACK/STA',4X)/' ',T25,4('H-LINE SPAL  PUMP',2X)//)
      DO 434 DIST = 1,6
      WRITE (UNIT,639) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,13),
     1       MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,13)
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434 CONTINUE
    WRITE (UNIT,640)  (MDB(7,6,PAVE,CAT,J),J=1,14),
   1                  (PERC(7,6,PAVE,CAT,J),J=1,13)
    GO TO 400
435 WRITE (UNIT,741)
741 FORMAT ('0',T47,'RAVELING AND FLUSHING'/'0',
   1     '  DISTRICT       NONE',T30,'LOCALIZED',T53,
   2     'WHEEL PATHS',T77,'ENTIRE LANE',T101,
   3     'TOTAL'/' ',T25,3('SLIGHT MODER. SEVERE',4X)//)
    DO 436 DIST = 1,6
    WRITE (UNIT,636) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,10),
   1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
436 CONTINUE
    WRITE (UNIT,637)   (MDB(7,6,PAVE,CAT,J),J=1,10),
   1      MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,10)
    GO TO 400
437 WRITE (UNIT,742)
742 FORMAT ('0',T46,'LONGITUDINAL CRACKING'/'0',
   1     '  DISTRICT       NONE',T26,'LESS THAN 1/4 INCH',T52,
   2     'OVER 1/4 INCH',T78,'SPALLED',T101,
   3     'TOTAL'/' ',T27,3('LINEAL FT/STATION',7X)/' ',
   4     T25,3('1-99  100-199   200+',4X)//)
    DO 438 DIST = 1,6
    WRITE (UNIT,636) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,10),
   1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
438 CONTINUE
    WRITE (UNIT,637)   (MDB(7,6,PAVE,CAT,J),J=1,10),
   1      MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,10)
    GO TO 400
439 WRITE (UNIT,743)
743 FORMAT ('0',T47,'TRANSVERSE CRACKING'/'0',
   1     '  DISTRICT       NONE',T29,3('NO./STATION',13X),T101,
   3     'TOTAL'/' ',T25,3(' 1-4    5-9     10 +',5X)//)
    DO 440 DIST = 1,6
    WRITE (UNIT,636) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,10),
   1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
440 CONTINUE
    WRITE (UNIT,637)   (MDB(7,6,PAVE,CAT,J),J=1,10),
   1      MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,10)
    GO TO 400
441 WRITE (UNIT,744)
744 FORMAT ('0',T52,'PATCHING'/'0',
   1     '  DISTRICT       NONE',T26,'0.10-0.50 IN THICK',5X,
   2     '0.50 - 1.0 IN THICK        OVER 1.0 IN THICK',T101,
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3      'TOTAL'/' ',T27,3('PCT AREA/STATION',8X)/' ',
4      T25,3(' 1-5    6-25    OVER25',4X)//)
    DO 442 DIST = 1,6
    WRITE (UNIT,636) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,10),
   1     MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
442 CONTINUE
    WRITE (UNIT,637)  (MDB(7,6,PAVE,CAT,J),J=1,10),
   1     MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,10)
    GO TO 400
450 WRITE (UNIT,646) DATE, GENER
    IF (CAT .EQ. 8) GO TO 464
    IF (CAT .EQ. 7) GO TO 462
    IF (CAT .EQ. 6) GO TO 460
    IF (CAT .EQ. 5) GO TO 458
    IF (CAT .EQ. 4) GO TO 456
    IF (CAT .EQ. 3) GO TO 454
    IF (CAT .EQ. 2) GO TO 452
    WRITE (UNIT,632)
    DO 451 DIST = 1,6
    WRITE (UNIT,633) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,4),
   1     MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,4)
451 CONTINUE
    WRITE (UNIT,634)  (MDB(7,6,PAVE,CAT,J),J=1,4),
   1     MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,4)
    GO TO 400
452 WRITE (UNIT,747)
747 FORMAT ('0',T53,'BLOWUPS'/'0',
   1     '  DISTRICT      NONE',T30,'1 PER MILE',T53,
   2     '2-3 PER MILE   ',T75,'OVER 3 PER MILE',T101,
   3     'TOTAL'//)
    DO 453 DIST = 1,6
    WRITE (UNIT,633) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,4),
   1     MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,4)
453 CONTINUE
    WRITE (UNIT,634)  (MDB(7,6,PAVE,CAT,J),J=1,4),
   1     MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,4)
    GO TO 400
454 WRITE (UNIT,748)
748 FORMAT ('0',T53,'CRACKING'/'0',
   1     '  DISTRICT      NONE',T29,'1 - 25 PERCENT',T52,
   2     '26 - 50 PERCENT',T76,'OVER 50 PERCENT',T101,
   3     'TOTAL'/' ',T27,3('UNITS PANEL LENGTH',6X)/' ',
   4     T27,3('1-2    3-4    OVER 4',6X)//)
    DO 455 DIST = 1,6
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      WRITE (UNIT,636) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
  455 CONTINUE
      WRITE (UNIT,637)  (MDB(7,6,PAVE,CAT,J),J=1,10),
     1      MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,10)
      GO TO 400
  456 WRITE (UNIT,749)
  749 FORMAT ('0',T34,'RAVELING, DISINTEGRATION, POP OUT, SCALING'/'0',
     1     '  DISTRICT      NONE',T28,'1 - 25 PERCENT',T51,
     2     '26 - 75 PERCENT',T75,'OVER 75 PERCENT',T101,
     3     'TOTAL'/' ',T25,3('SLIGHT MODER. SEVERE',4X)//)
      DO 457 DIST = 1,6
      WRITE (UNIT,636) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
  457 CONTINUE
      WRITE (UNIT,637)  (MDB(7,6,PAVE,CAT,J),J=1,10),
     1      MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,10)
      GO TO 400
  458 WRITE (UNIT,750)
  750 FORMAT ('0',T50,'JOINT SPALLING'/'0',
     1     '  DISTRICT      NONE',T28,'1 - 15 PERCENT',T51,
     2     '16 - 50 PERCENT',T75,'OVER 50 PERCENT',T101,
     3     'TOTAL'/' ',T27,3('WIDTH IN INCHES',9X)/' ',
     4     T25,3('1/4-1    1-3    3 PLUS',4X)//)
      DO 459 DIST = 1,6
      WRITE (UNIT,636) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
  459 CONTINUE
      WRITE (UNIT,637)  (MDB(7,6,PAVE,CAT,J),J=1,10),
     1      MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,10)
      GO TO 400
  460 WRITE (UNIT,751)
  751 FORMAT ('0',T49,'PUMPING, BLOWING'/'0',
     1     '  DISTRICT      NONE',T28,'0 - 15 PERCENT',T51,
     2     '16 - 35 PERCENT',T75,'OVER 35 PERCENT',T101,
     3     'TOTAL'/' ',T27,3('PCT PANEL LENGTH',8X)/' ',
     4     T25,3('1 - 9  10-50  OVER50',4X)//)
      DO 461 DIST = 1,6
      WRITE (UNIT,636) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,10),
     1      MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
  461 CONTINUE
      WRITE (UNIT,637)  (MDB(7,6,PAVE,CAT,J),J=1,10),
     1      MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,10)
      GO TO 400
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462 WRITE (UNIT,752)
752 FORMAT ('0',T37,'FAULTING, CURLING, WARPING, SETTLEMENT'/'0',
   1     '  DISTRICT       NONE',T28,'1 - 15 PERCENT',T51,
   2     '16 - 35 PERCENT',T75,'OVER 75 PERCENT',T101,'TOTAL'/' ',
   3     T32,3('INCHES',18X)/' ',T25,
   4        3('1/8-1/4 1/4-1/2  1/2+',3X)//)
    DO 463 DIST = 1,6
    WRITE (UNIT,636) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,10),
   1        MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
463 CONTINUE
    WRITE (UNIT,637)   (MDB(7,6,PAVE,CAT,J),J=1,10),
   1        MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,10)
    GO TO 400
464 WRITE (UNIT,753)
753 FORMAT ('0',T52,'PATCHING'/'0','  DISTRICT       NONE',T28,
   1     '1 - 5 PERCENT',T52,'6 - 25 PERCENT',T75,'OVER 25 PERCENT',
   2     T101,'TOTAL'/' ',T28,3('PCT AREA/PANEL',10X)/' ',
   3     T25,3(' 1-5    6-20    OVER20',4X)//)
    DO 465 DIST = 1,6
    WRITE (UNIT,636) DIST, (MDB(DIST,6,PAVE,CAT,J),J=1,10),
   1        MDB(DIST,6,PAVE,CAT,14), (PERC(DIST,6,PAVE,CAT,J),J=1,10)
465 CONTINUE
    WRITE (UNIT,637)   (MDB(7,6,PAVE,CAT,J),J=1,10),
   1        MDB(7,6,PAVE,CAT,14), (PERC(7,6,PAVE,CAT,J),J=1,10)
400 CONTINUE
390 CONTINUE
    STOP
    END
```