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Feasibility Study of a Pavement Management System For Washington Counties

Final Report

June 1984

Washington State Department of Transportation
Planning, Research and Public Transportation Division

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16. Abstract

The feasibility of adopting the Washington State Pavement Management System (WSPMS) for use by Washington counties was established. The WSPMS design offers a great deal of flexibility for adjusting the system to satisfy the counties needs. Some modifications to computer programs will be necessary and can be accomplished with relatively modest effort. The major adjustments will be in those counties input data. The only data that are absolutely essential are those for determining and evaluating pavement condition and the most cost effective rehabilitation strategies.

The state computer system has an adequate storage capacity to support usage of the WSPMS by a large number of counties. Dial-up capability is available for use of WSPMS from remote terminals. Data processing hardware options available to counties range from no data processing equipment to stand alone computer system.

A trial demonstration is recommended. Two counties, one large with in-house computer facilities and one small with no or minimal facilities would be chosen to test the system.

Significant benefits are anticipated from the use of WSPMS. Washington counties desiring to improve the process of pavement management may find adopting and operating the WSPMS to feasible and desirable.

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EXECUTIVE SUMMARY

The primary objective of this study was to evaluate the feasibility of adopting the Washington State Pavement Management System (WSPMS) for the needs of Washington counties. The main conclusion of the study is that it will be feasible and desirable to adopt and operate the WSPMS so as to assist the Washington counties in improving the process of pavement management.

The feasibility of adopting the WSPMS for the counties is established because of the following findings:

- The basic design of the WSPMS offers a great deal of flexibility in adjusting the system for county needs. Most of the adjustments will be in the input data, rather than in the computer software. Although some modifications in the computer programs will be necessary, these can be made with a relatively modest effort that is estimated to be in the range of one to two person-months.

- The WSPMS requires only those data that are absolutely essential for evaluating pavement condition and determining the most cost-effective rehabilitation strategies. Consequently, the effort necessary to collect and develop the required data is relatively small. The one-time effort to generate the necessary input data for a network of about 1000 miles is estimated to be in the range of 5 to 6 person-months including the initial pavement condition survey. The on-going data collection effort will involve the biennial pavement condition surveys. The estimated

effort for such a survey is 4 to 5 person-months for a network of about 1000 miles.

- Full advantage can be taken of the support that can be provided by the state data processing facilities. It appears that the state computer system has adequate storage capacity to support usage of the WSPMS by a large number of counties. Also, the dial-up capability is available so that counties can connect to the state computer facility through remote terminals.

- Several data processing options are feasible for accessing and executing the WSPMS programs. The computer hardware requirements for these options range from no data processing equipment at the county level to county data entry terminals all the way to a county stand-alone system. Because of this flexibility, any Washington county should be able to utilize the WSPMS, irrespective of the size of the county's road network, and available staff and computer resources.

Benefits of Adopting the WSPMS for County Usage

Significant benefits can be anticipated from the use of the WSPMS by an individual county, as well as from its collective use by a group of counties.

The following benefits can be expected from the routine use of the adopted WSPMS by an individual county:

- An objective, reliable, and current data base of information is provided to support management decisions of pavement maintenance and rehabilitation.

- The most cost-effective treatment can be determined for each project, based on the considerations of life-cycle costs.

- The impact of alternative funding levels on the performance of the system can be demonstrated.

- A schedule for timely and economical pavement maintenance and rehabilitation is developed in an attempt to protect the substantial capital investment in the road network.

- Improved response to special legislative, political, or public requests regarding plans for the improvement of certain roads is possible.

If the converted WSPMS is used by most of the Washington state counties to estimate budget requirements and to develop pavement rehabilitation programs, several benefits, in addition to those identified above, can be accrued. These benefits include the following:

- Uniform procedures will be developed for all participating counties to evaluate and summarize pavement conditions.

- A common basis will be provided for evaluating pavement rehabilitation needs across different counties.

- Common resources among the counties can be utilized more effectively. The activities which could be shared by all the counties include: a common training program for pavement condition survey personnel and the use of a statewide coordinator to assist all the counties in PMS implementation with the best utilization of the state's computer system.

Recommendations

The primary recommendation of the study is that the WSPMS should be implemented for a minimum of two counties on a trial basis. One county should be a relatively large county with adequate in-house computer facilities and staff support for data processing activities. The other county should be a smaller county with no or minimal in-house computer facilities and little staff support for data processing. If the WSPMS can be successfully implemented for two such counties with large differences in the size of road network and the availability of resources, the feasibility of adopting the system for statewide use will be demonstrated for all counties in the State of Washington.

If several counties get involved in PMS implementation, it will be necessary and desirable to use a statewide county coordinator specifically for the purposes of maintaining the county PMS on the state computer system and assisting the counties in PMS implementation.

Plans for sharing of common resources should be developed and evaluated by the counties. A common pavement condition survey manual should be developed. It will also be desirable to develop a common training program for survey personnel. It appears that an FHWA grant to the state under the Technology Transfer Program can be utilized by the counties to conduct training programs for pavement condition surveys.

Plans for sharing of common resources should be developed and evaluated by the counties. The appointment of a statewide county coordinator is just one such opportunity for sharing resources. Other opportunities include: a common pavement condition survey manual and a common training program for survey personnel. It appears that an FHWA grant to the state under the Technology Transfer Program can be utilized by the counties to conduct training programs for pavement condition surveys.

1. INTRODUCTION

The Washington Department of Transportation has developed a Pavement Management System (WSPMS) to generate a rehabilitation program for the state highway system. This system provides recommendations pertinent to budget requirements and performance standards based on a set of procedures designed to minimize costs. The "Washington Counties" feasibility study will be designed to evaluate the use of WSPMS by Washington counties.

Procedures developed by the Washington Department of Transportation are described in their final report titled, "Development and Implementation of Washington State's Pavement Management System," dated February 1983. The primary objectives of this feasility study were: (1) to determine the feasibility of Washington counties using the WSPMS for their own purposes, thereby taking advantage of the development and implementation work already accomplished; and (2) to provide a general procedural outline for counties to follow in adopting the WSPMS.

The key issues identified in a review of the WSPMS for county use and in discussions with county and state personnel are as follows:

1. Potential modifications to WSPMS to obtain early results, i.e., priorities and costs from interpreted data file;

2. Computer requirements and operating procedures required for implementation of WSPMS by counties;

3. Data requirements necessary for implementation of WSPMS by counties including such items as: (a) types of supporting information (traffic, costs, etc.) and (b) types of distress to include in condition surveys;

4. Identification of alternative actions and costs appropriate to specific conditions;

5. Accelerated estimates of "typical life" of original construction and feasible rehabilitation actions;

6. Establishment of selection matrix (based on functional class, pavement type, and traffic index) and rehabilitation alternatives in accordance with WSPMS necessary for project optimization.

Approach and Scope of Study

The general approach used for completion of the feasibility study for application of the WSPMS to Washington Counties has been divided into five parts, as follows:

1. Detail review of WSPMS procedures

2. Meeting with county representatives to obtain information pertinent to:

   - expectations from PMS

   - relevant distress types

   - segment identification

- threshold distress values
- information requirements to implement the WSPMS computer programs
- condition survey procedures
- selection matrix used in WSPMS
- data processing options
- evaluation of resources
- availability of information
- constraints

3. Meeting with representatives of Washington Department of Transportation to discuss the most effective procedures to modify WSPMS for implementation by Washington counties.

4. Presentation to and feedback from the Project Advisory Committee regarding project activities and objectives.

5. Trial runs of the WSPMS computer programs using Thurston County data.

Outline of the Report

This report has been divided into ten parts, including this introduction. Each part has been selected to provide a logical ordering of activities designed to satisfy specific tasks included in the project proposal as follows:

Part 2 - Description of WSPMS

- History and background
- Conceptual flowchart of operations
- Reports provided

Part 3 - Applicability of WSPMS for Washington Counties

- Development of data base
- Potential outputs
- Programming maintenance and rehabilitation by counties
- Statewide basis for estimating budget requirements
- Summary report of "health of the system" by counties and statewide

Part 4 - Data Collection/Handling Operations

- Data Requirements: Pavement condition surveys, supporting information, performance predictions, and performance standards
- Data handling options

Part 5 - Program Modifications for Use by Washington Counties

- Modifications in the process of developing the required data base

- Modifications in the input data parameters
- Modifications in the computer code
- Modifications in the output report formats

Part 6 - Data Processing Hardware and Software Requirements

Part 7 - Cost Estimates for Adoption of WSPMS for Use by Washington Counties

Part 8 - Costs and Benefits of Routine Operations of Modified WSPMS

Part 9 - Step-by-Step Procedure for County Adoption of WSPMS

Part 10- Conclusions and Recommendations

Appendix A - Output Reports from Trial Runs of WSPMS Computer Programs

The source document for this investigation is the Washington Department of Transportation report by Thomas L. Nelson and Roger V. LeClerc titled, "Development and Implementation of Washington State's Pavement Management System," WA-RD 50.1, dated February 1983. Tapes of the WSPMS computer programs were furnished through the Materials Laboratory of the Washington DOT with the assistance of Art Peters and Newton Jackson. Sample data for trial runs were furnished by Alva Williams of Thurston County. Counties participating in meetings of October 19-21, 1983 were: King County (Louis Haff), Pacific County, (John Trent and Norman Grier), Walla Walla (Steve Stanton), and Thurston County (Alva Williams).

2. DESCRIPTION OF WASHINGTON STATE'S PAVEMENT MANAGEMENT SYSTEM (WSPMS)

Since the primary objective of this study was to evaluate the feasibility of adopting the WSPMS for Washington counties, it is appropriate to review the development of that system, to describe its operations, and to identify the types of reports that are available from its use. The information summarized below is primarily drawn from the final report on WSPMS.

History and Background of WSPMS

The need for a systematic approach to managing pavements was recognized by key administrators within the Washington State Department of Transportation (WSDOT) in the 60's. A program to collect pavement rating data was started around 1965. A study to evaluate the feasibility of developing a Pavement Management System (PMS) was conducted in 1973-74. The study indicated that most of the resources required for PMS development were available and that it was feasible to attempt pavement management on a trial basis.

Based on the recommendations and findings of the feasibility study, the WSDOT administration authorized a research study to develop a PMS in 1975. The system was developed in stages between 1977 and 1980, with each stage providing improvements over the previous work and incorporating new capabilities. Finally, in the fall of 1982, 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. Since then, the PMS has been an integrated part of WSDOT operations.

A Conceptual Flowchart of WSPMS Operations

Figure 1 shows a conceptual flowchart of the operations involved in the WSPMS. 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.

A brief description of each phase follows.

1. Building the Data File

In this phase, the data essential for evaluating the current pavement condition and the future pavement performance are assembled in a computer to define a Master File. The Master File combines information from five other existing data files:

- Roadlife history (construction history).
- Roadway inventory (geometric data).
- Annual traffic file.
- Surface friction file.
- 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.

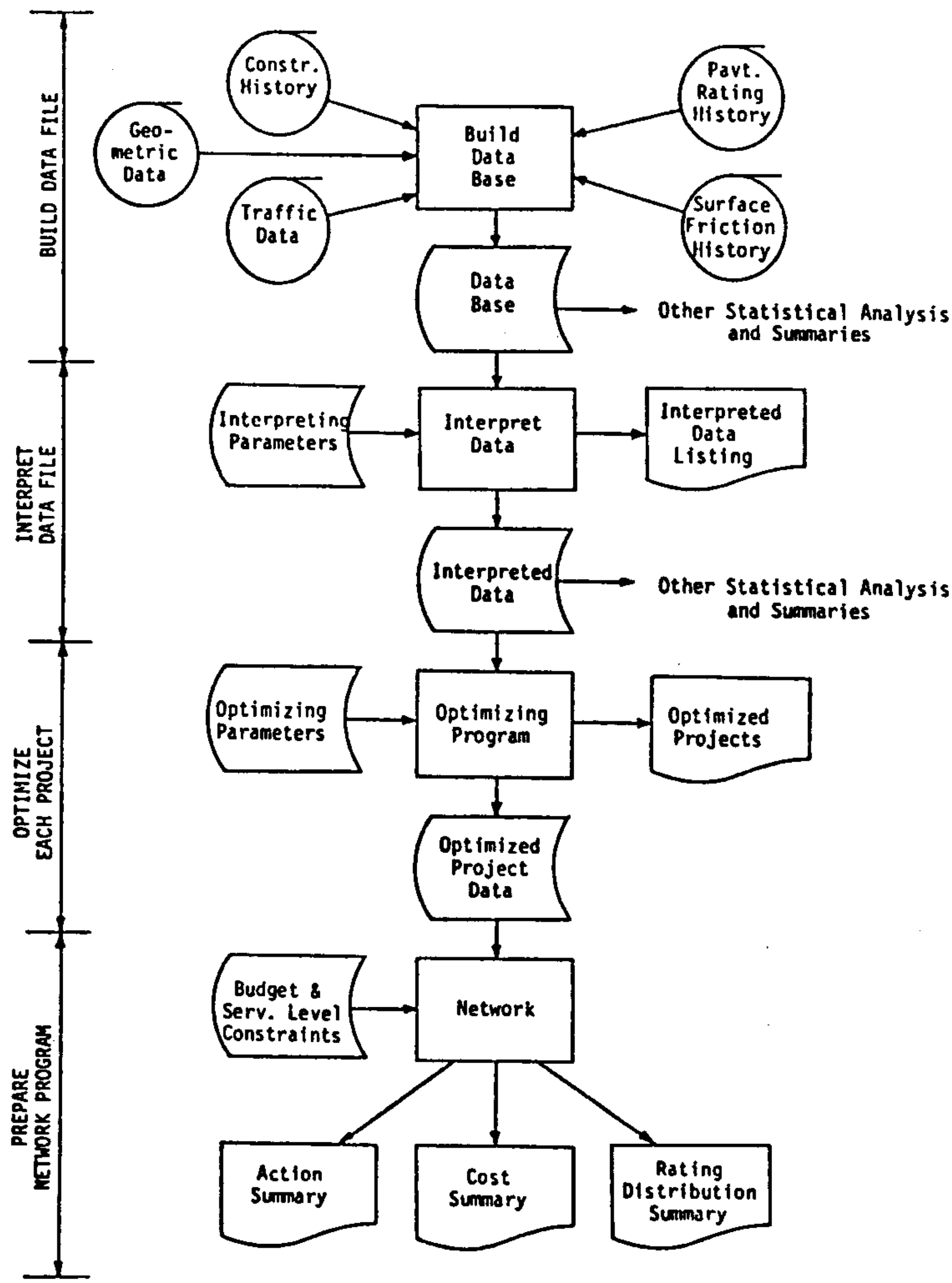

Figure 1. CONCEPTUAL FLOW CHART OF WSPMS OPERATIONS (Ref.1)

2. As input to the first of three computer programs in the system, the interpreting program.

2. Interpreting the Data File

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 next 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. A schedule of anticipated action, cost, and performance can be tabulated for a future number of years, through a system of aggregating the recommended rehabilitation alternatives and performance of all project segments on the network. The network program will produce an entire balanced rehabilitation program, by applying budget and condition-level constraints for each year. 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, by varying the budget and condition-level constraints and tabulating the results in projected performance with proposed budgets.

Reports Available for WSPMS

The reports available from the execution of the four phases of WSPMS are described below.

Master Index File - This file contains data related to roadlife history, roadway inventory, and traffic for each project identified from the most recent paving contracts.

Master File - For each project identified in the Master Index file, the Master File contains pavement condition ratings for each generation year and each mile in the project.

Interpreting program output - This output contains a summary of the performance history, traffic data, the form of the performance equation, and a plot of the performance equation with high, average, and low values shown. This information is produced for each project in the Master File.

Summaries of rating distributions - Summaries of the distribution of pavement condition ratings and distress types by districts and by functional classes are produced for each pavement type. Statewide distributions of rating and distress types are also summarized by functional classification and by district.

Summaries of ratings by generation - These summaries list raw pavement ratings and the translated score for each consecutive mile along a route for one generation of survey data.

Optimizing program output - For each project, the output of the optimizing program summarizes the economic evaluation of alternative rehabilitation strategies. The following parts are contained in the output:

- Project description and performance history
- Performance standards in terms of "should" and "must" levels (i.e., pavement condition when some type of rehabilitation should be applied and pavement condition when something must be done to rehabilitate it).
- Description of rehabilitation alternatives and their performance equations.
- Ranking of rehabilitation strategies based on the total life cycle costs.

Network action summary - For each project, the proposed rehabilitation action and its cost are listed for each year of a six-year maintenance program. The projects are listed by district.

<u>Network cost summary</u> - For each year, the number of miles which are rehabilitated and the cost are listed by functional class for each district, as well as for the whole state.

<u>Network rating distribution summary</u> - This summary lists the number of miles present in different pavement condition rating groups before and after the completion of all proposed actions for each year. This summary is produced for each district as well as for the whole state.

<u>Priority list of projects</u> - For a fixed budget (or a fixed performance goal), a prioritized list of rehabilitation projects is produced for each year of a six-year program. The criterion used in prioritizing projects is the change in pavement deterioration in one year, beyond the year being considered, if no action is taken at the present time.

3. DETERMINATION OF COUNTY NEEDS THAT CAN BE MET BY THE WASHINGTON STATE PAVEMENT MANAGEMENT SYSTEM

In order to assess the needs of the counties regarding more effective pavement management, meetings were held with the representative of four counties - Thurston, King, Walla Walla, and Pacific. This section summarizes the major findings of these meetings and provides an assessment of the county needs that can be met by the WSPMS.

Summary of Meetings with County Representatives

Meetings with county representatives were held during October 12-21, 1983. Representatives from King County, Thurston County, Pacific County, and Walla Walla County, and personnel from the Consultants participated in the meetings. Combined meetings with all county representatives were held on October 19 and the morning of October 20. Individual meetings with each county were held in the afternoon of October 20 and on October 21.

The purpose of the combined meetings was to discuss needs of the counties to improve current pavement maintenance practices and to identify resources available for PMS development. The following items were discussed:

- Results and expectations from PMS programs
- Identification of relevant distress types
- Segment identification

- Establishing threshold distress values
- Information requirements to implement the WSPMS computer programs
- Condition survey procedures
- Review of action selection matrix
- Evaluation of data processing options

The subjects discussed in individual meetings with county personnel included the following:

- Evaluation of available computer resources
- Sources and amount of information currently available
- Specific requirements and constraints for each county.

The major considerations that emerged from the meetings are noted below.

1. Provide for an intermediate deliverable in the form of a priority listing of "must" projects by functional class, using WSDOT combined condition score. This list should also contain a recommended action for each project, the cost of this action, and the total budget required for funding all "must" projects.

2. Add the distress type "longitudinal edge cracking." This distress can result in a loss of lateral support and cause significant damage to the pavement structure.

3. "Red flag" extreme longitudinal edge cracking. For example, the combinations of high extent and medium or high severity, and medium extent and high severity can be identified.

4. Consider the addition of "0.08' overlay with wedge cut" as a rehabilitation alternative in the selection matrix. This will apply in urban areas to pavements with curb and gutter.

5. It will be desirable to have a common pavement condition survey manual and a common training program for raters for all counties. This will provide consistency across all the counties in reporting observations and will maximize the effectiveness of the training effort.

6. Utility trenches are not included in the WSPMS since they are rarely present on state highway system. Although utility trenches will be present on many county roads, they need not be considered a separate distress type. The effect of trenches on ride quality can be considered. Also, transverse or longitudinal cracking at the trenches can be included in the total amount of cracking for the segment.

7. It would probably be best to exclude gravel roads from the PMS at the present time. A certain amount of budget can be allocated to these roads based on past experience.

8. It will be desirable to have a common PMS for all counties in the state. The common system will provide a uniform basis for establishing budget backlogs and for comparing conditions of road network within and across counties.

9. The available state resources should be used to the maximum extent possible. Such resources include computer facilities, computer software, particularly the data base system, personnel to maintain and update programs, and possibly personnel to run the computer programs and provide the results to the counties.

10. The maximum length of a segment in rural areas should be 1/2 mile. Breaks should be provided at major intersections, at easily visible construction limits, and breaks to account for systematic performance variations. For urban areas, the maximum segment length should be one block. Very short sections (less than 300 ft) should be avoided. Project boundaries should be identified by last construction and updated annually to reflect CIP or BST program.

11. Most of the counties have not conducted pavement condition surveys. Thurston county has recently completed such a survey, and King county is in the process of conducting one. The smaller counties may be able to commit adequate resources for conducting pavement conditions surveys.

12. Microcomputers with a printer and some data base management software are available to all counties. Some of the larger counties (such as King and Thurston) also have in-house mini- or main-frame computers. Many counties have accessed the state computer systems by telephone in the past for some particular data analysis needs.

13. Not much data processing staff support is available to the smaller counties (represented by Walla Walla and

Pacific). The preference of these counties will be to arrange for data processing support at the state level. Although the larger counties (represented by King and Thurston) have in-house data processing groups, it will be difficult to obtain the adequate support from these groups for PMS development activities. Consequently, even the larger counties may prefer the option of organizing data processing related to PMS programs at the state level.

14. Supporting data, such as traffic and construction history required for the WSPMS, are generally not available to most of the counties. However, reasonable estimates of the essential parameters can be made based on judgments.

<u>Assessment of County Needs that Can be Met by the WSPMS</u>

The need for systematic, consistent, objective, and technically sound methods for managing pavements becomes increasingly important, as resources become increasingly constrained. The development and implementation of a pavement management system as an aid in making decisions relative to the problems of what to do, when and where has generally been recognized as a useful resource tool for decision makers.

For counties in the State of Washington these systems, if properly coordinated, can provide a uniform and documented method for establishing resource needs necessary to maintain pavements, statewide, in a safe and serviceable condition at a minimum cost.

The Washington State Pavement Management System (WSPMS) offers a method which has been implemented and tested by the Washington State Department of Transportation. The system has the capability of determining pavement maintenance needs by establishing minimum levels of performance for various types of pavements, bituminous (BST), asphalt concrete or portland cement concrete, serving several functional classes subjected to a range of traffic volumes. The system has the capability of projecting budget requirements necessary to maintain the system above pre-assigned levels of performance.

The WSPMS has the advantage of having been designed in a modular mode. Useful information is available from each of several steps in the system. Specific "deliverables" possible from the system are:

1. Data base reports - master file
2. Performance and priorities - interpreted data
3. Optimizing Program - project maintenance and rehabilitation strategy
4. Network analysis - health of system with budget or rating constraints.

Each of these deliverables will be discussed in this report. The important consideration for the potential user of the program is to realize that there is useful information to be obtained at each stage in the development of the program. In addition to those which have specifically been developed for the Washington DOT, several additional reports are discussed as possibilities, e.g., priorities and costs from the interpreted data. This additional report offers an early set of criteria for managing pavements prior to developing the parameters necessary for the prediction models.

In summary, the potential benefits to the decision maker in justifying budget needs and for establishing policy are considered by many public agencies to be well worth the cost of implementation. This will be especially true for Washington counties since it will not be necessary to "re-invent the wheel" by taking advantage of the basic procedures that have already been developed by the Washington DOT.

4. DATA COLLECTION/HANDLING OPERATIONS FOR COUNTY ADOPTION OF WSPMS

In this section, the data requirements for the execution of the WSPMS computer programs are described; the sources and procedures for collecting the necessary data for counties are identified; and alternative procedures for transferring the data to a computer are developed.

Data Requirements for the WSPMS

Data requirements for the WSPMS can be defined by identifying the input data required for the execution of each computer program in the system. The various computer programs in the system and the purpose of each are as follows:

BUILD1 - This program reads roadlife history of every roadway segment and produces a file containing the project limits for the most recent consecutive surfacing contracts.

EQUATE19 - This program reads and stores roadway inventory data for each project identified by BUILD1.

EQUATE20 - This program matches the state route and control section mileposts for each project.

BUILD2SR - This program assigns relevant traffic data to the project limits developed. The output of this program is the Master Index file that contains project limits, description, and date of last surfacing contract, number of lanes, roadway and shoulder widths, base material type, and traffic information.

<u>BSKIDSR</u> - This program associates yearly summaries of surface friction data with each project. Since surface friction data will not be included for the county system at the present time, this program will not be required.

<u>BUILD4</u> - This program reads pavement condition survey data and produces the Master File which contains condition ratings for each mile within the limits of each project for each survey year.

<u>INTERP</u> - This 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.

Input for this program comes from two sources:

1. The Master File produced by the program BUILD4.
2. A direct access data set that contains the distress weighting matrix and other interpreting parameters.

<u>LISTMSTR</u> - This program lists the Master File with the distress ratings and combined ratings for each mile.

<u>RATGRP</u> - This program applies the distress weighting matrix to one generation of pavement condition survey data and produces summaries of the distribution of condition ratings by districts and functional classes, and also the systemwide distribution of condition ratings.

<u>RATGEN</u> - This program provides a consecutive listing of raw condition ratings with their translated score for all segments within a project.

<u>OPTAL</u> - This program evaluates alternative rehabilitation strategies for a given project based on life cycle cost comparisons and ranks the strategies in the order of the expected life cycle cost during a specified analysis period.

The input from this program comes from two sources:

1. The Master File produced by the program BUILD4.
2. A direct access data set that contains optimizing parameters necessary for the definition of alternative rehabilitation strategies and for their economic evaluation.

<u>NETWORK</u> - This program produces a multi-year pavement rehabilitation program that is based on the optimum rehabilitation strategies identified for different projects, and budgetary or performance constraints specified by the management.

Table 1 lists the input data items required for the major computer programs and the anticipated source of information for Washington counties to acquire each item. Several of the data

TABLE 1

INPUTS FOR COMPUTER PROGRAMS AND DATA SOURCES

INPUTS TO BUILDI AND THEIR SOURCES

Variable	Format	Description	Source	Note
DISTI	I1	District.	Project definition	
SEQI	A3	Sequence number.	Arbitrary	
SRI	I3	State route number.	Project definition	
CSI	I4	Control section number.	Project definition	Use county road number
BCSMPI	I4	Beginning control section mile post for project.	Project definition	
HTI1	I1	Highway type.	County records	
LANEI	A1	Lane of project.	Project definition	
SPI	A1	Part of contract number.	Arbitrary	
SNUMI	A4	Contract number.	Arbitrary	
CTYPI	I2	Contract type.	Arbitrary	
STYPI	I2	Surface type.	County road log	
STHKI	I2	Thickness of paving.	County records	
MNTHI	A1	Month last contract completed	Arbitrary	
YEARI	I2	Year last contract completed.	County records	
BS1I	I1	Type of pavement in first layer below present surface. Takes same values as STYPI.	County records, or estimated	
BS2I	I1	Type of pavement in second layer below present surface. Takes same values as STYPI.	County records, or estimated	
BS3I	I1	Type of base course.	County records, or estimated	
BS4I	I5	Depth and year placed for basement soil.	County records, or estimated	
PCCI	I3	Not used. Set to 0.	Set to 0	

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INPUTS TO EQUATEI9 AND THEIR SOURCES

EQUATEI9 reads all the variables written by BUILDI from unit 5 and reads the following variables from unit 4.

Variable	Format	Description	Source	Note
TFCI	A1	Functional class.	County road log	
TCSI	I4	Control section.	County road log	Use county road number
TSEQI	A3	Sequence number.	Arbitrary	
TCSMPI	I4	Ending control section mile post for record.	County road log	
TRUI	A1	Indicator for rural or urban highway.	County road log	
TLLI	I1	Number of lanes on left side for divided highway.*	County road log, and county records	
TLRI	I1	Number of lanes on right side for divided highway or total number of lanes for undivided highway.*	County road log, and county records	
TFLSWI	I2	Far left shoulder width for divided highway.*	County road log	
TLRWI	I2	Width of left roadway for divided highway.*	County road log, and county records	County road log does not show this information for divided highways
TNLSWI	I2	Width of inside shoulder on left for divided highway.*	County records	
TLSWI	I2	Inside right shoulder width for divided highway, or left shoulder width for undivided highway.	County road log, or county records	
TRRWI	I2	Roadway width on right for divided highway, or total roadway width for undivided highway.	County road log, or county records	
TRSWI	I2	Width of shoulder on right side.	County road log	
TOGI	A1	A key that indicates an equation exists.	County records	

* Set to 0 for undivided highway
2032c

INPUTS TO EQUATE20 AND THEIR SOURCES

EQUATE20 reads the file written by EQUATI9 from unit 5 and reads the state route mileposting information from unit 4.

The program EQUATE20 makes the correspondence between control section mile posts and state route mile posts. Since the counties do not use a dual mile posting system, this program will not be needed for the county system and the inputs do not have to be obtained.

Variable	Format	Description	Source	Note
TCSI	I4	Control section number.	Arbitrary	
TSEQI	A3	Sequence number.	Arbitrary	
TCSMPI	I4	Control section mile post.	Arbitrary	
TSRMPI	I5	State route mile post that corresponds to the control section mile post above.	Arbitrary	
DESCI	7A4, A2	Landmark description (i.e. cross roads).	Arbitrary	

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INPUTS TO BUILD2SR AND THEIR SOURCES

Variable	Format	Description	Source	Note
TSR2	I3	State route number.	County road log	Use county road number
TCS2	I4	Control section number.	County road log	Set equal to county road number
TEMP2	I5	Ending mile post for the data record.	County road log	Required only for user cost calculations
K2	I2	Factor for converting average daily traffic to peak hour traffic.	County records, or estimate	Required only for user cost calculations
D2	I2	Percent of peak hour traffic going in heaviest direction.	County records, or estimate	Required only for user cost calculations
GR2	I3	Growth rate of traffic.	County records, or estimate	Required only for user cost calculations
SU2	I2	Single unit truck percentage.	County records, or estimate.	Required only for user cost calculations
COMB2	I2	Combination truck percentage.	County records, or estimate	Required only for user cost calculations
ADT2	I6	Average daily traffic.	County road log	Required only for user cost calculations

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INPUTS TO BSKIDSR

BSKIDSR reads the file written by BUILD2SR from unit 5, and reads skid data from unit 4.

Note that skid values are not used for pavement maintenance planning by the pavement management system. Consequently BSKIDSR will not be used and its inputs need not be obtained.

Variable	Format	Description	Source	Note
SSR	I3	State route number.	Not required	
SCS	I4	Control section number.	Not required	
SMP	I5	Ending state route mile post for data record.	Not required	
DIR	A1	Direction.	Not required	
SKID	I2	Skid value.	Not required	
SYR	I2	Year of measurement.	Not required	

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INPUTS TO BUILD4

BUILD4 reads the file written by BSKIDSR from unit 5 and reads defect data from unit 4.

Variable	Format	Description	Source	Note
For All Pavement Types:				
GCS	I4	Control section number.	Defect survey	
GEMP	I4	Ending control section mile post for defect record.	Defect survey	
ST	A1	Pavement type for rated section (note that the pavement type in small sections of a project may be different from the surface type of the project as a whole).	Defect survey	
GLANE	A1	Lane to which the rating refers.	Defect survey	
For Asphalt or Bituminous Pavements:				
D1	A1	Rutting or pavement wear.	Defect survey	
D2	A1	Not used.	Defect survey	Place long. edge cracking here
D3	A1	Corrugation degree and extent.	Defect survey	Not used
D4	A2	Alligator cracking degree and extent.	Defect survey	
D5	A2	Raveling degree and extent.	Defect survey	Not used
D6	A2	Longitudinal cracking degree and extent.	Defect survey	
D7	A2	Transverse cracking degree and extent.	Defect survey	
D8	A2	Patching degree and extent.	Defect survey	
For Portland Cement Pavements:				
D1	A1	Rutting, pavement wear	Defect survey	Not used
D2	A1	Blowups	Defect survey	Not used
D3	A2	Cracking degree and extent	Defect survey	

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INPUTS TO BUILD4 (Continued)

BUILD4 reads the file written by BSKIDSR from unit 5 and reads defect data from unit 4.

Variable	Format	Description	Source	Note
D4	A2	Raveling, disinteg., popout scaling degree and extent	Defect survey	Not used
D5	A2	Joint spalling degree and extent	Defect survey	
D6	A2	Pumping, blowing degree and extent	Defect survey	Not used
D7	A2	Faulting, curling, warping settlement, degree and extent	Defect survey	Not used
D8	A2	Patching degree and extent	Defect survey	
For All Pavement Types:				
SPEED	A2	Speed at which pavement roughness measurement was made.	Defect survey	Not necessary to make program run
BUMPS	I5	Pavement roughness measurement in counts per mile.	Defect survey	Not necessary to make program run

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PARAMETERS FOR INTERP

Variable	Format	Description
AMTRX (I,J)	2I12	Deduct values for asphalt pavements
BMTRX (I,J)	2I12	Deduct values for bituminous pavements
CMTRX (I,J)	2I1s	Deduct values for concrete pavements
NEXP	I2	Number of values in EXP(J) array (below)
NOW	I2	Current year
MINR2	F3.2	Minimum acceptable R^2 value
WATE	I3	Not used
EXP(J)	20F4.2	Array of exponents to be tried in rating equation
EC(3,4)	4F5.1	Array of default performance equation constants
EV(3,4)	4F8.5	Array of default performance equation factors
EP(3,4)	4F4.2	Array of default performance equation powers

PARAMETERS FOR OPTAL

Variable	Format	Description
YEAR	I2	Present year
TRAFYR	I2	Year of traffic data
NPRDS	I2	Number of periods used for planning complete strategies (eg. 20)
NETPRD	I2	Number of periods included in action and cost summaries in program NETWK (eg. 6)
LPRD	F4.2	Length of the periods
EFFINT	F4.2	Effective interest rate
NOPR	I1	Not used
TFACT(I)	F3.2	Thickness factors for determining equations for alternatives
EXPACT(I)	F4.2	Equation factors for determining equations for alternatives when original pavement has been overlayed before
SHOULD(I)	F2.0	"Should" levels for each functional class
MUST(I)	F2.0	"Must" levels for each functional class

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PARAMETERS FOR OPTAL (Continued)

Variable	Format	Description
TIR(I)	I3.1	Traffic index ranges to be used for selecting the correct strategy for a given project.
FTMTRX(I,J,K)	5I1	Matrix which gives number of strategy to be used according to functional class, traffic index, and surface type of project
RMATRX(I,J)	3I1	Matrix containing the rehabilitation alternatives for each strategy
DES(I,J)	6A4	Description of rehabilitation strategy I
CONSTC(I)	I8	Construction cost of rehabilitation strategy I per 12 ft. lane
OTHK(I)	F3.2	Traffic interruption cost factor for rehabilitation alternative I.
AEQ(I)	F4.2	Equation factor for estimating life of rehabilitation alternative, used when existing surface has a surface type greater than or equal to 40*.
BEQ(I)	F4.2	Equation factor for surface types less than 30* (see AEQ).
CEQ(I)	F4.2	Equation factor for surface types greater than or equal to 30* and less than 40* (see AEQ)
MAXRAT(I)	F6.2	Constant to be used in performance equation for rehabilitation alternative I.
MS(I)	F7.2	Slope of performance equation for rehabilitation alternative I.

* These numbers refer to the code for surface type used in WSPMS report (See page 27 of Reference 1).

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PARAMETERS FOR OPTAL (Concluded)

Variable	Format	Description
NOTCOS	I2	A switch. If NOTCOS equals I, then costs due to traffic interruption are not included in strategy evaluation
NOMC	I2	A switch. If NOMC equals I, then maintenance costs are not included
NOPC	I2	A switch. If NOPC equals I, then prepartion costs are not included
NOUC	I2	A switch. If NOUC equals I, then user costs due to pavement condition are not included

PARAMETERS FOR NETWORK

Variable	Format	Description
YEAR	I4	Present year.
INFL	F4.2	Inflation rate.
STAT	I1	A switch. If state equals 1, statewide summaries are not compiled.
EI	F4.2	Effective interest rate.
ENGCST	F4.2	Engineering cost of project as a function of the preparation cost.
SHUD(I)	I2	"Should" level for functional class I.
MUST(I)	I2	"Must" level for functional class I.

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items currently in the state system are for informational purposes only; these are simply read and printed out, but not used in any analysis. These data items are so identified in Table 1. To minimize data collection effort for the counties, such data items will not be included in the county PMS.

The data items directly available from the County Road Log or construction record files will require no further analysis. However, other data items will need to be developed based on some analysis of available data, or based on experience and engineering judgments. Guidelines are provided in the following subsections for generating the necessary data for county usage of the WSPMS. The topics covered are: (i) pavement condition survey procedures, (ii) pavement condition data requirements, (iii) supporting data requirements, (iv) specification of interpreting parameters, and (v) specification of optimizing parameters.

Pavement Condition Survey Considerations

Figure 2 shows a pavement rating form for bituminous and portland cement concrete pavements. This form has been designed for the county project identification system and the distress types appropriate for county roadway networks. The following aspects of condition surveys need to be examined: preparation of a survey manual, productivity to be expected for the surveys, training and periodic calibration of survey personnel, and development of driving routes.

Preparation of a survey manual - In order to assure uniformity in the condition data from year to year or between agencies, a condition survey manual will be required. This manual should describe in detail the procedures to be used by field personnel in identifying and recording observed conditions of the

PAVEMENT CONDITION RATING

Date	Rater	Sheet No of

CONTROL DATA

ROAD NUMBER	BEGINNING MILE POST OF RATED SECTION	ENDING MILE POST OF RATED SECTION	FUNCTIONAL CLASS	PAVEMENT TYPE (A,B or C) ***	* PAVEMENT EXEMPTION	MULTI-LANE (L) (R) (B)

BITUMINOUS PAVEMENTS

RUTTING, PAVT. WEAR	CORRUGATION % of Roadway (1) 1 25% (2) 26 75% (3) Over 75%			ALLIGATOR CRACKING Whl Trk Station (1) 1 24% (2) 25 49% (3) 50 74% (4) 75 100%			RAVELING OR FLUSHING (1) Localized (2) Wheel Paths (3) Entire Lane				LONGITUDINAL CRACKING LINEAL Ft/Sta (1) 1 99 (2) 100 199 (3) 200 plus			TRANSVERSE CRACKING No./Station (1) 1 4 (2) 5 9 (3) 10 plus			PATCHING % Area/Sta (1) 1 5% (2) 6 25% (3) Over 25%			LONGITUDINAL EDGE CRACKING Ft/Sta (1) 1 99 (2) 100 200 (3) Over 200		
**	1/8–2" Change/10 ft	2–4" Change/10 ft	Over 4" Change/10 ft	HAIRLINE	SPALLING	SPALLING/PUMPING	SLIGHT	MODERATE	SEVERE	R-RAVELING F-FLUSHING	LESS THAN 1/4"	OVER 1/4" WIDE	SPALLED	LESS THAN 1/4"	OVER 1/4" WIDE	SPALLED	0.10–0.50" THICK	0.50–1.0" THICK	OVER 1.0" THICK	1/8–1/4"	1/4" plus (No Spalling)	1/4" plus (Spalled)

PORTLAND CEMENT CONCRETE

CRACKING Units Panel Length (1) 1 2 (2) 3 4 (3) 4 plus			RAVELING DISINTEGRATION, POP OUT, SCALING (1) Slight (2) Moderate (3) Severe			JOINT SPALLING Width (1) 0 1" (2) 1 3" (3) 3" plus			PUMPING BLOWING % Panel Length (1) 0-9% (2) 10 50% (3) 50% plus			BLOWUPS	FAULTING (1) 1-15% (2) 16-35% (3) 35% plus			PATCHING % Panels (1) 1 5% (2) 6 20% (3) 20% plus			PAVMNT WEAR	ROADMETER COUNTS PER MILE
1 - 25% PANELS	26-50% PANELS	OVER 50% PANELS	1 - 25% AREA	26 - 75% AREA	OVER 75% AREA	1 - 15% JOINTS	16 50% JOINTS	OVER 50% JOINTS	1 - 15% of PANELS	16 - 35% of PANELS	OVER 35% of PANELS	No./MILE	0–1/4"	1/4–1/2"	1/2" plus	1 - 5% AREA/PANEL	6 - 25% AREA/PANEL	OVER 25% AREA/PANEL	**	

* CODE: (1) Unpaved Roadways
(2) Roadways under construction
(3) Bridge
(4) Impassable road
(5) Other

** RUTTING/ PAVEMENT WEAR: (1) 1/4 to 1/2"
(2) 1/2 to 3/4"
(3) Over 3/4"

REMARKS: ______

*** A - Asphalt
B - Bituminous
C - Portland Cement

Figure 2. PAVEMENT CONDITION RATING FORM

pavement. Specifically, the manual should (1) provide some background information for the overall pavement management system being implemented, (2) describe methods for conduct of the field surveys, (3) provide examples (color photos, graphics) illustrating types and extent of each condition to be evaluated, (4) describe methods of recording (coding) information, (5) explain forms used to record information, e.g. Figure 2 herein, and (6) identify quality control procedures, e.g., checks between raters, previous year's ratings, etc.

Example manuals have been prepared by the Washington DOT and by Thurston County (Trowbridge, 1983). A number of manuals have been prepared by other agencies involved in the development of pavement management systems. Each such manual has been tailored to the needs of the system and to some extent to the resources available for conducting surveys. For trial implementation, the WSDOT manual can be used.

Productivity - Condition survey data must be reliable, and yet there is usually a limit on how many people and how much time is availale for the conduct of the survey.

Certain criteria need to be established in planning procedures for the conduct of the condition survey: (1) when, (2) how, and (3) by whom.

It is desirable to make condition surveys at least once every two years for the entire system. The surveys should be scheduled for the same time of year and should be completed in no more than three months. Annual surveys would be preferred if resources are available. If a biennial survey schedule is followed, it is recommended that the entire system be surveyed in one year, rather than 50 percent in each of the two years to be covered by the survey. A 50-percent schedule will result in comparisons that could be biased toward those sections surveyed in the latest year, i.e., one more year of wear.

The preferred time to do the survey would be in the early spring before heavy maintenance programs are initiated. The exact time will depend on when personnel or resources are available. If the information, i.e., budget and condition, is to be used for statewide evaluations, the surveys should be scheduled for the same period in each county. How the surveys are to be made brings into consideration the matter of reliability as well as productivity. It is recommended that two-person teams be used for the condition surveys. This recommendation takes into account safety, productivity, and quality control.

For urban areas where streets are laid out by blocks a continuous "windshield" survey can be used; however, for segments of one-half mile or more in length a sampling procedure will be necessary.

The question as to personnel requirements will depend on how much time is required per sample and how many samples are required per segment. For example, assume the roadway network consists of 1000 miles (2000 segments) and that two sampling units (survey sections) are considered a minimum for each segment. If four minutes are allotted to each sampling unit the total team time would be 45 days (six hours per day of productive time or 75 percent efficiency). Thus, approximately 90 person days or slightly more than 4 person months would be required for the survey. Adding another person month for support would increase this requirement to 5 person months.

A range of choices are available in selecting personnel for pavement condition surveys. Experience indicates that some maintenance people do well as surveyors since they are usually familiar with the road network and also with distinguishing characteristics of various types of distress. Experience also indicates that personnel who are used to working in the field can become bored with the routine associated with condition surveys. Part-time (summer) employees have been used for condition surveys; however, personnel of this type have very little if any experience in distress recognition and will be unfamiliar with road locations. In either case a thorough training program is considered essential in preparing for a condition survey.

Training - Approximately 3-5 days should be allocated for training. The four primary objectives of the training program are; (1) familiarization with objectives and procedures, (2) distress recognition, (3) methods of recording observations and (4) field observations and calibration of personnel.

Familiarization of objectives and procedures will involve an explanation of the system objectives and some explanation as to how the condition survey is to be made.

Distress recognition will involve the use of slides and graphics designed to illustrate the types, extent and severity of distress to be evaluated. If subjective ride quality (roughness) is to be included in the survey, in lieu of a road meter, some general criteria will be required. If subjective ride quality is included in the survey some additional time should be allocated to each segment for a second pass over the pavement for the sole purpose of evaluating ride at posted or prevailing speeds.

Procedures for recording information on appropriate forms become important to assure correct data entry into the data base.

Field observations with surveyors are very important. These observations will allow surveyors to compare impressions with other surveyors and with the instructor.

It will be useful to establish some method for early quality control of results from the condition survey. To do this the instructor along with two or more top management personnel should go into the field with results of the condition survey and confirm that the surveyors are correctly and consistently recording pavement conditions.

Driving Route - In order to simplify the field operations and to assure that all of the segments are surveyed, a driving route should be prepared in advance of actual field surveys. Two criteria should be considered in preparing the driving routes; (1) development of efficient driving patterns and (2) indication of daily production.

Driving routes can be prepared in the office with maps considered most reliable. Some changes may be made as part of the initial surveys and provision should be made for such modification. Subsequent changes may occur when new segments are added to the system.

Driving routes should be organized to represent one day's productivity. In this way it will be possible to monitor progress and modify schedules if necessary. Listings of the sequence of segments to be surveyed and maps should be provided to each team.

Pavement Condition Data Requirements

Relevant and reliable information concerning the condition of the pavement provides the basis for establishing feasible actions to correct deficiencies, priorities for actions, and for project optimization. Thus, the selection, acquisition, and interpretation of this information is extremely important. Condition survey information will require a significant percent of the total resources required for implementation of the PMS. This section of the report will discuss the types of information to collect and the use of the information for establishing priorities and budgets from the interpreting data, for monitoring the "health" of the pavements within the counties, and for project optimization.

The WSPMS includes provision for a fairly exhaustive list of types of distress which could be associated with bituminous or portland cement concrete pavement as follows:

Bituminous or asphalt concrete distress types

- corrugations, waves, sags, and humps
- alligator cracking
- raveling or flushing
- longitudinal cracking
- transverse cracking
- patching

Portland cement concrete distress types

- cracking
- raveling, disintegration, pop out, scaling
- joint spalling
- pumping, blowing
- blowups
- faulting, curling, warping, settlement
- patching
- pavement wear

Pavement roughness (ride quality) is measured for both pavement types.

For each pavement type, methods for categorizing the extent and severity of distress have been developed by the Washington DOT. In addition, manuals and training programs have been developed to support personnel assigned to make the condition survey.

In order to interpret the condition survey data, the Washington DOT staff has developed a method for assigning deduct values to each distress type as a function of extent and severity. A formula has then been developed for combining the raw coded distress data, including roughness, into a combined pavement rating as a function of the distress rating and ride rating.

Users of the WSPMS will need to review the condition data requirements as part of the implementation process. A first iteration of this review process has been included in this study and is summarized herein with some recommendations for modification.

In order to review the data requirements, a series of questions (criteria) are used to evaluate the need for information.

1. Will the particular type of distress trigger an action?

2. What deduct values should be applied in order to assure proper consideration with regard to the need for an action?

Of the six distress types identified for bituminous and asphalt concrete pavements, four have been retained by the Washington

DOT for calculating pavement ratings: (1) alligator cracking, (2) longitudinal cracking, (3) transverse cracking, and (4) patching. Of the eight distress types identified for portland cement concrete, three have been retained: (1) cracking, (2) joint spalling, and (3) faulting, curling, warping, and settlement. Counts per mile (roughness) are used for both pavement types.

Two considerations were used by the Washington DOT to select relevant factors:

1. consistency of the rating with time, and

2. relationship of each factor to rehabilitation criteria.

To these could be added consideration of productivity and reliability in data acquisition and the need for economy of data collection. The larger the number of factors, more is the time required in the field to observe and record, and more the chance for error in evaluating multiple conditions.

For County roads consideration should be given to the following modifications in the types of distress to include in the condition rating of bituminous (surface treatments and asphalt concrete) pavements.

1. Add longitudinal edge cracking - based on discussions with County representatives in October 1983 it was considered important to include longitudinal edge cracking (i.e., deterioration at the edge of paved surface) as part of condition evaluation. Recommended deduct values for this distress are shown below:

Deduct Values for Longitudinal Edge Cracking

Extent (lineal ft./sta.)	Severity: <1/4 Inch No Pumping No Spalling	<1/4 Inch Pumping Some Spalling	≥1/4 Inch Pumping Spalling*
1-99	5	10	15
100-200	10	15	20
>200	15	20	25

* Includes edge breakouts or potholes

The explanation for the relatively low deduct values is given in Section 5 of this report. Basically the reason for the low values is that this type of distress will be flagged out in a special report to alert authorities to the need for early maintenance on these sections.

2. Consider raveling - if surface wear or raveling is a problem within a county, it should be recorded in accordance with criteria given in Figure 2.

3. Counts per mile - This distress could be deleted or deferred, since its influence on pavement condition score may not be significant for county roads. If it is included, it could be measured with a Road Meter or evaluated subjectively if such equipment is not available. If a subjective evaluation is to be used, a recommended schedule for input into the data base is as follows:

Ride Quality (subjective rating)	Counts Per Mile		
	Bituminuous	Asphalt Concrete	PCC
Good	500	500	500
Fair	1700	1100	1100
Poor	5000	3000	3000

According to procedures used by the WSPMS the above factors would result in a percentage reduction in the pavement rating as follows:

Counts Per Mile	Percent Reduction
500	0
1100	1.5
1700	3.5
3000	11
5000	30

If ride quality is considered to be of more significance than shown by the above percentages, some adjustments should be made in the assigned roughness values. For example, poor ride could be assigned a value of 7050 resulting in a 60 percent reduction of the pavement rating obtained from distress factors alone. Thus, if the distress rating produced a value of 75 and ride was rated poor, the pavement rating would be 30 which would be classed as a "must" level for triggering an action for most functional classes.

Supporting Data Requirements

The WSPMS has been divided into four basic parts: (1) data base, (2) interpreting the data base, (3) optimization strategy at the project level (minimization of cost), and (4) network strategy to maximize benefits. This part of the report will review the data base and project optimization involving prediction models and rehabilitation alternatives.

The overall criterion used in evaluating supporting data requirements is the consideration of economy of data. Specifically, during the initial trials, collect only that information absolutely essential to obtain a priority ranking and cost estimates from the interpreting data file and for the development of project optimization from the project optimization file. As the agency develops increasing proficiency in using the WSPMS, it will be desirable to expand the data base to include additional information useful in fine tuning the system. Also, after a period of familiarization, the user agency may want to proceed to the network program. However, it is recommended that initial effort be designed to, first, develop a reliable data base of useful information, second, to modify the WSPMS to obtain a listing of projects according to their ranking by condition score, and third, to develop project optimization programs.

Five data files have been identified with the WSPMS: (1) roadlife history, (2) roadway inventory, (3) annual traffic file, (4) surface friction file, and (5) pavement condition file.

The roadlife history file serves to provide permanent identification for individual segments of roadway within the county system and to identify most recent construction projects.

In discussions with County representatives, it was the consensus that the rural county network be monitored in one-half-mile segments with the segments grouped together according to the most recent construction. In this way, each one-half-mile segment will remain as a permanent identifier regardless of project limits. Condition ratings would always be recorded in accordance with the one-half mile segments which would be considered to represent a homogeneous unit. Segments could be increased or decreased in length by ± 0.25 mile to accommodate project limits and political or jurisdictional boundaries within the county.

In urban areas, it was the consensus that roadways be divided into block-by-block units and grouped according to the most recent construction project. In so far as it is possible, blocks should be of uniform length. This may require combining short blocks to achieve a minimum length in the range of 300 to 500 feet.

Segment identification will require a significant level of effort initially; however, once segments are identified, little or no effort will be required thereafter. Discussions with county personnel indicate that the County Road Log data can be used as the basis for identifying roadway segments.

The roadway life file is also designed to provide the following information:

- complete construction history,
- contract numbers,
- functional classification,
- type of highway configuration,
- base material types and depths, and
- provision for locating added lanes and old PCC pavements.

Of these six items, only one is essential for the initial utilization of the WSPMS; specifically, the functional classification. This information will be used for selecting and comparing rehabilitation alternatives in the project optimization phase. The functional classification could also be useful for selection of feasible action and cost from priorities produced from the interpreting data file. It will be necessary to know the date for the last or most recent rehabilitation, but a complete construction history is not required. Contract numbers will be useful in locating background files and supporting information, e.g., project limits; however, dates of last construction will suffice. Type of configuration could be useful but is not necessary, i.e., knowing the number of lanes could help in dividing the network into segments suitable for management. This information can be coded as part of the initial condition survey if considered of sufficient importance; however, it is not essential. Base type and depths could be helpful in diagnosing causes of distress but is not necessary for initial implementation. The presence of old PCC pavements would fall in the same category as base type - interesting but not essential.

Each of the five items discussed in the previous paragraph can be useful in evaluating design parameters, for diagnosing types and causes of distress, or as information regarding the nature of the highway network. The information should be included in the data file as it becomes available; however, no special effort is necessary in order to initiate use of the WSPMS.

Five functional classifications in each of two categories (urban and rural) were recommended for use by the counties during our meetings in October 1983:

1. Principal arterial
2. Minor arterial
3. Major collector

4. Minor collector
5. Local access

The roadway inventory represents data pertinent to geometrical, physical and other descriptive features of the state highway system. Of the eleven plus items identified with this file, only those factors related to area; i.e., lane width and shoulder width are essential for initial implementation of the WSPMS. Junctions with other political jurisdictions, such as cities within the county can be useful but not essential.

Pavement width and shoulder width will be necessary in order to calculate cost of alternate rehabilitation actions. In most cases, this information can be scaled from county maps. If maps are not available, this information can be obtained as part of the initial condition survey for those segments where data is not available.

In order not to duplicate areas, guidelines are necessary for establishing segment limits through intersections, especially in urban areas with short segments. A general set of guidelines could be to carry the dominant roadway classification to the centerline of the intersection with the lower classification to the nearside curb or pavement line. If roadways are of the same classification, the one with higher traffic would be carried to the centerline.

The annual traffic file provides information relative to traffic volumes and types on each segment of the network. In the WSPMS this file includes average annual daily traffic (AADT), growth rates, single unit truck percentages, combination truck percentages, K factor for reducing AADT to a design hour volume, D factor for splitting the design hourly traffic into directions and three previous years' AADT.

For the WSPMS, the primary objective is to calculate traffic index (TI) from truck percentages based on the average annual daily traffic. In the absence of truck counts or AADT information, it will be necessary to use default values for TI. Suggested values of TI are shown in the following tabulation.

<u>Traffic Index</u>

Principal arterial: 7.0 and above
Minor arterial: 6.5
Major collector: 6.0
Minor collector: 5.0
Local access: 4.0 or less

The above values are for illustration only; if such a proxy procedure is used, it should be based as much as possible on objective traffic information. It would not be necessary for each county to assign the same TI to each classification. However, if statewide budget needs are to be accumulated by using the WSPMS, it will be desirable to retain common functional classification designations for all of the counties using the system. In this way, it may be possible to estimate needs even though less than 100 percent of the counties have implemented the system.

The <u>surface friction</u> file summarizes measurements of pavement friction when using an ASTM type skid trailer. This information is useful but not necessary for implementation of the WSPMS.

In summary, for the roadlife history, road inventory, annual traffic, and surface friction files, only seven are essential for implementation of the WSPMS as follows:

1. Segment identification
2. Date of last major construction
3. Functional classification
4. Pavement width
5. Shoulder width
6. Traffic index
7. Pavement type

Specification of Interpreting Parameters

The main interpreting parameters for which some analysis will be required are the distress weighting values. A weighting value is assigned to each combination of severity and extent of every distress type. The sum of weighting values is subtracted from 100 to establish the overall distress rating. The distress rating is then multiplied by the ride rating to obtain the combined pavement rating.

It is recommended that for the trial implementation of the system, the distress weighting values currently used by WSDOT be assigned. However, these values should be reviewed and revised, as necessary, by the county personnel. Possible modifications for weighting factors have been discussed in a previous section Pavement Condition Data for WSPMS. To maintain uniformity among the Washington counties, it will be desirable to establish a single set of weighting values which will be used by all counties. One approach to assessing the weighting values will be to form a panel of representatives from each of the Washington counties involved in PMS development and develop a consensus of the panel regarding the weighting value of each combination of severity and extent of a given distress type. The implementation of this approach will involve the following steps:

1. <u>Form the assessment panel</u> - One or two representatives from each of the counties involved in PMS development should be included in the assessment panel.

2. <u>Develop an understanding of different distress levels</u> - The panel members should review the definitions of different combinations of severity and extent of each distress type. Some field trips should also be conducted so that the panel members get to observe pavements in different distress levels. Photographs of different pavement conditions should be taken to provide visual images of the specific distress levels which may be evaluated.

3. <u>Make preliminary assessment of weighting values</u> - The various distress types should be ranked according to the degree of concern for the worst combination of severity and extent of each distress type. Weighting values for these worst combinations should then be assessed by each panel member. A panel consensus can be arrived either through group discussions or, more formally, using a procedure such as the Delphi method (see, for example, Reference 3). Once the weighting value of the worst combination is established for each distress type, this will define the range within which the weighting values of other combinations should lie. The corner combinations--low severity and high extent, high severity and low extent--should be evaluated next, followed by the intermediate combinations.

4. <u>Verify the reasonableness of the preliminary assessments</u> - A group of 15 to 20 pavements in different distress levels should be selected for purposes of verification. The panel members should drive over these pavements to observe their condition and then rank them based on the need for

rehabilitation. An independent survey team of two persons should survey the pavements and assess the extent and severity of each distress type. The combined pavement ratings should be then calculated by applying the preliminary weighting values. The ranking of the pavements based on the combined rating should be compared with the subjective ranking of the panel members. If major discrepancies are found between the two rankings, potential causes for such discrepancies should be examined and resolved through discussions.

5. Revise the preliminary weighting values - The results of the verification should be used to decide if any revisions in the preliminary assessment of the weighting values will be necessary. Appropriate revisions in the weighting values should be made to obtain consistency between numerical pavement ratings and the perception of the panel members regarding the need for rehabilitation of the various pavements.

Specification of Optimizing Parameters

The major optimizing parameters and guidelines for estimating each parameter are given below.

Present year - The economic analysis of rehabilitation strategies will start at the present year.

Year of traffic data - Growth in traffic will be estimated starting from the specified year of traffic data.

Number of periods in consideration span - A typical value of this parameter is 20 one-year periods.

<u>Number of periods in network program span</u> - The network program will prepare a rehabilitation program for the specified number of periods. A typical value is 5 to 6 years.

<u>Length of periods</u> - A typical value is one year.

<u>Effective interest rate</u> - This is the difference between desired rate of return on capital investment and the rate of inflation. A typical value is 4 percent.

<u>"Should" and "Must" level arrays by functional class</u> - In order to provide some basis for setting "should" and "must" levels for rehabilitation a limited parametric evaluation was made using the WSPMS program. For this purpose the should level was always 10 points higher than the must level. Cost calculations were based on information contained in the previously referenced report by Nelson and LeClerc. Costs have been discounted to present worth using a discount rate of 4 percent. A summary of calculations is shown in Table 2.

From the examination of the minimum total cost in Table 2, it could be concluded that the "must" level would be 10-20 for low traffic volume roads, 20-30 for intermediate traffic and 30-50 for high traffic volumes.

The rationale for selecting the "must" level is based on the overall accuracy of estimating costs, i.e., maintenance, construction and user costs, and in selecting a discount rate. Assuming that total costs that vary by less than five percent are about the same, the "must" levels previously indicated would seem reasonable.

In summary, "should" and "must" levels can tentatively be specified for different functional classes in accordance with the tabulation shown below:

Table 2. COST COMPARISIONS AS A FUNCTION OF "MUST" LEVEL FOR REHABILITATION

Must	ADT = 200				ADT = 10,000				ADT = 80,000			
Level	M. Cost	C. Cost	U. Cost	T. Cost	M. Cost	C. Cost	U. Cost	T. Cost	M. Cost	C. Cost	U. Cost	T. Cost
10	77,957	141,787	1,165	185,411	75,445	140,854	55,710	256,667	74,489	138,588	426,653	635,943
20	74,492	138,593	1,066	193,333	74,492	138,593	53,333	260,745	72,497	136,761	411,365	631,714
30	72,501	136,766	1,028	204,884	72,501	136,766	51,422	270,513	72,501	136,766	411,378	636,001
40	63,298	181,138	994	215,986	63,298	181,138	49,705	287,173	60,347	180,612	393,363	641,417
50	55,681	184,958	967	235,163	55,681	184,958	48,374	305,290	55,681	184,958	386,994	652,532
60	26,211	310,760	920	338,051	26,211	310,761	46,008	416,001	26,211	310,761	368,064	753,189
70	18,956	377,812	910	380,367	17,709	379,160	45,410	463,207	17,709	379,160	363,282	796,335
80	9,216	374,043	902	366,951	8,759	375,471	45,045	450,338	8,759	375,471	360,365	780,914

Where: M. Cost is routine cost of maintenance

C. Cost is cost of construction

U. Cost is excess user costs.

T. Cost is total cost.

	Functional Class	"Should" Level	"Must" Level
1.	Principal arterial	60	50
2.	Minor arterial	50	40
3.	Major collector	40	30
4.	Minor collector	40	30
5.	Local access	30	20

It is significant to note that the "must" level for three of the five classes falls below the rating for pavements with the highest negative value for alligator cracking. However, the program will check at the "should" level to determine if a more economical alternative is possible before the pavement reaches a high level of distress. These values should be reviewed and revised, as necessary, before the routine use of the system starts. One approach to establishing the "should" and "must" levels is to select 20 to 30 pavements which are at different stages of deterioration. A panel of maintenance engineers from the counties involved in PMS development is then asked to divide these segments into three groups:

(1) Those for which it will be desirable, but not essential to consider rehabilitation;

(2) Those for which it will be essential to consider rehabilitation; and

(3) Those for which no rehabilitation is desirable or necessary.

A consensus among the panel members should be obtained through group discussions regarding which pavements fall in each group. Using the latest condition survey data, the combined pavement rating of each pavement should be calculated. The average ratings of the pavements which fall in the first and second groups will define the "should" and "must" levels, respectively.

Traffic index intervals for strategy array selection - If feasible rehabilitation alternatives change as a function of traffic index, the appropriate intervals of traffic index are specified such that one set of rehabilitation alternatives is feasible for each traffic index interval. The traffic index intervals used in the WSPMS can also be considered to be appropriate for the county system.

Strategy array selection matrix - This matrix defines the criteria to be used in identifying feasible rehabilitation alternatives for different pavements. The state currently uses three criteria: traffic index, pavement type, and functional class. These criteria also appear to be appropriate for the county system. The actual levels of each criteria will have to be adjusted for the conditions of the counties. The following levels are suggested:

Criterion	Levels
Traffic index	Five intervals as noted in the previous subsection
Pavement type	Asphalt, bituminous, PCC
Functional class	Principal arterial, minor arterial, major collector, minor collector, local access

Alternative array matrix - This matrix defines feasible rehabilitation alternatives for different cells in the selection matrix, i.e., different combinations of traffic index, pavement type, and functional class. This matrix should be established by the counties after reviewing the past rehabilitation actions that have been used for different pavements. It will be necessary first to establish a master list of rehabilitation actions. Three appropriate actions from this list are then assigned to each cell in the selection matrix.

In selecting the appropriate action array consider those actions which are feasible for the conditions most likely to exist for a particular type of pavement subjected to a general level of traffic. For example, it is unlikely that a heavy overlay would be feasible for a bituminous pavement on a local access roadway with a Traffic Index of 6.0 to 6.5. A set of feasible actions for this condition could include: (1) single bituminous surface treatments, (2) double bituminous surface treatments, or (3) surface with 0.15 ft of asphalt concrete.

It is pertinent to note that the WSPMS will always assign some estimated cost for routine maintenance. Specific actions, i.e., crack sealing, patching, preleveling, etc., are not stipulated by the program. The assumption is that sufficient funds are allotted for routine maintenance to keep the pavement above the "must" rating level.

If such items as crack sealing are to be considered as a separate rehabilitation alternative it will be necessary to develop values for m and B used in the performance equation with the WSPMS program. These parameters are discussed in the section below.

Rehabilitation alternative parameters - The system assumes the following form of an equation to project future pavement performance under a given rehabilitation alternative:

$$R = C - mA^B$$

where R = combined pavement rating

A = pavement age

C = pavement rating immediately after rehabilitation; this is generally set to 100

m = slope coefficient

B = degree of curvature exponent.

The parameters C and m are to be specified for each rehabilitation alternative. The constant B is calculated internally in the program based on the specification of an equation factor discussed below. After condition surveys have been conducted for 4 to 5 years, the values of C, m and B can be estimated directly from the data using non-linear regression analysis. Until that time, however, these parameters must be estimated subjectively based on experience and engineering judgments. The following approach is suggested: for each rehabilitation alternative, estimate the pavement rating immediately after rehabilitation and the time to reach the "must" level. Next, sketch the shape of the performance curve to indicate how a pavement under this alternative would deteriorate from a perfect rating of 100 to the "must" level. Now, select an intermediate point from this curve and the "must" level point. Solve for m and B from the simultaneous equations defined for the two points. The values of m and B for similar rehabilitation actions included in the state system can be used as guidelines.

In addition to m and B values, the program requires an "equation factor" for each rehabilitation alternative, defined as follows:

$$\text{Equation factor} = \frac{\text{Typical life of altern. for pavement type A}}{\text{Typical life of pavement type A}}$$

Consider that a bituminous surface treatment (BST) for a road with a Traffic Index of 6.0 has a typical service life of 10 years. When overlaid with 0.15 ft of asphalt concrete the pavement will, under normal conditions last an additional 15 years. The equation factor for the 0.15 ft AC overlay on the existing bituminous surface treatment would be:

$$\text{Equation factor} = \frac{\text{15 years (0.15 ft AC)}}{\text{10 year (BST)}} = 1.5.$$

This equation factor is essentially identical to the value given in the WSPMS report by Nelson and LeClerc.

When estimating the life expectancy of a 0.15 ft AC overlay on a specific BST project consideration is given to the projected life of the pavement. For example, if the projected life of the BST is 8 years, instead of the typical life of 10 years, the program would estimate the overlay to last 12 years (8 x 1.5) rather than the 15 years considered average for such a treatment.

<u>Cost model delimiters</u> - Construction costs and traffic interruption cost factors for rehabilitation alternatives are specified. There are also control parameters to indicate whether or not each of the following costs is to be included in the analysis: traffic interruption cost, maintenance costs, pavement preparation costs, and user costs.

Data Handling for County Usage of WSPMS

Four options are feasible for the counties to transfer the input data to a computer for the execution of the various computer programs in the WSPMS. These options have been defined to offer increasing capabilities, but require increasing computer hardware/software resources. The motivation for considering different options was that even small counties in Washington with no or limited computer resources should be able to take advantage of the WSPMS for improving their maintenance practices. At the same time, larger counties with adequate in-house computer resources should be able to put these resources to effective use, if so desired by the county personnel.

Option A - No data processing equipment at county level

In this option, all the computer programs are maintained on the state's computer system by a statewide coordinator specifically appointed for assisting counties in the implementation of the PMS. The county personnel will enter the required input data on special forms designed to facilitate the transfer of data into the computer. These forms then will be sent to the coordinator by mail or courier. The coordinator will enter the data into the state computer system, make the runs requested by the county, and mail the outputs back to the county. After reviewing the outputs, the county personnel may revise certain inputs and send copies of the outputs, appropriately marked to reflect the revisions, back to the coordinator. Additional runs will be made after entering the revisions to the data base and results mailed to the county. One limitation of this option will be the potential time delays because of the communication through mail. The advantage, of course, is that no data processing equipment will be needed at the county level.

Option B - Data entry terminals at county level

The computer programs will still be maintained on the state system by a coordinator. All input data are entered on specially designed forms. A county person with some computer background will dial up the state computer and enter the data into the data base. The execution of desired runs is requested on the county terminals and the program outputs can be either directed to the county printer or mailed to the county (if the county has no printer). Revisions to the input data can also be made via the data entry terminals. This option will facilitate the communication between the county and the state in terms of transfer of input data, transfer of program outputs, and revisions to the data base. However, a data entry terminal will be required and a printer will be desirable. Also, a part-time person with some data processing background will be necessary.

Option C - A data base computer program maintained by the county

This option will require a micro- or mini-computer and a data base management software package. Input data will be entered into the data base by county personnel. Appropriate data files will be prepared using the data base software. These files will then be transmitted to the state system and the execution of the computer programs will be requested. Note that the computer programs will still reside on the state system and will have to be maintained by a county coordinator. The program output files can be directed to county printer for review and revisions, as appropriate. The advantage of this option over Option B is that an independent data base will be maintained at the county level. Revisions to the data base can be readily made and appropriate reports can be generated on the county equipment. Additional hardware and software, however, will be required, and a person familiar with data base management software will be required.

Option D - A county standalone system

In this option, the county will use its own mini- (or possibly micro-) computer to maintain the data base as well as the various computer programs. This will provide complete flexibility to the county for building the data base, executing the computer programs, and preparing appropriate reports. However, the installation and maintenance of the computer programs will require support from the county's data processing group. Also, ready access to the computer system and sufficient data storage should be available so that data could be entered and revised, and the various computer programs could be executed without long time delays.

The hardware/software requirements for the above four options are described in more detail in a following section.

Given the fact that even the small Washington counties have data entry terminals currently available and that dialup capability to the state computer system is available to each county, Option B can be used by any county and may be preferred to Option A. Much in-house computer expertise is not required for Option B, since a temporary person can be hired for the task of data entries and revisions. For larger counties which do have significant in-house computer facilities and an in-house data processing group, Options B, C, and D could all be considered. If the support of the in-house data processing group is not satisfactory, Option B may still be preferred. If a good data base software is already available and the county does not want to assume the responsibility of maintaining the computer programs, Option C should be preferred. However, if ready access to a mini- or mainframe-computer is available and the the in-house data processing support is adequate, Option D (the stand-alone system) may be preferred.

The time commitments of a county coordinator required under the first three options will depend on the option selected and the number of counties participating in the PMS program. Option A obviously will require the largest time commitment. A full-time job is anticipated for the coordinator if Option A is chosen and more than five counties are participating. Under Option A, the coordinator would need temporary assistance in keypunching the data from the forms into the computer. Although keypunching of data will not be required under Option B., the coordinator will still need to devote close to full time to maintaining the PMS software and executing the county-requested runs. Option C probably will require a lesser time commitment on the part of the coordinator. If five or less counties are involved, a half-time assignment for the coordinator may be adequate. As the number of participating counties increases, a higher time commitment will be necessary. If ten or more counties are involved, even Option C is likely to require a full-time involvement for the county coordinator.

5. MODIFICATIONS FOR ADOPTING WSPMS FOR COUNTY USE

The necessary modifications for adopting the WSPMS for county use can be divided into the following groups:

- Modifications in the process of generating the Master File
- Modifications in the input data parameters
- Modifications in the computer code
- Modifications in the output report formats.

The specific modifications in each of these groups are described below.

Modifications in the Process of Generating the Master File

The WSPMS has been designed to use the WSDOT's existing data bases. The counties generally will not have existing data bases containing all the information needed to execute the data base programs. The process of generating the Master File of data base, therefore, will have to be modified for county usage of WSPMS.

The data base building process will be structured around four data base programs from the WSPMS. Two other programs in the state system - EQUATE20 and BSKIDSR - are not needed for county implementation and are not included. The four remaining programs and their purposes are:

1) BUILD1: defines project boundaries and enters information about pavement structure and history;

2) EQUATE19: adds geometric data for each project;

3) BUILD2SR: adds traffic data for each project; and

4) BUILD4: adds defect data for each project.

A data base will be constructed for each of these programs. Figure 3 shows the basic steps required for constructing the data bases and for running the programs to build the master file which is the input to INTERP.

The sections below explain the steps needed for using each of the programs.

BUILD1

The input data file for BUILD1 contains the project definitions and information about the pavement structure and construction history for each project. The output of BUILD1 is a file which contains one record for each project, specifying the road number milepost limits and pavement structure for the project.

EQUATE19

The input file for EQUATE19 contains geometric information. This file is not organized by project. Instead, each record of the file corresponds to a stretch of roadway (defined by a road number and milepost limits). Each record contains information about the roadway geometry for that stretch of road.

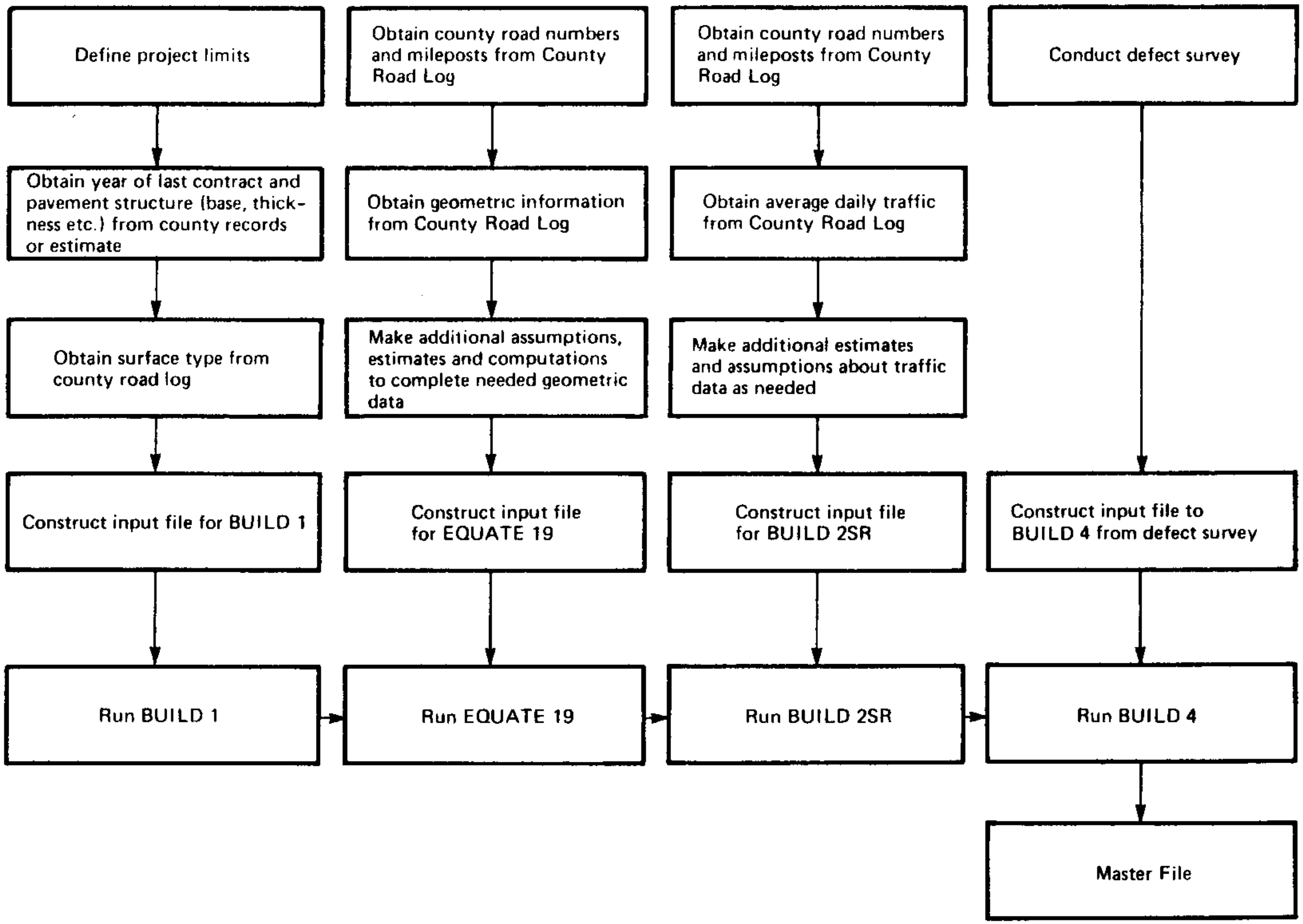

Figure 3. PROCESS OF GENERATING THE MASTER FILE FOR WASHINGTON COUNTIES

EQUATE19 reads one record from the output file of BUILD1 which specifies the milepost boundaries of a project. It then searches its input file to find the geometric data corresponding to that project. It then adds the geometric information to the project record and writes the record to the output file.

Part of the information needed for constructing the input file to EQUATE19 can be obtained from the county road log. The remaining information must be obtained directly or computed from other county records, or estimated. In fact, a large part of the geometric information read by EQUATE19 has no effect on future computations and can be set arbitrarily. The input data items which can be set arbitrarily were identified in Table 1.

BUILD2SR

BUILD2SR adds traffic information to the records from each project. Its input file is organized in the same way as that for EQUATE19: each record gives the traffic information for a given stretch of roadway which may not correspond to a project. Similar to EQUATE19, BUILD2SR reads a project record from the output file of EQUATE19, searches its input file for the record(s) that correspond to the project boundaries, and reads the traffic data for the project. It then adds the traffic data to the project record and writes the record to the output file.

Only the Average Daily Traffic (ADT) will be available from the County Road Log. Other traffic parameters will probably be estimated.

BUILD4

This program adds the pavement condition survey data to each project record. The input file contains observations of severity and extent of different distress types. Each observation records the condition of the pavement over a short section of road on a specific date. For the county system, it is recommended that pavement condition be evaluated at half-mile intervals for rural roads and block-by-block for urban streets starting at the beginning of each route. Biennial pavement condition surveys, used by the WSDOT, are also appropriate for the counties. The input file for BUILD4 should contain data for up to five previous condition surveys.

BUILD4 reads a project record from the output file of BUILD2SR. Then it searches its input file and finds all the condition survey records contained within the project's milepost boundaries. It writes one output record to the master file for each pavement distress observation. The first part of the output record contains all the data for the project accumulated so far, and the second part of the record contains the information for one distress observation. Thus, if there are 15 distress observations for a given project, BUILD4 will output 15 records to the master file. The first part of all 15 records will be identical, showing the information for the project as a whole.

The input file for BUILD4 is constructed from the pavement condition survey. In this survey, each pavement distress observation is recorded as a line on a rating form. Each line is then keypunched exactly as written. In the Washington State system, a utility program is then used to read each line and reformat it to the format required by BUILD4. If the WSDOT computer system is used for the county system, the same utility program can be used. For other computer systems, a similar program will have to be prepared.

Modifications in the Input Data Parameters

The input data parameters for the various computer programs in the WSPMS were discussed in the previous section. The following parameters will have to be modified from their current values to reflect the county needs.

Additional distress type - Longitudinal edge cracking is a distress type that is currently not in the WSPMS but is of concern to the counties. If excessive longitudinal edge cracking is present, actions different from surface maintenance will be necessary . A logical approach to evaluating this distress type will be to flag road segments with excessive distress but not to include it in calculating pavement conditions ratings or assign it small weighting values. With this approach, projects requiring edge repair will be identified separately, but the evaluation of alternative maintenance actions will not be affected by longitudinal edge cracking.

Distress weighting values - An approach to determining appropriate distress weighting values for county conditions was described in the previous section. Initially, the weighting values currently in the WSPMS may be used until a set of values appropriate for the counties is developed.

Should and must level arrays by functional class - The procedure described in the previous section may be used to develop should and must levels appropriate for different functional class roads in the county networks.

Traffic index intervals for strategy array selection - The range of traffic index applicable for Washington counties should be estimated from the available traffic data. Once the applicable range is defined, 4 or 5 equal-sized intervals of traffic index can be identified for purposes of specifying feasible rehabilitation alternatives.

Alternative array matrix - A master list of rehabilitation alternatives appropriate for county maintenance practices should be first established based on past experience and judgments of maintenance engineers. The three most appropriate rehabilitation alternatives should then be selected for each combination of pavement type, functional class, and traffic index.

Performance equation parameters for rehabilitation alternatives - The slope coefficient, m, and the time to reach the must level need to be estimated for each rehabilitation alternative in the master list. A procedure for estimating these parameters was discussed in the last section.

Equation factors - Equation factors should be estimated for the rehabilitation alternatives using the procedure described in the previous section.

Construction cost of each rehabilitation action - Construction costs per 12-ft lane-mile are input to the program. Bid prices for previous contracts may be used to estimate the construction cost of each rehabilitation action. If significant variations in the construction costs have been observed for different parts of the county, the costs adjusted for the given project location should be input. Note that the costs of previous contracts should be adjusted for inflation to bring to present-day costs.

Cost of pavement preparation - The WSPMS defines an equation that relates pavement preparation cost to pavement rating. Three predominant types of preparation applied to asphalt pavements prior to an overlay are considered in the system: crack sealing, preleveling, and pavement removal and replacement. Data related to the costs of these items should be collected by the counties and the present equation for pavement preparation cost should be revised as necessary. In the interim, the present equation may be adjusted, based on subjective judgments of county personnel.

Routine maintenance cost - A sigmoidal curve has been developed in the WSPMS to relate pavement maintenance cost to pavement rating. The development of the curve was based on estimates of maintenance costs on several control sections. Similar data should be collected by the counties to calibrate this curve to county pavement maintenance costs. In the interim, the present curve in the system may be adjusted based on subjective judgments of county personnel.

User costs - Two types of user costs are included in the WSPMS: those incurred due to deteriorated pavement conditions and those incurred due to traffic interruption during construction of a rehabilitation alternative. The currently available information on user costs is limited and may not provide reliable estimates of user costs for paved roads in Washington counties considering the applicable range of roughness. An additional factor to consider is that the speed limit on county roads is generally lower than that on state highways, and hence the impact of a rougher road on factors such as fuel consumption, vehicle wear and tear, and slowing down of vehicles may not be very significant. Because of these limitations, it is recommended that user costs not be used in the economic evaluation of rehabilitation actions for county roads. However, user costs may be used to document the consequences of reduced maintenance budgets. For this purpose, the user cost equations currently in the WSPMS may be considered to be reasonable.

Modifications in the Computer Code

Modifications to the existing WSPMS computer codes necessary to handle county road networks are discussed below. Modifications relative to output report formats are described in the next section.

Inclusion of additional distress type - As noted above, longitudinal edge cracking needs to be added as a distress type. The WSPMS software has provisions for considering up to eight different distress types. Only four distress types are currently assigned weighting values and used in calculating pavement condition rating. An additional distress type can be readily accommodated. However, minor changes in the data base and interpreting programs will be necessary to read and print the additional distress type correctly. Raveling for asphalt concrete pavements can also be included as a distress type since the current WSPMS provides for this type of deterioration.

Project identification system - The WSPMS includes two different systems of mileposting--state route mileposting and control section mileposting. Some of the state's data, such as traffic and surface friction, are collected on state route mileposts, while other data, such as bump counts, pavement condition survey, and construction history, are collected on control section mileposts. The counties use only the state route mileposting system, and hence the references to control section mileposts will need to be eliminated for the county PMS.

Direct assignment of traffic index - Traffic index is calculated internally in the WSPMS using input data on percentage of single unit and combination trucks. For the county system, such data may not be readily available and hence an option for the direct assignment of an estimated traffic index should be provided.

Assignment of default performance equations - When a given project does not have at least three previous rating values, the WSPMS assigns a typical equation based on pavement type, surfacing depth, and geographical area. The typical equations should be reviewed and revised, as appropriate, based on the experience of the county personnel.

Machine-dependent subroutines or functions - The WSPMS software uses certain subroutines or functions which are machine-dependent and hence will require minor changes in order to execute these on computer machines different from that of the WSDOT. Many of such changes have already been made in the process of making the programs run on a PR1ME computer system. However, additional changes will be necessary, particularly when executing the network-level program under performance or budget constraints. This program contains an extensive list of job control language (JCL) statements which will need to be replaced by similar JCL statements if a different computer system is to be used.

Prioritizing function in the network program - When applying either a performance or a budget constraint, the network program currently prioritizes projects based on the "effect of delay" (i.e., the decrease in pavement condition rating if the rehabilitation of a project is delayed by one year). Other factors such as traffic and functional classes are not taken into account in determining the priority of a project. The prioritizing function can be expanded to include such additional factors. However, such a modification will require a significant research effort and hence it is recommended that this modification be deferred to a later time. It is possible that the WSDOT might make some changes in the prioritizing function in which case those changes can be incorporated in the county system. One modification that should be made at the present time is to revise the output format of the network program such that separate priority lists for different functional classes, as well as a combined priority list, are produced.

Modifications in the Output Report Formats

Some changes in the existing report formats, as well as some new reports, will be necessary for the county PMS. These modifications are discussed below.

Priority listing of projects - Currently the WSPMS develops a priority list of all candidate projects for rehabilitation over a six-year period. This listing is produced by the network program using the criterion of the drop in the pavement condition rating if the project is not selected for rehabilitation. However, the discussions with county representatives indicated that some of the counties may want to implement the WSPMS in stages. For example, the data base development and interpreting program may be implemented initially. The project optimization and network-level programs may be implemented at some subsequent time when resources permit. Since a priority list of projects in need of some rehabilitation is an important output from a PMS, this list should be made available to counties even prior to implementing the project optimization and network-level programs. One approach will be to assign priorities to projects based on the pavement condition ratings. Separate priority lists for projects in different functional classes and traffic categories may be prepared. Such priority lists will be available after implementing only the data base development stage of the WSPMS, thus providing an early deliverable to counties which may not want or be able to implement the entire system because of a lack of necessary resources. A small new computer program will be necessary to produce a priority list based on pavement condition ratings.

Flagging excessive longitudinal edge cracking - Longitudinal edge cracking appears to be a problem of particular concern on many county roads. If excessive edge cracking is present, the surface treatment actions being evaluated in the PMS will not be appropriate corrective actions. A logical approach, therefore, will be not to include this distress, or use relatively small deduct values, in calculating pavement condition ratings, but to flag out those projects associated with excessive edge cracking. These projects, then, could be reviewed separately, and appropriate corrective actions could be selected. A small computer program will be necessary to screen the pavement condition survey data and to print a lst of projects with excessive edge cracking.

Miscellaneous changes in report headings - Examples of these changes are: replacing "statewide" with "countywide," replacing "district" with whatever is appropriate for a county, and eliminating the columns in the reports which are not applicable or required for county usage of the PMS.

Illustration of the WSPMS for County Usage

In order to illustrate how different components of the WSPMS would work for a county road network, twelve projects were selected from Thurston County. A pavement condition survey was conducted in 1983 by Thurston County for all paved county roads. Data from this survey were used to define for the twelve projects the severity and extent of the various distress types included in the system. Data from the county road log were used to estimate road life history and roadway inventory for the projects. The Master File was created manually for the twelve projects. The distress weighting values currently used in the WSPMS were assumed for this illustrative example. The interpreting, project optimization, and network computer programs were executed for the set of the twelve projects. In the process of executing these programs on a PR1ME system, several machine-dependent statements were identified. These had to be revised in order to make the programs run. The revised programs can now be expected to run on other than the Washington State computer system without much difficulty.

The data base programs and the parts of the network program in which performance and cost constraints are applied could not be run, since these contain some machine-dependent subroutines or job control language which would require significant modifications to fit on other computer systems. Making such modifications was outside the scope of this feasibility evaluation study.

The various computer outputs for the illustrative example are included in Appendix A.

6. DATA PROCESSING HARDWARE/SOFTWARE NEEDS

Four options were identified in Section 4 for the transfer of data from a county to the state's (or county's own) computer system and the execution of the WSPMS software. These options are as follows:

Option A - No data processing at county level;

Option B - Data entry terminals at county level;

Option C - A data base program at county level;

Option D - A county stand-alone system.

Computer hardware and software needs for each of these options are described below.

Option A - No Data Processing at County Level

In this option, all data processing activities will be performed at the state level by a county coordinator. No data processing hardware or software will obviously be required at the county level.

Option B - Data Entry Terminals at County Level

Input data will be transferred via remote data entry terminals from the county to the state's computer system. A simple terminal would be adequate, in which data are entered by typing and checked by examining the typed entries on paper. A terminal with advanced features such as a CRT screen and some editing capabilities will obviously be more convenient. A modem will be necessary to connect to the state's computer system by telephone. It will also be desirable to have a printer, so that program outputs would be directed to the county. Most counties have such terminals available to them, and many have connected to the state system in the past for certain data processing needs without much difficulty.

Option C - A Data Base Program at County Level

This option will require a micro computer (i.e., a personal computer), a printer, and a modem to connect to the state system. A data base management software package will also be needed.

The option allows the county to update, review, and modify its PMS data base in house. A machine that can handle an efficient data base management software and has a large mass storage capacity will be required. The Random Access Memory (RAM) necessary for executing the software will be fairly small (less than 100 k), but the amount of storage needed for storing all the Master File data will be large. The Master File is the input to the program INTERP. Each record in this file contains one observation of pavement condition for one generation of condition survey data for each project. Since each generation contains five observations, there will be 20 records for each project. Each record requires 116 bytes of storage, so that the total storage requirement is 20 x 116 bytes, or 2.32 k bytes per project.

A floppy disk for an IBM-type micro computer will hold only 320 k bytes and thus will hold enough data for, at most, 137 projects (probably less due to storage overhead). This is probably not enough to be useful to a county since several disks will be required, and performing any operations on the data base will be quite inconvenient. However, a hard disk will hold upwards of 5 megabytes of data, enough for 2155 projects. This should be adequate for county needs.

It should be noted that the WSDOT Materials Laboratory staff is planning to use this option to enter and edit data on a personal computer (PC) and transfer the data to the state's mainframe computer for the execution of the WSPMS programs. The PC being considered for this operation is the IBM PC 3270 with 256 k of RAM and a hard disc with 10 megabytes of mass storage capacity. The system will also have a printer and a software terminal emulator to be able to examine and edit long data records.

Option D - A County Stand-Alone System

Under this option, the county would have its own self-contained system. If either a mainframe computer (such as IBM or CDC) or a mini computer (such as PRIME or VAX) with a FORTRAN compiler is available to the county, the WSPMS software should readily fit and can be executed with some minor modifications to the machine-dependent subroutines and functions.

It appears that the programs could also run on a large micro computer. The amount of storage required by each of the programs when running on a PRIME System are:

INTERP	31 k bytes,
OPT	145 k bytes, and
NETWK	105 k bytes.

These figures include the memory required to store the programs and all the internal variables and arrays . They do not include the external read and write files, but these would be maintained on disk in a micro computer system.

For the programs to run on a micro computer, one must allow overhead for the FORTRAN compiler; but, even allowing a substantial amount of memory for the compiler, it appears that the program will run on a micro computer with 256 k bytes of memory. Several micro computer models have this size memory and, in fact, can be upgraded to 600-900 k bytes rather cheaply and easily. Of course, the micro computer will still need a hard disk with a mass storage capacity of about 10 megabytes to store the data base.

Given these requirements, the IBM PC 3270 that is being considered by the WSDOT or some similar machine should be adequate to provide a stand alone system for the counties. Some program modifications probably will be required in order to execute the programs on the FORTRAN compiler available on a micro computer. Also, as noted before, the subroutines in the network program that apply performance and budget constraints will have to be completely rewritten in order to fit on a micro computer.

7. COST ESTIMATES FOR ADOPTING WSPMS FOR COUNTY USE

In this section, the one-time costs of adopting the WSPMS for county use are estimated. Cost estimates for the on-going routine operation of the converted WSPMS are provided in the next section.

The effort necessary for adopting the WSPMS for county use can be divided into four basic categories:

- Data collection
- Data transfer
- Software modifications
- Acquisition of data processing hardware and software

The specific activities under each category, and the estimated level of effort and cost for completing each activity are summarized in Table 3. In estimating the labor cost, it is assumed that some of the work would be performed by a consulting firm and that the cost of one person-day will vary from $250 to $500, depending upon the type of personnel used. The labor cost and computer cost of executing the various computer programs in the WSPMS are not included in the estimates shown in Table 3. These costs are considered in the next section, which deals with the costs of routine operation of the converted WSPMS for county use.

Brief descriptions of the activities identified in Table 3 are provided below.

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TABLE 3. COST ESTIMATES FOR ADOPTING WSPMS FOR COUNTY USE

Activity		Level of Effort (Person-Days)	Unit Cost ($/person-day)	Estimated Cost ($)
1. **Data Collection**				
1.1 Prepare a pavement condition survey manual		7	400	2,800
1.2 Train personnel for condition surveys		3	400	1,200
1.3 Develop condition survey routes		6	400	2,400*
1.4 Conduct condition survey		2/20 miles	250	25,000*
1.5 Develop supporting data from files (construction history, geometric data, traffic)		30	300	9,000*
1.6 Develop parameters for interpreting and project optimization programs		10	500	5,000*
2. **Data Transfer**				
2.1 Enter data into computer	Labor cost	15	250	3,750*
	Computer cost	--	--	500*
3. **Software Modifications**				
3.1 Make changes in the computer code		20	400	8,000
3.2 Make changes in report formats		10	300	3,000
4. **Acquisition of Data Processing Hardware/Software**				
Option A		--	--	--
Option B	Hardware cost		--	3,000
Option C	Hardware plus software cost		--	8,000
Option D	Hardware plus software cost		--	15,000

* Assumes a network of approximately 1000 miles

1. Data Collection

1.1 Prepare a pavement condition survey manual - The manual will describe in detail how the condition survey is to be conducted and how the data are to be recorded. The manual will provide a basis for standardizing the subjective evaluation of pavement distresses. Sketches and photographs will be necessary as an aid to the raters and a reminder of the conditions to be recorded.

1.2 Train personnel for condition surveys - For maintaining continuity and consistency in condition surveys, it will be desirable to assign the same persons to conducting the surveys. These persons may be either from the permanent county staff or outside persons specifically hired for purposes of conducting the surveys. Whether or not the same persons are used to conduct the surveys, it is important to train them before each survey. The training will involve some classroom instructions and then field trips with an experienced rater to calibrate the subjective ratings on predetermined road segments.

1.3 Develop condition survey routes - The urban portions of a county road network need to be divided into efficient driving routes compatible with daily productivity. Trash collection routes, street sweeping routes, mail routes, etc. can be used as a starting point in establishing driving patterns. These routes can then be revised, based on the experience gained through actual surveys.

1.4 Conduct condition survey - The condition survey should cover the entire network of roads every other year. For rural sections, the rating segments should be of 0.5 mile length. Block-by-block segments will be desirable for urban sections.

1.5 Develop supporting data from files - Data on roadlife history, roadway inventory, and traffic will be required in addition to the pavement condition data to develop the data base. Table 1 in Section 4 identified the necessary data items and the anticipated source of information for estimating each item.

1.6 Develop parameters for interpreting and project optimization programs - The parameters required as input for these two programs, and procedures for estimating them, were discussed in a previous section. The parameters requiring the most effort will be the distress weighting values, "should" and "must" levels, performance equations for rehabilitation alternatives, routine maintenance cost, and pavement preparation cost prior to an overlay.

2. Data Transfer

2.1 Enter data into computer - Data files will have to be prepared to define the inputs for the computer programs BUILD1, EQUATE, BUILD2, and BUILD4. Depending upon the data processing option chosen, the data will be entered either by the county coordinator directly into the state computer system, or by county personnel into the state system using remote data entry terminals, or by county personnel directly into the county's in-house computer system.

3. Software Modifications

3.1 Make changes in the computer code - The necessary computer changes were identified in a previous section. If the state computer system is used, no revisions in the machine-dependent subroutines or functions will be necessary. A significant effort will be required to modify the programs if they are to be installed on a micro computer.

3.2 Make changes in report formats - As noted previously, these changes will be to write new programs to prepare a priority list of projects in need of rehabilitation and to flag projects with excessive longitudinal edge cracking, and to make certain changes in report headings.

4. Acquisition of Data Processing Hardware/Software

The costs of acquiring the necessary hardware and software for each of the data processing options are shown in Table 3. It should be noted that these costs will be incurred only if the necessary hardware/software is currently not available or is not adequate for PMS data storage requirements. From the survey of four counties, it appears that almost all counties should have remote data entry terminals, and many have large-size micro or mini computers. Some of the larger counties have in-house mainframe computers along with remote terminals and micro computers.

8. COSTS AND BENEFITS OF ROUTINE OPERATION OF MODIFIED WSPMS

Assuming that the necessary modifications are made to adopt the WSPMS for the pavement management needs of the Washington counties, it will be possible to use the modified system each year to identify cost-effective rehabilitation treatments for various projects in the network, to estimate budgetary requirements, and to prepare a six-year pavement rehabilitation program. The costs and potential benefits of the routine operation of the converted WSPMS are discussed in this section.

Costs of Routine Operation of the Converted WSPMS

Table 4 lists the various activities involved in the routine operation of the converted WSPMS, the level of effort in person-days, and the labor and computer costs. The estimates of level of effort and computer costs are based on the experience of the WSDOT staff in operating the system for the statewide network of approximately 8300 miles. For purposes of Table 4, a county network of 1000 miles is assumed. All of the routine operation activities are assumed to be carried out by the county staff with the assistance of a county coordinator. A unit cost of $250/person-day is assumed in converting person-days into labor costs. The computer costs are estimated assuming that the state computer system will be used.

The activites listed in Table 4 are briefly described below.

1. Conduct pavement condition survey - A productivity of 25 miles/crew-day (or 50 half-mile segments/crew-day) is assumed. This is a conservative estimate and the actual productivity after some experience may be in the range of 40 to 50 miles/crew-day. Note that the entire network will be

TABLE 4 - COST ESTIMATES FOR THE ROUTINE OPERATION OF CONVERTED WSPMS*

	Activity	Level of Effort (Person-Days)	Labor Cost ($)	Computer Cost ($)
1.	Conduct pavement condition survey	80	20,000	--
2.	Revise supporting data	6	1,500	--
3.	Enter data into computer	15	3,750	200
4.	Execute data base programs	2	500	100
5.	Execute interpreting program	1	250	100
6.	Edit output from interpreting program manually	10	2,500	--
7.	Enter data base changes into the computer	10	2,500	200
8.	Execute optimizing program	3	750	100
9.	Execute network program	2	500	100
10.	Prepare a six-year pavement rehabilitation program	20	5,000	100

* Assumes a network of 1,000 miles

surveyed every two years. The estimated cost includes the cost of retraining the survey personnel.

2. Revise supporting data - Based on the last year's rehabilitation activities, the project limits and the description of the most recent rehabilitation action should be changed. Any other changes, such as road or shoulder widening and traffic growth will also need to be made.

3. Enter data into computer - The mode of entering data into the computer will depend on the data processing option chosen. The data will have to be reviewed and edited to remove any entry errors or other inconsistencies.

4. Execute data base programs - The computer programs BUILD1, EQUATE, BUILD2, and BUILD4 will be executed to create the Master File.

5. Execute interpreting program - Using the Master File and interpreting parameters as the input, the program INTERP is executed to produce the interpreted data file.

6. Edit output from interpreting program manually - The performance curves produced by the models used in the interpreting program may not always produce satisfactory projection of future performance. The performance curves, therefore, should be carefully reviewed and revised, as appropriate. This is best done in two steps. First, the printout from the interpreting program is reviewed and appropriate changes are made on paper. Second, the changes are entered into the computer.

7. Enter data base changes into the computer - This is the second step noted above in revising the performance equations produced by the interpreting program.

8. Execute the project optimizing program - The computer program OPT is executed for each project to identify the most cost-effective rehabilitation strategy. Estimates of construction costs, routine maintenance costs, preparation costs, user costs, and salvage value are printed for several top-ranked strategies.

9. Execute network program - The network program is executed under no constraints, as well as under different performance and budget constraints. Each run of the network program identifies priorities of the candidate rehabilitation projects and develops a six-year program with projects identified and budget estimated for each year.

10. Prepare a six-year pavement rehabilitation program - The outputs from the network program are analyzed to identify the six-year pavement rehabilitation program that best meets the objectives and constraints of the department. In the process of analyzing the network program outputs, the need for some additional runs may be identified. Such runs can be made before finalizing the pavement rehabilitation program.

Benefits of Routine Operation of the Converted WSPMS

A commitment of staff and computer resources will have to be made in order to use the converted WSPMS on a routine basis. In order to justify the commitment of these resources, specific benefits of using the system must be identified. These benefits can be divided into two groups: (1) benefits derived from the system use by individual counties and (2) benefits derived from the system use by all or most of the Washington state counties. Brief descriptions of these two types of benefits are provided below.

1. <u>Benefits derived from the system use by individual counties</u>

The following benefits can be associated with the routine use of the PMS by an individual county:

- An objective, reliable, and current data base of information is provided to support management decisions of pavement maintenance and rehabilitation.
- The most cost-effective treatment can be determined for each project based on the considerations of life cycle costs.
- The impact of alternative funding levels on the performance of the system can be demonstrated.
- A schedule for timely and economical pavement maintenance and rehabilitation is developed in an attempt to protect the substantial capital investment in the road network.
- Improved response to special legislative, political, or public requests regarding plans for the improvement of certain roads is possible.

2. <u>Benefits derived from the system use by all or most counties</u>

If the converted WSPMS is used by most of the Washington state counties to estimate budget requirements and to develop pavement rehabilitation programs, several benefits, in addition to those identified above, can be accrued. These benefits include the following:

- Uniform procedures will be developed for all participating counties to evaluate and summarize pavement conditions.

- A common basis will be provided for evaluating pavement rehabilitation needs across different counties.

- An objective procedure will be developed to allocate maintenance funds among the various counties based on the evaluation of needs and life cycle costs.

- Common resources among the counties can be utilized more effectively. The activities which could be shared by all the counties include: a common training program for pavement condition survey personnel and the appointment of a statewide county coordinator to assist all the counties in PMS implementation with the best utilization of the state's computer system.

9. STEP-BY-STEP PROCEDURE FOR ADOPTION OF WSPMS BY COUNTIES

In meetings with the representatives from four Washington counties, a strong recommendation was made for adopting the WSPMS in phases. Each phase should increase the capability of the Counties to use the WSPMS, should serve as a building block for the following phases, and should produce some usable output for users of the system.

Basic criteria to be used in adopting the WSPMS for Counties includes the following: (1) it should be capable of being used by both small and large counties with a range of resources in personnel, (2) it should be capable of being used with or without computer facilities located in County offices, (3) it should retain its modular form for future modifications, and (4) it should retain all of the capability for both project and network application as designed by the WSDOT staff.

The procedures recommended for adoption and implementation by Counties are divided into three phases as follows:

Phase I - Feasiblility Study

Phase II - Trial Implementation by Two Washington Counties

Phase III - Statewide Implementation by Washington Counties

The steps involved in achieving each phase are described in this section of the report.

Phase I: <u>Feasibility Study</u>

The results of the feasibility study are reported in this report. The report attempts to review the WSPMS and to make specific recommendations pertinent to the use, modification, and implementation of the WSPMS. Options are provided to accommodate alternative levels of resources necessary to support the system and to provide usable results.

Phase II: <u>Trial Implementation by Two Washington Counties</u>

The objective of the trial implementation will be to modify the WSPMS programs to meet County needs and to "debug" the entire process based on using (1) County personnel, (2) County data, and (3) Washington DOT computers. Four steps are recommended for trial implementation: (1) modifications to the WSPMS computer programs, (2) data acquisition, (3) data entry, and (4) program execution, including preparation of required reports.

Step 1: <u>Program Modifications</u>

Section 5 of this report, titled "Modifications for Adopting WSPMS for County Use" summarizes the modifications which could be made in the WSPMS programs for use by the Counties. Not all of these modifications need to be considered in the Phase II trial implementation. Five specific modifications are recommended for Phase II, as follows:

1. <u>Longitudinal edge cracking</u> (see Page 68) - This type of distress should be added to the master file to describe the pavement condition history. This field would be added as an input for the BUILD4 file described in Table 1, Page 25, herein.

2. Project identification (see Page 71) - A single milepost system is used by the Counties and hence some modifications in the BUILD1 file (Page 20) will be necessary.

3. Priority listing (see Page 73) - In order to produce a priority listing at an earlier stage in the calculating process, a new report is proposed in connection with the interpreted data (see Page 8). The output represents an early priority listing in the system which would not require implementation of the optimization or network subroutines.

4. Flagging longitudinal edge cracking (see Page 73) - A second new report from the interpreted data should be a listing of those sections containing excessive longitudinal edge cracking. Any section with a weighting value of 15, 20, or 25 (see Page 41) should be included in this report and should be listed according to the level of the weighting value with 25 being listed first.

5. Functional classification (see Page 46) - When projects are listed according to priorities, either from the interpreted data or from the network optimization program, a special (new) listing should be provided which identifies priorities according to assigned functional classes.

Based on the above recommended modifications and by retaining input values and factors currently used with the WSPMS (refer to source document by Nelson and LeClerc), it will be possible to proceed with the trial implementation by two Washington counties providing the information summarized in Table 1 (Page 24) herein can be obtained.

Step 2: Development of Data Base of Information

Three types of information will be required for the County version of the WSPMS: (1) pavement condition data, (2) supporting data, and (3) cost information.

Pavement condition data - Pavement condition information required for the WSPMS is enumerated in Table 1, Pages 25 and 26, and discussed in Pages 32-43 herein. A form for recording observations is provided in Figure 2, Page 33.

For trial implementation, adherence to WSDOT methods should be followed as closely as possible. Survey manuals, personnel training, and field procedures should all be patterned after State procedures. At a later phase, some modifications in procedures may be appropriate.

Supporting data - Requirements for supporting data are discussed on Pages 43-48 herein. This information will, in most cases, be obtained from office files. In some cases, it may be necessary to supplement the lack of information by field measurements, e.g., pavement and shoulder width, or by judgment, e.g., traffic index. In the absence of traffic information, values can be assigned by functional class. The purpose of the traffic index is to provide one of three elements in the selection matrix used to identify alternate rehabilitation treatments and, as such, does not need to be identified precisely (see Page 75 of source document by Nelson and LeClerc).

A form suitable for recording supporting data is provided as Figure 4 herein.

Project Coding	Road Number	Pavement Type (A,B,orC)*	Functional Class	Beginning Mile Post	Ending Mile Post	Year of Last Major Construction	Roadway Width	Shoulder Width Right	Shoulder Width Left	Traffic Index

* A – Asphalt
B – Bituminous
C – Portland Cement

FIGURE 4. FORM FOR RECORDING ESSENTIAL SUPPORTING DATA FOR WSPMS

Cost Information

The cost of routine maintenance and preparation for rehabilitation proposed by the WDOT should be retained for trial implementation. User costs are currently included in the project optimization model and may be included, at the option of the user, for trial implementation. If user costs are included, the information used by the current version of the WSPMS should be used to calculate these costs. Construction costs for various rehabilitation alternatives are a user input and should be provided by Counties for trial implementation.

Step 3: Data Entry

Steps 1 and 2 have described program modifications and data requirements for trial implementation of the WSPMS. The next step will be to transfer the raw data into the data base management system. For trial implementation, it is recommended that the data be entered in and stored on the WSDOT computers. Data entry requirements for the WSPMS, using WSDOT facilities are summarized in Table 1 herein. The specific files which will be used are the following:

BUILD1 - See Pages 16, 20, and 64
EQUATE19 - See pages 16, 21, and 64
BUILD2SR - See Pages 16, 23, and 66
BUILD4 - See Pages 17, 25, and 67
INTERP - See Pages 17 and 27
OPTAL - See Pages 18, 28, 29, and 30
NETWORK - See Pages 18 and 31

Step 4: Reports from Modified WSPMS

Based on program modifications and information in the data base, it will be possible to run the program and produce the various reports inherent to the system.

The specific reports or deliverables which can be produced by the trial implementation are summarized as follows:

Deliverables from Phase II - Trial Implementation

1. Master Index file - This file contains data related to roadlife history, roadway inventory, and traffic for each project.

2. Master File - For each project identified in the Master Index file, the Master File contains pavement condition ratings for each generation year and each mile in the project.

3. Interpreting program output - This output contains the results of the performance analysis of each project. A curve projecting future performance is plotted, and the times to reach should and must levels are identified.

4. A priority list of projects - Projects are listed going from the lowest to the highest pavement condition rating. A preferred rehabilitation action is specified for each project below a certain cutoff rating value, and the budgetary requirements for the preferred rehabilitation program are identified. By changing the cutoff values, the rehabilitation programs can be adjusted in order to meet a budgetary constraint.

5. A list of projects with excessive edge cracking - These projects are listed separately, so that appropriate corrective actions could be identified.

6. Optimizing program output - For each project, the output of the optimizing program summarizes the economic evaluation of alternative rehabilitation strategies. The following parts are contained in the output:

   - Project description and performance history.

   - Performance standards in terms of "should" and "must" levels.

   - Description of rehabilitation alternatives and their performance equations.

   - Ranking of rehabilitation strategies based on total life cycle costs.

7. Network action summary - For a given performance or budget constraint, this summary will list the recommended action and its cost for each project for every year of a six-year maintenance program.

8. Network cost summary - For a given performance or budget constraint, this summary will list the number of miles which are rehabilitated and the cost by functional class for each district (or region) of a county.

9. Network rating distribution summary - This summary will list the number of miles present in different pavement condition rating groups before and after the completion of all proposed actions for each year in a six-year program.

In summary, the trial implementation in two Washington Counties will provide the basis for evaluation of the utility of the WSPMS for use by Washington counties with a minimum of changes in the program. The current subroutines and JCL are specifically applicable for the state's computer system; it is, therefore, recommended that trial implementation be based on use of the state's computers. In order to satisfy system requirements, it is recommended that, except as discussed in this section, necessary inputs be based on use of information contained in the source document by Nelson and LeClerc. This will include such items as weighting values, selection matrix, rehabilitation alternatives, prediction parameters, and cost information as appropriate.

Phase III: <u>Statewide Implementation of Washington County Pavement Management System</u>

Upon completion of the trial implementation phase, it will be possible to expand and modify the program for use by Washington counties. No precise identification of needed modifications can be made at this time. After completion of Phase II, more specific recommendations will be possible. However, based on our evaluation of the WSPMS and discussions with county and state personnel, certain candidate improvements or modifications are identified.

1. <u>Weighting values</u> - Weighting values are the deduct values used by the State to develop a condition score for each project. In the event that modifications are necessary or as a verification of the reasonableness of such values, it may be necessary to implement procedures for developing weighting values. A technique which can be used is briefly described on Pages 49 and 50 herein.

2. Selection matrix and rehabilitation alternatives - In order to satisfy the needs of the Counties, it may be necessary to evaluate the selection matrix referred to in the WSPMS. This matrix combines projects according to pavement type, traffic, and functional class and selects a set of alternative rehabilitation actions appropriate for a specific project. The trial implementation makes use of procedures developed for the state system which may require some modification by the Counties.

3. Performance parameters - In order to satisfy the requirements of the project optimization subroutine, it is necessary to estimate the future performance of the pavement for each rehabilitation alternative from the selection matrix. For trial implementation, state parameters are used; however, for counties, some consideration should be given to modified values based on local experience. Procedures for estimating these parameters are described in Pages 56, 57, and 58 herein.

4. Cost of Rehabilitation - In order to compare alternate rehabilitation strategies, the WSPMS requires information relative to construction costs, maintenance costs, preparation costs, and user costs. Salvage value is calculated by the program. For trial implementation, the maintenance, preparation, and user costs are provided based on state experience. These costs factors may be improved by further evaluation at the county level. Also, inclusion of user costs should be evaluated to determine its impact on the choice of a rehabilitation strategy.

In summary, Phases I and II will establish ways and means for use of the WSPMS by Washington counties. Phase III will allow the counties to make the system more site specific for local use. It should be emphasized that the activities included in Phase III will not require a major effort and, in all probability, will evolve from the use of the system on a continuing basis.

10. CONCLUSIONS AND RECOMMENDATIONS

The main conclusion of this study is that it will be feasible and desirable to adopt and operate the WSPMS to satisfy the needs and expectations of the Washington counties relative to pavement management. This conclusion is based on the following findings of the study:

- The WSPMS employs a flexible design in which the parameters for the main computer programs are user-specified. Because of this flexibility, the basic structure of the WSPMS can be used by any agency with appropriate adjustments of the parameters. These parameters include:

  - specific pavement distress types to be evaluated by the system.

  - definition of severity and extent of each distress type.

  - weighting values assigned to different combinations of severity and extent of each distress type.

  - performance standards in terms of "should" and "must" levels for different functional classes.

  - length of the unit segment which would be rated for its condition.

  - definition of project boundaries.

  - selection of rehabilitation alternatives for a particular project.

- projected cost and performance of rehabilitation alternatives.

Since all of these parameters are user input, they can be changed for county conditions without having to change any computer programs within the WSPMS.

- Although some modifications will be required to the various computer programs in the WSPMS, these modifications can be made with a relatively modest effort. A preliminary estimate of the required level of effort is one to two person-months.

- The WSPMS requires only those data that are absolutely essential for evaluating pavement condition and determining the most cost-effective rehabilitation strategies. Consequently, the effort necessary to collect and develop the required data is relatively small. The one-time effort to generate the necessary data for a network of about 1000 miles is estimated in the range of 5 to 6 person-months. The on-going data collection effort will involve the biennial pavement condition surveys. The estimated effort for such a survey is 4 to 5 person-months for a network of about 1000 miles.

- Several data processing options are feasible for accessing and executing the WSPMS programs. These options range from no data processing equipment at the county level to county data entry terminals, all the way to a county stand-alone system. Because of this flexibility, every Washington county, irrespective of the size of its road network and available staff and computer resources, should be able to utilize the WSPMS.

- Significant benefits can be anticipated from the use of the system by individual counties, as well as collectively by a group of counties.

- Full advantage can be taken of the support that can be provided by the state computer system. It appears that the state computer system has adequate storage capacity to support county usage of the WSPMS and that a dial-up capability is available so that counties can connect to the state computer facility through remote terminals.

The primary recommendation of the study is that the WSPMS should be implemented for a minimum of two counties on a trial basis. One county should be a relatively large county, with adequate in-house computer facilities and some staff support for data processing activities. The other county should be a small county with no or minimal in-house computer facilities and little staff support for data processing. If the WSPMS can be successfully implemented for the two counties with large differences in the size of road network and availability of resources, the feasibility of adopting the WSPMS for county use will be demonstrated for all counties in the State of Washington.

Several other suggestions are also appropriate for county adoption of the WSPMS:

- The WSPMS uses one-mile-long rating segments for condition surveys. For the county system, it is recommended that half-mile rating segments be used in rural areas and block-by-block segments be used in urban areas.

- If several counties are involved in PMS implementation, it will be necessary and desirable to appoint a statewide county coordinator specifically for the purpose of maintaining and executing the county PMS on the state's computer system. Some thought should be given by the counties, perhaps through the State Aid Organization and/or the County Road Administration Board, as to how the funding for hiring such a person could be arranged.

- Plans for sharing of common resources should be developed and evaluated by the counties. The appointment of a county coordinator is one opportunity for sharing resources. Other opportunities include: a common pavement condition survey manual and a common training program for survey personnel.

- In the state system, project limits are sometimes changed, based on field observations at the time of conducting condition surveys. For keeping the process simple for the counties, it is recommended that pavement condition be evaluated at fixed half-mile segments for rural roads and block-by block segments for urban streets. The rating segments should begin at the start of each route. At the end of a route, if the last rating segment is less than or equal to a quarter mile, it should be merged with the previous segment; if it is more than a quarter mile (but less than a half mile), it should be treated as a separate segment. Once defined, these rating segments should not be changed during field surveys.

REFERENCES

1. T.L. Nelson and R.V. LeClerc (1983), "Development and Implementation of Washington State's Pavement Management System," WA-RD 50.1, Materials Laboratory Report No. 177, Washington State Department of Transportation.

2. D.B. Trowbridge (1983), "Thurston County Surface Maintenance Program," Prepared for Thurston County Public Works Department.

3. Linstone, H.A., and M. Turoff, eds., (1975), The Delphi Method: Techniques and Applications, Addison-Wesley, Reading Massachusetts.

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APPENDIX A

OUTPUT REPORTS FROM TRIAL RUNS OF WSPMS COMPUTER PROGRAMS

APPENDIX A
EXAMPLE RUN OF PAVEMENT MANAGEMENT SYSTEM

This Appendix presents the inputs and outputs for an example run of the pavement management system using data typical of county roads. The material is divided into the following sections:

Table A-1: Input Data Used for Example Run

This table lists the contents of the master file input to the program INTERP. Note that the projects are identified by SRI (state route number), BSMPI (beginning state route milepost), and ESMPI (ending state route milepost). These columns are set off in the three parts of the table.

Output from INTERP

One page is output for each project showing the information about that project and its performance equation.

Output from OPTAL

One page is output for each project showing information about the project, the optimal strategy for the project along with several of the suboptimal strategies, and the total costs of the strategies.

Output from NETWK

NETWK summarizes actions, costs, and rating by year, by district, and statewide.

Note that, for this example, it has been assumed that all projects belong to District 1. Therefore, results are only produced for District 1, and the systemwide summaries are the same as the District 1 summaries.

The output tables for NETWK can be divided into two groups.

1) The first section of output gives action, cost, and rating summaries for District 1 by year. Only the 1983 summary is shown in this appendix.

2) This is followed by a table summarizing costs and ratings for District 1 by year. Again, only the 1983 summary is shown in this appendix.

TABLE A-1

INPUT DATA USED FOR EXAMPLE RUN

Table A-1.
INPUT DATA USED FOR EXAMPLE RUN *

						Project																				
CSI	UCMPI	BCMPI	SEQI	DI	SRI	BSMPI	ESMPI	LENGI	UHI	FCI	LANEI	HTI	NLI	RWI	RSI	LSI	SPI	SNUMI	CTYPEI	SURFI	THKI	MNTHI	YRI	BASEI
0	0	0	999	1	730	0	144	144	U	4	R	0	2	24	10	10	0	0000	20	20	6	1	79	11
0	0	0	999	1	730	144	150	6	U	4	R	0	2	24	10	10	0	0000	20	20	6	1	74	11
0	0	0	999	1	730	150	151	1	U	4	R	0	2	24	10	10	0	0000	20	20	6	1	76	11
0	0	0	999	1	730	151	165	14	U	4	R	0	2	24	10	10	0	0000	20	20	6	1	80	11
0	0	0	999	1	875	0	5	5	U	4	R	0	2	24	10	10	0	0000	20	20	6	1	80	11
0	0	0	999	1	875	5	10	5	U	4	R	0	2	24	10	10	0	0000	20	20	6	1	79	11
0	0	0	999	1	875	10	15	5	U	4	R	0	2	24	10	10	0	0000	20	20	6	1	79	11
0	0	0	999	1	875	15	20	5	U	4	R	0	2	24	10	10	0	0000	20	20	6	1	75	11
0	0	0	999	1	875	20	25	5	U	4	R	0	2	24	10	10	0	0000	20	20	6	1	79	11
0	0	0	999	1	875	25	28	3	U	4	R	0	2	24	10	10	0	0000	20	20	6	1	75	11

* See Table 1, Page 25, for an explanation of the input data parameters.

Table A-1. (cont'd.)
INPUT DATA USED FOR EXAMPLE RUN

Project																
SKI	BSMPI	ESMPI	ADTI	GRWI	SUI	COMBI	KI	KDI	TI	GENI	EMP	SIDE	SFED	COUNT
730	0	144	200	56	6	10	15	60	6.1	81	144	B	0	0
730	144	150	200	56	6	10	15	60	6.1	81	150	B	0	0
730	150	151	200	56	6	10	15	60	6.1	81	151	B	0	0
730	151	165	200	56	6	10	15	60	6.1	81	165	B	0	0
875	0	5	200	56	6	10	15	60	6.1	81	5	B	0	0
875	5	10	200	56	6	10	15	60	6.1	81	10	B	0	0
875	10	15	200	56	6	10	15	60	6.1	81	15	B	0	0
875	15	20	200	56	6	10	15	60	6.1	81	20	B	0	0
875	20	25	200	56	6	10	15	60	6.1	81	25	B	0	0
875	25	28	200	56	6	10	15	60	6.1	81	28	B	0	0

* See Table 1, Page 30, for an explanation of the input data parameters.

Table A-1 (cont'd)
INPUT DATA USED FOR EXAMPLE RUN

	Project																	
SRI	DSMPI	ESMPI	PTYP	D1	D2	D3A	D3B	D4A	D4B	D5A	D5B	D6A	D6B	D7A	D7B	D8A	AVSKI	CROSS
730	0	144	A	N		1	N	2	1	1	N	1	N	1	N	1	50	0
730	144	150	A	N		1	1	1	2	1	N	1	N	1	N	3	50	0
730	150	151	A	3		1	N	1	1	3	2	1	N	1	N	3	50	0
730	151	165	A	N		1	N	1	N	1	N	1	N	1	N	1	50	0
875	0	5	A	N		2	2	1	N	2	1	1	N	1	N	1	50	0
875	5	10	A	1		2	3	1	1	2	1	1	N	1	N	1	50	0
875	10	15	A	N		1	1	1	1	2	1	1	N	1	N	1	50	0
875	15	20	A	N		1	1	1	3	2	2	1	N	1	N	1	50	0
875	20	25	A	1		2	2	1	N	2	2	1	N	1	N	3	50	0
875	25	28	A	N		2	2	1	1	2	1	1	N	1	N	3	50	0

OUTPUT FROM INTERP

D	SR	BEG SRMP	END SRMP	CS	SEQ	BEG CSMP	END CSMP	PROJ LENG	FNC CLS	SIDE	HWY TYP	NUM LNS	RDW-FSH-LSH WIDTHS			LAST CONTR	COMPLT M-YR	CNT TYP	SURFACE TYP-THK		BASE TYPE
1	730	0	144	0	959	0	0	144	U-4	R	0	2	24	10	10	00000	1-79	20	20	6	11

PERFORMANCE HISTORY

YEAR	81
AGE	2
RIDE RATING	1.00
STRUCR RATING	75.0
COMBD RATING	75.0
HIGH RATING	75.0
LOW RATING	75.0
HIGH FRICTION	50
LOW FRICTION	50
AVG FRICTION	50

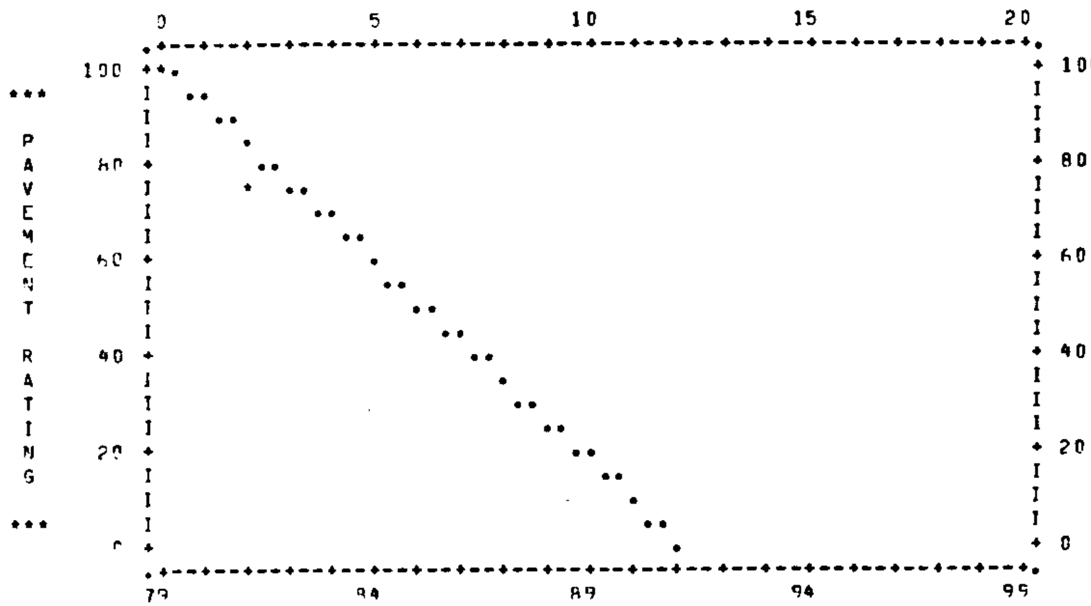
APPROXIMATE TRAFFIC DATA

80 ADT	200
GROWTH RATE	5.6%
SINGLE UNITS	6%
COMBINATIONS	10%
TRAFFIC INDEX	6.1
K = 15%	D = 60%
2 AXLE TRUCKS =	4.0 %
3 AXLE TRUCKS =	4.0 %
4 AXLE TRUCKS =	1.3 %
5 AXLE TRUCKS =	6.7 %

PERFORMANCE EQUATION

EQUA CONST =	100.00
EQUA COEFF =	-8.30000
EQUA POWER =	1.00
R SQUARE =	0.00000
STD ERROR =	0.00
TIME TO 60 =	4.82
TIME TO 50 =	6.02
TIME TO 40 =	7.23
TIME TO 30 =	8.43
CURVE =	1

* AGE *



**** NOTE ****

+ = HIGH VALUE

- = LOW VALUE

* = MEAN VALUE

. = COMPUTED VALUE

* YEAR *

OUTPUT FROM OPTAL

R677300PT

@@@@@@@@

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	COMPLT M-YR	CNT TYP	SURFACE TYP-THK	BASE TYPE
*	***	*****	*****	****	****	****	****	***	****	***	***	***********	*****	******	***	*******	****
1	730	0	144	0	0	0	144	U-4	R	0	2	24 10 10	00000	1-79	20	20 6	11

PERFORMANCE HISTORY	
YEAR	81
AGE	2
RIDE RATING	1.00
STRUCR RATING	75.0
COMBD RATING	75.0
HIGH RATING	75.0
LOW RATING	75.0
HIGH FRICTION	50
LOW FRICTION	50
AVG FRICTION	50

APPROXIMATE TRAFFIC DATA	
80 ADT	200
GROWTH RATE	5.6%
SINGLE UNITS	6%
COMBINATIONS	10%
TRAFFIC INDEX	6.1
K = 15%	D = 60%
2 AXLE TRUCKS =	4.0 %
3 AXLE TRUCKS =	4.0 %
4 AXLE TRUCKS =	1.3 %
5 AXLE TRUCKS =	6.7 %

PERFORMANCE EQUATION	
EQUA CONST =	100.00
EQUA COEFF =	-8.30000
EQUA POWER =	1.00
R SQUARE =	0.00000
STD ERROR =	0.00
TIME TO 60 =	4.82
TIME TO 50 =	6.02
TIME TO 40 =	7.23
TIME TO 30 =	8.43
TIME TO 20 =	9.64

****

SHOULD REHABILITATE AT 40.0 WHICH WILL OCCUR IN 1986
MUST REHABILITATE AT 30.0 WHICH WILL OCCUR IN 1987
CONSIDERATION SPAN = 20 PERIODS, EACH PERIOD = 1.0 YEARS
EFFECTIVE INTEREST RATE = 4.0% FACTORS : 100.0% 150.0% 200.0%

DESCRIPTION OF THE ALTERNATIVES	PERFORMANCE EQUATIONS	CONSTRCT COST 12' LANE MILE	MIN LIFE AT SHUD	MAX LIFE AT MUST
ALTERNATE 1 ROUTINE MAINTENANCE	R = 100.00 - 8.30000 P ** 1.00	0	7.23	8.43
ALTERNATE 2 BITUMINOUS SURF TREATMNT	R = 100.00 - 8.27404 P ** 1.00	14300	7.23	8.43
ALTERNATE 3 OVERLAY 0.15 CLASS B	R = 100.00 - 0.22686 P ** 2.26	35800	11.82	12.65
ALTERNATE 4 OVERLAY 0.25 CLASS B	R = 100.00 - 0.05231 P ** 2.55	57800	15.88	16.87

ITEMIZED COSTS

ROUT MAINT COST +	COST OF CONSTR INCL PR +	COST OF TRAFFIC INTERPT +	USER COST -	SALVAGE VALUE =	EXPECTED TOTAL COST	NUMB POSS	1ST REHAB	2ND REHAB	3RD REHAB	4TH REHAB
						40	(ALTERNATIVE - PRD APPLIED)			
72501	136766	73	1028	5484	204884	4	2-87	2-95		
71156	137547	73	1027	0	209803	1	2-86	2-94		
50457	220164	85	980	26577	245109	14	3-87	2-99		
46865	224281	85	965	21261	250935	9	3-86	2-98		
45769	267806	92	965	9293	305339	6	4-87			
43340	273828	91	960	0	318219	6	4-86			

OUTPUT FROM NETWK

DISTRICT 1
1983 ACTION SUMMARY

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

FC	SR	BEG SRMP	END SRMP	LENG	CS	SIDE	REF RTNG	PROPOSED ACTION	COST, CURRENT $	COST, INFLATED $
U 4	730	144	150	6	0	R	25.3	BITUMINOUS SURF TREATMNT	4506	4956
U 4	975	15	20	5	0	R	33.6	BITUMINOUS SURF TREATMNT	3505	3855
U 4	975	25	28	3	0	R	33.6	BITUMINOUS SURF TREATMNT	2103	2313

NOTE: DISTANCES ARE IN 0.01 MILES.

R67XXY

6000

DISTRICT 1
1983 COST SUMMARY

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

FC	RTNG AVG BEF ACTN	RTNG AVG AFT ACTN	NUMB PROJ	MILES ACTED ON	TOTAL MILES	% ACTED ON	COST, CURRENT $	COST, INFLATED $	COST, DISCOUNTED $
1	0	0	0	0	0	0 %	0	0	0
2	0	0	0	0	0	0 %	0	0	0
3	0	0 .	0	0	0	0 %	0	0	0
4	64	69	3	14	193	7 %	10114	11124	9725
5	0	0	0	0	0	0 %	0	0	0
ALL	64	69	3	14	193	7 %	10114	11124	9725

NOTE: DISTANCES ARE IN 0.01 MILES.

DISTRICT 1
1983 RATING DISTRIBUTION SUMMARY

	FC 1	FC 2	FC 3	FC 4	FC 5
	****	****	****	****	****
SHUD	50	50	40	40	60
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.2	1.6	0.0	0.0	0.1	0.1	0.0	0.0	64.8	1.9
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL	0.0	0.0	0.2	1.6	0.0	0.0	0.1	0.1	0.0	0.0	64.8	1.9

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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.1	0.0	0.2	1.6	0.0	0.0	0.0	0.0	0.0	0.0	69.9	1.9
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL	0.1	0.0	0.2	1.6	0.0	0.0	0.0	0.0	0.0	0.0	69.9	1.9

DISTRICT 1
RATING AND COST YEARLY SUMMARY

YEAR	RATING BEFORE	RATING AFTER	MILEAGE % AFF.	COST, CURRENT $	COST, INFLATED $	COST, DISCOUNTED $
1983	64.8	69.9	7 %	10114	11124	9725
1984	61.6	61.9	0 %	701	848	648
1985	53.6	53.6	0 %	0	0	0
1986	45.3	45.3	0 %	0	0	0
1987	37.0	91.8	82 %	111469	179519	91620
1988	83.5	90.0	9 %	13320	23596	10526
				135604	215087	112519

6-YR AVG RATING = 63.2