U.S. Department
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Statewide Transportation
Planning and Management

PAVEMENT MANAGEMENT

REHABILITATION PROGRAMMING:

EIGHT STATES' EXPERIENCES

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This document was originally published as one in a series of publications on Statewide Transportation Planning and Management. Because on continuing interest in the the specific topic of pavement management and resource allocation in the maintenance field, this single volume has been reprinted.

Acknowledgement

In the spring of 1982, the Federal Highway Administration (FHWA) Office of Engineering, with support from the Office of Management Systems, undertook a review of State Pavement Management practices. That review produced the digests of eight State Pavement Management practices which form the body of this text. The FHWA Office of Highway Planning wishes to acknowledge the considerable efforts of the Offices of Highway Operations, Engineering, and Management Systems in researching the material contained in this report, and wishes to thank them for providing that material for this compendium.

Introduction

This report is a collection of concise descriptions of the pavement management practices of eight States. Information for the report came from a 1982 Federal Highway Administration (FHWA) review of State Pavement Management activities. Pavement Management is a broad concept that encompasses a large number of State highway agency functions, including data collection, planning, research, design, construction, maintenance, and rehabilitation. In short, pavement management activities impact all functions necessary to design, construct, maintain, and improve a State's network of roadways.

The reports contained herein deal with one element of pavement management - the rehabilitation programming process. This activity includes those data collection, planning and programming practices which lead to an objective, optimized mating of rehabilitation needs and available funding. Rehabilitation priority programming also serves as an effective management tool by detailing both those projects which could be implemented at varying funding levels, and, conversely, the costs associated with varying levels of service. This flexibility is invaluable when dealing with a State legislature or the general public, and the objectivity of the process lends credence to the entire rehabilitation program and its associated costs.

The following descriptions provide insight into the data collection, analysis, and prioritization/optimization activities of eight selected States. This report is intended to serve as a resource document for those States wishing to either incorporate pavement management practices into their highway programming process, or improve their rehabilitation priority programming process within a pavement management context.

Arkansas — The State undertook a study of pavement management as practiced by other States. Concentrating on data collection and storage, and on the development of a prioritization program, the State began to implement a pavement management program. The State has completed an inventory of pavement condition on all State maintained roads, and wishes to plot deterioration curves and predict pavement failure, as well as explore the relationship between pavement deterioration and 18 kip equivalent single axle loadings.

Florida	The State's pavement management program has been in place for approximately 10 years, but improvements to it are an ongoing process. The State has: (1) established thorough pavement monitoring procedures, (2) applied pavement condition ratings to a priority programming routine, (3) accepted the use of pavement management information in its network analysis and planning programs, and (4) integrated all data bases into a centralized, computerized format. The State has successfully applied pavement management practices to its 10,000 mile State maintained system.
Idaho	The State reviewed existing pavement management programs in order to locate one to adapt to its own use. The Utah Pavement Performance Management Information System was purchased and put on line. Development of the system has resulted in methodologies for pavement condition monitoring, section ranking based on condition, and prediction of pavement performance.
Nevada	The State has conducted a pavement condition survey to provide data input to a new pavement management program. The pavement management program was designed to assist project-level decisionmaking by assessing pavement condition on the State system and placing each mile of system into one of several repair categories. The pavement management program is expanding into a tool to prioritize proposed repair projects.
Ohio	The State, with a consultant, is developing a prioritizing scheme for resurfacing pavements. The State intends to develop a model to evaluate alternative maintenance strategies and to generate data to create performance and cost models.
Washington	The State developed its pavement management system to provide administration with the information necessary to more efficiently manage roadway pavements. The State's efforts have been to address pavement performance, select cost-effective

rehabilitation strategies, and assemble a systemwide rehabilitation program. The pavement management system contains a master file, an interpreting program, a project-level optimizing program, and a network-level program.

Arizona

In the mid-1970's, Arizona decided to focus its pavement management efforts on the development of decisionmaking models. With support for the project from top ADOT management, and a steering committee to provide guidance and support, a consultant was hired to develop the models. The models were largely completed by 1979, with first application of the optimization model occurring in 1980. The models provide a rationale for ADOT management to select an optimum, initial structural design and maintenance strategy for new pavements, and to optimize maintenance strategies for existing pavements.

California

The State developed its Pavement Management System to relate rehabilitation expenditures to actual needs, to provide the appropriate repair to deserving road segments using a logical strategy, to improve programming capabilities, and to provide a better service to the public. Top management support was obtained for an understandable system which would: (1) identify rehabilitation needs and rank them, (2) insure appropriate repair strategies to address those needs, and (3) be operational two years.

Pavement Management in Arkansas

I. Introduction

In 1980, the Arkansas State Highway and Transportation Department (AHTD) undertook a broad study of the state-of-the-art of pavement management (PM) as practiced by other States. Based on the knowledge gained from this study, AHTD began to implement a PM program, concentrating on data collection and storage and the development of a prioritization program. At this point (May 1982), Arkansas has largely completed its first inventory of pavement conditions (a distress survey) on all State maintained roads, a system totaling roughly 16,000 miles. With the accumulation of several years of distress survey data, AHTD hopes to be able to plot deterioration curves and to predict pavement failure. The Department also intends to explore the relationship between pavement deterioration and 18 kip equivalent single axle loadings and to incorporate maintenance data into the PM program.

The following sections describe the data collection/storage efforts, the methods by which the data is analyzed, and its use in programming and prioritizing projects.

II. Data Collection/Storage

The AHTD collects pavement-related data on its entire State maintained system and is currently using three basic elements in its PM program: a pavement distress rating, a ride rating, and average daily traffic (ADT). Skid data is also collected but is not, at this point, an integral part of the PM program. In addition, the AHTD collects truck weight data which may eventually play an important role in Arkansas' PM program. Each of these data collection efforts is discussed below.

A. Pavement Condition Survey

The pavement condition survey is the central and most time-consuming data collection effort in the Arkansas program. All three of the State's roadway systems (Interstate, Primary (non-Interstate), and Secondary) have been divided into sections based on the latest paving project. The surveys for sections less than 2 miles long are conducted at a designated milepost which is selected to correspond, as is best possible, to the midpoint of the section. For sections greater than 2 but less than 5 miles in length, two samples are taken at mileposts that split the section approximately into thirds. Finally, for sections greater than 5 miles, three samples are selected at specified mileposts. The only exception to this sampling procedure occurs on the secondary road system for sections on which the ADT is less than 500. On these infrequently traveled roads, one sample is taken for sections up to 5 miles in length, and only two samples are taken for sections greater than 5 miles. Arkansas estimates that the survey work for PM has been reduced by 30% by adopting this modification for low ADT secondary roads.

Originally, the AHTD planned to adopt the following survey frequencies: Interstate - every 2 years, Primary - every 3 years, and Secondary - every 5 years. However, the State has found that to survey the entire system requires about 3 years. In order to keep its inventory current, Arkansas is considering adopting this interval (3 years) as the standard survey frequency for all classes of roads.

The surveys themselves are conducted by two crews each with two persons from the Headquarters Office's Planning Division. Training sessions are held periodically (recently on an average of every 4 months) to instruct new survey personnel and to refresh others. The sessions' content is not formally documented. The crew drives to the designated milepost, exits the automobile, and walks the length of the sample (100 feet for flexible and 300 feet for rigid pavements). A different set of pavement distresses is then examined depending on pavement type. On flexible pavements, the following distresses have been selected for examination: cracking, rutting, patching, depression, pumping, and swell. On rigid pavements, the selected distresses are: cracking (various types), patching, pumping, faulting, swelling, and depressions. The guidelines for examining, measuring, and coding the various distresses are detailed in the Department's "Manual for Coding Pavement Condition Worksheets." An example of the coding form for the flexible pavement condition survey is provided in Figure 1. In order for the survey crew to complete this form, some distresses must be measured while others are estimated. For example, cracking is measured in linear feet and is recorded as a percentage (the area of the pavement that is cracked divided by the total area). Patching, however, is only estimated for severity of deterioration, (no area measurements are taken). The values that are coded are printed out on the summary for each pavement section (discussed below in the "Data Analysis" section).

The distress rating is determined by deducting points for both the severity and extent of each defect. With no defects, a maximum score of 100 is obtainable. Different weights are assigned to each class of defects, and these weights differ depending on the type of pavement: flexible, PCC jointed, or continuous rigid. For example, on flexible pavements, a maximum of 20 deduct points can be obtained for rutting that is both severe and extensive. On rigid pavements, a maximum of 30 points is possible for pumping. The weights were established based on the experience of AHTD highway engineers and the results of other States' PM surveys (notably Florida's). The rating that is given to a section sample is not adjusted for conditions beyond the limits of the sample (that is, the 100 or 300 foot segment that is inspected by the crew). The AHTD believes it can achieve better control over the survey results by restricting it to a small milepost-specific segment. An additional benefit may be that the deterioration curve that is obtained over time may be a more accurate reflection of a specific pavement's history. Also, the AHTD indicated that the entire section is monitored for ride which, when determining the overall rating, should account for the condition of the pavement segments not included in the sample.

B. Ride Survey

The ride survey is the second major data collection element of the PM program. When factored with the distress survey, it helps determine a pavement section's pavement condition rating (PCR). As indicated earlier, the ride survey is conducted for the entire State maintained system, and not merely on a sample basis. The survey is performed independently of the distress survey. The equipment used is the Mays Ride Meter, mounted on a modified skid trailer. A digitizer has been recently purchased which will facilitate data collection, retrieval, and interpretation. The Mays Meter has been calibrated each year on selected Arkansas roads and will be calibrated this year in Austin, Texas, against a GM profilometer. The State is constructing its own calibration track for both the Mays Meter and its skid trailers. The ride rating is designed to reflect the amount of roughness and is on a theoretical scale of 0-100. In practice, AHTD established the scale based on conditions found on an extremely smooth and extremely rough

Figure 1

FLEXIBLE PAVEMENT CONDITION SURVEY

		COL
1.	Date	1-4
2.	District	5-6
3.	County	7-8
4.	Route	9-11
5.	Section	12-14
6.	Begin Log Mile	15-19
7.	Length	20-23
8.	Surface Type	24

CODE	TYPE
1	Asphalt
2	Concrete
3	DBST or SBST

		COL
9.	Directions of Travel	25

CODE	DIRECTIONS	CODE	DIRECTIONS
1	North bound	3	West bound
2	South bound	4	East bound

		COL
10.	Date Opened to Traffic	26-29
11.	Class 1 Cracking (Percent)	30-31
12.	Class 2 Cracking (Percent)	32-33
13.	Class 3 Cracking (Percent)	34-35
14.	Rutting (Measurement)	36-39

CODE	SEVERITY
5	Light (1/4"-1/2")
10	Medium (1/2"-1")
15	High (greater than 1")

		COL
15.	Patching (Light = L, Medium = M, High = H)	40
16.	Depression (Square Feet)	41-43
17.		44-46
18.	Pumping (L, M, H)	47
19.	Swell (Square Feet)	48-50
20.	Pavement	

road and placed respective scores of 90 and 20 for these two roadway extremes. However, after the scale was established, several very rough roads have achieved scores of less than 0, and a minimum score of 1 for such roads has been set.

C. Traffic and Truck Data

The AHTD obtains 24-hour traffic counts at approximately 3,000 locations and, by applying a number of statistical factors, arrives at an ADT for all roads on the State system. As will be explained in Data Analysis section below, the ADT is used to adjust the PCR.

Arkansas also obtains truck classification data and is currently using on a limited basis an electronic classification device for greater data collection speed and for manpower savings. With a greater number of electronic classifiers, the Department would like to be able to produce a map of all truck volumes on the State system. Coordinated with this effort, the AHTD obtains truck weight data at 16 permanent sites and would like to use weigh-in-motion equipment to obtain additional, accurate truck weights. However, no concealable weigh-in-motion equipment has been demonstrated to Arkansas which meets its criteria for portability and reliability. Yet, the State remains highly interested in weigh-in-motion equipment since accurate truck weight data will be of use not merely for enforcement purposes but, more importantly, for correlation with pavement deterioration. The AHTD believes that a pavement deterioration curve will be more meaningful when plotted not against time but against accumulated 18 kip equivalent axle loadings. Thus, although it is not now a part of the PM program, the truck data may eventually play an important role in the State's priority programming and prediction.

D. Skid

The State uses a skid trailer to conduct friction tests on all State maintained roads. The tests are conducted at approximately every 1/2 mile. The trailer is calibrated in Texas periodically but will be calibrated annually in the future on the State's own track. The skid information is made available to the Districts and to the Safety Division for input into the safety program. The only expected interface with the PM program will occur when the Programming and Scheduling Section examines potential projects in both PM and Safety areas to ensure the absence of conflict or overlap.

E. Data Files

The AHTD is working toward the creation of a centralized information system. The State has completed its first major step in the development of a data base management system: the preparation of a Data Dictionary. With this dictionary, the Department's data collection and usage has been standardized and made more consistent throughout all Divisions. The first file to be created will be the Roadway file, containing the State highway route section, log mile, structures, ADT, pavement type, etc. Eventually, the Department will tie all files to this core file. Fortunately, the AHTD has already maintained most all its data files by a single identifier: route section and milepost. Construction data is stored by station number, but this identifier can be converted to the milepost system when required. Maintenance data is available only for route and section number (but not by milepost). An average maintenance cost per section can be obtained but the actual maintenance activity cannot be identified down to a specific milepost. Some of the State's data is not computerized, notably the as-built data. Construction plans and all change orders are microfilmed and must be consulted if as-built data is desired.

One PM-related data parameter is not currently obtained on a systemwide basis: structural capacity. After experimenting with the Dynaflect on fifteen projects, Arkansas found the results to be inconsistent, conflicting, and unhelpful in making pavement overlay decisions. At this point, the Dynaflect will be used in only a few circumstances: establishing truck weight limits on secondary roads, designing overlays where soil knowledge is limited, and for the Long-Term Monitoring Project.

The next step in Arkansas' data base system's development will be to acquire the data communication programs, that is, the software needed to permit program managers to have direct access to the system without involving the work of processors and programmers. A number of other States' experiences and the software packages offered by private companies will be examined and compared before the AHTD makes its decision on which software packages it will acquire.

III. Data Analysis

To date, the Arkansas PM program has used the results of its data collection efforts largely for purposes of ranking or prioritizing projects. Additional uses of the data are planned. The following sections provide a brief overview of Arkansas' method for establishing project rankings and of the expected uses to be made of PM data.

A. Project Ranking

Projects are ranked based on the "adjusted rating" which is obtained by combining the three basic data collection measures: ride, roughness, and ADT. However, to arrive at the adjusted rating is a two-step process, the first step of which is to obtain the "basic rating" by combining the ride and roughness measures. For flexible pavements, the ride and distress ratings are given equal weight and are combined by taking the square root of their product. The equation is shown below.

$$\text{Basic Rating} = \sqrt{\text{ride rating x distress rating (flexible)}}$$

For rigid pavements, Arkansas believes that the ride rating is not so important an indicator and can mask serious structural problems. Therefore, a different basic rating is obtained by weighing the distress rating by 65% and the ride rating by 35 %. The equation is shown below.

$$\text{Basic Rating} = (.35)(\text{ride rating}) + (.65)(\text{distress rating}) \text{ (rigid)}$$

The basic ratings can then be used to rank projects, listing them in order of lowest to highest rating, vice versa, or by district/county/route number. The latter listing would be of use to a District interested in having an inventory of its pavements or in selecting projects in need of maintenance and/or rehabilitation. An example of a listing by Interstate route number for flexible pavement is provided in Figure 2. This listing contains the raw data as recorded on the coding sheet (Figure 1) which in the case of certain distresses can be the actual deduct points but in other cases must be factored with specified weights before the deduct values are known. For example, for cracking, a value of 3 does not equate to 3 deduct points but must be multiplied by a weighing factor, depending on severity, to arrive at the deduct points. For rutting, however, the value on Figure 2 is the actual deduct point.

FLEXIBLE PAVEMENT CONDITION SURVEY

DATE	DI	CO	RTE	SEC	LOGMI	BINV	EINV	LGTH	S	D	OPEN	C1	C2	C3	RUT	PA	DEP	PJ	SWE	SN	DEF	RID	BAS	DYN	ADJ
																					PAVEMENT CONDITION RATINGS				
0680	03	29	030	012	21.00	20.07	22.31	2.29	1	4	1170	03	00	00	0	0	0.0	0	5.0		99.10	46.80	68.10		
0680	03	29	030	012	27.00	22.31	27.02	4.71	1	3	UC	00	00	00	0	0	0.0	0	0.0		100.00	77.29	87.91		
0680	03	29	030	012	27.00	22.31	27.02	4.71	1	4	UC	00	00	00	0	0	0.0	0	0.0		100.00	76.04	87.20		
0780	01	18	055	011	12.00	10.32	13.56	3.24	1	1	1078	00	00	00	5	0	0.0	0	0.0		95.00	73.94	83.81		
0780	01	18	055	011	12.00	10.32	13.56	3.24	1	2	1078	00	00	00	5	0	0.0	0	0.0		95.00	78.98	86.62		
0780	01	18	055	011	14.00	13.56	16.80	3.24	1	1	1078	00	00	00	10	0	0.0	0	0.0		90.00	74.72	82.00		
0780	01	18	055	011	14.00	13.56	16.80	3.24	1	2	1078	00	00	00	5	0	0.0	0	0.0		95.00	76.80	85.42		
0780	01	18	055	011	18.00	16.80	18.91	2.11	1	1	0878	00	00	00	5	0	0.0	0	0.0		95.00	79.40	86.85		
0780	01	18	055	011	18.00	16.80	18.91	2.11	1	2	0878	00	00	00	0	0	0.0	0	0.0		100.00	85.38	92.40		
0780	01	18	055	011	20.00	18.41	21.02	2.11	1	1	0878	10	00	00	5	0	0.0	0	0.0		94.50	78.31	86.02		

Figure 2

The second step in the process to arrive at the "adjusted rating" is to incorporate ADT with the basic rating. The formula for arriving at the adjusted rating is:

where: T = average daily traffic for rated section

T^S = average daily traffic for system

BAS = basic rating

ADJ = adjusted rating

$$ADJ = BAS + \frac{BAS^2 - 100\ BAS}{50\ \text{Log}\ T_S} (\log T - \log T_S)$$

Essentially, this adjustment will provide a higher priority for those sections with a greater than average ADT and reduce it for those with a lower than average ADT. The State believes that this adjustment will help PM decisionmakers select those sections which, because of their higher ADT, will provide a greater economic benefit once improved. Since the ADT data is only now being loaded into the computer, the PM program's output has been restricted to the basic rating. Once the ADT data is available, the adjusted rating will be more frequently used for most applications.

B. Future PM Applications

The AHTD has not yet developed an optimization program nor a complex economic analysis program. However, the State is interested in the development of deterioration curves for specific pavement segments and for generalized pavement types. Eventually, the Department wants to be able to predict pavement failure and when different types of pavement should receive improvement. The State is also concerned with new pavement types, new construction techniques, and the life cycle costs associated with all pavements. Finally, the State anticipates that PM information will assist its maintenance management personnel in selecting improvement projects and in scheduling different types of maintenance for different pavement types and ages.

IV. Programming

A. Project Level

The Programming and Scheduling (P&S) Section has the chief responsibility for establishing construction and rehabilitation project priorities. However, the Districts, the Construction Division, and the Roadway Design Division all provide the major input on which the P&S Section makes its decisions. Using planning guidelines approved by the Arkansas Highway Commission and the requests from the various Divisions and Districts, the P&S Section programs projects for the following year, matching projects with appropriate funding sources.

The overlay program has been a special funding category for a number of years. The Districts submit their proposed overlay projects to the P&S Section which has generally provided an even distribution of funds to all Districts. Recently, the program was reduced in size by the Highway Commission providing only enough funding to overlay 10-12 miles per District. The 3R/4R program funds are similarly spread evenly among the Districts. The P&S Section feels that since the needs are sufficiently great in all Districts and since the 4R and overlay funds are inadequate to address all these needs that an even distribution to the Districts will be both fair and well spent.

Maintenance funds are distributed to the Districts based on an estimate of needs. This estimate, performed in each District, involves the assignment of historically-based planning values for each maintenance activity, modified for expected conditions in the coming year, and adjusted for the District's mileage. Once the annual maintenance budget is approved, the District has the opportunity to use the PM data to establish the District's priorities for pavement-related maintenance. At least one District plans to use the data in this way, as a supplement to the input received from the District's maintenance superintendent.

In establishing priorities for all programs, the P&S Section considers the following: 1) the Federal Program's criteria and requirements, 2) project costs compared to availability of funds in each category, and 3) geographic (District) distribution. In the future, PM data will play a greater role in programming projects in several categories by moderately modifying the geographic distribution of funds when the PM program has shown the needs to be greater in certain Districts.

The PM input became important in the past year in the Interstate 4R program, wherein the pavement condition ratings were used to establish project need and priority. As more of the highway system is surveyed and analyzed, the ratings will be more extensively used for selecting and ranking rehabilitation projects. Overall, the AHTD foresees the PM information as providing a major input into its growing rehabilitation programs.

PM data, however, is only one informational resource used by the P&S Section. The AHTD's Statewide Inventory provides data on various categories besides pavement condition: shoulder condition, drainage adequacy, horizontal alignment adequacy, capacity, access control, etc. Essentially, the Statewide Inventory is a drive-through inspection of the roadway system where a two-man crew observes any significant change in the physical characteristics and documents them on an Inventory Worksheet. The purpose of the Inventory is to help determine what improvements are needed on Arkansas' roads and is used by various Divisions as well as the P&S Section in preparing the overall work program. The inventory is conducted on a continuing basis and will be coordinated with the PM (distress and ride) surveys in the future. All pavement condition data will be taken from the PM program.

B. Network Level

The Planning Division and the P&S Section develop systemwide assessments of a variety of highway conditions and needs. Using the Statewide Inventory and, in the future, the PM Program, the AHTD prepares assessments of pavement conditions for different highway functional classes, information on bridge age and conditions, estimates of costs of construction needs, analyses of the impact of delayed construction/rehabilitation on maintenance costs, etc. This information is useful in preparing long-term planning documents which provide guidelines on which projects should be undertaken given appropriate funding. The P&S Section also prepares network-level descriptions of the State highway system's conditions, needs, and responses for legislative purposes. The PM data is expected to help substantially in future legislative efforts, particularly by reinforcing an understanding of the need for additional revenue for the highway program.

Pavement Management in Florida

I. Introduction

The Florida Department of Transportation (FDOT) has been developing its pavement management (PM) program for over 10 years. Its interest in the subject has been continuous and has led to several accomplishments: the establishment of thorough pavement monitoring procedures, the application of pavement condition ratings to a priority programming routine, the accepted use of PM information in its network analysis and planning programs, and the use of PM data in other FDOT operations, notably design. Another accomplishment, one that has facilitated the implementation of the PM program, has been the Department's move to integrate all of its data bases into a centralized, computerized format. Florida's interest in improving its PM program has been fed by its desire to: 1) reduce errors, 2) lower the variability in pavement design life, 3) reduce costs, and 4) improve communication among the Department's program offices. The State has successfully applied PM practices to its approximately 10,000 mile State maintained system.

The following summary utilizes information contained in several FDOT reports and publications as well as an onsite visit during which several of the Department's PM specialists and users were interviewed. The discussion below focuses first on the data collection efforts and the data files, secondly on the data analysis (project prioritization), and finally on the PM planning and programming activities of the Department.

II. Data Collection

The FDOT collects the following types of pavement-related data: a distress (defect) measurement, a roughness (ride) measurement, skid data, traffic counts and classification, and truck weights. In addition, a roadway inventory file has been established which contains a great deal of information from Planning, Safety, Maintenance, and Traffic Operations offices. Each of these data collection efforts are discussed below.

A. Pavement Condition Survey

The FDOT has been monitoring the condition of flexible pavements since 1972 and of rigid pavements since 1975. The surveys are physical inspections of the roadway and are limited to the Interstate, primary, and selected urban roads. The State has developed a slightly different definition of the primary system and, therefore, includes in its survey some Federal secondary roads. The FDOT surveys all 10,000 miles of State-maintained roads for pavement conditions. The Districts conduct the surveys for the State Maintenance Office, which provides overall guidance and establishes policies concerning pavement condition monitoring.

For the pupose of conducting condition surveys, the system is divided into pavement sections whose lengths are determined by a major "break" in the system. The following typical breaks form the limits of a section:

1. County line.
2. County section or subsection.
3. Past/present construction project limits.
4. Structural design changes.
5. Geometric changes.
6. Major changes in visual appearance or pavement condition.

Both flexible and rigid pavement surveys are conducted on an annual basis during the same time frame, from June 1 to November 1. Before conducting the survey, the District's rating team prepares a diagram map designating the limits of each section with major physical characteristics identified. Once in the field, the rating team makes the final selection of section limits and indicates these by mileposts on the map and on the coded data sheet.

The distress survey is conducted in tandem with the ride survey by two crews. The second rating team drives along the pavement section at a slower speed than the first team and records observed distresses on the evaluation form. At a representative location, the second team stops the vehicle and examines a selected segment more carefully. For flexible pavements, a 100 foot section is evaluated and the following distresses are recorded:

1. Rutting (average rutting in inches).
2. Cracking (percentage area of three types of cracking).
3. Patching (percentage area).

Additional distresses (potholes, raveling, bleeding) may be recorded in the "Remarks" section of the coding form. The report "Instructions and Procedures for the Flexible Pavement Condition Survey" provides details on the examination and recording of all of these distresses.

For rigid pavements, the team conducts the Mays Ride Meter measurements and then makes a second ride at a slower speed to examine the entire length of the section and to estimate the amount of faulting at a minimum of five consecutive slabs. Additional distresses are evaluated and measured (or estimated) according to procedures that have been outlined in FDOT's report, "Instructions and Procedures for the Rigid Pavement Condition Survey." The distresses examined for rigid pavements are comprehensive and include the following: surface deterioration, spalling, patching, cracking (transverse, logitudinal, corner), shattered slabs, pumping, and joint condition. A sample rating form for rigid pavements is provided in Figure 1.

The State Maintenance Office helps maintain quality control over the survey teams' work by providing, in conjunction with the Office of Materials and Research, a 1-week training session in Gainesville, FL, for all survey crews. The sessions are intended to ensure that all Districts rate pavements in approximately the same manner. Additionally, Statewide meetings are held every 3 or 4 months for District survey personnel to compare results and discuss problems that arise in the course of conducting the surveys. Finally, the Office of Materials and Research annually checks the survey ratings in conjunction with its inspection of the consistency of the Mays Ride Meter ratings in each District.

B. Ride Survey

The FDOT uses a Mays Ride Meter to measure the roughness of 100% of the entire length of each pavement section included in the distress survey. The survey crew operates the Mays Meter typically at 50 mph, but can vary this depending on conditions. Florida uses a digitized recorder (a PCR 100), into which the crew must enter recordkeeping information, such as date, county, direction, lane, and control data such as vehicle speed and beginning and ending mileposts. Florida's digitized recorder computes the number of counts per mile and calculates the ride rating automatically. It is also capable of calculating the defect rating and the basic (combined) rating, if the data from the distress survey has been entered.

FORM 671-34
4/78

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

RIGID PAVEMENT CONDITION SURVEY

D	CO	SECT.	SUB
2	3	5	8

MO.	YR.	UNT	S	S.R. NO.	U.S. NO.
17	19	21	23	24	28

CT	RD	BEGIN MP	END MP	NET LENGTH	SP	MMC	ADT	REMARKS
1								

CT	SURFACE DET		SPALLING		PATCHING		TRANSVERSE CRACK			LONG CRACK			CORNER CRACK			SHAT. SLAB		FAULT MEAS	PUMP			J T
	MOD	SEV	MOD	SEV	FAIR	POOR	LT	MOD	SEV	LT	MOD	SEV	LT	MOD	SEV	MOD	SEV		L	M	S	
2																						

1 11 12 17 21 25 28 31 34 37 40 43 46 47 52 55 58 61 64 67 70 74 77

CT	RD	BEGIN MP	END MP	NET LENGTH	SP	MMC	ADT	REMARKS
1								

CT	SURFACE DET		SPALLING		PATCHING		TRANSVERSE CRACK			LONG CRACK			CORNER CRACK			SHAT. SLAB		FAULT MEAS	PUMP			J T
	MOD	SEV	MOD	SEV	FAIR	POOR	LT	MOD	SEV	LT	MOD	SEV	LT	MOD	SEV	MOD	SEV		L	M	S	
2																						

1 11 12 17 21 25 28 31 34 37 40 43 46 47 52 55 58 61 64 67 70 74 77

CT	RD	BEGIN MP	END MP	NET LENGTH	SP	MMC	ADT	REMARKS
1								

CT	SURFACE DET		SPALLING		PATCHING		TRANSVERSE CRACK			LONG CRACK			CORNER CRACK			SHAT. SLAB		FAULT MEAS	PUMP			J T
	MOD	SEV	MOD	SEV	FAIR	POOR	LT	MOD	SEV	LT	MOD	SEV	LT	MOD	SEV	MOD	SEV		L	M	S	
2																						

1 11 12 17 21 25 28 31 34 37 40 43 46 47 52 55 58 61 64 67 70 74 77

CT	RD	BEGIN MP	END MP	NET LENGTH	SP	MMC	ADT	REMARKS
1								

CT	SURFACE DET		SPALLING		PATCHING		TRANSVERSE CRACK			LONG CRACK			CORNER CRACK			SHAT. SLAB		FAULT MEAS	PUMP			J T
	MOD	SEV	MOD	SEV	FAIR	POOR	LT	MOD	SEV	LT	MOD	SEV	LT	MOD	SEV	MOD	SEV		L	M	S	
2																						

1 11 12 17 21 25 28 31 34 37 40 43 46 47 52 55 58 61 64 67 70 74 77

CT	RD	BEGIN MP	END MP	NET LENGTH	SP	MMC	ADT	REMARKS
1								

CT	SURFACE DET		SPALLING		PATCHING		TRANSVERSE CRACK			LONG CRACK			CORNER CRACK			SHAT. SLAB		FAULT MEAS	PUMP			J T
	MOD	SEV	MOD	SEV	FAIR	POOR	LT	MOD	SEV	LT	MOD	SEV	LT	MOD	SEV	MOD	SEV		L	M	S	
2																						

1 11 12 17 21 25 28 31 34 37 40 43 46 46 52 55 58 61 64 67 70 74 77

Figure 1

Each District's Mays Meter is calibrated annually at the training sessions in Gainesville, and is checked by the Office of Materials and Research during the rating season in the Districts. Each District also maintains a test section on which the Mays Meter is run before undertaking the day's survey work.

C. Skid

The FDOT's Office of Materials and Research has operated skid trailers on its Interstate and primary systems since 1974. The entire system is monitored every 2 or 3 years, with a sample of approximately 40% of the system covered each year. The skid data is not formally a part of the PM program. However, the data is provided to the Districts which use it for assistance in selecting projects for its safety program. In addition, certain safety projects are prioritized Statewide and their selection is based in part on the results from the friction survey.

D. Traffic and Truck Data

The Department's Office of Planning has acquired advanced hardware in order to obtain accurate traffic counts and truck weights and to reduce manpower costs. Traffic counts are collected from 10,000 periodic count sites and from 86 permanent sites. The permanent installations are connected to a central computer via a telemetry network. At the 86 sites, 25 stations also have the capability to collect speed data. In addition, 20 of these sites have the hardware to relate speed data to a truck/car classification.

For detailed vehicle classification, the FDOT still relies on manual counts at 2,000 person-sites. However, the State is investigating the use of loop detectors for this purpose and the possibilities associated with video camera classification.

For truck weight data, Florida has set up 20 weigh-in-motion stations and a portable system which is relocated from site to site to conduct the survey. Although 20 installations have been completed, data collection occurs only when a trailer with the computer and software is hooked up to transducers which are inserted in frames permanently installed at the site. Three full-time technicians operate this trailer, moving the equipment as needed from site to site. The weigh-in-motion set up is not intended to be concealed. The program's existence was publicized to the trucking industry to make sure it was understood that the equipment was not being used for enforcement purposes. The truck weight data is collected in one lane, one direction and includes speed, distance between axles, number of axles, weight per axle, total weight of the vehicle, and a classification of the vehicle.

The PM program primarily uses the traffic count data (ADT), in adjusting the rating obtained from the ride and distress surveys. All of the traffic and truck data are entered into the State's Roadway Characteristics Inventory and can therefore be of use to any office in the Department (design, construction, maintenance, etc.).

E. Additional Data: Roadway Characteristics Inventory

The Roadway Characteristics Inventory (RCI) is a computerized data file designed to contain 480 features that are of use to various units throughout the Department. Over 90% of the data has now been entered, although some entries are in the process of being verified. The RCI currently contains data from Planning, Safety, Maintenance and Traffic Operations, including roadway data such as District, County, section, system type, physical dimensions, layer thicknesses and materials, ADT, skid numbers, etc. All HPMS data has been integrated with the RCI. A portion of the construction data file (as built and historical files) have been loaded but have not been updated recently and are known to contain errors. Finally, selected maintenance data is also available as average figures but do not reflect the actual work on a specific mileposted section (since such data has not been collected to date). In the future, certain pavement-related maintenance items will be entered by milepost.

The RCI has been designed to be a general information system for the Department with easy access via remote terminals. The Districts as well as Headquarters' staff can enter and retrieve data. The file was constructed with built-in checks for data uniformity (edit criteria) and for reasonableness. The Department has undertaken limited photologging activity and is considering tieing it to the RCI. (With this tie-in, the user could examine photos of the roadway section while reading its file.)

Some data is not routinely collected in Florida on a systemwide basis, notably Dynaflect measurements. Deflection readings are obtained for pavement design purposes and to estimate layer moduli.

F. Data Files

After undertaking a study of data processing limitations, problems and possibilities, the FDOT decided in 1974 to develop a management information system (MIS) that included the acquisition of new hardware, the use of time-sharing facilities among different offices, and the development of software to interrelate a wide range of Departmental activities. A plan was established to address several problems. Briefly, the Department recognized that the flow of information was inadequate among various offices, that the integrity of reports was suspect since information collection was inconsistent, and that although the automated systems were satisfactorily oriented towards daily operations, they were inadequate to produce top management reporting or non-routine data analyses.

To attack these and other problems, the Department explored and developed an MIS to be implemented in phases. The entire Department was defined to be one overall system capable of operating with a large data base viewed as a pyramid of hierarchically related information and with all components of the MIS interrelated through an Information System Matrix. Fifty-seven subsystems were identified for implementation and approximately one-fifth of them are currently operational. The RCI file is one of these operational subsystems.

Undoubtedly, the MIS approach has assisted the FDOT in its PM program by requiring that all data be tied to an integrated data base. Since PM is an interdisciplinary activity, the presence of an MIS can greatly assist in establishing good communication among PM users and managers. In fact, according to FDOT personnel, the improvement in overall Departmental communication has been a major benefit of adopting the MIS. In the near future, the PM program will benefit from improved maintenance management data input, wherein certain maintenance costs will be allocated to specific highway sections rather than be reported only as countywide averages. Such changes have been made possible partially by the impact of the MIS. Finally, the MIS has been instrumental in utilizing PM and other information to acquire additional appropriations from the Legislature. By having the necessary information and the ability to provide it in a variety of formats to key decisionmakers, the Department has been able to offer convincing presentations of network conditions and consequences associated with specified funding levels.

III. Data Analysis

The results from the distress survey and the ride survey are used to arrive at Florida's structural rating for each pavement section. The defects recorded in the distress survey are weighed and deducted from a score of 100 (for a perfect pavement) to obtain the defect rating (DR). The ride rating (RR) is also on a 0 - 100 scale. The structural rating (SR) is computed for each section by the following equation:

$$SR = RR \times DR$$

The SR is also known as the "basic rating," the term generally used by the State Maintenance Office. This rating is used by the Office of Planning to establish priorities and in projecting needs in a 5-year plan.

The components of the structural rating (DR & RR) are projected separately using different formulas. The only variable that Florida has found to correlate with the DR is age, and it is used to project the DR in a straight line fashion for 5 years. The RR is projected using a model which relates ride to the variable "age" and a constant "B." A matrix of "B" values has been established for each Florida District for surfacing type (new vs. resurfaced), and for traffic conditions (urban vs rural). Using this model and the appropriate "B" value, the RR is also projected for 5 years. A projected SR can be calculated from the projected DR & RR values. The goal of developing the projected ratings for pavement sections is to be able to predict when resurfacing projects will be needed and to prioritize the projects based on this prediction. In addition, the model will assist the FDOT in making assessments of pavement performance (i.e., in distinguishing pavements which perform above or below expected values). This information is of significant use to Design and Construction engineers.

The Florida PM program also calculates an operational rating (OR) for pavement sections which is largely a function of volume/capacity relationships. Based on traffic and truck data, the OR is used in determining which pavement sections are in need of receiving geometric improvements (additional lanes, lane widening, etc.). The OR is also used by Planning to make assessments of network performance and needs.

The OR and SR are combined to produce an "engineering rating (ER)." The equation is:

$$ER = SR \times OR$$

This rating is not currently used by the FDOT, although it still appears on consolidated printouts of Florida's highway system. Since the ER combines two distinctly separate types of deficiencies (structural and operational) and since the funding sources to remedy these deficiencies are generally different, the combined rating does not assist decisionmakers in allocating program funding levels or in selecting projects. The only combined rating (besides the SR) which is used is an "adjusted rating" which is the basic rating adjusted for ADT. The Districts use this adjusted rating in establishing their annual work program for resurfacing.

IV. Programming

A. Project Level

The results of the pavement condition survey are printed out with the pavement sections ranked based on the basic (structural) rating. A printout of sections based on route number is also possible. The Districts use the priority ranking list for both maintenance and resurfacing project selections. The Districts first examine the list for the projects with the lowest basic rating, compare the ranking with their onsite experiences, check for ADT (the adjusted rating), and then estimate the cost to resurface the highest priority projects (and to perform any needed additional work). The Districts have two funds available for 3R/4R work - a Federal-aid program and a State-funded program. As the fiscal year progresses, the Districts can add or subtract projects to these resurfacing programs as the actual contract costs of the work become known. In making these changes, the Districts refer back to the project priority list.

The State Maintenance Office also uses the project priority list to select Interstate 3R/4R projects. Although the Districts provide significant input to the decisions made on these projects, the central office has the prime responsiblity for this program and relies heavily on the distress survey results in its decisionmaking.

The Division of Transportation Planning also uses the priority list to check on the projected, annual programs submitted by the Districts, compare the programs with the structural and operational ratings for the District's roadway system, and ensure that sufficient money is available in the appropriate funding category. If a project selection appears to be questionable, then the Division of Transportation Planning can discuss it with the District using the priority rankings as background information. If no satisfactory explanation of the project selection is made, then the Executive Committee (composed of Division Directors and the Deputy Secretary of the Department) will be informed of the problem when the program is submitted for approval. In general, the priority rankings are used as a valuable guide in programming projects for both resurfacing and selected pavement maintenance work and in approving these work programs; but exceptions to the rankings are not uncommon due to circumstances known best by the local District personnel.

B. Network Programming

The Office of Transportation Priorities has the primary responsibility for conducting systemwide analyses of the FDOT highway network. This office produces deficiency maps of the entire State-maintained system for each District, using the structural and operational ratings. These maps are used in the Districts and in the central office for programming and planning purposes. Current distress and ride ratings are also projected for 5 years and are available in a milepost format for inventory purposes and in a work program format for budgetary purposes. The budget item sequence printout and the code explanations are provided in Figures 2 and 3, respectively. An executive summary of the budget item sequence is also compiled and provides the estimated cost of the project and the appropriate funding category from which the project can be financed (see Figure 4). Finally, all of the projected projects are displayed in a 5-Year Construction Plan which identifies the type of work to be undertaken and the fiscal year in which the work is planned to occur (see Figure 5). Although a number of

DCDSECSUB	S D	*MILEPOSTS* BEGMP	ENDMP	ST RD	US RD	N L	YR LI	*1982* * ADT*	...STRUCT ADEQ... 82	83	84	85	86	87	AI SR	...OPERAT ADEQ... 82	83	84	85	86	87	AI OR	...ENGR RATING... 82	83	84	85	86	87	CH ER	BUDGET ITEM #	TP WK	P L	PH	PH YR	FUND
403001000	1	15730	21830	0084	0000	2	66	2758	74	72	71	70	69	68	90	95	95	94	93	92	91	98	84	83	82	81	79	78	16	441414	07	4	40	87	I
403002000	1	21386	29186	0084	0000	2	68	3000	82	81	81	80	79	79	90	95	94	93	93	92	91	98	88	87	87	86	85	84	10	441415	07	4	40	90	I
493220000	1	00000	04900	0009	9095	6	74	23023	84	83	82	81	81	80	80	81	80	79	77	76	74	84	83	82	80	79	78	77	5	447494	05	8	40	87	I
486470000	1	11610	15610	0091	0000	4	68	10365	81	80	79	78	77	75	90	71	68	66	63	60	57	63	76	74	72	70	68	65	6	451448	06	2	90	85	PKYI
486470000	1	07610	09510	0091	0000	4	67	12229	83	82	81	80	79	78	90	61	57	54	51	47	43	92	71	69	66	63	61	58	27	451477	06	6	40	85	PKYI
486470000	1	02610	07610	0091	0000	4	64	12175	82	81	81	81	80	80	90	61	58	55	51	48	44	93	71	69	67	64	62	59	25	451491	06	6	40	84	PKYI
486470000	1	00000	02610	0091	0000	4	68	11750	64	62	60	58	56	54	0	63	60	58	54	51	47	0	63	61	58	55	53	50	0	451492	06	6	40	81	PKYI
486470000	1	15610	20610	0091	0000	4	66	8461	84	83	82	81	80	79	90	79	78	76	74	72	70	95	82	80	79	77	76	74	19	451509	06	6	90	90	PKYI
486470000	1	00000	15610	0091	0000	4	67	11655	79	78	77	76	74	73	0	64	61	58	55	51	48	0	71	69	66	64	61	59	0	451519	23	4	40	79	PKYI
486470000	1	09510	12049	0091	0000	4	73	11912	85	83	82	81	78	77	90	63	59	56	53	49	45	63	73	70	68	65	62	59	2	451526	09	6	40	82	PKYI
486470000	3	16220	25916	0091	0000	2	66	7604	76	75	73	72	71	70	0	78	77	75	73	71	69	0	77	76	74	73	71	70	0	451529	23	2	40	80	PKYI
486470000	1	00000	25916	0091	0000	4	66	10109	80	79	78	77	76	75	0	70	67	65	62	59	56	0	74	73	70	68	66	64	0	F451531	98	0	10	80	PKYI
486470000	1	22147	22247	0091	0000	4	63	7115	79	78	77	76	75	74	0	79	77	76	74	72	70	0	79	78	76	74	73	72	0	451535	98	0	10	80	PKYI
486470000	1	02898	04598	0091	0000	4	64	12175	81	81	80	80	79	79	90	61	58	55	51	48	44	93	70	68	66	64	61	58	23	451537	06	6	40	83	PKYI
486470000	3	16290	25820	0091	0000	2	66	7604	76	75	73	73	71	70	90	78	77	75	73	71	69	78	77	76	74	73	71	70	7	451546	08	4	40	82	PKYR
489470000	1	00000	12900	0091	0000	4	56	9265	89	88	87	86	85	84	0	57	52	46	40	33	29	0	71	67	63	59	53	49	0	456419	23	4	40	80	PKYI
493470000	1	05550	44665	0091	0000	4	56	7706	65	65	63	62	61	60	0	70	68	66	63	61	58	0	67	65	63	62	59	57	0	457528	23	5	40	81	PKYR
493470000	1	36000	36100	0091	0000	4	56	7993	68	67	66	65	65	63	0	82	80	78	77	76	74	0	74	73	71	70	69	67	0	457535	05	2	40	81	PKYI
493470000	3	25679	35899	0091	0000	2	56	7265	77	77	76	76	75	74	90	76	74	72	70	68	66	76	76	75	74	73	71	70	6	457536	08	4	40	82	PKYR
493470000	1	00000	15199	0091	0000	4	56	7265	61	60	59	58	57	56	90	72	70	68	66	63	61	72	66	64	62	61	58	56	15	457540	08	4	40	82	PKYR
493470000	1	35899	44665	0091	0000	4	56	9456	73	72	72	71	70	70	90	58	55	52	48	45	41	58	65	63	61	58	55	53	7	457541	08	4	40	82	PKYR
494470000	1	00000	15104	0091	0000	4	64	7162	88	87	86	85	84	83	0	75	73	69	67	63	59	0	81	79	77	75	72	70	0	458406	08	4	40	78	PKYI
494470000	1	14767	30767	0091	0000	4	70	5775	89	88	87	86	85	85	0	82	80	77	75	72	69	0	86	84	83	81	79	77	0	458409	23	4	40	80	PKYI
494470000	1	30767	35494	0091	0000	4	70	5775	90	89	88	87	86	86	0	82	80	77	75	72	69	0	86	84	83	81	79	77	0	458411	08	4	40	80	PKYI

Figure 2

OFFICE OF TRANSPORTATION PRIORITIES - WORK PROGRAM
BUDGET ITEM SEQUENCE
PRS OF MO/DA/YR

D	CO	SEC	SUB	S D	*MILSPOSTS* BEGMP	ENDMP	ST RD	US RD	N L	YR LI	*1981* * ADT*	...STRUCT ADEQ... 81 82 83 84 85 86	AI SR	...OPERAT ADEQ... 81 82 83 84 85 86	AI OR	...ENGR RATING... 81 82 83 84 85 86	CH ER	BUDGET ITEM #	TP WK	P L	PH	PH YR	FUND
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	4 17	18	19	20	21	22	23	24

1. District - (1) digit
2. County - (2) digits
3. Section - (3) digits
4. Subsection (3) digits
5. Side (1) digit
   1..Composite
   2..Left
   3..Right
6. Beg. Milepost - (5) digits
7. Ending Milepost (5) digits
8. State Road Number - (4) digits
   1st digit indicates
   1...A-1-A
   2...A (Alternate)
   3...B (Business)
   9...ID
9. U.S. Road Number - (4) digits
   1st digit indicates
   2...A (Alternate)
   3...B (Business)
   9...Interstate
10. No. of Lanes - (1) digit
11. Yr. Last Improvement - (2) digits
12. ADT - (6) digits each
13. Structural Adequacy - (2) digits; each relates to physical characteristics of roadway. Scale: 0-99; 99 is a perfect road.
14. After improvement structural rating (2) digits; expected structural rating in construction year due to improvement.
15. Operational Adequacy - (2) digits; each relates to effective movement of traffic on roadway. Scale: 0-99; 99 is a perfect roadway.
16. After improvement operational rating (2) digits; expected operational rating in construction year due to improvement.
17. Engineering Rating - (2) digits each = /Struct. Adequacy X Oper. Adequacy
18. Change in Engineering Rating (2) digits; increase in Engineerting Rating due to improvement in construcion year.
19. Budget Item Number - (8) digits
    first digit indicates:
    C - Return to city
    D - Interstate funds from outside Florida realm
    S - Returned to county
    W - Work file
    I - Interstate connector
    T - Traffic connector
20. Type Work - (2) digits;
    01...New construction
    02...Re-construction
    04...Re-alignment
    05...Add Lane to existing Lanes
    06...Add Lane and Re-construct Lanes
    07...Add Lane and Resurface Lanes
    08...Resurface and Repave
    09...Widen and Resurface
    10...Widen Only
    11...Grade and Pave
    12...Interchange only
    14...Mineral seal
    18...Surface Treatment
    19...Second stage resurfacing
    23...Pave Shoulders and Resurface
    38...Skid Hazard (Resurface)
    70...Rights-of-way
    80...Preliminary Engineering
    98...Planning
21. Planned Lanes - (1) digit
22. Phase of Work - (2) digits
    10 - Planning
    20 - Prelim. Eng.
    30 - Right/Way
    40 - Construction
    50 - Miscellaneous
    60 - Const. Eng.
    70 - Maintenance
    80 - Strat. R/W
    90 - Strat. Const.
23. Year of Phase - (2) digits
24. Fund (Type) See Attachment - (4) digits;

Figure 3

OFFICE OF TRANSPORTATION PRIORITIES
EXECUTIVE SUMMARY OF PROJECT PRIORITIES
BUDGET ITEM SEQUENCE
PRS OF 04/21/82

DESCRIPTION LOCAL NAME	FROM	TO	LENGTH (MI)	82 SR	82 OR	SYR ER	DLTA ER	CE TERM	%RANK (TOP)	BUDGET ITEM#	TP WK	PLN LNS	ST	PH	PH YR	FUND	ESTCST $1000
BROW BLVD/SR-842/CP7	EAST OF TURNPIKE	SR-7/US-441	01.000	59	47	46	26	145	34	410071	06	6D	01	40	84	MFL6	2371
SR-A1A	SR-822/SHERIDAN ST	DANIA BRIDGE	01.505	77	49	46	37	145	22	410080	06	4U	01	40	91	MFL6	4196
ATLANTIC BLV/814/CP3	POWERLINE RD	I-95/SR-9	01.267	69	45	47	30	145	28	F410100	06	6D	01	40	85	MFL6	6163
SR-5/US-1	OLD DIXIE IN DANIA	BR#860001	01.260	60	24	28	11	50	36	410105	08	5U	01	40	91	PR	287
DIXIE HWY/SR-811	COMMERCIAL BLVD	ATLANTIC BLVD/SR-814	03.034	50	54	25	61	145	6	410121	06	5U	01	40	91	MFL6	10112
DIXIE HWY/SR-811	OAKLAND PARK BLVD	COMMERCIAL BLVD	01.593	77	41	43	40	145	19	410123	06	5D	01	40	91	MFL6	7846
SR-A1A/ONE-WAY PAIRS	S LAUD BY SEA C/L	N LAUD BY SEA C/L	01.031	65	36	37	29	145	22	410138	06	4D	01	40	91	MFL6	5597
FEDERAL/SR-5/US-1	DADE CO/L	HALLANDALE BD/SR-824	00.768	65	65	56	29	145	39	410192	06	6D	01	40	91	CP	6345
SR-7	S. OF SAMPLE RD	N. OF SAMPLE RD	00.814	66	22	23	36	145	11	410201	07	4D	01	40	91	CP	4590
SR-7/US-441	N OF SAMPLE RD	HOLMBURG RD	01.336	66	12	19	56	145	6	410202	06	4D	01	40	91	CP	6104
SR-A1A	BOUGAINVILLA TERR.	N OF VIRGINIA ST.	00.400	53	68	30	47	145	9	410207	06	6D	01	40	87	MFL6	3470
COMPLETES 6 LANING TO THE HOLLYWOOD BOULEVARD BRIDGE																	
SR-5/US-1	SR-842	SR-838	01.002	65	22	30	7	145	51	410211	08	6D	01	40	91	PR	295
SR-A1A	MARINE STREET	PALM BEACH CO LINE	04.894	59	69	46	25	20	26	410212	08	2U	01	40	91	PR	472
SR-A1A	END MEDIAN S. SR-870	PINE AVE	00.827	60	23	35	9	50	44	410213	08	2U	02	40	83	PR	79
SR-811/DIXIE HWY	ATLANTIC BLVD/SR-814	SR-810	06.197	62	57	47	37	145	23	410219	06	4D	00	40	91	MFL6	16380
SR-AIA	N OF SR-820	S OF SR-822	01.300	56	80	64	20	50	60	410226	08	5U	01	40	83	PR	424

Figure 4

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
FIVE YEAR CONSTRUCTION PLAN
FISCAL YEARS 1982-83 (FY83) THRU 1986-87 (FY87) 04/19/82

VOLUSIA COUNTY

PROJECT PHASE PROGRAMMED AMOUNT ($1000) BY FUND, BY FY

WORK ITEM #	US# SR#	PROJECT DESCRIPTION	LENGTH	TYPE WORK	FISCAL 1983	FISCAL 1984	FISCAL 1985	FISCAL 1986	FISCAL 1987	BEGN CST
518961	A1A	SR A1A PT.ORANGE CSY FM-SR 5 TO-S. ATLANTIC AVE BR=01#518855	1.2 MI URBAN	ADD LANES		PE 100 MDB2				FY91
518962	17 15	SR 15/600 FM-INT. GOLF CLUB DR. TO-(EXT SB LT TN LN) PE=99005-1507	0.2 MI URBAN	TRAF OPS	CST 33 DTO					FY83
518978	1 5	SR 5 HOLLY HILL FM-MASON AVE TO-HAND AVE PE=99005-1507, UT=6510(NO PH)	3.5 MI URBAN	TRAF OPS	CST 293 CP CEI 53 CP					FY83
518980	17 15	SR 15/600 DELAND FM-BERESFORD AVE TO-PLYMOUTH AVE PE=99005-1507,UTIL=6527(NO PH)	2.0 MI URBAN	TRAF OPS			CST 242 CP CEI 44 CP			FY85
518983	400	SR 400 BEVILLE FM-BEGIN CURB & GUTTER TO-US 1	2.2 MI URBAN	RESURFACE		PE 25 CP	CST 844 CP CEI 118 CP			FY85
518985	15A	SR 15A DELAND FM-INT WINNEMISSETT AVE TO-(RET.WALL NW CORNER) PE=99005-1507	0.3 MI URBAN	TRAF OPS	CST 10 DTO					FY83
518987	1 5	SR 5 FM-SR 400(BEVILLE RD) TO-SR 600 G/W 518988	2.1 MI URBAN	TRAF OPS		PE 10 CP	CST 200 CP CEI 36 CP			FY85
518988	1 5	SR 5 FM-SR 600 TO-MADISON AVE G/W 518987	1.0 MI URBAN	TRAF OPS		PE 10 CP	CST 100 CP CEI 20 CP			FY85
518990	44	SR 44 DELAND FM-STONE ST TO-AMELIA AVE	1.0 MI URBAN	TRAF OPS		PE 10 CP	CST 110 CP CEI 22 CP			FY85

Figure 5

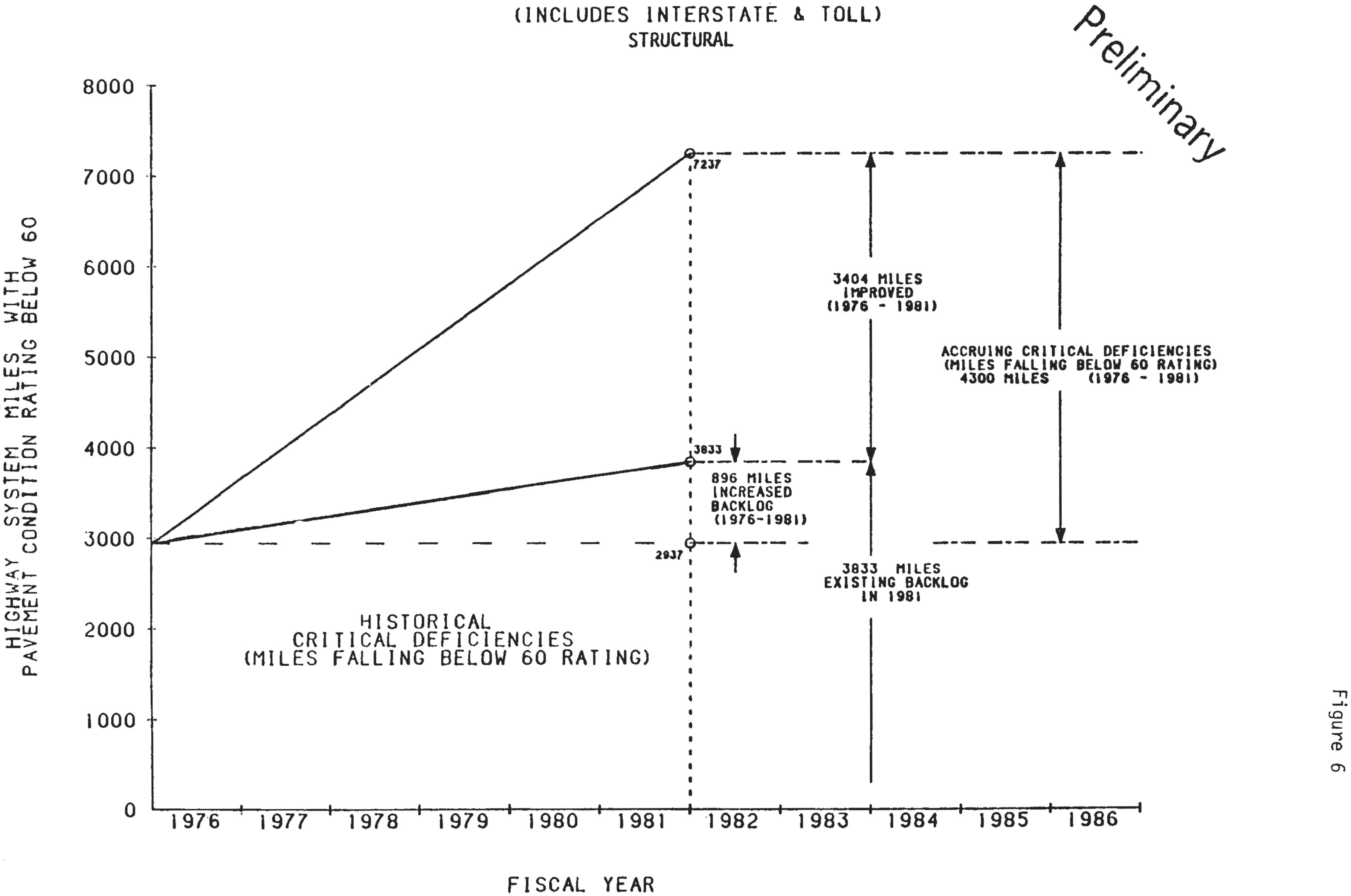
safety, operational, and other factors are considered in arriving at the 5-Year Program, the PM data plays a major role in identifying resurfacing projects. The FDOT currently uses a projected basic rating of 60 as a value to trigger programming resurfacing projects in the 5-Year Plan.

In addition to its planning applications, the PM program is used in a network analysis of the operational and structural conditions of the State highway system. As the responsible unit for this analysis, the Division of Transportation Planning prepares a comprehensive set of analytical charts, including diagrams showing historical trends in pavement deterioration (see Figure 6) and bar charts illustrating the distribution of lane miles by pavement condition rating (see Figure 7). These diagrams and charts are used for top management's understanding and as input in their decisionmaking. In addition, the information on these charts is also packaged for presentations to the State legislature. This Florida network analysis has been successfully packaged to convince the legislature to appropriate additional funds for resurfacing.

DATE. 3/12/81

STATE HIGHWAY SYSTEM

(INCLUDES INTERSTATE & TOLL)
STRUCTURAL



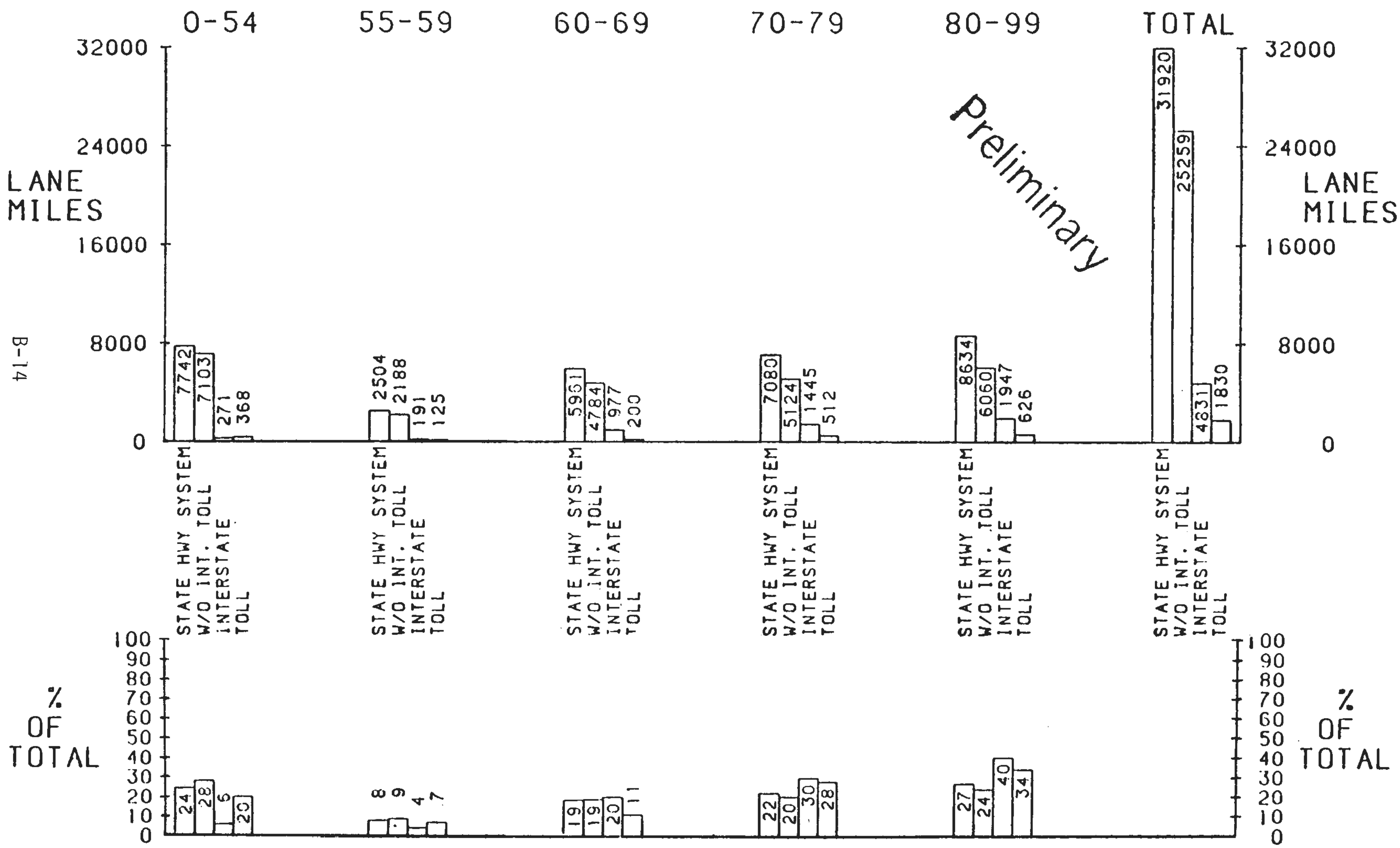
B-13

Figure 6

OFFICE OF TRANSPORTATION PRIORITIES

DATE. 3/12/81

1981 STRUCTURAL RATINGS FOR THE STATE HIGHWAY SYSTEM



RATINGS BASED ON 1980 ROAD INVENTORY AND 1980 PAVEMENT CONDITION

OTP

Figure 7

Pavement Management in Idaho

I. Introduction

In 1977, the Idaho Transportation Department (ITD) began a review of existing pavement management (PM) programs in order to adapt one to Idaho's needs. The following year, the Utah Pavement Performance Management Information System (PPMIS) was acquired and made operational on ITD's central IBM 370 computer. Since 1978, the PPMIS has been adapted to conditions in Idaho, tested, and refined on a phased basis, primarily by consultant contract. The principal consultant has been Pavement Management Systems International, Inc., of Ontario, Canada. Development to this point has resulted in methodologies for pavement condition monitoring, ranking of highway sections based on condition, and prediction of pavement performance. Computer models are used to generate a ranked set of needs at the network level, and to assist in pavement overlay design at the project level. Development is expected to conclude with implementation of a proposed economic analysis/optimization program.

The following sections will discuss the collection of pavement condition and other data, its analysis to aid in project and network decisions, and the proposed further development of Idaho's PM program.

II. Data Collection

A. State Highway System

The Idaho State Highway System consists of approximately 5,000 miles of paved or oiled highways, including about 612 miles of Interstate. For PM and other purposes, the system has been divided into relatively stable sections up to 9 miles in length, with the following breakpoints:

1. All Federal-aid urban boundaries.
2. State lines.
3. County lines.
4. Intersections or interchanges where major changes in traffic volumes occur.
5. All Federal-aid system changes (FAI, FAP, FAS, FAU).
6. Jurisdictional boundaries.
7. Locations where there are changes in the physical characteristics of the roadway.
8. Functional classification changes.

B. Pavement Condition

Pavement condition data is one of the chief inventory components that feed into the ITD Planning and Budget Cycle. Survey crews operate from the Headquarters Materials Lab in Boise from April to November. The entire 5,000 mile State highway network has undergone one complete survey. Subsequent condition surveys will be conducted on 2 or 3-year cycles, depending on which is shown by experience to be more practical and effective. Two-lane roads are monitored in one direction and four-lane roads are monitored in both directions.

Individual pavement condition data elements are collected as follows:

1. Structure and Surface Distress

   Structural measurements are taken as deflections using a Dynaflect. For purposes of the network survey, two deflections per mile are taken; for pavement overlay design purposes on specified highway sections (see Sec.III.B.), ten tests per mile are made. This additional testing occurs on sections already on the approved construction program, and is generally worked into the network survey schedule.

   Pavement surface distress is inventoried concurrently with deflection testing. The initial 1/10 of each centerline mile is observed for extent of cracking, using a set of reference photographs developed by Arizona. Crack type and severity are not measured, nor is any other type of surface distress. More detailed pavement distress surveys may be undertaken on designated highway sections for project design purposes.

   Crew size for the combined structural/surface distress survey is two individuals, with additional personnel providing traffic control measures. In 1981, the combined deflection and distress survey covered 2,400 miles of highway. Average production rate was 6.4 tests/hour at an average total cost of $33.51/mile.

2. Ride Quality

   Ride measurements are taken by a Cox ultrasonic (PCA type) roadmeter. Ride roughness is measured continuously in the travel lane and summarized for each mile. Data is recorded as counts per mile, and then converted to Present Serviceability Index (PSI) based on relationships developed from periodic panel rating sessions conducted on Idaho roads covering a wide range of roughness characteristics.

   The ride survey is conducted separately from the structural/surface distress survey, utilizing a crew of two. In 1981, 1,496 miles of Idaho highway were surveyed for ride. The production rate was 14.2 miles/hour at an average cost of $1.98/mile.

3. Skid

   Skid (surface friction) data is currently obtained with a locked-wheel skid trailer. One test is conducted at each milepost in the left wheel path. ITD has also obtained a MuMeter, and is attempting to correlate readings between the two devices. The MuMeter has a cost advantage over the locked-wheel (roughly $70,000 vs. $120,000) and can interface directly with the onboard minicomputer (see Sec.II.C. below). The locked-wheel trailer requires additional equipment to achieve the same degree of automation.

   In 1981, skid testing took place on 1,308 miles of highway. The two-person crew production rate was 10.5 miles/hour at an average cost of $3.90/mile.

C. Other Inventory Data

Other major system inventory data elements are collected for network programming purposes. Among these are the following:

1. Traffic Data

Data pertaining to traffic volumes and speeds, as well as vehicle size (i.e., number of vehicles more than 45 feet in length), is collected by a series of Telac Data Recorders spotted throughout the State. Each unit stores traffic data on magnetic tape, and "calls" it into the ITD computer on a daily basis. There are currently 28 Telacs in operation, with 20 more scheduled for installation in 1982.

2. Vehicle Weight Data

With the acquisition of portable weigh-in-motion equipment, ITD has the capability to collect vehicle weight data at any location throughout the State. PAT portable weigh plates (capable of weighing vehicles traveling up to 15 mph) may be transported by a 1-1/2 ton van. The van is converted to house micro computers to which the PAT plates can be connected. The van may also be hooked up to PAT weigh pads which are permanently installed in the roadway surface. In this mode, weights can be measured at speeds up to 80 mph. Additional weight data is obtained at permanent Radian weigh-in-motion facilities located at four ports-of-entry.

3. Photolog and Geometric Data

The ITD has acquired a TechWest II van for logging a variety of roadway features at driving speeds. Among the data elements that may be measured are cross slope, grade, horizontal curvature, altitude, bearing, and distance.

D. Automated Data Collection

Due to limited staff size, the ITD has attempted to minimize the manual data handling requirements at every step of the network inventory. This is accomplished by collecting data on magnetic tape and processing it through a Datapoint computer into the IBM 370 computer. ITD uses Hewlett Packard HP-85 Micro Computers on its pavement condition survey equipment to achieve this automation. As a result, no manual keypunching forms are required. The HP-85s store the raw data, such as PCA counts-per-mile. The keyboard is used to input supplementary and locator data (e.g., date, milepost, temperature, etc.) directly onto the tape. Pavement distress data is also keyed into the HP-85 during the Dynaflect survey.

E. Data Base Management

The data used in the PM program is stored in a number of separate data files. The basic pavement condition data is kept in one file. Other key data elements are contained in the Roadway Environmental Data Base (REDB), which consists of two sets of files: Milepost and Coded Segment (MACS) files, and Roadway Segment (ROSE) files. The MACS system cross-references such categories of roadway data as Federal-aid system, functional class, etc. It eliminates the need for each individual data file to carry identical information regarding the roads. The ROSE is a user system that directly accesses the MACS files and other ROSE files (e.g., traffic volume) in producing various reports. The ROSE is generally used as a retrieval system to access all PM data. This capability is currently limited to the Headquarters office; at present, the districts cannot access PM data through their terminals.

Two other files are used as repositories for PM data. The HWYNEEDS model (see Sec.III.A.1.) contains such data as truck weights. In addition, a climatological data base has been built to supply temperature data for correcting Dynaflect readings.

The REDB is used to establish segment codes for purposes of the automated Maintenance Management System (MMS) as well as for the PM program. The MMS is a data base that can provide cost data (labor, equipment, materials) for both contract and State force work on a centerline mile-by-mile basis. The system contains data for 55 maintenance activities plus betterment activities.

III. Data Analysis

A. Network-Level Analysis

The various data discussed in Section II. provide input to a number of evaluation models used to assist in making program decisions. The PPMIS adapted from Utah contained evaluation models for asphalt pavements only. For these pavements, remaining structural life is estimated using relationships developed from the AASHO road tests, together with additional field work done in Utah. Further modifications were made for Idaho by Pavement Management Systems International, Inc. Programs for the remaining structural life of PCC pavement were developed by Austin Research Engineers. These are based on mechanistic considerations, including layer moduli and critical stresses.

The ratings for structure, distress, and roughness are converted to an index ranging from 0 (very poor) to 5 (very good). The basic monitoring data for each roadway section appears on the individual section printout (Figure 1). All monitoring data for the section appears on this printout, together with estimates of remaining service life. The detailed surface distress format appearing on this sheet has been simplified to reflect the fact that routine distress evaluation consists of recording the extent of cracking only. The detailed format was used on the initial survey of the Interstate system, and is still available for detailed distress analysis for project design purposes.

```
* IDAHO PPMIS (2)  MACS: 08070A E  42.000  DIST: 3  COUNTY: ADA                  1  CITY: MERIDIAN          1070 FAI-80        3/28/81      *
* IDAHO ROUTE:  80  TEN MILE RD                 MILEPOST:  42.000      EAST MERIDIAN IC                MILEPOST:  44.348  LENGTH:    2.35*
* MATERIAL: PLANT MIX SEAL COAT  BIT. SF. (PMSC)  MAINTENANCE SHED:           WIDTH: 12.00                                              *
* YEARLY INCREASE IN 18KIP LOADS:     3.9%      PRESENT 18KIP LOADS:        0.56535E+06       T. S. I. 2.5                               *
*-----------------------------------------------------------------------------------------------------------------------------------------*
*                                             ***DYNAFLECT READINGS AND SUMMARY***                                                       *
*  DATE    9/10/79  HR 14 MIN  1      TEMPERATURES: AIR  72.0 SURFACE  97.7 PAVEMENT    N/A                                               *
*  WHEEL PATH  OSWP       LANE EB-1    LAST REVISION 091079                                                                               *
*                                                                                        100 +                                           *
*  TEST        SNSR  SNSR  SNSR  SNSR  SNSR       SCI   BCI   REMAINING SERVICE       %      I                                           *
*   NO           1     2     3     4     5                    LIFE (STRUCTURAL)          80 +                                           *
*                                                             18K LOADS YEARS        O      I                       55                   *
*      1       0.55  0.36  0.20  0.12  0.04       0.19  0.08  6.269E+06    9         F  60 +                       **                   *
*      2       0.58  0.39  0.23  0.13  0.09       0.19  0.04  5.246E+06   10                I                       **                   *
*      3       0.63  0.42  0.25  0.15  0.11       0.21  0.04  3.931E+06    9         T  40 +                       **                   *
*      4       0.64  0.45  0.28  0.16  0.11       0.20  0.06  3.780E+06    9         E      I             11 11 11 ** 11                 *
*      5       0.63  0.43  0.25  0.15  0.09       0.20  0.06  3.931E+06    9         S  20 +             ** ** ** ** **                 *
*      6       0.65  0.47  0.31  0.20  0.13       0.18  0.07  3.637E+06    9         T      I             ** ** ** ** **                 *
*      7       0.84  0.63  0.40  0.24  0.14       0.20  0.10  1.674E+06    6         S   0 +--+--+--+--+--+--+--+--+--+--+--+            *
*      8       0.74  0.53  0.32  0.18  0.10       0.21  0.08  2.449E+06    8                0  1  2  3  4  5  6  7  8  9 10 >10          *
*      9       0.78  0.55  0.33  0.20  0.12       0.24  0.07  2.078E+06    7                                                             *
*                                                                                          REMAINING STRUCTURAL LIFE (YEARS)             *
* MEAN         0.67  0.47  0.29  0.17  0.10       0.20  0.07  3.666E+06  8.4                                                             *
* STD DEV.     0.10  0.09  0.06  0.04  0.03       0.02  0.02  1.475E+06  1.2                                                             *
* MEAN - SD    0.58  0.38  0.23  0.13  0.07       0.18  0.05  2.191E+06  7.2                                                             *
* MEAN + SD    0.77  0.56  0.35  0.20  0.13       0.22  0.09  5.141E+06  9.7                                                             *
* OUTLIERS *******************************                                                                                               *
*                                                                                                                                        *
*                     ***(FOR A DESIGN PERIOD OF 10 YEARS, DMDREQ IS  0.60 )***                                                          *
*----------------------------------------------------------------------------------------------------------------------------------------*
*        ***CONDITION SUMMARY***          *                 ***SERVICEABILITY SUMMARY***                    *  ***SKIDMETER SUMMARY***   *
* AVERAGE CONDITIONS                      * DATE   9/10/79                                                  * DATA IS SPEED-COMPENSATED *
* SURFACE WEAR   5.0  POPOUTS        N/A  * TEST       SERV LIFE    100 +                                   *   TEST NO.    SKID INDEX  *
* WEATHERING     5.0  UNIFORMITY     N/A  *  NO.  PSI   REMAIN   %      I                                   *      1            37      *
* RUT DEPTH      0.0                      *  1    4.0     11        80 +                          66        *      2            38      *
*                                         *  2    3.9     10     O      I                          **        *      3            37      *
* AVG. CRACKING AND PATCHING              *  3    3.9     10     F  60 +                          **        *   MEAN           37.3     *
*  ( PER 1000. SQ. FT.)                   * MEAN  3.9    10.3           I                          ** 33     *   S.D.            0.6     *
* TRANSVERSE        (FT.)        0.       * S.D.  0.0     0.6    T  40 +                          ** **     *                           *
* LONGITUDINAL      (FT.)        0.       *                      E      I                          ** **     *                           *
* MAP             (SQ.FT.)       0.       *                      S  20 +                          ** **     *                           *
* ALLIGATOR       (SQ.FT.)      N/A       *                      T      I                          ** **     *                           *
* PATCH-SKIN      (SQ.FT.)       0.       *                      S   0 +--+--+--+--+--+--+--+--+--+--+--+  *                           *
* PATCH-DEEP      (SQ.FT.)       0.       *                            0  1  2  3  4  5  6  7  8  9 10 >10 *                           *
* AVG CONDITION OF TRANS,LONG CRACKS      *                                                                 *                           *
* OPENING          5.0    ABRASION   N/A  *                            REMAINING STRUCTURAL LIFE (YEARS)    *                           *
* MULTIPLICITY     5.0                    *                            BASED ON PSI                         *                           *
*                                         *                                                                 *                           *
```

Figure 1

Individual Section Printout

The sections are ranked on the basis of a final index, which is a weighted average of the structural (deflection), cracking (distress), and PSI (roughness) indices. The final index (FI) is calculated as follows:

$$FI = 0.47\ (F_1\ (PSI)^{1.5} + F_2(SI)^{1.5} + F_3(DI)^{1.5})$$

where: PSI = Present Serviceability Index
SI = Structural Index
DI = Distress Index, and
F_1, F_2, F_3 = weighting functions from table below (the system includes alternative tables for the cases where only one or two of the indices are available)

WEIGHTING FUNCTIONS USED TO ESTABLISH FINAL INDEX[a]

FUNCTIONAL CLASS	LOW AADT[b]			MEDIUM AADT			HIGH AADT		
	F1	F2	F3	F1	F2	F3	F1	F2	F3
1	0.45	0.25	0.30	0.50	0.20	0.30	0.55	0.15	0.30
2	0.40	0.30	0.30	0.45	0.25	0.30	0.50	0.20	0.30
3	0.35	0.35	0.30	0.40	0.30	0.30	0.45	0.25	0.30
4	0.30	0.40	0.30	0.35	0.35	0.30	0.40	0.30	0.30
5	0.25	0.45	0.30	0.20	0.40	0.30	0.35	0.35	0.30

[a]If speed limit is greater than 40 mph, F1 is increased by 0.05 and F2 is reduced by 0.05. If percent heavy trucks is greater than 5%, F2 is increased by 0.1, and F1 and F3 are reduced by 0.05.

[b]Annual average daily traffic.

A final summary table (Figure 2) lists all section average indices for all sections.

Figure 3 summarizes this information in the form of a histogram showing what percentages of the total mileage fall into various categories of distress and severity level. A similar representation is available for surface friction (skid rating). Currently, skid rating is provided on an information-only basis, and is not included in the network programming models described in Sec.IV. below.

Figure 4 lists all sections ranked on the basis of structural adequacy; similar reports are available for cracking, PSI, and surface friction.

The computer programs in the Idaho PPMIS will run with one index or any combination of indices. This represents a refinement over the Utah system on which Idaho's system is based. This is potentially significant to other States that may wish to adapt these programs, but may not possess the capability to collect all the data collected by Idaho.

Output from the PPMIS models is fed into two FHWA-sponsored computer models--Highway Needs (HWYNEEDS) and Highway Investment Analysis Package (HIAP)--to compare proposals on the basis of user benefits. The HWYNEEDS and HIAP packages were adapted to Idaho's needs under contract by Boise State University. Each is discussed below.

FINAL SUMMARY TABLE OF PAVEMENT EVALUATION FOR DISTRICT NO. 3

STRUCT=STRUCTURAL INDEX

CRACK=CRACKING INDEX

PSI=PSI INDEX

AVG FRIC=AVERAGE FRICTION INDEX

	COUNTY	ROAD SEGMENT CODE	LENGTH	BEGINNING TERMINI	START	ENDING TERMINI	END	FINAL INDEX	RANKING OF STRUCTURE, FRICTION CRACKING & PSI: STRUCT	CRACK	PSI	AVG FRIC
1	75	08070A	4.30	CL BLACK CANYON IC	12.90	CANYON CO. LINE	17.20	2.3	2.0	2.3	2.6	40.0
2	27	08070A	0.27	10TH STREET	27.62	MP 27.893	27.89	2.6	3.0	2.7	2.2	33.0
3	39	08070B	2.55	MP 82.300	82.30	MAINT. CROSSING	79.75	2.7	3.0	3.1	2.3	44.0
4	27	08070A	0.38	5TH AVE	27.25	10TH STREET	27.62	2.8	1.5	3.5	3.3	32.0
5	39	08070B	7.18	MAINT. CROSSING	79.75	ADA CO. LINE	72.57	2.8	3.5	2.9	2.3	43.0
6	1	08070A	0.79	JCT I-180	49.35	OVERLAND RD	50.14	2.8	2.0	4.1	2.6	37.0
7	1	08070B	0.51	BROADWAY AVE	54.28	BOISE EUL	54.79	2.8	2.5	4.1	2.3	31.0
8	1	08070A	1.51	ORCHARD AVE	51.81	VISTA AVE	53.32	2.9	2.3	4.1	2.5	35.0
9	1	08070A	0.95	VISTA AVE	53.32	BROADWAY AVE	54.28	2.9	2.3	4.1	2.6	35.0
10	75	08070A	4.30	CANYON CO. LINE	17.20	CL BLACK CANYON IC	12.90	2.9	3.0	2.5	3.2	43.0
11	1	08070B	5.69	MP 59.890	59.89	CMP DRAINPIPE	65.58	3.0	1.0	3.6	3.9	42.0
12	27	08070A	0.40	MP 27.893	27.89	MP 28.294	28.29	3.0	3.0	2.9	3.0	32.0
13	1	08070A	1.67	OVERLAND RD	50.14	ORCHARD AVE	51.81	3.0	2.5	4.1	2.6	37.0
14	75	08070A	6.93	CL BLACK CANYON IC	12.90	BOX CULVERT	5.97	3.0	2.5	3.4	3.2	43.0
15	1	08070B	3.48	BOISE EUL	57.75	BROADWAY AVE	54.28	3.1	2.5	4.1	2.8	36.0
16	27	08070A	0.27	MP 27.893	27.89	10TH STREET	27.62	3.1	3.0	4.1	2.5	39.0
17	39	08070B	6.58	MAINT. CROSSING	109.25	MAINT. CROSSING	102.67	3.1	3.8	3.3	2.6	39.0
18	1	08070A	2.30	BOISE NWUL	47.02	JCT I-180	49.35	3.2	2.5	4.0	3.1	37.0
19	75	08070A	6.93	BOX CULVERT	5.97	CL BLACK CANYON IC	12.90	3.2	3.0	3.4	3.2	40.0
20	27	08070A	0.34	BOISE AVE	26.90	5TH AVE	27.25	3.2	3.0	3.4	3.2	36.0
21	1	08070A	1.51	VISTA AVE	53.32	ORCHARD AVE	51.81	3.2	2.5	4.1	3.1	35.0
22	1	08070A	0.96	BROADWAY AVE	54.28	VISTA AVE	53.32	3.3	2.8	4.1	3.1	34.0
23	1	08070A	1.67	ORCHARD AVE	51.81	OVERLAND RD	50.14	3.3	2.8	4.1	3.1	35.0
24	1	08070A	2.05	MERIDIAN EUL	44.96	BOISE NWUL	47.02	3.3	2.8	4.1	3.1	37.0
25	1	18070A	1.09	FRANKLIN ROAD	1.09	JCT I-80	0.00	3.3	3.3	4.1	2.8	33.0
26	1	08070B	2.14	MP 59.890	59.89	BOISE EUL	57.75	3.3	3.3	4.1	2.8	36.0
27	1	08070A	0.61	MERIDIAN EUL	44.96	EAST MERIDIAN IC	44.35	3.3	2.8	4.1	3.2	40.0
28	1	08070A	2.05	BOISE NUL	47.02	MERIDIAN EUL	44.96	3.3	2.8	4.1	3.2	36.0
29	1	18070A	1.63	CURTIS ROAD	2.72	FRANKLIN ROAD	1.09	3.3	3.0	4.1	3.1	31.0
30	75	08070A	5.97	BOX CULVERT	5.97	OREGON STATE LINE	0.00	3.3	3.5	3.4	3.2	45.0
31	1	08070A	0.79	OVERLAND RD	50.14	JCT I-180	49.35	3.4	3.3	4.1	3.0	35.0
32	1	08070A	2.34	JCT I-180	49.35	BOISE NUL	47.02	3.4	3.0	4.1	3.2	34.0
33	39	08070B	5.23	MAINT. CROSSING	109.25	NEAR HAMMETT	114.49	3.4	3.8	3.8	2.9	45.0
34	1	08070B	2.14	BOISE EUL	57.79	MP 59.890	59.89	3.4	4.3	4.1	2.4	31.0
35	1	08070B	6.99	ELMORE CO. LINE	72.57	CMP DRAINPIPE	65.58	3.4	3.0	3.3	3.8	42.0
36	75	08070A	5.97	OREGON STATE LINE	0.00	BOX CULVERT	5.97	3.4	4.0	3.3	3.1	41.0
37	1	18070A	0.50	ORCHARD AVE	3.22	CURTIS ROAD	2.72	3.4	2.8	4.1	3.3	34.0

CONTINUED...

Figure 2

SUMMARY DISTRIBUTIONS
OF ROAD MILES BY
EVALUATION INDICES FOR
DISTRICT NO. 3

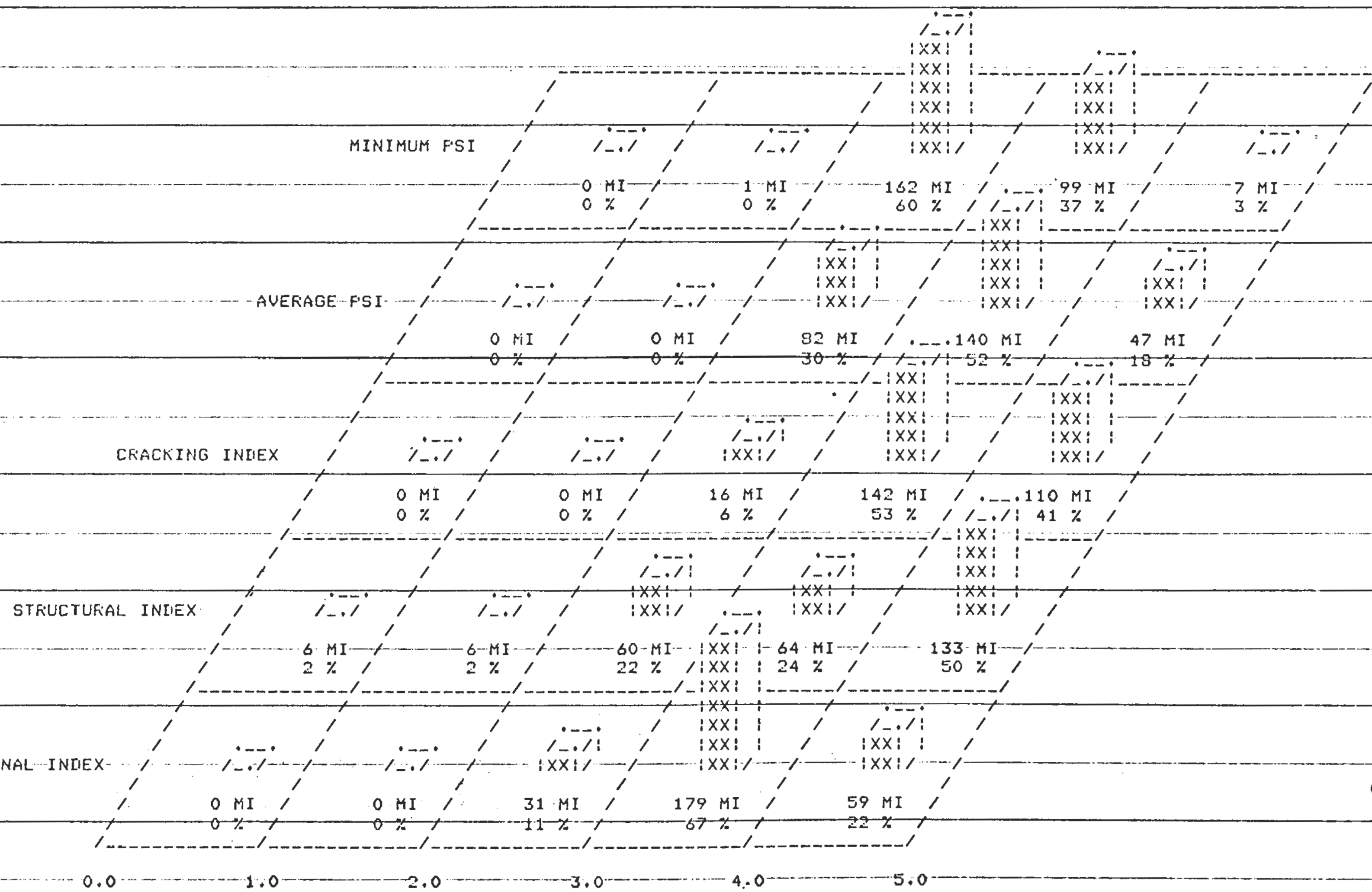


Figure 3

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*   ** SUMMARY **   *

*   DISTRICT NO. 3   *

--*-*-*-*-*-*-*-*-*

STRUCTURAL ANALYSIS

ORDER	ROAD SEGMENT CODE	COUNTY	LENGTH	BEGINNING TERMINI	START	ENDING TERMINI	END	INDEX	YEAR
1	08070B	1	5.69	MP 59.890	59.89	CMP DRAINPIPE	65.58	1.0	79
2	08070A	27	0.40	CALDWELL UL	25.94	MP 26.343	26.34	1.5	79
3	08070A	27	0.38	5TH AVE	27.25	10TH STREET	27.62	1.5	79
4	08070A	75	4.30	CL BLACK CANYON IC	12.90	CANYON CO. LINE	17.20	2.0	79
5	08070A	1	0.79	JCT I-180	49.35	OVERLAND RD	50.14	2.0	79
6	08070A	1	1.51	ORCHARD AVE	51.81	VISTA AVE	53.32	2.2	79
7	08070A	1	0.95	VISTA AVE	53.32	BROADWAY AVE	54.28	2.2	79
8	08070A	1	2.30	BOISE NWUL	47.02	JCT I-180	49.35	2.5	79
9	08070A	1	1.67	OVERLAND RD	50.14	ORCHARD AVE	51.81	2.5	79
10	08070A	75	6.93	CL BLACK CANYON IC	12.90	BOX CULVERT	5.97	2.5	79
11	08070A	1	1.51	VISTA AVE	53.32	ORCHARD AVE	51.81	2.5	79
12	08070B	1	0.51	BROADWAY AVE	54.28	BOISE EUL	54.79	2.5	79
13	08070B	1	3.48	BOISE EUL	57.75	BROADWAY AVE	54.28	2.5	79
14	08070A	1	2.05	MERIDIAN EUL	44.96	BOISE NWUL	47.02	2.7	79
15	08070A	1	0.61	MERIDIAN EUL	44.96	EAST MERIDIAN IC	44.35	2.7	79
16	08070A	1	2.05	BOISE NUL	47.02	MERIDIAN EUL	44.96	2.7	79
17	08070A	1	1.67	ORCHARD AVE	51.81	OVERLAND RD	50.14	2.7	79
18	08070A	1	0.96	BROADWAY AVE	54.28	VISTA AVE	53.32	2.7	79
19	18070A	1	0.50	ORCHARD AVE	3.22	CURTIS ROAD	2.72	2.7	79
20	08070A	75	6.93	BOX CULVERT	5.97	CL BLACK CANYON IC	12.90	3.0	79
21	08070A	27	0.34	BOISE AVE	26.90	5TH AVE	27.25	3.0	79
22	08070A	27	0.27	10TH STREET	27.62	MP 27.893	27.89	3.0	79
23	08070A	27	0.40	MP 27.893	27.89	MP 28.294	28.29	3.0	79
24	08070A	75	4.30	CANYON CO. LINE	17.20	CL BLACK CANYON IC	12.90	3.0	79
25	08070A	27	7.64	IC SH 44	24.84	CANYON CO. LINE	17.20	3.0	79
26	08070A	27	0.27	MP 27.893	27.89	10TH STREET	27.62	3.0	79
27	08070A	1	2.34	JCT I-180	49.35	BOISE NUL	47.02	3.0	79
28	08070B	1	6.99	ELMORE CO. LINE	72.57	CMP DRAINPIPE	65.58	3.0	79
29	08070B	39	2.55	MP 82.300	82.30	MAINT. CROSSING	79.75	3.0	79
30	18070A	1	1.63	CURTIS ROAD	2.72	FRANKLIN ROAD	1.09	3.0	79
31	08070A	1	0.79	OVERLAND RD	50.14	JCT I-180	49.35	3.2	79
32	08070B	1	2.14	MP 59.890	59.89	BOISE EUL	57.75	3.2	79
33	18070A	1	1.63	FRANKLIN ROAD	1.09	CURTIS ROAD	2.72	3.2	79
34	18070A	1	1.09	FRANKLIN ROAD	1.09	JCT I-80	0.00	3.2	79
35	08070A	27	7.64	PAYETTE CO. LINE	17.20	IC SH 44	24.84	3.5	79
36	08070A	27	1.11	IC SH 44	24.84	CALDWELL WUL	25.94	3.5	79
37	08070A	1	0.61	EAST MERIDIAN IC	44.35	MERIDIAN EUL	44.96	3.5	79
38	08070A	75	5.97	BOX CULVERT	5.97	OREGON STATE LINE	0.00	3.5	79
39	08070A	27	0.34	MP 26.343	26.34	CALDWELL UL	25.99	3.5	79
40	08070A	27	0.34	5TH AVE	27.25	BOISE AVE	26.90	3.5	79
41	08070A	27	0.40	MP 28.294	28.29	MP 27.893	27.89	3.5	79
42	08070B	39	7.18	MAINT. CROSSING	79.75	ADA CO. LINE	72.57	3.5	79
43	18070A	1	0.50	CURTIS ROAD	2.72	ORCHARD AVE	3.22	3.5	79
44	18070A	1	0.36	ORCHARD AVE	3.22	JCT US 20	3.62	3.5	79
45	08070B	39	5.23	MAINT. CROSSING	109.25	NEAR HAMMETT	114.49	3.7	79

CONTINUED...

Figure 4

1. HWYNEEDS

The HWYNEEDS model is designed to assess deficiencies in highway sections, and generate recommended improvements, along with associated costs. In Idaho, the following data is input to the model:

a. PPMIS - distress index (non-Interstate), final index (Interstate), foundation rating as the base curvature index (BCI) from Dynaflect readings (both Interstate and non-Interstate).

b. Roadway Environmental Data Base (REDB) - traffic volumes (current and projected), mileposts, etc.

c. TechWest II Van - geometric and photolog data (cross slope, grade, horizontal curvature, etc.).

Based on this data, as well as such additional information as design standards, the model generates recommended improvements, along with associated costs, in the following categories: new construction; reconstruction; major widening; minor widening; resurfacing (with and without shoulder improvements); bridges; and railroad crossings. This information can be cross-referenced by Federal-aid system, functional class, or type of improvement, on either a Statewide or district basis. Through an interface program developed for Idaho, the recommended improvements and associated costs are input directly to the HIAP model.

2. HIAP

The HIAP is a computerized evaluation and investment programming model. It analyzes individual roadway sections and limited networks of sections by their physical, traffic, and operational characteristics. Estimates of both highway user (e.g., vehicle operating costs, travel times, accidents) and non-user impacts (e.g., noise and pollution levels), as developed specifically for conditions in Idaho, are produced.

The HIAP package is used in Idaho to perform limited economic analysis, producing a list of projects ranked by benefit-cost. Budget parameters constrained by Federal-aid system, functional class, or type of improvement may be input, or the programs may be run assuming an unconstrained budget. Economic analysis can be performed Statewide or by district. The analysis is performed at two levels: the micro-analysis model compares the benefit-cost of alternative improvements to a single project, and the macro-analysis model compares the benefit-cost of each improvement project in competition with all others.

B. Project-Level Analysis

The Idaho PPMIS provides an automated Pavement Overlay Design (POD) model for individual project analysis. The computer programs for overlay design are based on deflection data (10 deflections per mile). The program produces a report as depicted in Figure 5. The analysis computes the overlay thickness (up to six inches) required at each test location. This information is used by district personnel in combination with other evaluations (e.g., borings) to arrive at the proper overlay design.

SECTION : I-84

MILEPOST	DYNAFLECT SENSOR READINGS (TEMP. CORRECTED) NO.1	NO.2	NO.3	NO.4	NO.5	SCI	BCI	SPD	YRS TO FAIL	OVERLAY THICKNESS	PAVEMENT SYSTEM CONDITION
3.60	0.70	0.45	0.24	0.15	0.10	0.25	0.04	46.8	10	3.16	SURFACE WEAK
3.70	0.82	0.51	0.27	0.15	0.09	0.31	0.06	44.9	8	3.88	SYSTEM WEAK
3.80	0.89	0.57	0.29	0.15	0.09	0.32	0.06	44.7	7	4.28	SURFACE WEAK
3.90	0.51	0.35	0.21	0.14	0.10	0.16	0.04	51.3	14	1.98	SURFACE WEAK
4.00	0.36	0.25	0.16	0.12	0.09	0.11	0.03	54.3	16	0.00	BASE MARGINAL
4.10	0.55	0.36	0.21	0.13	0.09	0.19	0.04	48.4	13	2.22	SURFACE WEAK
4.20	0.62	0.40	0.23	0.15	0.10	0.22	0.04	48.7	11	2.65	SURFACE WEAK
4.30	0.54	0.34	0.19	0.11	0.07	0.20	0.04	46.4	14	2.12	SYSTEM WEAK
4.40	0.54	0.34	0.19	0.10	0.07	0.19	0.04	46.1	14	2.12	SYSTEM WEAK
4.50	0.60	0.38	0.19	0.11	0.07	0.22	0.04	45.2	11	2.55	SURFACE WEAK

C-11

SUMMARY FOR SEGMENT NO. 5 OF THIS SECTION

	NO.1	NO.2	NO.3	NO.4	NO.5	SCI	BCI	SPD	OVERLAY THICKNESS
MEAN VALUE	0.61	0.39	0.22	0.13	0.09	0.22	0.04	47.7	2.50
MINIMUM	0.36	0.25	0.16	0.10	0.07	0.11	0.03	44.7	0.00
MAXIMUM	0.89	0.57	0.29	0.15	0.10	0.32	0.06	54.3	4.28
STD. DEVIATION	0.15	0.09	0.04	0.02	0.01	0.06	0.01	3.1	1.17
VALUE REQ'D FOR 15 YRS ADEGUACY	0.50		AVERAGE REQUIRED VALUE			0.18	0.04		

Figure 5

IV. Network Programming

The process of programming highway projects, including 4R projects, begins in each of ITD's six highway districts. The HIAP-generated list of projects, ranked in each district by benefit-cost, is reviewed along with other PPMIS output by district personnel. Based on these documents, as well as other onsite evaluations, each district proposes a 10-year developmental program. Each district's program is reviewed by the Central Office's program development staff. The program is assembled, and individual projects on it prioritized, within the broad framework of such ITD policies as increasing safety, conserving energy, stretching available funds to preserve the existing system, etc. Once the 10-year program is agreed upon between the Central and district offices, it is submitted to the three-member Idaho Transportation Board for formal approval of a 6-year program. From the 6-year program, a 3-year construction plan and a 1-year construction schedule are prepared.

The Central Office allocates funds to the districts according to the following formula:

- 1/3 - lane miles by Federal-aid system
- 1/3 - vehicle miles of travel by Federal-aid system
- 1/3 - highway needs as generated by the HWYNEEDS model

V. Proposed System

A. Maintenance

At the present time, Idaho's automated Maintenance Management System has not been formally integrated into the PPMIS. The data files are being linked to the Department's Milepost and Coded Segment (MACS) System so that the information can be directly accessed by various users throughout the Department. In the future, it is planned to use per-mile maintenance costs in the highway needs and pavement performance evaluation models. Intensity of work activities, such as crack sealing, seal coating, etc. will be examined for potential use.

B. Economic Analysis/Optimization

Sometime in calendar year 1982, ITD proposes to let a contract for the development of what it considers the final phase of a comprehensive pavement management system (PMS): an economic analysis/optimization program. Under this contract, an existing economic optimization program will be adapted to accept input from the pavement condition summary programs. The result will be a system which economically compares pavement rehabilitation projects as well as within-project alternatives over a programming period.

The proposed program is intended to be more powerful than the current HWYNEEDS/HIAP models which provide limited economic analysis and no optimization capability. These two models emphasize operational deficiencies such as alignment, capacity, and lane width. In their treatment of serviceability-related rehabilitation, they are less detailed than the program proposed by ITD. The program's output, however, will be integrated with these two models.

The completed system will optimize programs of rehabilitation and maintenance given budget constraints and given existing pavement condition as defined by the Idaho PPMIS. Consideration will be given to capital costs, maintenance costs, road user costs, and effects of advancing or delaying projects. Economic analysis will include consideration of both capital costs for rehabilitation and annual maintenance costs for various rehabilitation alternatives. Interfacing with the ITD maintenance management system will determine appropriate annual maintenance costs. Vehicle operating costs associated with various levels of pavement condition will be included.

Pavement Management In Nevada

I. Introduction

In 1980, the Nevada Department of Transportation (NDOT) conducted its first pavement condition survey to provide data input to a new pavement management (PM) program. The initial thrust of this program was to assist decisionmaking at the individual project level. It was used to assess current pavement condition on each mile of the State's completely mileposted 5,000 mile system, placing each of those miles into one of several broad repair categories. More recently, the PM program has begun to expand into a tool for prioritizing proposed repair projects.

The current PM program rates pavement surface condition only; evaluations of underlying structure are made only for design purposes. It is based on dealing with pavements in current worst condition. Additional experience in conducting the program will lead to the ability to project pavement behavior over time. Further evolution is planned through such means as more automated pavement data collection, and the development of an optimization program.

The following sections discuss the collection of pavement data, its analysis to arrive at measures of current condition, and the manner in which the PM program is begining to be used to prioritize repair projects.

II. Data Collection

A. Pavement Condition Survey

1. General

Nevada's formalized Pavement Condition Survey (PCS) was initiated in order to eliminate the subjectivity that had characterized the previous ratings conducted by the districts on a more independent basis. The PCS was initially conducted in 1980 on flexible (asphalt) pavements, which constitue 97.6% of the Nevada State highway system. Rigid pavements were surveyed beginning the following year, using somewhat different procedures.

The PCS is conducted annually over the entire State system on a mile-by-mile basis in both directions. Bridge decks and approach slabs are excluded. On multi-lane facilities (10% of the system), only the most heavily traveled lane is rated.

2. Flexible Pavements

It was decided to retain the use of district personnel to conduct the flexible PCS, but to centrally coordinate it. An 8-hour training course was prepared and presented in each of the districts by Materials Division (now Materials and Testing Division) personnel, and a Manual of Rating Instructions was prepared. Twenty-two crews of two or three people each were formed to conduct the PCS, and a coordinator was assigned to each district to monitor the crews' work.

The initial flexible PCS was conducted in August and September of 1980; it was later decided to conduct subsequent surveys in November and December. This small survey "window" was chosen to reduce seasonal variations in test measurements and to maximize the utilization of district personnel during a traditionally slow time of the year. Survey results were verified by Materials Division personnel, who randomly selected 30-40 miles of pavement in each district to compare their observations against PCS results. Adjustments to the survey program were made (e.g., measurements of bleeding and raveling were added), the Manual was updated, and the second PCS was conducted in late 1981. Unless otherwise noted, all following discussion deals with the 1981 flexible pavement survey.

The survey crews conduct their measurements on a single section of pavement in each mile that is most representative of the entire mile. This "rating section" is selected by driving the first two-thirds of each mile and noting general condition. A 1000 square foot (100 feet x 10 feet) pavement section is generally then chosen on the final one-third mile that represents average condition on the first two-thirds. In some instances, the rating section may be chosen from the first two-thirds mile. The actual section milepost is recorded using the car odometer, and its boundaries delineated using a "Roll-a-Tape" measuring wheel. Condition measurements and observations are taken using the Manual of Rating Instructions as a reference, and recorded on the Pavement Condition Input Form (Figure 1). This computer-generated form is preprinted with identifier data, including milepost numbers, for each mile of roadway to be rated by a given team. Data is keypunched directly from the form.

An examination of the following conditions is made during the PCS:

a. Cracking

   1) Alligator. The type of alligator cracking (Type A, B, C, or D) is noted. Severity is noted by taking a surface width (including raveling) measurement to the nearest 0.05 inch. Extent in square feet is then measured with the measuring wheel.

   2) Linear. This is classified as predominantly longitudinal, predominantly transverse, or both (if longitudinal and transverse cracking occur in approximately equal measure). Severity is measured the same as for alligator cracking. Extent is then noted as the total length of longitudinal plus transverse cracking as measured by the measuring wheel.

   3) Sealed. Sealed cracks are noted as either remaining sealed or having reopened.

b. Rutting. Using a rut depth gauge fabricated by NDOT, three measurements 25 feet apart are taken in each wheel path. Each measurement is recorded to the nearest 0.05 inch.

c. Patching. The lengths and widths of all patches are measured, multiplied, and recorded as total extent of patching in square feet.

d. Bleeding and Raveling. The severity of bleeding or raveling is noted by coding the appropriate photograph number from the Manual of Rating Instructions. Each condition is respresented by three photos depicting varying degrees of severity.

STATE OF NEVADA
DEPARTMENT OF TRANSPORTATION
MATERIAL & TESTING DIVISION
PAVEMENT CONDITION INPUT FORM

PMS-FLEXIBLE PAVEMENT

DIST	CO	HWY NO	M.POST NO	DIR	NO LANES	LANE TEST	TEST DATE	ACTUAL M.POST	CRACKING T	CRACKING ALLIGATOR SEV	CRACKING ALLIGATOR EXT	CRACKING T	CRACKING LINEAR SEV	CRACKING LINEAR EXT	SEAL	RUT DEPTH 1	RUT DEPTH 2	RUT DEPTH 3	RUT DEPTH 4	RUT DEPTH 5	RUT DEPTH 6	PATCH SQ FT	PICTURE NO. 1	PICTURE NO. 2	PICTURE NO. 3
1	CL	US 095	132.00	N	2			.		.			.			.	.	.	.	.	.				
TOTAL WIDTH			LT. SHLD			RT.SHLD		REMARKS:																	
1	CL	US 095	132.00	S	2			.		.			.			.	.	.	.	.	.				
TOTAL WIDTH			LT. SHLD			RT.SHLD		REMARKS:																	
1	CL	US 095	132.14	N	2			.		.			.			.	.	.	.	.	.				
TOTAL WIDTH			LT. SHLD			RT.SHLD		REMARKS:																	
1	CL	US 095	132.14	S	2			.		.			.			.	.	.	.	.	.				
TOTAL WIDTH			LT.SHLD			RT.SHLD		REMARKS:																	
1	NY	US 095	1.00	N	2			.		.			.			.	.	.	.	.	.				
TOTAL WIDTH			LT.SHLD			RT.SHLD		REMARKS:																	
1	NY	US 095	1.00	S	2			.		.			.			.	.	.	.	.	.				
TOTAL WIDTH			LT.SHLD			RT.SHLD		REMARKS:																	
1	NY	US 095	2.00	N	2			.		.			.			.	.	.	.	.	.				
TOTAL WIDTH			LT.SHLD			RT.SHLD		REMARKS:																	
1	NY	US 095	2.00	S	2			.		.			.			.	.	.	.	.	.				
TOTAL WIDTH			LT.SHLD			RT.SHLD		REMARKS:																	

NAME OF RATERS: ______________________

____

____

PICTURE * 1 PAVEMENT CONDITION
NO 2 BLEEDING & RAVELING
3 SHOULDER CONDITION

Figure 1

e. Pavement Condition. The general overall surface appearance of each rating section is summarized by selecting the appropriate photograph from the Manual and coding its number. A variety of pavement distress conditions and ranges of severity are depicted in a series of 19 photos.

f. Shoulder Condition. The overall shoulder condition is rated in the same manner as overall pavement condition, using a separate series of six photos.

g. Total Width. The total paved width, including shoulder, is measured for each section being surveyed.

3. Rigid Pavements

Nevada's 120 miles of rigid (PCC) pavements were surveyed for the first time in 1981. The survey was conducted by Materials and Testing Division personnel utilizing a Rigid Pavement Manual of Rating Instructions. The rigid pavement survey was basically similar to the flexible pavement survey, being conducted mile-by-mile in both directions. A representative rating section consisting of 10 consecutive slabs was selected in each mile. Measures of the following pavement conditions were recorded on computer-generated input forms:

a. Cracking (first, second, and third interval)
b. Faulting
c. Patching
d. Spalling
e. Scaling
f. D Cracking
g. Joint sealant damage
h. Joint width
i. Special distress (e.g., blowups, popouts)
j. Lane-shoulder differential and separation

Additional data included overall pavement and shoulder condition (selected from photographs), and pavement and shoulder width measurements.

4. Future Pavement Condition Surveys

NDOT plans to substantially automate the collection of pavement-related data in the future through the use of an ARAN Automatic Road Analyzer. The ARAN, manufactured by Highway Products International, Inc., of Ontario, Canada, is a fully self-contained van possessing equipment and instruments to perform the following measurements/functions:

a. Road roughness
b. Roadway distance
c. Cross-fall angle
d. Grade angle
e. Rut depth (right and left)
f. Different coded categories of pavement distress and maintenance features
g. Pavement surface photologging
h. Conventional (horizontal) photologging

Data is recorded in computer compatible format on magnetic tape directly from the various sensors. Other data is entered via the keyboard.

The NDOT ARAN unit is undergoing a period of testing, evaluation, etc. It is expected that one more manual PCS will take place before the ARAN becomes fully operational.

B. Other Data

1. Ride. Ride data is collected by Materials and Testing Division personnel during the summer months. Two Cox and Sons Road Meters (one ultrasonic, one mechanical) are used to rate the entire State system, excluding bridge decks and approach slabs. The ride survey covers both directions on all routes; on multi-lane routes, the most heavily traveled lane is surveyed. Ratings are conducted on a mile-by-mile basis. Axle displacements in 1/8 inch increments are accumulated as counts per mile (CPM). Locator data, CPMs, and calibration/correction factors (e.g., speed, temperature) are printed out for each mile. The data is then transcribed directly onto a computer input form by one of the operators.

   Prior to the initial ride survey, personnel from the Materials and Testing Division took one Cox unit to Sacramento, CA, for correlation with the California Department of Transportation (Caltrans) ride rating system. Several of their standard reference surfaces were used in the determination of the correlation. Once correlation was determined with Caltrans, reference surfaces were established in Nevada for correlation and standardization of the NDOT units. Thereafter, at intervals while conducting the survey, both units would return and run the reference surface to determine if there was any drift in the instrumentation. This calibration procedure assures that all data collected with both units is in correlation and that the data is consistent throughout the duration of the survey.

2. Skid. Skid (surface friction) data is not routinely collected as part of the annual PCS for Nevada's project-level PM program. A skid value is used, however, in the priority ranking process (see section IV.) currently undergoing refinement. Skid testing is conducted with a K. J. Law locked-wheel trailer. Randomly selected sections on all routes are tested, with one test per mile being conducted in the left wheel path. Regular test frequency varies from every year (on Interstate routes) up to every 5 years. In addition, tests may be triggered by such factors as maintenance work or new construction that would alter surface friction. Tests are also conducted at high accident locations and at locations where a low test value was indicated the previous year.

3. Structural. NDOT uses a Dynaflect to measure structural capacity (deflection). This is not part of the PCS, however, and is used only to assist in overlay designs.

C. Data Files

Ride and PCS data are keyed into a data entry terminal and stored on discs in two separate batches. These two batches are then read into the State's central computer to create ride and PCS files. The system also uses a traffic file supplied by the Planning Division. This file contains route, county, milepost, average daily traffic, percent trucks, and number of accidents. The ride, PCS, and traffic files are merged and sorted to create a pavement condition master file. Two other files used in conjunction with the PM program are the Maintenance Cost and Master Milepost files.

III. Data Analysis

Once the data is stored in the pavement management master file it is used to arrive at an overall Pavement Conditon Rating (PCR) for each section of flexible pavement, and also serves as a basis for various user data reports. Efforts have also been made to use the data as a means to determine appropriate maintenance strategies. Discussions of each of these aspects of data analysis follow.

A. Pavement Condition Rating

Seven factors are used to arrive at an overall PCR for each section of pavement. These factors are:

1. Rut depth
2. Cracking (alligator and linear)
3. Patching
4. Bleeding
5. Raveling
6. Ride*
7. Present Seviceability Index (PSI)

* Converted from Road Meter counts per mile (CPM) to a slope variance ($\overline{SV}$) in inches per mile according to the formula $\overline{SV} = 0.68\Sigma(D)^2 + 0.8$, where ΣD = CPM

The first six factors are measured during the annual survey. The seventh factor, PSI, is derived from four of these measured values. It is calculated as follows:

$$PSI = 5.03 - 1.91 \log_{10}(1 + \overline{SV}) - 1.38\ \overline{RD}^2 - 0.03\sqrt{C + P}$$

where : $\overline{SV}$ = Slope variance
$\overline{RD}$ = Rut depth
C = Cracking
P = Patching

These seven factors have been assigned relative weights so that they may be converted into a system that awards points as pavement condition deteriorates (Figure 2). In most instances, the factors have been subdivided into several categories of severity or extent, and points awarded appropriately. Points are added together to yield the total PCR for each mile. The PCR is used to place each mile into one of four broad repair categories, as follows:

Category	Points
Do nothing	0 - 49
Maintenance	50 - 399
Overlay	400 - 699
Reconstruct	700 and over

As illustrated in Figure 2, point values awarded by the computer program generally vary according to the Terminal Serviceability Index (TSI) of the route on which the rated section occurs. The TSI is merely a predetermined PSI level at which a roadway is judged to have reached its lowest acceptable level of service. Nevada's roads are built to two different levels of serviceability design life, as reflected in the use of two different TSIs. In conformance with nationally recognized standards, a TSI of 2.5 is used on all Interstate and primary routes, and on secondary routes where the ADT exceeds 750. For all minor highways with an ADT of less than 750, the TSI is 2.0.

Figure 2

FLEXIBLE PAVEMENT

TABLE OF VALUES FOR DETERMINATION OF CAGEGORY STATUS

	TERMINAL SERVICEABILITY INDEX - 2.5	TERMINAL SERVICEABILITY INDEX - 2.0
PSI	Greater than 2.51 = 0 2.50-2.01 = 50 less than 2.00 = 500	Greater than 2.01 = 0 2.00-1.51 = 50 less than 1.50 = 500
RIDE:	0-5 = 0 6-10 = 75 11-14 = 150 15-19 = 300 20 and over = 500	0-7 = 0 8-12 = 75 13-16 = 150 17-21 = 300 22 and over = 500
RUT DEPTH:	Less than 0.25 = 0 0.25-0.49 = 30 0.50-0.74 = 200 0.75-0.99 = 300 Greater than 0.99 = 500	Less than 0.45 = 0 0.45-0.69 = 30 0.70-0.94 = 200 0.95-1.19 = 300 Greater than 1.19 = 500
ALLIGATOR CRACKING:	Type A = 1.50 x Extent B = 2.00 x Extent C = 1.00 x Extent D = 1.00 x Extent	Type A = 1.00 x Extent B = 1.50 x Extent C - 0.50 x Extent D = 0.50 x Extent
LINEAR CRACKING:	400 x Severity + 10% Extent	400 x Severity + 10% Extent
PATCHING:	0.5 x Extent	0.25 x Extent
BLEEDING:*	14 = 0 15 = 100 16 = 250	14 = 0 15 = 100 16 = 250
RAVELING:*	17 = 100 18 = 250 19 = 500	17 = 100 18 = 250 19 = 500

* The rating factors for these parameters are photograph numbers.

B. User Reports

The PM analysis program produces a number of printout reports that are available to assist in developing repair strategies. Another set of reports used in prioritizing projects is discussed in Section IV.

1. Data Summary Report

The Data Summary (DS) report is a summary of all processed data for each mile of the highway system. It displays identifier/locator data (e.g., county, route number, milepost), raw condition data (e.g., PSI, slope variance), traffic file data (e.g., ADT, number of trucks), PCR, and corrective action.

2. Predominant Distress Reports

The Predominant Distress (PD) reports list the three most predominant modes of pavement distress for each roadway mile. The program lists these three modes in descending order based on their contribution to the total point score for the mile. Various identifier/locator data, traffic file data, and total PCR are also listed. Three separate PD reports are generated, each one listing roadway miles falling into one of the three general repair categories: PD-1 is maintenance category, PD-2 is overlay category, and PD-3 is reconstruct category.

C. Maintenance Strategy

Nevada's PM analysis program contains a routine that can assist district personnel in arriving at maintenance decisions. It generates suggested maintenance strategies based on the assigned point values of the following pavement condition parameters: alligator cracking, linear cracking, slope variance, rut depth, patching, bleeding, and raveling. For roadway miles placed in the maintenance category by total PCR (i.e., PCR 49 and 400), the program analyzes these parameters and recommends one or more of eight maintenance strategies. This process is depicted in Figure 3. Output of this program is contained in another computer-generated user report, the MS-1. The MS-1 report is used to project maintenance costs.

IV. Programming

A. Priority Rating

The NDOT is currently refining an analysis routine that prioritizes each directional mile of highway. The program applies two different sets of weights to six different parameters to assign each directional mile a Total Priority Rating. The parameters used in this analysis are: overall PCR; current traffic (ADT); number of trucks; 5-year average maintenance cost; adjusted skid number; and number of pavement and wet pavement-related accidents. The first weighing takes place when the raw value for each of these parameters is plotted against a curve (Figure 4 is an example) that translates the raw value into an Importance Value (IV). Each IV covers a range from 0 to 10, with 0 representing the most severe

Figure 3

Determination of Maintenance Strategies

Machine Patch or Heater Planing

1. Rut Depth, points ≥ 200, ≤ 400

Machine Patch

1. A. Cracking, points ≥ 200, ≤ 400

Chip Seal or Sand Seal

1. Slope Variance, points > 75, ≤ 400
2. L. Cracking, points > 100, ≤ 350
3. Raveling, points > 100
4. Patching, points ≤ 400
5. A. Cracking, points ≥ 200, ≤ 400

Crack Filling

1. L. Cracking, points ≥ 100 and crack sealed "no"

Heater Planing or Cold Milling

1. Bleeding, points $= 100$

Flush Seal

1. Raveling, points $= 100$
2. L. Cracking, points ≤ 100

Hand Patching

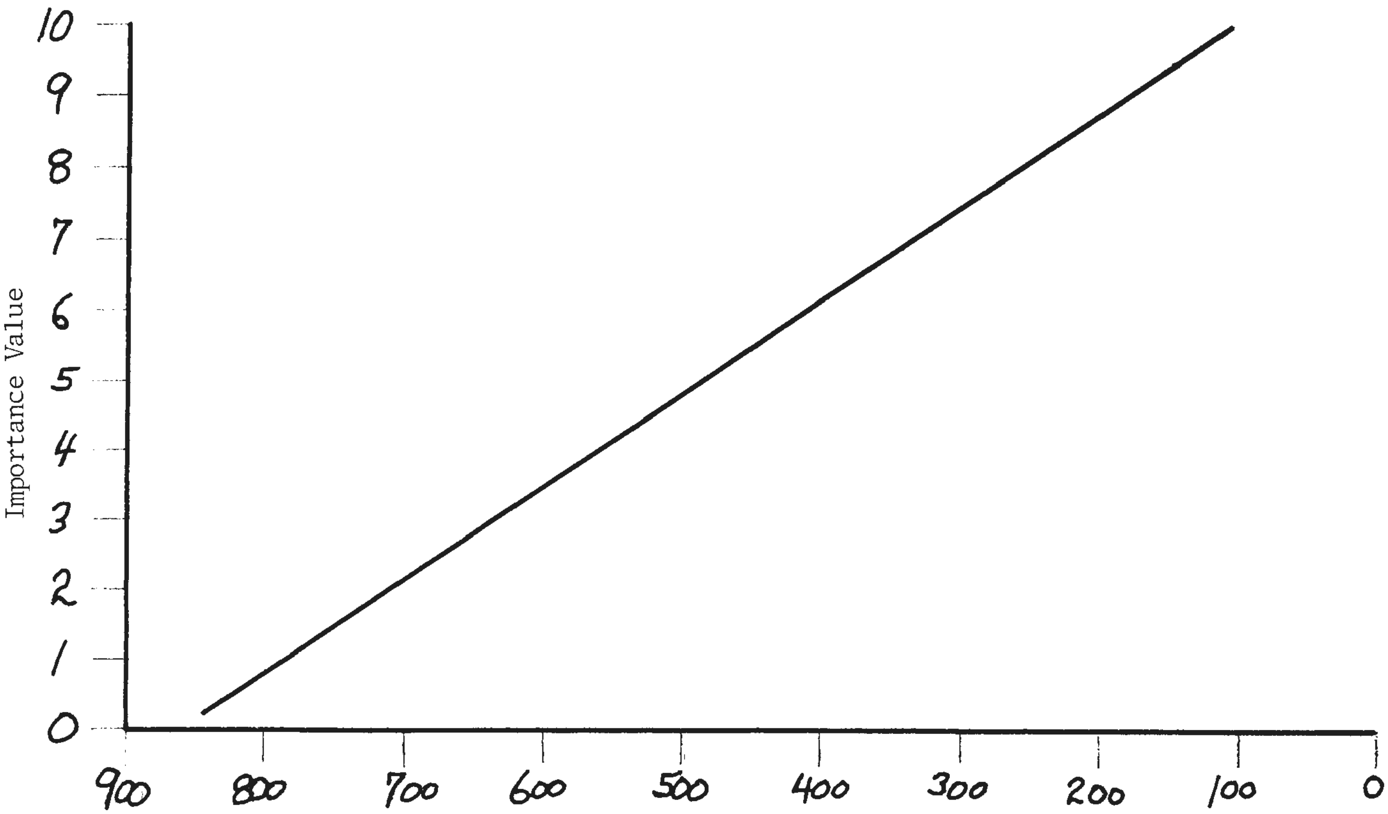
1. A. Cracking, points ≤ 200
2. Slope Variance, points ≥ 75, ≤ 400

Chip or sand seal is a preemptive repair strategy for flush seal.

Machine patch preempts hand patch.

Heater planing preempts flush seal.

Figure 4



5-Year Average Maintenance Cost per Directional Mile

>825	825–751	750–676	675–601	600–526	525–451	450–376	375–301	300–226	225–151	150–0
0	1	2	3	4	5	6	7	8	9	10

Importance Value

condition (e.g., highest average maintenance cost) and 10 the least severe. Each IV is then multiplied by a second weighting factor (Figure 5). The resulting values are summed to arrive at the Total Priority Rating for the mile. The lower this Rating, the higher the relative priority of the mile section.

Priority Ranking Summary

			Repair Strategy	
			Maintenance	Overlay or Reconstruct
Overall PCR	IV	x	0.78	0.72
Current Traffic	IV	x	0.11	0.12
No. Trucks	IV	x	0.11	0.06
5-Year Avg. Maint. Cost	IV	x	0.00	0.05
Skid Number	IV	x	0.00	0.03
No. Accidents	IV	x	0.00	0.02
			1.00	1.00

Figure 5

The computer program generates a report with line entries for each directional mile. Currently, this report is visually examined for adjacent miles of roadway with the same indicated repair strategy and similar Priority Rating. These adjacent sections are then grouped into proposed repair projects of 3 to 20 miles in length. A computer program then computes an average priority rating for each project and prints a prioritized list which includes a project description, terminal mileposts, and estimated cost.

Proposed projects are field surveyed by the Design team, with highest priority projects also being surveyed by a State 3R team. The purpose of the field survey is to verify the report data, identify locations where increased investigation may be required, and, if necessary, adjust project termini. The 3R team makes recommendations to the Programming Section, where a program is assembled based on a 2-year funding schedule.

B. Future Adjustments

Both the first- and second-level weighting factors used to arrive at Total Priority Rating are continually being examined; as more experience is gained, the routine will be further fine-tuned. Ultimately, enough data will be analyzed to develop trend lines (life curves) to predict pavement performance.

Pavement Management in Ohio

I. Introduction

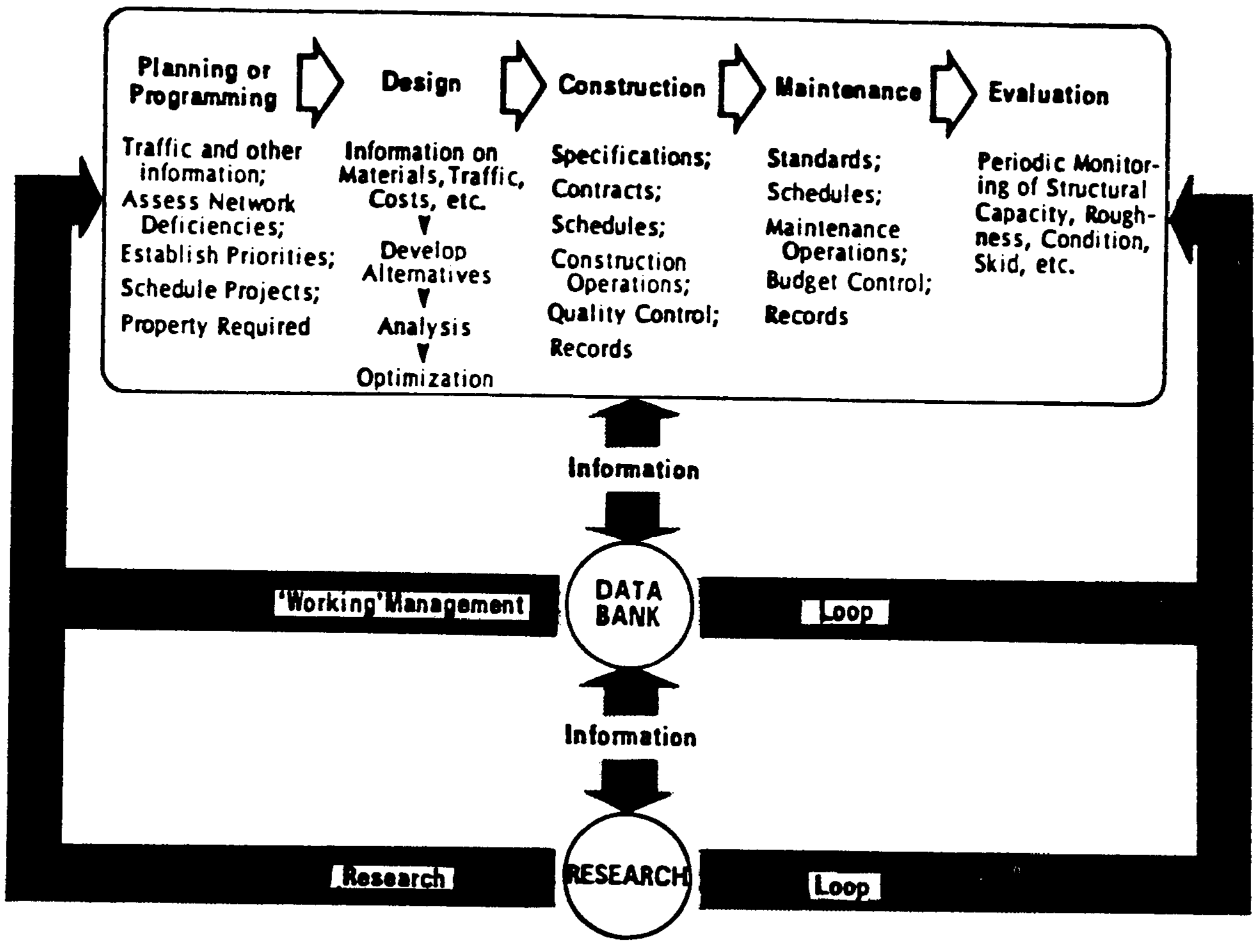
The Ohio Department of Transportation's (ODOT) report, the Development and Implementation of a System for Evaluation of Maintenance Repair Needs and Priorities, is based on the concept that a comprehensive pavement management system integrates through a centralized data bank a number of State Highway activities. These activities, illustrated in Figure 1 (from this report), include Planning (or Programming), Design, Construction, Maintenance, and Evaluation. As a first step, however, the ODOT, with the assistance of its consultant, Resource International, Inc., has concentrated on the development of a basic framework for the establishment of a prioritization scheme for resurfacing pavements on 16,000 of its 19,000 centerline mile system of State maintained roads. Over the next several years, ODOT plans to develop a model to evaluate alternative maintenance strategies and to generate sufficient pavement evaluation data to create performance and cost models. The ODOT's concern with alternative maintenance strategies is an important step in the program's development since, in Ohio, "maintenance" is defined to include pavement resurfacing, the focus of the prioritization program to date. As a result of these efforts, the ODOT's pavement management resources have been and will continue for some time to be directed toward the development of a pavement evaluation program which involves the establishment of a comprehensive data bank and should lead to improving its pavement rehabilitation program's effectiveness.

The following sections describe the data collection efforts undertaken to support the pavement evaluation program, the storage of this collected data, and the manner in which the data is analyzed and compiled in the prioritization program. Additional sections discuss the ODOT's plans for developing an optimization scheme and the basic elements of the State's programming operations at the project and network levels.

II. Data Collection/Storage

The development of a pavement evaluation program requires the establishment of an explicit set of monitoring criteria, (i.e., which pavements should be monitored, which elements should be used in data collection, how frequently should the data be collected, etc.). The ODOT has initially defined its network for the pavement evaluation program to consist of Interstate and four-lane roads located outside of urban areas (roughly 4,000 centerline miles). Two-lane rural roads are in the process of being added to the program's network (an additional 12,000 centerline miles). On a networkwide basis, the ODOT collects data for several basic pavement-related parameters: a roughness (ride) measure, a skid resistance measure, traffic counts, and truck counts. For each type of pavement condition data collected, the ODOT has established a "trigger" value, which is then used to initiate a more detailed evaluation of the pavement condition. The information coming from this more detailed evaluation, called the Pavement Condition Rating (PCR), in turn becomes part of the pavement evaluation data bank and is also the requisite step leading to the performance of the needed maintenance and/or repairs. The ODOT is also considering the use of "age of surface" data as an additional data element which could trigger the conducting of a PCR. The age of surface data must be computerized and made accessible for pavement sections compatible with the rest of the pavement evaluation program before this element can be added.

Figure 1



Major Activities

Pavement Management System

(Ref. 1)

The basic elements used in data collection by ODOT are identified in the following paragraphs, and the manner in which the data is collected is also discussed. Section II contains a discussion that ties these elements together to explain the functioning of the pavement evaluation program, including the prioritization methodology.

A. Ride (Present Serviceability Index (PSI))

The PSI, as computed from the digitized Mays meter roughness measurements conducted by the Bureau of Transportation Technical Service in the ODOT Central Office, is one of the elements against which data is collected on a networkwide basis. The ODOT uses the AASHTO Road Test method of computing PSI. Trigger values for PSI have been established depending on pavement type and roadway system (see Figure 2), and are intended to correlate with expected non-routine maintenance needs. However, the system, which has been operational to date only on four-lane roads, has produced PSI figures that are not sufficiently accurate to warrant a high degree of reliability. There is concern that the Mays meter results do not correlate well with the District's assessments of the roadway conditions. In addition, the Mays meters require frequent calibration, and the variability of the results from year to year makes the data unuseable for the development of projections and/or long-term performance curves. Therefore, ODOT has purchased a non-contact (light) inertial profilometer which is designed to provide a more reliable indication of surface roughness through the actual measurement of the pavement's profile. Additional profilometers, with acoustical probes, may be purchased for routine monitoring by the Districts, while the more sophisticated inertial profilometer will be operated by the Central Office.

Figure 2

PSI MONITORING CRITERIA: TRIGGER VALUES

SYSTEM	PAVEMENT TYPE		
	RIGID	COMPOSITE	FLEX.
INTERSTATE	2.60	3.40	3.40*
MULTILANE & HIGH TYPE 2 LANE	2.40	3.00	3.20
LOW TYPE 2 LANE (ADT <1000)	2.20*	2.80*	3.00*

*NO STUDY OF THESE FACILITIES. EXTRAPOLATED FROM HIGH TYPE 2 LANE ROADS.

B. Skid

In addition to PSI, the State monitors skid resistance using ASTM E-274 Skid Trailers manufactured by K.J. Law Engineers, Inc. Three (3) units cover the Interstate and primary systems annually and the secondary system every 2 or 3 years. The ODOT has established a skid number (SN) of 30 as the trigger value, indicating that a safety hazard may exist and that a detailed condition evaluation is warranted. This monitoring of frictional characteristics is the result of systemwide coverage of a pavement's mean skid properties.

C. Other Elements

Two other trigger values are included in the monitoring criteria: an increase in truck traffic exceeding 25% within 2 years, and a maximum of 6 years permitted between visual ratings (PCR) of a highway section. When either of these trigger values are reached, a pavement condition rating survey is conducted. The basic resource used in determining the truck traffic increase is the State's Traffic Survey Report. As indicated earlier, data regarding the age of the pavement surface is also to be added as a trigger value.

D. Pavement Condition Rating (PCR)

Finally, the pavement monitoring data base includes the PCR, which is the result of a standardized procedure for inspecting a number of defined pavement distresses, and assessing their severity and extent. This survey is conducted when any one of the pavement condition monitoring elements reaches its trigger value. District personnel were trained in this procedure in the Central Office in order to try to obtain some degree of consistency among the survey results. In addition, a manual with photographs of the different levels of severity and extent for each distress was prepared and distributed to the Districts. The surveys are conducted at approximately the same time of year (mid-summer) in order to enhance the consistency of the data from year to year. The Central Office also encourages the Districts to use the same trained two-person crew to further reduce variability in the ratings. The ODOT points out, however, that raters' biases inevitably creep into the surveys, especially since the "average" roadway condition varies significantly from District to District. Some consideration is being given to having these surveys conducted by the Central Office in hopes of reducing this bias. Also, ODOT is having prepared a PCR training manual so they can train their own new raters as necessary.

The survey itself consists of: 1) traveling each highway section at 40 mph, 2) making a second pass with stops at each 1 mile interval to make detailed inspections, and 3) preparing the survey form before undertaking the next section (see Figure 3). Since no measurements are taken of any of the distresses, the survey is basically a subjective evaluation. However, some consideration is now being given to adding some limited measurements such as number of cracks and crack width. The survey form lists the distresses per pavement type, their relative weights (out of a total of 100), plus weights for severity and extent. The total number of weighted distress points are then subtracted from 100 to give the PCR number. Certain distresses, depending on the pavement type, are designated as reflecting structural problems, and a total number of "structural deduct" points is also calculated. If a specified structural deduct number is reached (depending on the class of the roadway), then the Central Office will schedule a Dynaflect to be sent to measure the section's structural adequacy. This information is not used directly in the pavement evaluation program since the data has not been

Section: ____________
Log mi.: ______ To ______
Sta.: ______ to ______

Date:
Rated by: ____________

JOINTED CONCRETE

PAVEMENT CONDITION RATING FORM

DISTRESS	DISTRESS WEIGHT	SEVERITY WEIGHT * L	M	H	EXTENT WEIGHT ** O	F	E	DEDUCT POINTS ***
SURFACE DETERIORATION	10	.4	.7	1.0	.6	.8	1.0	
POPOUTS	5	1.0	1.0	1.0	.4	.6	1.0	
PATCHING	5	.4	.7	1.0	.5	.8	1.0	
PUMPING	15	.7	.7	1.0	.3	.7	1.0✓	
FAULTING	10	.4	.7	1.0	.5	.8	1.0✓	
SETTLEMENTS	5	.4	.7	1.0	.5	.8	1.0	
JOINT SPALLING CIRCLE IF D-CRACKED	15	.4	.7	1.0	.5	.8	1.0	
JOINT SEALANT DAMAGE	5	1.0	1.0	1.0	.5	.8	1.0	
PRESSURE DAMAGE	5	1.0	1.0	1.0	.5	.8	1.0	
TRANSVERSE CRACKING	10	.3	.8	1.0	.4	.8	1.0✓	
LONGITUDINAL CRACKING	5	.5	.7	1.0	.4	.9	1.0✓	
CORNER BREAKS	10	.4	.8	1.0	.5	.8	1.0✓	

TOTAL DEDUCT =	
SUM OF STRUCTURAL DEDUCT (✓) =	
100 - TOTAL DEDUCT = **PCR** =	

* L = LOW
M = MEDIUM
H = HIGH

** O = OCCASIONAL
F = FREQUENT
E = EXTENSIVE

*** Deduct pts. = Distress Wt. X Severity Wt. X Extent Wt.

Remarks:

Figure 3

automated, but it is an important input for rehabilitation design. The ODOT is preparing to undertake the research needed to integrate dynaflect measurements into the pavement evaluation program. The first step in this effort is to develop a manual for operation and use of the dynaflect for pavement evaluation so that the technical expertise of ODOT engineers in this area can be increased.

E. Data Files

The ODOT has not established a master pavement management data file but has several compatible data banks from which information can be retrieved. The Pavement Section file was created from a computer program which combines segments of highway from the Basic Road Inventory file having the same surface type, base type, and similar average daily traffic (ADT). These "combined segments" become the sections for which most pavement-related information can be retrieved. Certain maintenance information (activity type, log mile points, year) and traffic information (ADT, truck counts, growth factors) can be obtained for these sections. Geometric data is stored in the Supplemental Road Inventory and can be accessed for the same sections. In addition, a Pavement Management file, using the same section identification, contains the PSI, SN, PCR, and deflection data for each section. From this file, the ODOT can generate listings and rankings of projects and can create routine and special reports to assist management in making decisions regarding the maintenance and rehabilitation programs.

All data from the Basic Road Inventory, the Supplemental Road Inventory, the Pavement Management file, and the Maintenance Management file utilize Ohio's milepost system for location identification. This system contains three components: the county name, the route number, and the mileage which is measured from south to north and west to east, beginning at each county boundary.

Additional work is needed to integrate data files on construction and testing records, as-built data, and axle loadings data with the pavement management files. As part of the ODOT's efforts to improve the pavement evaluation program, a research proposal has been developed and approved which will examine the adequacy of the current data base and propose a computerized methodology for data processing, reduction, and analysis.

F. Recordable Condition Survey

In addition to the data collected for the pavement management program, the ODOT conducts a "windshield survey" of 14 maintenance items on a randomly selected sample of highway segments. This survey, called the Recordable Condition Survey, aims to develop numerical data from observations and measurements of selected maintenance conditions on a sample of highway sections representing all highway types and counties in the State system. In effect, it is intended to measure the performance of selected District maintenance activities. The conditions surveyed include shoulder drop-off, signing deterioration, striping and marking deterioration, mowing, pavement surface, etc. The data is recorded as "conditions per mile" and compared on bar charts to each District's expenditure per lane miles for the corresponding maintenance activity. The Bureau of Maintenance conducts the surveys quarterly, prepares the bar charts, and sends these and other reports to the Districts. The information is used to assist the District in monitoring the allocation of its time and resources among the various maintenance activities. By demonstrating an imbalance between the number of deficiencies and the amount of money spent on the corresponding activity, this program can help the Districts redirect their efforts and thus improve the management of their maintenance workload. At some point in time, it is ODOT's intent to correlate the recordable condition survey data with the PCR data.

III. Data Analysis

A. Project Ranking

The data collected for PSI, skid, PCR, and traffic and truck counts are all used to rank pavement sections in need of resurfacing. The ODOT combines these data elements by organizing the raw data into groupings and then ranking the sections according to these groupings, using the measured data only to rank projects within a group.

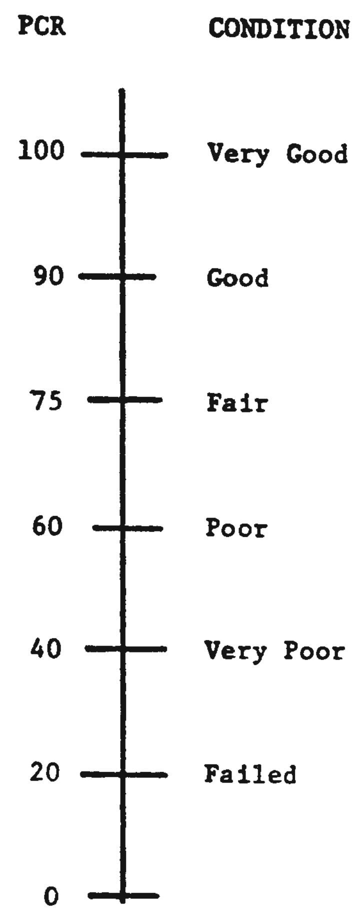
The first grouping, the PCR group (PCRGRP), organizes all surveyed sections into six categories, from very good to failed (see Figure 4). This category, where 1 = failed, provides the first "sort" in ranking projects for resurfacing. The second grouping, the Maintenance Urgency Category (MUC), places all sections into one of eight groupings, where 1 = the most urgent category. In order to determine the MUC, three quantitative pavement ratings (PSI, PCR, SN) are separated into either low or high categories and then are combined in such a way that PCR has the most influence in determining to which MUC level the project belongs with PSI having the second degree of influence, and with skid having the remainder (see Figure 5). The MUC provides the second "sort" in ranking projects.

Three traffic categories, based on lane ADT, have been established, with 1 = very high traffic (over 10,000 vehicles per day (VPD)), 2 = normal traffic (between 3,000 and 10,000 vpd), and 3 = very low traffic (below 3,000 vpd). This category provides the third "sort" for ranking projects. If two or more project sections were to have the same PCR grouping, MUC, and traffic category, then the projects are prioritized based on the PCR score. For those few remaining projects with the same PCR, the PSI is the final ranking factor. An example of a priority listing for Interstate sections for the entire State is provided in Figure 6.

A large number of other reports can be generated from the pavement management file: District priority listing and summary data for different highway systems, and for different monitoring elements. In addition, a summary of all pavement condition data for a specific highway section can be retrieved (see Figure 7 for an example).

B. Optimization

The ODOT recognizes that its pavement evaluation data base has not been in existence sufficiently long to create all of the elements of an optimization program, including a performance model and a cost model. It therefore will be examining the results from other States with longer-lived data bases and the performance of related, in-State pavement activities (recycling, fabric use) in order to create a larger, coordinated data base. At the same time, the State is developing a methodology for selecting alternative maintenance strategies to meet the range of conditions diagnosed by the pavement condition survey. From these efforts, each maintenance strategy can be evaluated according to specified performance and cost parameters and the optimal strategy can be selected. At this point, the State has not specified the components to be considered in its optimization program but expects to have the basic models in place in



Pavement Condition Rating Scale

Figure 5

MAINTENANCE URGENCY CATEGORY

PCR	PSI	SN: LOW	SN: HIGH
LOW	LOW	(1) PCRGRP = 1, 2, 3	(2) PCRGRP = 1, 2, 3
LOW	HIGH	(3) PCRGRP = 1, 2, 3	(4) PCRGRP = 1, 2, 3
HIGH	LOW	(5) PCRGRP = 4, 5, 6	(7) PCRGRP = 4, 5, 6
HIGH	HIGH	(6) PCRGRP = 4, 5, 6	(8) PCRGRP = 4, 5, 6

UNRATED - PCRGRP = 7

LEVELS

PCR - LOW IS BELOW 65 - INTERSTATE
60 - MULTILANE & H.T. 2-LANE
55 - LOW VOLUME 2-LANE

PSI - LOW IS WITHIN BOTTOM 10 PERCENTILE PER MAINTENANCE CLASS PER PAVEMENT TYPE STATEWIDE

SN - LOW IS <30

RANK WITHIN PCR GROUP FOR EACH MAINTENANCE CLASS

1) URGENCY CATEGORY;
2) TRAFFIC CATEGORY WITHIN SAME URGENCY CATEGORY;
3) PCR WITHIN SAME TRAFFIC CATEGORY;
4) PSI FOR SECTION WITH SAME PCR.

INTERSTATE PRIORITY LISTING

REPORT NO. 1 - STATEWIDE LISTING

IOR	DIST	COU	RTE	STATION	BLOG	ELOG	LENGTH	CMILES	PCRGRP	MUC	TC	PCR	SN	PSI
1	4	TRU	080R	UP	3.03	6.30	3.27	3.27	1	1	2	31	23.7	1.23
2	4	TRU	080R	UP	11.42	12.33	0.91	4.18	1	2	2	25	40.2	0.96
3	11	BEL	070R	UP	21.65	22.40	0.75	4.93	1	2	2	20	39.0	1.14
4	11	BEL	070R	DOWN	22.77	23.69	0.92	5.85	1	2	2	33	41.2	1.29
5	11	BEL	070R	UP	16.60	19.17	2.57	8.42	1	2	2	34	48.4	1.26
6	4	TRU	080R	DOWN	9.58	11.42	1.84	10.26	1	2	2	36	37.4	1.07
7	4	TRU	080R	UP	9.58	11.42	1.84	12.10	1	2	2	37	40.2	1.03
8	4	TRU	080R	UP	1.57	3.03	1.46	13.56	1	2	2	38	38.6	1.01
9	7	CLA	070R	UP	19.57	20.87	1.30	14.86	1	2	2	39	30.1	1.41
10	4	TRU	080R	DOWN	11.42	12.33	0.91	15.77	1	2	2	39	43.2	1.25
11	4	SUM	076R	DOWN	8.42	8.63	0.21	15.98	1	3	1	33	22.2	1.45
12	8	WAR	071R	DOWN	5.61	8.41	2.90	18.78	1	3	2	28	29.5	1.68

Figure 6

SECTION 83515 DPRIOR: 3 SPRIOR: 28 DATE: 9/18/80
DISTRICT: 5 COUNTY:LOG ROUTE:070 DIRECTION:DOWN RATED BY:PER & RLM
ELOG:5.34 FLOG:8.74

JOINTED CONCRETE PAVEMENT CONDITION RATING FORM

DISTRESS	WEIGHT	SUMMARY	
SURFACE DETERIORATION	HE	TOTAL DEDUCTIONS	62.7
POPOUTS	E	STRUCTURAL DEDUCTIONS	28.2
PATCHING	HF	PAVEMENT CONDITION RATING	37
PUMPING	LF	PRESENT SERVICEABILITY INDEX	3.26
FAULTING	ME	SKID NUMBER	33.3
SETTLEMENTS	LO	NUMBER OF LANES	4
JOINT SPALLING	ME	LANE VOLUME ADT	27310
JOINT SEALANT DAMAGE	F	TRAFFIC CATEGORY	2
PRESSURE DAMAGE		MAINTENANCE URGENCY CLASS	4
TRANSVERSE CRACKING	MF	PCR GROUP	1
LONGITUDINAL CRACKING	LO		
CORNER BREAKS	MF		

KEY:

L = LOW O = OCCASIONAL
M = MEDIUM F = FREQUENT
H = HIGH E = EXTENSIVE

Figure 7

approximately 5 years (see Figure 8 for the overall framework for the optimized pavement management program). To date, a great deal of the development of the pavement evaluation program has been the result of the cooperative efforts of the Division of Operations and the Bureau of Research and Development. The Bureau of Research and Development will continue to play a key role in refining and improving the program, although much of this developmental work is also based on the research proposals submitted by Resources International, Inc.

IV. Programming

A. Project Level

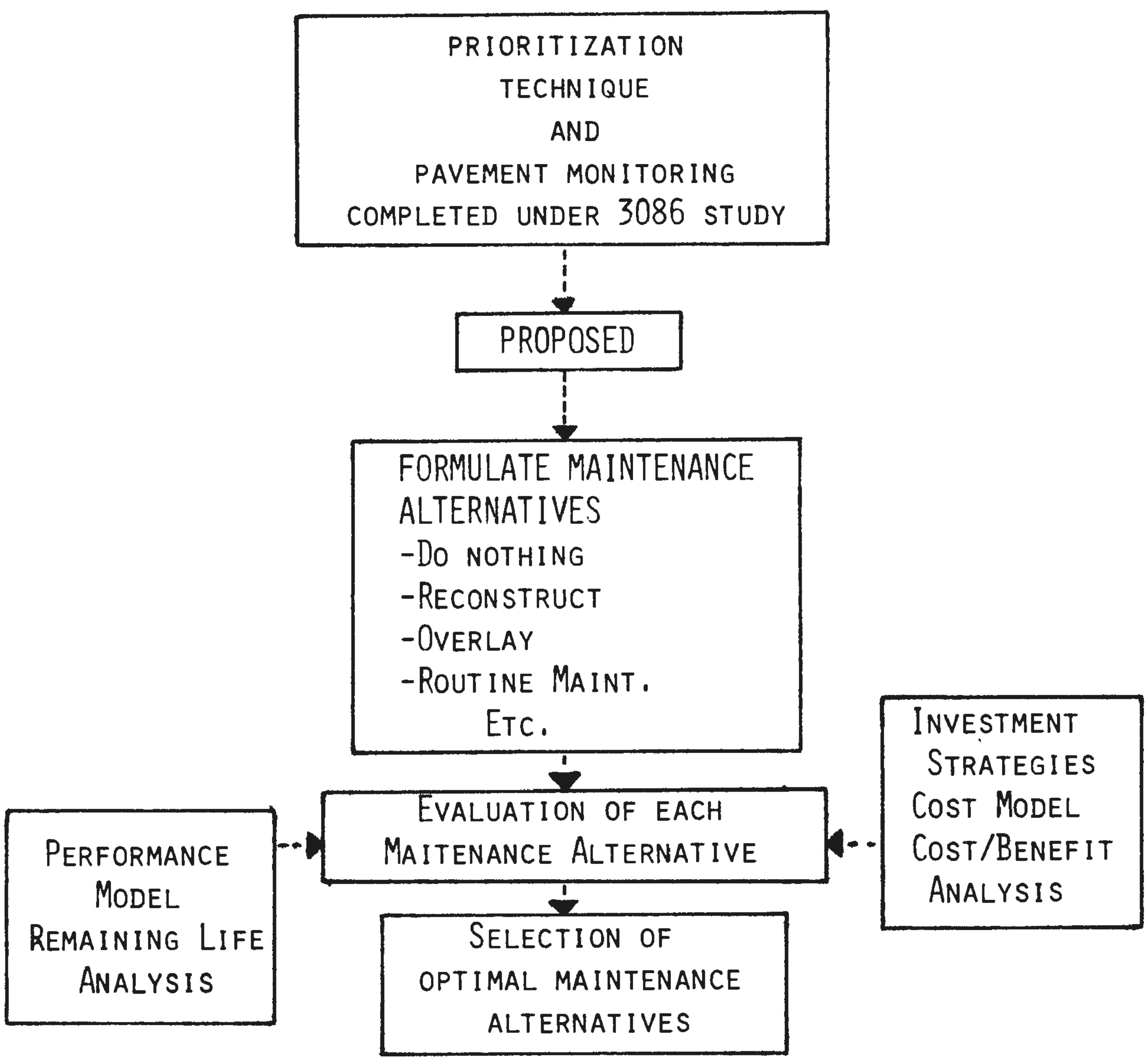
The ODOT finances resurfacing projects with State funds matched with either Federal 3R (4R) appropriations or other Federal money, depending on which highway system the project lies. State funds may be used alone if the project has very high priority and no matching Federal appropriation is available at the time. The priorities for all resurfacing projects are established by the Division of Operations based on the ranking procedures previously described. The resulting list of projects is forwarded to the Bureau of Programming which uses this list to maintain a strict control over releasing resurfacing funds to the Districts. Formerly, the Districts selected their own resurfacing projects without regard to the relative needs in the other Districts. In 1981, however, the Division of Operations began to use the Statewide list of priority resurfacing projects and, through the Bureau of Programming, has adjusted the amount of resurfacing money given to each District in accordance with the number and ranking of each District's projects that appear on this list. The Districts are expected to program the resurfacing projects as designated by this procedure, although the Bureau of Programming, in consultation with the Division of Operations, makes exceptions and adjustments to the program given the District's sufficient justification.

In ODOT, resurfacing is viewed as a part of the overall maintenance program. The Districts are responsible for programming the individual resurfacing and maintenance projects and are given wide latitude in deciding when and which projects require maintenance and/or resurfacing, so long as the resurfacing priority list is considered. However, separate funding is made available for maintenance contract work. In addition, the Districts receive, for force account work, a line-item budget, consisting of funding categories for labor, materials and supplies, and equipment. Therefore, although the Districts operate the resurfacing and maintenance programs interdependently, relating the relative needs of the two programs to the District's workload capacity, the funding for these programs are derived from separate sources.

B. Network Level

The network level programming is conducted by the Bureau of Planning for long-term purposes. The priorities established by Planning are not based on the pavement management data base nor on a sufficiency rating system but rely on the general directions established by the State legislature and top ODOT management. Now that an increased amount of highway revenue will be forthcoming, the construction and maintenance programs will be substantially expanded. The current network plan calls for a two-phased approach so that an orderly work program can be established for highway construction and maintenance. The Division of Operations and the Bureau of Planning expressed interest in having Planning become more involved with the prioritization program established for resurfacing and in possibly expanding on it (or a similar program) to incorporate Planning activities.

FRAMEWORK OF
PAVEMENT MANAGEMENT SYSTEM
OHIO DEPARTMENT OF TRANSPORTATION



Pavement Management in Washington State

I. Introduction

A. Outline of the System

The overall goal of the Washington Department of Transportation's (WSDOT) pavement management program is to provide the Department's administration with the necessary information for more efficiently managing its investment in roadway pavement. This goal and much of the information contained in this summary is discussed in WSDOT's Materials Office Report No. 171, "Washington State's Pavement Management System." The following synopsis is based on this report, several other WSDOT documents, and the information obtained in FHWA's visit with the Department's pavement management specialists.

Although WSDOT recognizes that the phrase "Pavement Management" (PM) applies to a large number of highway engineering functions (from research to construction to evaluation), the major thrust of the agency's efforts in this field has been in addressing pavement performance, selecting cost-effective rehabilitation strategies, and assembling a systemwide, 6-year rehabilitation program. Essentially the system contains four basic components: a master file, an interpreting program, a project level optimizing program, and a network-level program. Each of these components will be discussed below, but their relationship in the PM process is shown in Figure 1 (from WSDOT's Report #171). These components represent basic steps or processes in any PM operation: data collection and storage, data analysis, and project programming. WSDOT has developed and refined each of these PM components over a number of years and, as a result, can be said to have one of the most advanced PM programs in the country.

B. Short History

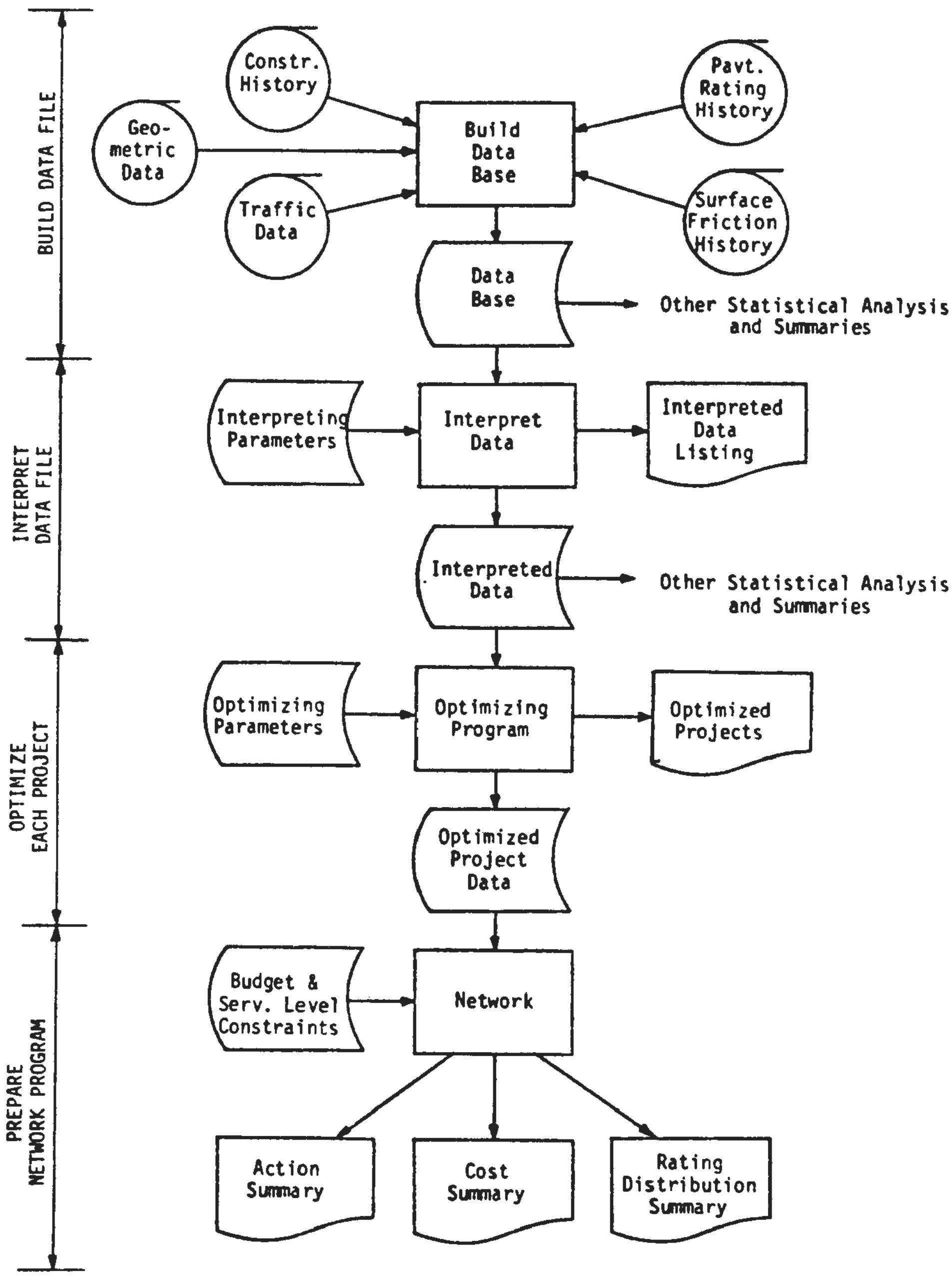
Since the mid 1970's, highway agencies have begun to face the problems of rehabilitating increasing miles of pavements while tax revenues have been in decline and/or eroded by inflation. This dilemma has forced some States like Washington to seek means of improving the management of its pavement programs, that is, to obtain greater accomplishment for each dollar expended. Management improvement requires that information for decisionmakers be reliable, consistent over time, and appropriate for problem solving. In this case WSDOT sought to improve its understanding of pavement performance and established two goals:

1. To predict and forecast existing pavement performance as well as to derive successive rehabilitation alternatives.

2. To develop accurate cost modeling that would reflect real world experience.

In order to achieve these goals WSDOT hired a consultant in 1972 to study the feasibility of establishing a PM system. The consultant's report contained recommendations which were the basis for the development of WSDOT's PM system. In the late 1970's, the Department began to work actively on a pavement management system, involving a refinement of its distress weightings and a new rating formula. The basic rating procedure, however, has not changed since the mid-1960's. Much of the new work was accomplished while studying projects on I-90. A large number of changes resulted: new performance equations, revisions to the constituents of the data base, plus changes in the methods for analyzing yearly

Figure 1



A Conceptual Flow Chart
of PMS Operations

performance ratings and performance equations. A new modular optimization program was also written. All of these improvements were made with the goals of optimizing the expenditure of pavement funds and of obtaining a means of managing pavement serviceability (i.e., predicting, planning, and executing the proper actions to achieve serviceable roads).

C. Current Status

As the first step in a 2-year cycle, in the spring of each odd-numbered year WSDOT conducts distress and ride surveys of its entire State-run system (6900 miles). The results of these surveys are used to rank pavements in a Priority Array, a book which contains a list of analysis sections grouped into a variety of deficiency categories. These deficiency groupings which are listed in order of their priority provide the basic framework for the Priority Array. It is sent to the Districts as a guide for assembling a 6-year construction program. The 6-year construction program, completed by the spring of even-numbered years, contains descriptions of projects, their cost per biennium, and the timing of each phase of the project. While developing the 6-year program the Districts also prepare for each project in the first biennium a "Project Prospectus." This document defines the scope of the project and must receive Headquarter's approval. After most project prospectuses have been approved, the Districts develop a more detailed description of the work to be accomplished in the upcoming biennium, the operating program. The legislature reviews the 6-year program in the spring of each odd-numbered year and appropriates funding for the operating program for the upcoming biennium.

Two recent refinements to this process have been implemented. First, WSDOT now identifies and ranks deficient pavement sections from projected (rather than present) conditions. Second, the Headquarters, using refined project costs from the Districts, conducts additional network programming exercises to anticipate a variety of options and/or constraints on the 2-year operating programs. Also, the Districts may now obtain additional information other than the Priority Array to prepare the 6-year program, such as performance curves, project optimizing, and network programming information. An optimization program has received a great deal of developmental work but is not yet fully operational.

The value of the current system, as described above, depends on the quality of the input information, the data collection. The following is a description of this effort, most of which is centrally stored in a computerized master file.

II. Data Collection/Storage

A. The Master File

In order to build a PM Master File, WSDOT first identified the essential elements for the PM system and then identified a number of items capable of contributing the needed data in an appropriate format. These items are: 1) the Pavement Condition Survey, 2) Surface Friction, 3) Roadlife History, 4) Roadway Inventory, and 5) Annual Traffic.

These data files that were identified as being essential to the PM system were also examined for compatibility with one another and/or suitability for inclusion in the Master File. A problem of incompatibility among the files arose from the fact that two different mileposting (reference) systems are in use. The first system is a strict mileposting system beginning at the southern or western terminals and increasing in a northerly or easterly direction, respectively, until the end of the route. The second reference system is a control section system, wherein the identification numbering is tied to jurisdictions, legal entities and boundaries such as city limits. The control section reference system is used to relate costs to specific geographical units, and all pavement surveys are conducted by control section mileposting, that is, sequential mileposting within each control section.

The problem arises from the fact that the pavement condition survey uses, to identify a section, the control section system which is different from the mileposts that were used to establish the limits of a construction or rehabilitation project. A control section is not determined by major breaks in type of pavement, pavement age, or pavement condition, nor are they delineated by previous paving contract limits. Since it is of prime importance to WSDOT's PM system to relate pavement performance to construction/rehabilitation activity, this lack of section identification compatibility creates a serious problem. Fortunately, the Roadway Inventory File contains both reference systems and is utilized as one of the first steps in building the Master File. An "equate" computer program has been written which permits accessing and inputting data in terms of both reference systems. Therefore, all data in the Master File can be accessed for both a specific milepost and a specific control section.

The components of the Master File are described below. All of the files described below are merged to form this computerized resource. The editing, retrieval, and display of this data is by direct access via remote terminals. The data is aggregated by project, with mileposts corresponding to the most recent pavement surfacing contract.

1. Pavement Condition Survey

   This file contains the results of a pavement condition (distress) survey and a ride (roughness) survey. The distress survey, conducted in the spring of odd-numbered years on the entire State system, consists of a visual inspection of a variety of pavement distresses.

   The surveys are conducted by four two-man crews, each covering about 75 miles per day. The crews evaluate the pavement conditions in 1-mile intervals (called subsections) at the origin of each control section.

   Although the subsections are generally 1 mile in length, they may be shorter or longer so that they may help designate significant changes in pavement conditions. Bridges, ramps, weigh stations, and rest areas are rated separately. The survey crew stops near the middle of each subsection, exits the vehicle, and physically examines a 200 foot segment of the pavement. The defects are measured and the rating for this 200 foot area is applied to the 1-mile subsection.

   On bituminous pavements, the following distresses are examined for severity and extent: corrugations, alligator cracking, raveling, transverse cracking, and patching. A different set of distresses has been established for PCC pavements: cracking, raveling, joint spalling, pumping, blowups, faulting, and patching. The pavement condition rating form is used to record all appropriate distresses, their severity and extent per control sections, and is shown in Figure 2.

CARD TYPE 1 P 2 R

STATE OF WASHINGTON
DEPARTMENT OF TRANSPORTATION

PAVEMENT CONDITION RATING

DATE | RATER | SHEET OF

CONTROL DATA

DISTRICT NO.	STATE ROUTE	FUNCT. CLASS	CONTROL SECTION	CONTROL SECTION SEQ.	ENDING CONTROL SECTION MILEPOST FOR RATED SECTION	PAVEMENT TYPE "A", "B", "C"	* PAVEMENT EXEMPTION	MULTI-LANE (L), (R), (B)
3	7	10	11	15	16	22	23	24

BITUMINOUS PAVEMENTS

RUTTING PAVT. WEAR		* *
CORRUGATION, WAVES, SAGS, HUMPS	% Roadway (1) 1 - 25% (2) 26 - 75% (3) Over 75%	1/8" - 2" CHANGE/10 FT.; 2" - 4" CHANGE/10 FT.; OVER 4" CHANGE/10 FT.
ALLIGATOR CRACKING	(1) Hairline (2) Spalling (3) Spalling & Pumping	1-24% WHL. TRK/STA.; 25-49% WHL. TRK/STA.; 50-74% WHL. TRK/STA.; 75-100% WHL. TRK/STA.
RAVELING OR FLUSHING	(1) Slight (2) Moderate (3) Severe	LOCALIZED; WHEEL PATHS; ENTIRE LANE; R = RAVELING F = FLUSHING
LONGITUDINAL CRACKING	Lineal Ft/Sta. (1) 1 - 99 (2) 100 - 199 (3) 200 Plus	LESS THAN 1/4"; OVER 1/4" WIDE; SPALLED
TRANSVERSE CRACKING	No./Station (1) 1 - 4 (2) 5 - 9 (3) 10 Plus	LESS THAN 1/4"; OVER 1/4" WIDE; SPALLED
PATCHING	% Area/Sta. (1) 1 - 5% (2) 6 - 25% (3) Over 25%	0.10"-0.50" THICK; 0.50"-1.0" THICK; OVER 1.0" THICK

PORTLAND CEMENT CONCRETE

CRACKING	Units Panel Length (1) 1 - 2 (2) 3 - 4 (3) 4 Plus	1-25% PANELS; 26-50% PANELS; OVER 50% PANELS
RAVELING DISINTEGRATION, POP OUT, SCALING	(1) Slight (2) Moderate (3) Severe	1-25% AREA; 26-75% AREA; OVER 75% AREA
JOINT SPALLING	Width (1) 1/8" - 1" (2) 1 - 3" (3) 3 Plus Inches	1-15% JOINTS; 16-50% JOINTS; OVER 50% JOINTS
PUMPING BLOWING	% Panel Lgth (1) 1 - 9% (2) 10 - 50% (3) Over 50%	1-15% OF PANELS; 16-35% OF PANELS; OVER 35% OF PANELS
BLOWUPS		NO. / MILES
FAULTING, CURLING, WARPING, SETTLEMNT	(1) 1/8" - 1/4" (2) 1/4" - 1/2" (3) 1/2" Plus	1-15% OF PANELS; 16-35% OF PANELS; OVER 35% OF PANELS
PATCHING	% Panels (1) 1 - 5% (2) 6 - 20% (3) Over 20%	1-5% AREA/PANEL; 6-25% AREA/PANEL; OVER 25% AREA/PANEL
PAVT. WEAR		* *

ROADMETER COUNTS PER MILE

DUPLICATE

COLUMNS

3 THRU 17

O	SR	FC	C. S. No.	C.S.S.	ENDING CSMP	TY	EX	LRB	BITUMINOUS PAVEMENTS	PORTLAND CEMENT CONCRETE	ROADMETER COUNTS PER MILE

REMARKS:

* CODE = (1) Unpaved Roadways, (2) Roadways under Construction, (3) Bridge, (4) Road Impassable, (5) Other

** Rutting - Pavt. Wear
(1) 1/4" to 1/2"
(2) 1/2" to 3/4"
(3) Over 3/4"

DOT 177-016 REV. 1-81

Figure 2

To provide quality control over the surveys, WSDOT has developed a manual (the "Manual for Pavement Condition Surveys") and provides periodic inspections (checks) of the survey teams' work. In addition, training sessions are provided periodically by the Materials Lab in Headquarters with special attention given to new raters, and survey teams are used in Districts other than their own.

While four crews are in the process of rating pavement distress, an additional, two-man crew employs a Cox Ride Meter to measure roughness. The Cox Meter, used on 1978 Ford LTDs, is calibrated in each District annually and can provide a complete coverage of Washington's State maintained road system in about 3 months, at a rate of around 320 miles/day.

2. Surface Friction

This file contains the results of the annual survey of the State's road system, using a K.J. Law Model 1270 Surface Friction Tester. One-half of the State system is covered each year, an effort requiring approximately 6 weeks per year. The surface friction trailer is calibrated in Austin, Texas, every other year.

3. Roadlife History

This file provides a detailed account of the construction activity for each homogeneous roadway section. It includes all surfacing actions by type, depth, and date, and provides information such as contract number, functional classification, type of highway configuration, base material types and depths, etc. The information is maintained by control section milepost, and the file is kept current.

4. Roadway Inventory

The information contained in the Roadway Inventory includes the following: both mileposting identifications; description of the nearest physical landmark; lane median, and shoulder widths; type of terrain; junctions with other roads; Federal-aid classification, etc. This file does not contain environmental data or the results of materials testing, although such data is maintained for highway projects in a noncomputerized data file.

5. Annual Traffic

Average Daily Traffic Volume (ADT) data are recorded for the State system based on the results of 45 counting locations located throughout the State. Physical observation is used to classify vehicles by type (two/three axle trucks, buses, combination vehicles, etc.). Truck weight information is derived from the State's annual loadometer studies. In the pavement management system, truck weight information in the loadometer tables (W-4) is related to the truck percentages in the traffic file to produce a Traffic Index.

B. Future Data Management Improvements

WSDOT plans to expand the pavement management Master File to include climatological data, construction quality measurements (degree of compaction, void content, etc.), and annual maintenance costs. Improvements will also be made to provide easier and faster access to the Master File data. At this point, WSDOT believes that it would not be cost-effective to attempt to institute a structural (deflection) survey of its pavements, to computerize its materials testing files, or to conduct systemwide analysis of the properties of in-place pavements.

III. Data Analysis

A. Performance Curves

The information contained in the Master File is analyzed on a project-by-project basis, a step in the PM system that WSDOT calls the "interpreting phase." In essence, the WSDOT system is designed to have predictive capability, that is, to provide numerical ratings which can be used to compare serviceability (or a pavement condition rating - PCR) over time so that the point of pavement falure can be predicted. The relationship of PCR and time is demonstrated with the use of performance curves. The steps to arrive at these curves are described below.

1. PCR Calculations

The PCR is obtained by taking the raw data from the distress and ride surveys and, after applying varous weights to different distresses, relating the two survey results with the following equation:

$$PCR = (100 - \Sigma D)\left(1.0 - 0.3\left(\frac{CPM}{5000}\right)^2\right)$$

where: D = defects (or distress)
CPM = counts per mile (ride)

In this equation, the major factor in determining PCR is the defect rating, while the impact of the ride factor is very small. Average PCRs are then assigned to each project, a process which requires additional calculation since the project milepost limits may incoporate several PCR values. As indicated before, the pavement condition survey requires serviceability ratings for each mile of the system.

2. PCR Plotting (Performance Curve Determination)

Once the PCR values for a project are determined, regression analysis is applied if the project has had at least three ratings. If the regression analysis does not produce a good "fit," then the first and last PCR values are used to produce a "typical" regression. In addition, if three rating values are not available for a specific project, then a typical curve is plotted based on the equations of other projects with similar pavement type, surfacing depth, and geographical area. Exceptions to these methods for determining performance curves occur when unreliable results are obtained. Several statistical tests (for variance, R^2, etc.) are conducted to ensure the performance curve is reasonable and useful for forecasting.

3. Project Performance Prediction

Once a performance curve for a project has been established, critical levels of "serviceability" are noted. Figure 3 presents a typical curve. As PCR (serviceability) declines, it reached a point where rehabilitation should be applied. As described by WSDOT (in its Report, #171):

> "This is a state of deterioration at which deterioration is showing, but is not yet severe enough to call for remedial action. Unfortunately, this level of condition is all too often exceeded and the pavement continues to deteriorate until something must be done to rehabilitate the pavement. These two points on the performance curve, appropriately named the "should" and "must" levels, define the most probable rehabilitation period."

B. Project Level Optimization

Although the WSDOT has not made its optimization program fully operational, a number of the elements of the program have been developed. WSDOT's PM system is designed to utilize the performance curves in an optimization program in order to provide a specified level of service at a minimum cost. The overall goal of optimization is to establish a cost-effective rehabilitation program out of a number of possible rehabilitation strategies. Figure 4 shows how different rehabilitation strategies could be pursued on a hypothetical project with a given performance curve. In order to determine the most cost effective strategy, a number of costs must be considered. WSDOT has identified the following cost parameters as being germane:

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

WSDOT also calculates the present worth of these costs by considering the impacts of the inflation rate and the interest rate. Once all costs for each strategy are calculated, then the economic benefits of each action can be compared, and the one with the least total cost can be selected. However, a number of other decisions must be made before these costs can be calculated. For example, not all rehabilitation strategies are appropriate for a specific project in need of repair. A decision can be made only after relating pavement type, traffic patterns, functional system, and other factors to specific rehabilitation strategies.

Therefore, WSDOT developed a set of factors for input into its computerized optimization program; these factors, the optimizing parameters (see Figure 5), provide the necessary information to guide the computer program into selecting only "reasonable and/or desired choices." The optimizing parameters provide guidance that is not available from the interpreted data file and are read by the computer as its initial step in the processing of the optimization program. The flow chart of procedures in this program is provided in Figure 6. In short, this program, having read the optimizing parameters, obtains the performance data for a selected pavement section from the interpreted data file, selects a number of reasonable rehabilitation alternatives, combines these alternatives into several

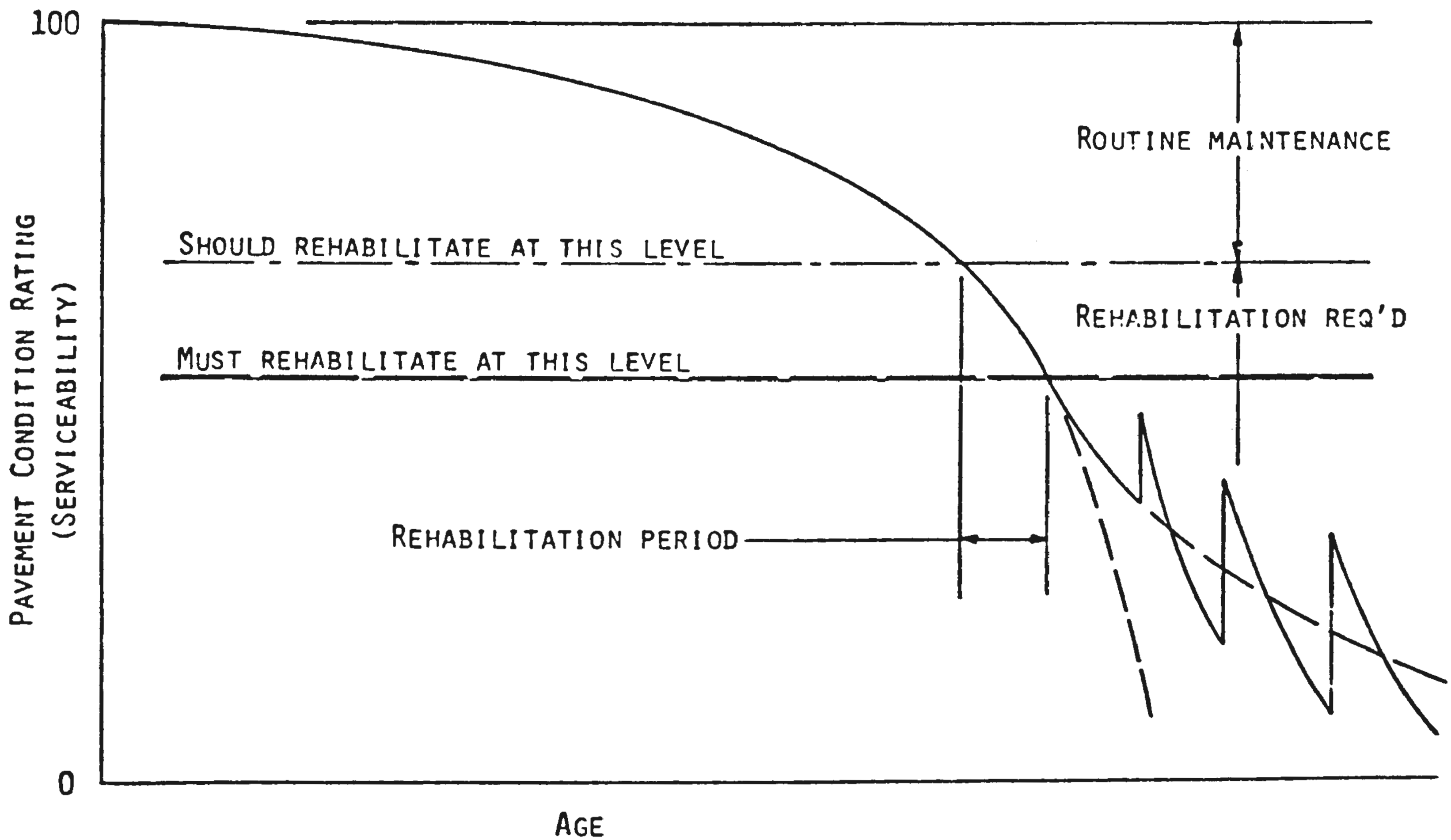
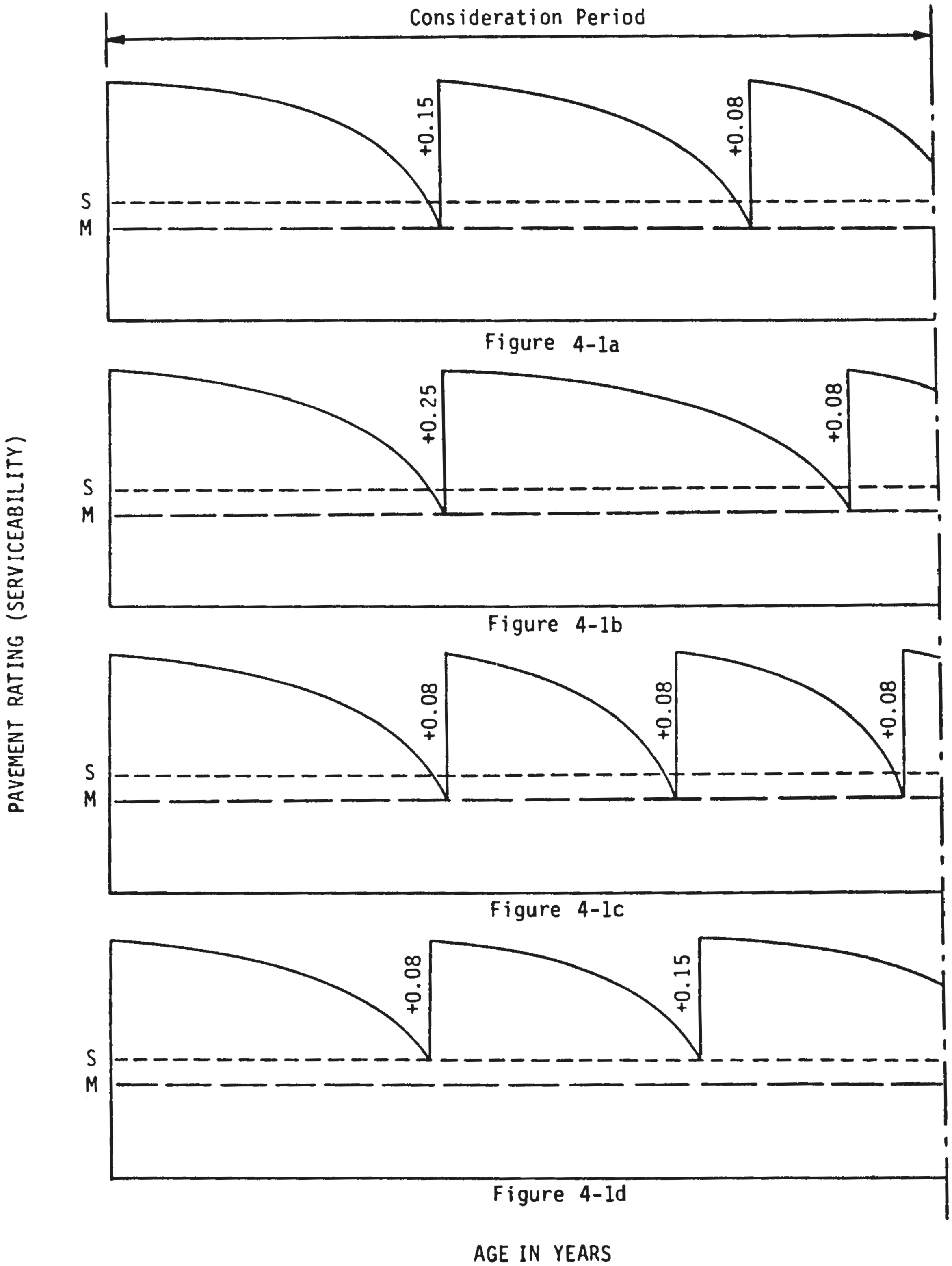

100
0
PAVEMENT CONDITION RATING
(SERVICEABILITY)
AGE
ROUTINE MAINTENANCE
SHOULD REHABILITATE AT THIS LEVEL
REHABILITATION REQ'D
MUST REHABILITATE AT THIS LEVEL
REHABILITATION PERIOD

Figure 3

Figure 4

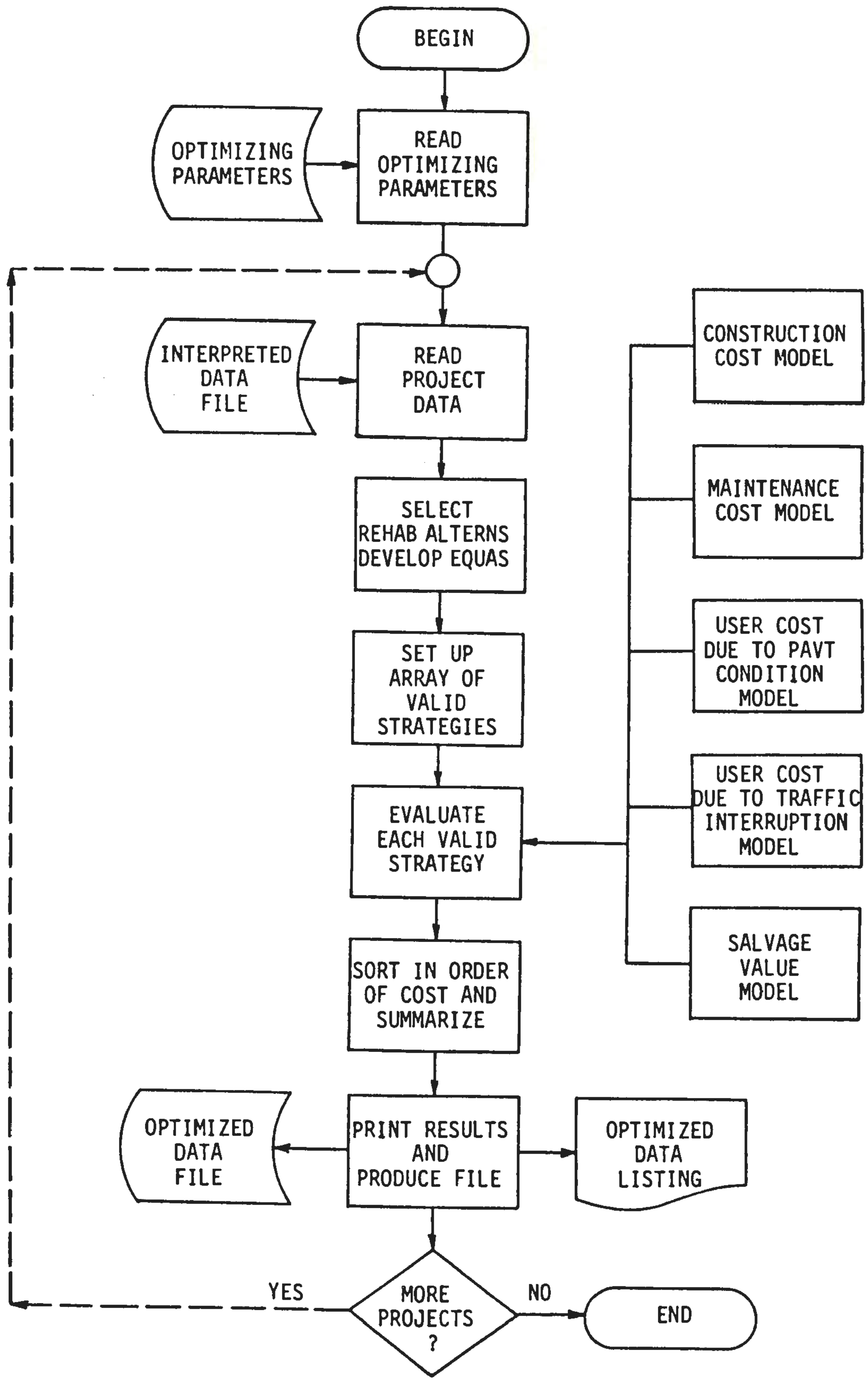

Consideration Period
+0.15
+0.08
S
M
Figure 4-1a
+0.25
+0.08
S
M
Figure 4-1b
+0.08
+0.08
+0.08
S
M
Figure 4-1c
+0.08
+0.15
S
M
Figure 4-1d
PAVEMENT RATING (SERVICEABILITY)
AGE IN YEARS

LIST OF OPTIMIZING PARAMETERS

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

Figure 6

OPTIMIZED PROGRAM



strategies, and then analyzes the strategies using a cost model to determine the optimum (most economical) rehabilitation course. An example of the output of this program is provided in Figure 7. This figure indicates for a specific project the costs of applying rehabilitation alternatives in different sequences. It also provides the project's performance data, optimizing parameters, a description of the rehabilitation alternatives with performance equations, predicted time to the "should" and "must" levels, construction costs, and a listing of the optimized rehabilitation strategies and their costs.

IV. Priority Programming

A. Project Level: Priority Array

The Priority Array represents the Department's policy on establishing the Districts' biennial Work Programs. It is composed of fifteen priority groups which operate as the guiding framework which the Districts must generally follow when selecting projects for their upcoming work schedules.

The Priority Array is used by WSDOT to interface candidate pavement projects with roadway sections that suffer from other deficiencies, such as poor bridge condition, hazardous accident locations, volume/capacity deficiencies, horizontal curvature problems, etc. The Priority Array is developed bienially and compares roadways within the same functional class within each highway district. The ratings represent the "current" condition made at a given point in time from an engineering analysis (an inventory survey) and do not reflect anticipated improvements or deterioration since the survey's completion. The only exception to this is that pavement condition data is now projected ahead 3 years through the use of the performance curves. Each roadway section is ranked according to the priority group which identifies its most critical deficiency.

These fifteen priority groups, listed in the order of the seriousness of the type and severity of deficiency, are as follows:

1. Bridge condition.
2. Pavement condition (I).
3. Hazardous Accident Location Index.
4. Volume/Capacity (I).
5. Horizontal curves.
6. Pavement condition (II).
7. Bridges - Roadway width.
8. Bridges - Posted
9. Pavement Width (I).
10. Bridges - Verticle clearance.
11. Volume/Capacity (II).
12. Pavement Condition (III).
13. Stopping Sight Distance.
14. Roadway Width (II).
15. Pavement Condition (IV).

The pavement condition projects have been separated into four priority groups in the Priority Array, with each group representing a limited range of pavement conditions. The pavement condition priority groups' rankings reflect their relative priority compared with other deficiency categories. If a pavement section falls

R677300PT 01/18/82

D	SR	BEG SRMP	END SRMP	CS	BEG CSMP	END CSMP	PROJ LENG	FNC CLS	SIDE	HWY TYPE	NUM LNS	RD-RSH-LSH WIDTHS	LAST CONTR	COMPLT M-YR	CNT TYP	SURFACE TYP-THK	BASE TYPE
4	5	2638	2930	801	560	852	292	R-5	L	3	2	36 10 6	08759	9-71	0	40 70	21

PERFORMANCE HISTORY

YEAR	73	75	77	81	81
AGE	2	4	6	8	10
RIDE RATING	1.00	1.00	1.00	1.00	1.00
STRUCR RATING	100.0	100.0	100.0	97.4	89.7
COMBD RATING	100.0	99.9	99.8	97.2	89.5
HIGH RATING	100.0	100.0	99.9	99.9	99.7
LOW RATING	99.8	99.8	99.6	94.8	69.9
HIGH FRICTION	40	59	49	49	46
LOW FRICTION	40	56	48	48	41
AVG FRICTION	40	58	48	48	43

APPROXIMATE TRAFFIC DATA

80 ADT 28300
GROWTH RATE 8.2%
SINGLE UNITS 5%
COMBINATIONS 14%
TRAFFIC INDEX 7.8%
K = 13% D = 58%
2 AXLE TRUCKS = 3.3%
3 AXLE TRUCKS = 4.4%
4 AXLE TRUCKS = 1.8%
5 AXLE TRUCKS = 9.4%

PERFORMANCE EQUATION

EQUA CONST = 100.46
EQUA COEFF = -0.0010
EQUA POWER = 4.00
R SQUARE = 0.97184
STD ERROR = 0.78
TIME TO 60 = 13.98
TIME TO 50 = 14.77
TIME TO 40 = 15.45
TIME TO 30 = 16.06
TIME TO 20 = 16.60

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

DESCRIPTION OF ALTERNATIVES	PERFORMANCE EQUATIONS	CONSTRCT COST 12' LANE MILE	MIN LIFE AT SHUD	MAX LIFE AT MUS
ALTERNATE 1 ROUTINE MAINTENANCE	R = 100.46 - 0.00106 P ** 4.00	0	13.02	14.77
ALTERNATE 2 OVERLAY 0.06 CLASS D	R = 100.00 - 0.28783 P ** 2.25	23100	7.89	9.90
ALTERNATE 3 OVERLAY 0.15 CLASS B	R = 100.00 - 0.02713 P ** 3.00	35800	10.34	12.26
ALTERNATE 4 RECYCLE +0.06 CLASS D	R = 100.00 - 0.01551 P ** 3.00	68100	12.46	14.77

ITEMIZED COSTS

ROUT MAINT COST	+	COST OF CONSTR INCL PR	+	COST OF TRAFFIC INTERPT	+	USER COST	-	SALVAGE VALUE	=	EXPECTED TOTAL COST
31930		452691		41189		322760		31555		817015
27999		458887		40685		321859		15777		833653
33687		574218		47638		323015		81219		897339
23987		585276		47069		321377		64975		912723
31883		907635		70386		321932		111519		1220317
21925		932029		69312		320058		95588		1247736

NUMR POSS: 80

STRATEGY DESCRIPTION

(ALTERNATIVE - PRO APPLIED)

NUMR POSS	1ST REHAB	2ND REHAB	3RD REHAB	4TH REHAB
26	2-85	2-94		
18	2-84	2-93		
9	3-85	2-97		
9	3-84	2-96		
9	4-85	2-99		
9	4-84	2-98		

Figure 7

into more than one priority group, it is listed only once (in the highest group), but with the other deficiencies identified by underlining below tolerable values. An example of a Priority Array listing for a District is provided in Figure 8.

The Priority Arrays are distributed to the Districts which use the rankings to assemble a 6-year Legislative Plan and a 2-year "Work Book." The Work Book provides details on the projected operating program for the upcoming 2 years and describes project start times, carry-over projects, and periods when projects are expected to have high rates of expenditure. Districts use the Priority Array and other PM output to varying degrees to develop these work programs. The priority rankings established by the PMS are not absolute, since the Districts also use engineering judgment in selecting projects, rehabilitation strategies, and in assessing overall needs. However, the PMS produces information that assists the Districts in making informed decisions and answers questions concerning the impacts of different plans, rehabilitation strategies, and maintenance operations.

B. Network level

Network programming in WSDOT strives to provide decisionmakers with the necessary information in order to 1) assemble a rehabilitation program, 2) establish effective funding levels, and 3) identify future needs.

In order to provide this information, the network analysis combines the results of the "interpreting phase" (the performance curves) and the "optimizing phase" (cost effective rehabilitation). This analysis is performed for the entire network so that systemwide performance levels and costs can be derived and corresponding levels of funding can also be estimated.

1. Systemwide Summaries

Three summaries of the system are generated for each year of the consideration period. The first is the Action Summary, which is a listing of all projects by State route number which fall below a specified "should" or "must" level. The Action Summary also indicates which type of rehabilitation is required and the associated construction and preparation costs.

The Cost Summary, the second output generated, is a summary by functional class of the gain in average pavement rating that would result if all of the actions listed in Action Summary were undertaken. It also lists the number of miles acted on and the impact on the budget for that year in present, inflated, and discounted dollars. An example of a Cost Summary is shown in Figure 9.

The third summary, the Rating Distribution Summary, indicates how many lane-miles exist in each pavement condition rating group before and after the actions listed in the Action Summary are undertaken. In actuality, the sum of all of these actions far exceed the manpower and budgetary capabilities of the WSDOT. Therefore, the proposed actions contained in the three summaries above are adjusted to provide a more manageable, steady work program, within a more realistic budget.

1982 PRIORITY ARRAY

DATE 7/13/83

DISTRICT NO. 1 INTERSTATE

State Route	Mile Post	TO	Mile Post	Exist Length	1980 ADT	No. Lanes	U R	BRIDGE Life EXP	BRIDGE Post	BRIDGE VERT CL DEV	BRIDGE RDWY WIDTH DEV	PMS PROJ PAVT RATG	HAZ ACCID LOC INDEX	VOL/CAP	PAVT WIDTH DEV	RDWY WIDTH DEV	DEFIC CURVES /MILE DEV	STOP SIGHT DIST PCT DEF	PRIORITY RANK
PRIORITY GROUP 2 PAVEMENT CONDITION												**							
5	Lakeview Oxing to SR 522																		
	166.98	TO	170.81	3.83	175,800	14	U					1230	0.0	0.93	116		0.0	0	76
5	Dearborn St. Oxing to Lakeview Oxing																		
	164.62	TO	166.98	2.36	171,800	12	U					1390	0.0	1.00	92		0.0	0	77
405	SR 169 Oxing to NE 44TH ST Oxing																		
	4.04	TO	7.47	3.43	64,600	4	U					139A	0.0	1.25	20		0.0	0	78
90	E Channel Bridge to Richards RD Oxing								OLD PCC										
	8.58	TO	10.21	1.63	47,800	6	U					154A	0.7	0.76	24		0.0	0	79
PRIORITY GROUP 3 HAZARDOUS ACCIDENT LOCATION													**						
90	Lake Washington Floating Bridge												SPOT						
	5.30	TO	5.40	0.10	52,300		R						78.0F						80
90	Lake Washington Floating Bridge												SPOT						
	5.42	TO	5.45	0.03	52,300		R						52.0F						81
5	Dearborn Street Interchange												SPOT						
	164.60	TO	164.62	0.02	154,950		R						26.0F						82
5	Off Ramp to NE 45/50TH Streets												SPOT						
	168.96	TO	169.04	0.08	173,750		R						16.0F						83
405	124TH Street Interchange												SPOT						
	20.29	TO	20.35	0.06	52,800		U						0.9						84
90	Richards RD Oxing to SR 901 Oxing								OLD PCC										
	10.21	TO	13.77	3.56	29,000	8	U					186A	0.9	0.38	48		0.0	0	85
5	128TH Street Interchange												SPOT						
	186.41	TO	186.51	0.10	61,600		U						0.8						86
5	Alderwood Manor Interchange												SPOT						
	181.51	TO	181.61	0.10	57,850								0.7						87
90	Factoria Interchange												SPOT						
	9.84	TO	9.94	0.10	42,100		U						0.7						88

FIGURE 8

08/29/80

DISTRICT 3
1981 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	PRESENT COST	INFLATED COST	DISCOUNTED COST
1	53	90	157	312	644	48%	30632400	33695545	29454227
2	54	83	104	115	278	41%	8557393	9413074	8228260
3	36	87	30	82	144	57%	6888495	7577323	6623550
4	0	0	0	0	0	0%	0	0	0
5	71	90	21	39	107	36%	10969766	12066726	10547840
ALL	53	88	312	550	1174	46%	57048054	62752668	54853883

Figure 9

2. Network Rehabilitation Program

The WSDOT rehabilitation program is built using the systemwide summaries discussed above but uses two factors to constrain (manage) its size: budget and serviceability. The first constraint, the budget, is used to identify which projects can be built given a limited funding level. A budget constraint can also be applied to show the impact on serviceability that a specified funding level can have. The serviceability constraint identifies those projects that must receive action if a desired level of service is to be maintained. It also points to a required level of funding needed to attain this level of serviceability.

By employing different budgetary and/or serviceability constraints, many different "pictures" of network programming possibilities can be produced. By varying the "should" and "must" levels (for rehabilitation), a different set or mix of proposed projects is also generated. In addition, a number of other factors can be applied to the prioritization program before final decisions can be made: the effect of delay before rehabilitation occurs (i.e., some projects deteriorate faster than others and may require action sooner), the impact of ADT, the demands placed on the maintenance budget, plus the need to coordinate with other, non-pavement deficiencies (capacity, safety, geometric demands). (This last item is addressed in WSDOTs report, the Priority Array.) All of these factors have a role in the decisionmaking process. WSDOT's network programming capabilities have greatly assisted this process by providing answers to a great many "what if" questions and by showing the corresponding impacts that administrators' decisions can have on Washington's highway system.

Pavement Management In Arizona

I. Introduction

The Arizona Department of Transportation (ADOT) initiated its formal efforts at developing a pavement management system (PMS) in the mid-1970's. Earlier, the Materials Office staff had performed some pavement monitoring, including measuring structural adequacy, skid, roughness, and distress. The Research and Materials offices had undertaken this monitoring as part of an investigation into ADOT's design procedures. In the mid-1970's, with support from top ADOT management, Arizona focused its pavement management efforts on the development of a decisionmaking model. Specifically, this model was to provide a rationale for ADOT management to select an optimum, initial structural design and maintenance strategy for new pavements and to optimize maintenance strategies for existing pavements. A steering committee composed of high-level representatives from ADOT management was established to provide guidance and support for the PMS project. It was also decided at this time to use a consultant to develop the actual PMS models. The PMS development was largely completed in 1979, with the first application of its optimization model in a rehabilitation program occurring in 1980.

The following summary relies primarily on information obtained from the Demonstration Project 61 Project Development Team's field visit to Arizona in July, 1982. The summary focuses on data collection, data analysis, and the programming aspects of pavement management.

II. Data Collection

The Arizona data collection effort consists of an annual survey which primarily involves measurement of roughness and cracking. Skid resistance data is also collected, but is not regarded as a major input into the PMS. Similarly, deflection data is collected, but only for design purposes.

The Pavement Services Branch with a permanent staff of 11 people has the responsibility for conducting the annual survey, analyzing the results, preparing reports related to the survey, and performing other pavement management related work. This Branch also conducts training for the technicans, on an as-needed basis based on normal turnover of personnel. To date, quality control has been very satisfactory.

The entire 7,400 miles of the surveyed highway system (6,088 centerline miles plus 1,330 miles of opposite direction roadway) are divided into 1-mile segments. The milepost reference system is used to delineate the beginning and end of each segment with each segment assumed to be homogenous. The vast majority of the ADOT highway system is asphalt concrete (AC); only 180 miles is Portland Cement Concrete (PCC). The PCC segments are treated separately in the PMS.

The two major components of the ADOT survey - roughness and condition - are discussed below. In addition, two other components of the ADOT PMS - "roadway categories" and "condition states" - are also discussed. An understanding of these concepts is necessary before attempting to understand the analytical portion (the models) of the system.

A. Roughness

The ADOT measures roughness for every mile of the highway system annually, measuring undivided roads in one direction and divided roads in both directions in the travel lane only. The survey is conducted from May to September and employs two vehicles equipped with Mays ride meters. The vehicles are calibrated weekly on a test pavement and less frequently using wooden calibration strips (a test procedure described in NCHRP 228, "Calibration of Response Type Ride Roughness Measuring Systems"). In 1982, ADOT acquired a digitalized data processor and a printer, equipment that will reduce the amount of time to process the raw data.

The Mays ride meter scores are reported as "inches per mile" (with a greater number of inches per mile indicating a rougher road) and are correlated with panel ratings on a scale of 0 to 5. Using a panel's ratings, ADOT determined levels of service that are called "desirable" and "undesirable." The desirable and undesirable roughness levels are set as follows:

Desirable	$<$ 165 inches/mile
Undesirable	$\geq$ 256 inches/mile

These levels of service play an important role in ADOT's data analysis and in the optimization models, as discussed below (see Section III).

B. Condition Survey

The ADOT's condition survey consists largely of measuring the percentage of an area of a pavement section that is cracked. The cracking survey is conducted at each milepost where a 1,000 sq. ft. area is measured. A rating crew is to observe the pavement cracking condition and assigns a percentage cracking number using photographs as a guide. The photographs represent the full range of pavement cracking. If the cracking is greater than 0 at the milepost, then the rating crew is to observe a second 1,000 sq. ft. area at the ½ milepost. The two values are then averaged for an overall score for the roadway segment. Recently, ADOT decided to add in a factor for percentage of the pavement that is patched. For example, if 50% of the area is patched, this is recorded. Subsequently, a computer program adds 10% of the patching value (5%) to the observed cracking.

In 1979 - 1980, the roughness survey cost about $35,000/year and the cracking survey cost about $25,000/year, for a total PMS survey cost of $60,000. These costs translate to approximately $8.13/mile.

In order to store and retrieve its PMS data in an efficient, rapid manner, ADOT has developed a computerized, interactive management information system. The pavement performance data bank includes for each route number, milepost, and direction the following data: skid, condition, deflection[1/], and roughness measurements; maintenance costs; pavement design and as-built data; and traffic and accident data. Eventually, the data bank will also include priority rating and cash flow information. All of this information can be readily retrieved through use of on-line and remote terminals. Printed copies of the displayed data are also available. Exception reports are also available whereby the computer will search files and indicate all segments which do not meet prescribed standard values (as entered by the user).

1/ Deflection data is no longer collected systemwide, but the data base still contains the values from prior years.

C. Roadway Categories and Condition States

Roadway categories are groups of roads with similar traffic characteristics and with similar climatic conditions. By establishing three levels of ADT and three regional factors, nine roadway categories have resulted. The ADT levels are:

1. 0 to 2,000 (low)
2. 2,001 to 10,000 (medium)
3. > 10,000 (high)

The regional factors are based primarily on elevation and rainfall and thus reflect different rates of deterioration of pavement condition attributable to climate. Different ADT levels also correlate with different rates of pavement deterioration. Therefore, ADOT believes that by assigning each segment to its appropriate roadway category and looking at each roadway category separately, its rate of deterioration can be judged more accurately and feasible rehabilitation fixes can be determined for each segment with greater reliance.

Condition states represent a numerical index whereby numbers are assigned to roadway segments which describe the present or expected (future) conditions of roadway segments, based on a combination of four physically measurable parameters. The four parameters are:

1. present roughness,
2. present cracking,
3. change in cracking, and
4. index to first crack.

Each of these parameters is then divided into ranges. The first parameter, present roughness, contains three ranges:

1. Good : <165 inches/mile
2. Fair : 165 to 255 inches/mile
3. Poor : >255 inches/mile

The second parameter, present cracking, is the percent cracking from the condition survey and similarly contains three ranges:

1. Good : < 10%
2. Fair : 10 to 30%
3. Poor : >30%

The third parameter is the change in percent cracking from one survey to the next and similarly contains three ranges:

1. Low : ≤5%
2. Medium : 6 to 10%
3. High : >15%

The fourth parameter is an index tied to the estimated time it takes for the first crack to appear after a rehabilitation action is applied. It is used primarily to define how well a given rehabilitation action is expected to last. There are five ranges for index to first crack. The first range contains those roadway segments expected to take 16.1 to 20 years for the first crack to appear. At present, ADOT is using only this range. This represents a default value ADOT currently uses until they have a better handle on this parameter through operation of the system. The second range will contain segments expecting cracking in 0 to 4 years. The remaining ranges similarly cover 4-year spans, up to 16 years.

By combining all possible combinations of the different ranges for these four parameters and after eliminating 15 physically impossible conditions (i.e., a "low" present cracking and a "high" change in cracking, etc.), 120 possible condition states are produced. Figure 1 provides the numbers that ADOT has assigned to the 120 condition states and also indicates how each condition state is defined (i.e., which ranges of the four paramaters apply to it).

In summary, each roadway section is assigned to a "roadway category" based on ADT and environment and is further assigned to a "condition state" based on physical conditions. Both the "roadway category" and the "condition state" are used below in Arizona's various models (see Section III).

III. Data Analysis

A. The Network Optimization System: Overview

The heart of ADOT's data analysis capabilities rests with a "Network Optimization System" or NOS. It is a computerized program used to assist in optimizing expenditures of rehabilitation funds to meet prescribed system performance standards. By relating expenditures to performance, the NOS can not only assist in minimizing costs for achieving a prescribed standard but can determine system performance standards that can be achieved with a given budget (i.e., maximize system pavement performance). "System performance" is defined in terms of a minimum percentage of roadways that have acceptable roughness and cracking and a maximum percentage of roadways that are tolerated with unacceptable roughness and cracking. Different system performance standards (i.e., different levels of acceptable and unacceptable roughness and cracking) are established for ADT ranges in each of the nine roadway categories. Separate standards have also been recently established for the Interstate system.

The NOS' capability to relate performance to expenditures permits ADOT to compute costs for various standards, to determine the impact of budgetary changes, and to deal more effectively with Arizona's legislature and the Transportation Board. Other applications and objectives of the NOS include assistance in allocating resources Statewide based on an objective process (rather than on the opinions of District personnel). Finally, the NOS output forms the basis for ADOT's 1-year and 5-year preservation programs.

The NOS model is really a combination of three models (see Figure 2). These models - the prediction model, the cost model, and the optimization model - are further explained below, along with their input requirements.

B. Prediction Model

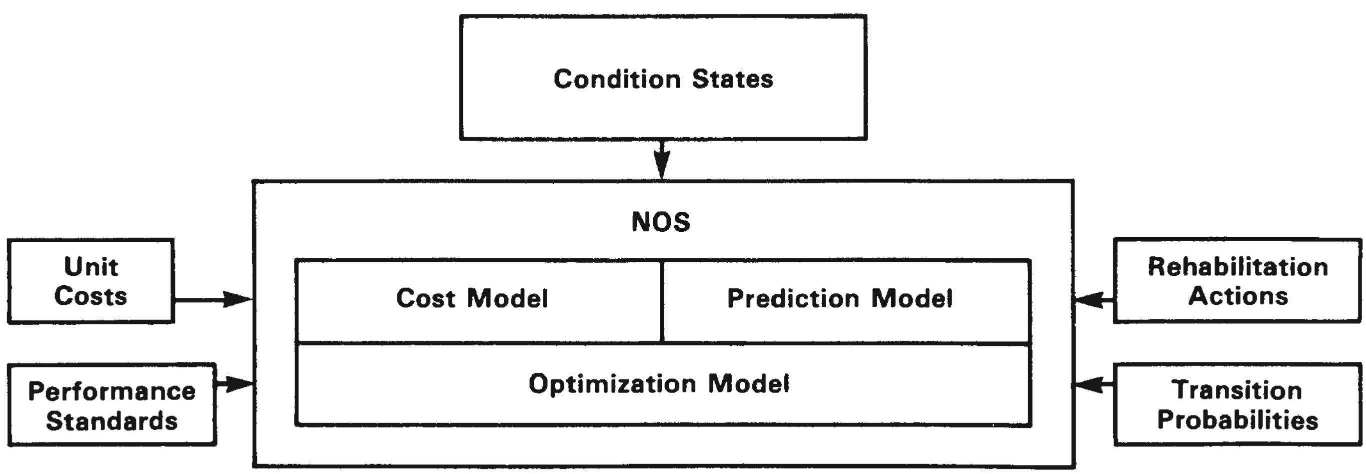
The first model, the prediction model, attempts to predict with a specified probability what condition state a roadway segment will be in 1 year after a rehabilitation fix has been applied to it. It requires three inputs: 1) current condition states, 2) rehabilitation actions and associated feasibility determinations, and 3) transition probabilities. The condition states are the 120 combinations of the various ratings for: present roughness and cracking; change in cracking during

Figure 1

Ride Now		% Cracking Now		Δ% Cracking	Condition States Index 1st Crack				
1	Good	1	Good	1 Low	1	25	49	73	97
1		1		2 Med	2	26	50	74	98
1		2	Fair	1 L	3	27	51	75	99
1		2		2 M	4	28	52	76	100
1		2		3 High	5	29	53	77	101
1		3	Poor	1 L	6	30	54	78	102
1		3		2 M	7	31	55	79	103
1		3		3 H	8	32	56	80	104
2	Fair	1	Good	1 L	9	33	57	81	105
2		1		2 M	10	34	58	82	106
2		2	Fair	1 L	11	35	59	83	107
2		2		2 M	12	36	60	84	108
2		2		3 H	13	37	61	85	109
2		3	Poor	1 L	14	38	62	86	110
2		3		2 M	15	39	63	87	111
2		3		3 H	16	40	64	88	112
3	Poor	1	Good	1 L	17	41	65	89	113
3		1		2 M	18	42	66	90	114
3		2	Fair	1 L	19	43	67	91	115
3		2		2 M	20	44	68	92	116
3		2		3 H	21	45	69	93	117
3		3	Poor	1 L	22	46	70	94	118
3		3		2 M	23	47	71	95	119
3		3		3 H	24	48	72	96	120

Assignment of Condition State Numbers
to Various Ranges of Physical Conditions

Figure 2



Three Models Comprising NOS

previous year, and the estimated time before the first crack. The rehabilitation actions consist of 17 fixes ("actions") for AC pavements determined from ADOT's historical experience with rehabilitation work. The fixes include routine maintenance, seal coats, various overlay thicknesses with and without crack retarding treatment, and recycling (see Figure 3).

Based on input from the pavement design shop, maintenance shop, and the districts, ADOT determined which rehabilitation actions were feasible for roadway segments in each of the 120 possible condition states. This determination was made for each of the roadway categories and constitutes the first step in the NOS process. Figure 4 is an example of a matrix of feasible rehabilitation fixes for a roadway category (x traffic, y region), although, for the sake of convenience, the matrix lists the infeasible actions. (All unlisted fixes are assumed to be feasible.) By limiting the actions to only the feasible ones, the NOS is prevented from selecting unrealistic actions and is saved from going through numerous, unnecessary iterations.

The NOS selects a trial fix and predicts performance over a 1-year period. Performance prediction is based on four primary factors: roadway condition, fix selected, loads applied, and environment. Since not all roadways will deteriorate exactly the same, even after taking into consideration the above four factors, ADOT assigns a transition probability factor to assist in predicting future performance. Transition probabilities recognize not only that a fix will improve the condition state of a roadway segment (rejuvenation) but that a deterioration process sets in as soon as the fix is applied. Transition probabilities predict the end result after 1 year of this rejuvenation/deterioration process through the use of a normal distribution. This concept is based on the assumption that if an identical fix is applied to a group of roads in the same condition and their condition is measured at a later date (1 year, for NOS), then they will not all be in the same condition state but will be distributed among the condition states as determined by the formula for a normal curve. The transition probability is often thought of in the aggregate, i.e., the percentage of miles of the initial condition state that will move to each of the other condition states after a given time period (1 year) when a particular rehabilitation action is applied. Figure 5 provides a simplified example of applying transition probabilities (TP) to 1,000 miles in an initial condition state. As shown, the TP of going to condition state 1 is equal to .800; thus, 800 miles end up in this condition state. The TP of going to condition state 50 is shown to be 0.195, producing 195 miles; and the TP of going to condition state 120 is 0.005, totaling 5 miles. In the actual NOS, every beginning condition state is assigned a TP of ending up in each of the 120 condition states. The result looks like Figure 6, except that the TP's are developed for all 120 condition states.

The transition probabilities formula is developed through a regression analysis by roadway category of historical data on: 1) initial condition, 2) particular fix applied, and 3) condition one year after fix. The TP formula is used to develop a probability matrix for each combination of condition state and rehabilitation action (fix) and for each roadway category. ADOT used historical data on these variables to develop the regression equation for the probability formula. In addition, the model was later successfully tested using historical data on segments not included in the model's development.[2/]

2/ The methodology involved in the NOS prediction model includes the Markovian decision process and linear programming. For more complete discussions of these aspects of NOS, please see "Development of a Network Optimization System," two volumes, Report No. FHWA/AZ-80/155 A & B, HPR-1-17(155).

Figure 3

Alternative Rehabilitation Actions

AC Roads

Action Index	Action Description
1	Routine Maintenance Only
2	Seal Coat
3	ACFC
4	ACFC + Asphalt Rubber (AR)
5	ACFC + Heater Scarifier (HS)
6	1.5″ AC
7	1.5″ AC + AR
8	1.5″ AC + HS
9	2.5″ AC
10	2.5″ AC + AR
11	2.5″ AC + HS
12	3.5″ AC
13	3.5″ AC + AR
14	3.5″ AC + HS
15	4.5″ AC
16	5.5″ AC
17	Recycling

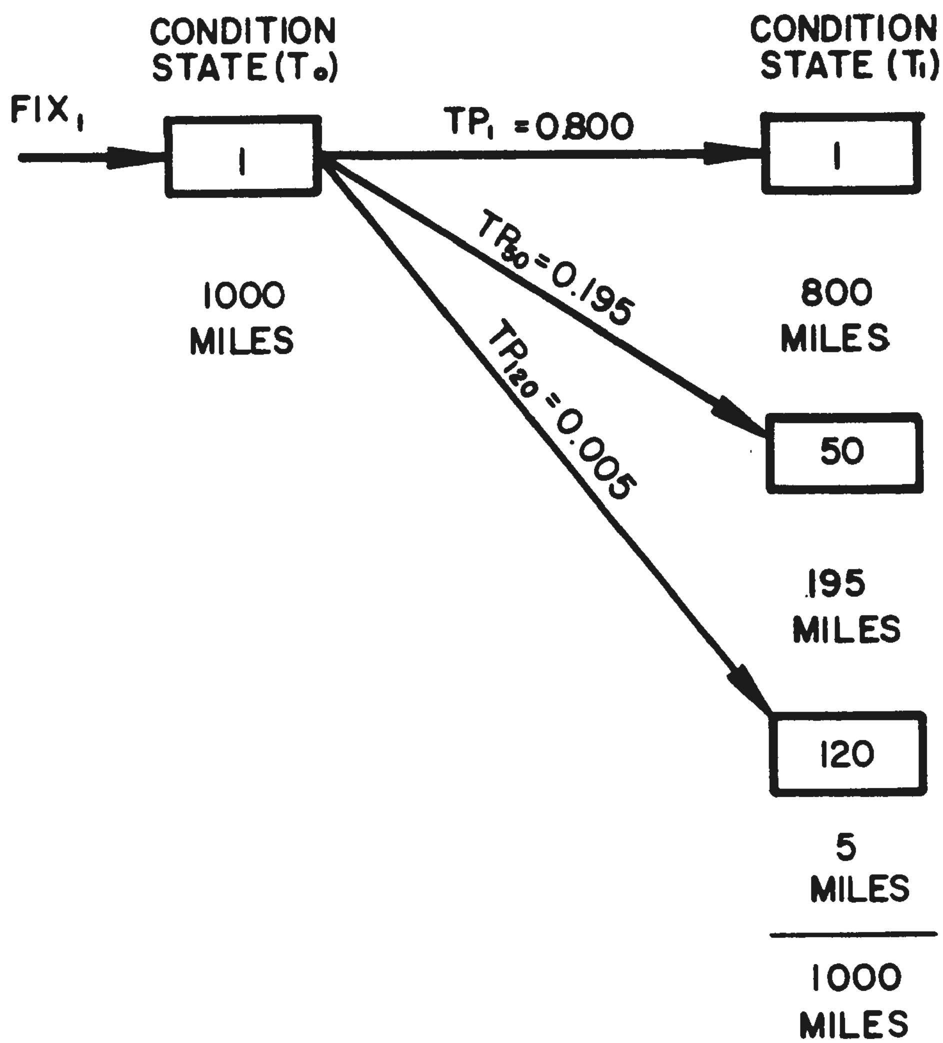
ADOT Rehabilitation Actions
for Asphalt Concrete Pavements

Figure 4

X Traffic—Y Region

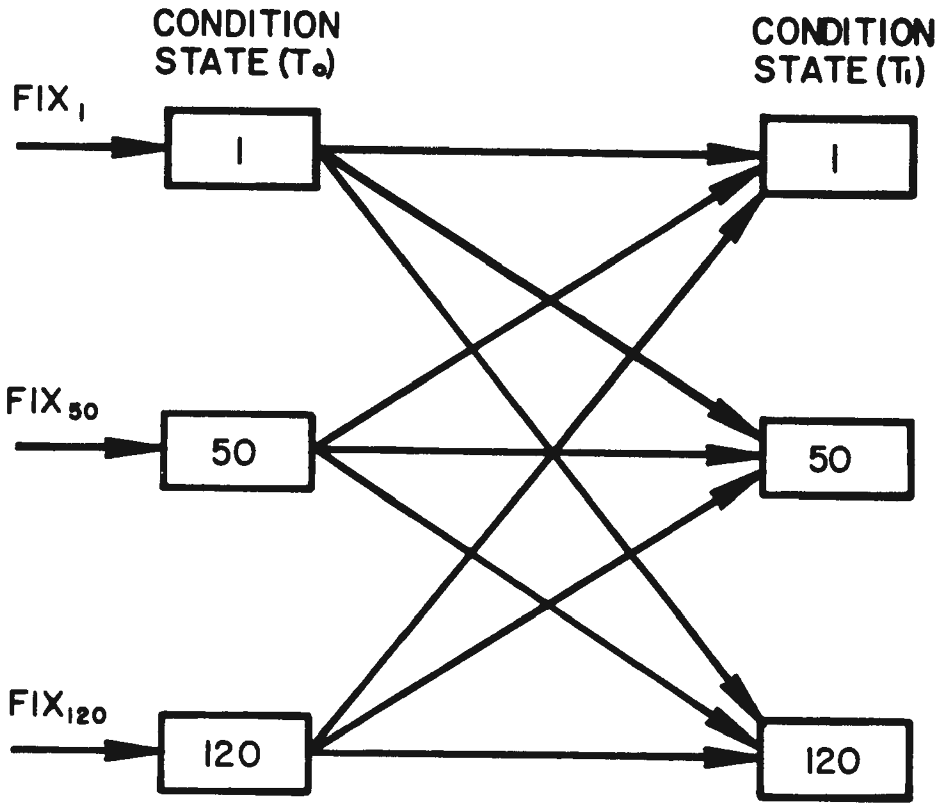
Ride Now		% Cracking Now		Δ% Cracking	Condition States Index 1st Crack					Infeasible Actions
1	Good	1	Good	1 Low	1	25	49	73	97	2-17
1		1		2 Med	2	26	50	74	98	
1		2	Fair	1 L	3	27	51	75	99	4,6-17
1		2		2 M	4	28	52	76	100	
1		2		3 High	5	29	53	77	101	2, 3, 6, 9-17
1		3	Poor	1 L	6	30	54	78	102	
1		3		2 M	7	31	55	79	103	
1		3		3 H	8	32	56	80	104	
2	Fair	1	Good	1 L	9	33	57	81	105	2, 4, 7, 8, 10-17
2		1		2 M	10	34	58	82	106	
2		2	Fair	1 L	11	35	59	83	107	2, 3, 6, 13-17
2		2		2 M	12	36	60	84	108	
2		2		3 H	13	37	61	85	109	2, 3, 6, 9, 13-16
2		3	Poor	1 L	14	38	62	86	110	
2		3		2 M	15	39	63	87	111	
2		3		3 H	16	40	64	88	112	
3	Poor	1	Good	1 L	17	41	65	89	113	2-7, 10, 13, 14
3		1		2 M	18	42	66	90	114	
3		2	Fair	1 L	19	43	67	91	115	2-7, 9
3		2		2 M	20	44	68	92	116	
3		2		3 H	21	45	69	93	117	2-9
3		3	Poor	1 L	22	46	70	94	118	
3		3		2 M	23	47	71	95	119	
3		3		3 H	24	48	72	96	120	

Figure 5



Application of Transition Probabilities

Figure 6



Transition Probability Results

C. Cost Model

The second model in the NOS is the cost model. In this model, each rehabilitation action is assigned a cost factor, composed of a construction cost and a maintenance cost. The construction cost represents the initial cost (on a unit price basis) of implementing a rehabilitation action. ADOT surveyed its construction bid price file and developed a Statewide average cost for each type of rehabilitation activity. The unit prices are constant for all roadway categories and for all condition states. The construction costs for all 17 rehabilitation actions for AC are shown in Figure 7.

The maintenance costs represent the cost of providing continual maintenance to a highway segment for 1 year after application of a rehabilitation action. These costs, which were developed from a study of a few select projects, vary not only with the rehabilitation action applied but also with the initial condition state. The cost of maintenance when the fix is "Routine Maintenance" only (fix #1) is derived from the formula:

Routine maintenance cost = 950 - (200 x Ride Index) + (43 x % cracking)

This formula indicates that the ride index and the percent cracking play a major role in determining maintenance costs. In addition, in this formula, the routine maintenance costs become higher as the ride worsens (a lower ride index) and as the percentage cracking increases. Using this formula, ADOT has calculated a cost matrix (in $/sq.yd.) for the routine maintenance only category (fix #1) . For the seal coat category (fix #2), a separate maintenance cost formula is used based on percent cracking. For all other rehabilitation actions (fixes 3 - 17), a set cost of $0.036/sq.yd. has been established.

The cost model is updated annually to reflect changes in the unit price of labor, material, and equipment. In addition, since NOS is used to produce a 5-year optimized program of projects, the cost model contains an inflation factor and a discount factor to relate costs in terms of real dollars.

D. Optimization Model

The optimization model combines the results of the prediction and cost models and relates these to system performance standards. Its objective is to find the cheapest combination of rehabilitation actions to be applied to the various highway segments that will just meet the established system performance standards. These standards are essentially a policy input requiring management action. Initially, ADOT established standards which varied with ADT but has since supplemented them with separate standards for Interstate. The first standard is a minimum proportion of roads that must be in acceptable condition, with acceptable defined as:

roughness $<$ 165 in./mile
cracking $<$ 10%

The second standard is the maximum proportion of roads that will be tolerated in unacceptable condition, with unacceptable defined as:

roughness $\geq$ 256 in./mile
cracking $\geq$ 30%

Figure 7

Construction Costs of Various Rehabilitation Actions

Action Index	Action Description	$/Square Yard
1	Routine Maintenance	0
2	Seal Coat	0.55
3	ACFC	0.75
4	ACFC + (AR)	2.05
5	ACFC + (HS)	1.75
6	1.5″ AC	1.575
7	1.5″ AC + AR	2.875
8	1.5″ AC + HS	2.575
9	2.5″ AC	2.625
10	2.5″ AC + AR	3.925
11	2.5″ AC + HS	3.625
12	3.5″ AC	3.675
13	3.5″ AC + AR	4.975
14	3.5″ AC + HS	4.675
15	4.5″ AC	4.725
16	5.5″ AC	5.775
17	Recycling (Equivalent to 6 Inches AC)	6.30

The non-Interstate performance standards for each range of ADT are found in Figure 8. This figure shows that the higher ADT category standards require a higher proportion of roads in acceptable condition and a lower proportion of roads in unacceptable condition. The performance standards shown in Figure 8 reflect the current ADOT policy decision to maintain the roadway system at its current level of performance (that is, to establish a steady state roadway system condition). These standards basically reflect the actual condition distribution of the system mileage in 1980 when the PMS was implemented.

E. NOS in Operation

The NOS model begins by comparing the predicted condition state distribution resulting from applying the cheapest mix of rehabilitation actions to the performance standards. This process is performed separately for each of the nine roadway categories. The probability of the lowest cost mix of fixes leading to the achievement of performance standards is low. Therefore, the NOS incrementally adds a higher order (more expensive) mix of improvements. This process of increasing the costliness of the mix is continued iteratively until the system performance standards are met.

All of the work to this point has produced the least expensive set of fixes that will meet system performance standards but only for the first year. However, since a 5-year program is the expected output of the NOS, the entire sequential process must be run again for each of the 5 years. On each run, the predicted conditions must meet the performance standards; furthermore, a minimum cost for all 5 years must be obtained. This requirement causes the NOS to run through the 5-year cycle literally thousands of times. Figure 9 provides a simplified summary of the entire, iterative NOS process. When the NOS finally obtains a 5-year mix of actions that meet system performance standards for each year at the lowest possible overall cost, then the NOS provides an optimum program for review and submission to the ADOT priority planning committee. This program, unless modified by this committee, is then sent to the Arizona Transportation Board and the Governor for approval.

IV. Programming

A. Project Level

The project and network levels of programming are interrelated activities in Arizona, largely as a result of the comprehensive capabilities of the NOS. Figure 10 depicts the flow of the entire PMS from initial data collection through the monitoring phase. The NOS is the primary tool to develop an overall rehabilitation program over a 5-year period and is the primary guide for determining specific rehabilitation actions (including routine maintenance) for each highway segment. An important requirement for the NOS to produce an optimum rehabilitation program (with an associated minimum cost) is to specify system performance standards as discussed in Section III D above.

Using its computer capabilities and an extensive data file, ADOT management was provided with timely and accurate historical condition information. The data showed that the Arizona network was generally in good condition, and thus a decision was made to use the 1980 distribution of mileage in various conditions as the system performance standards.

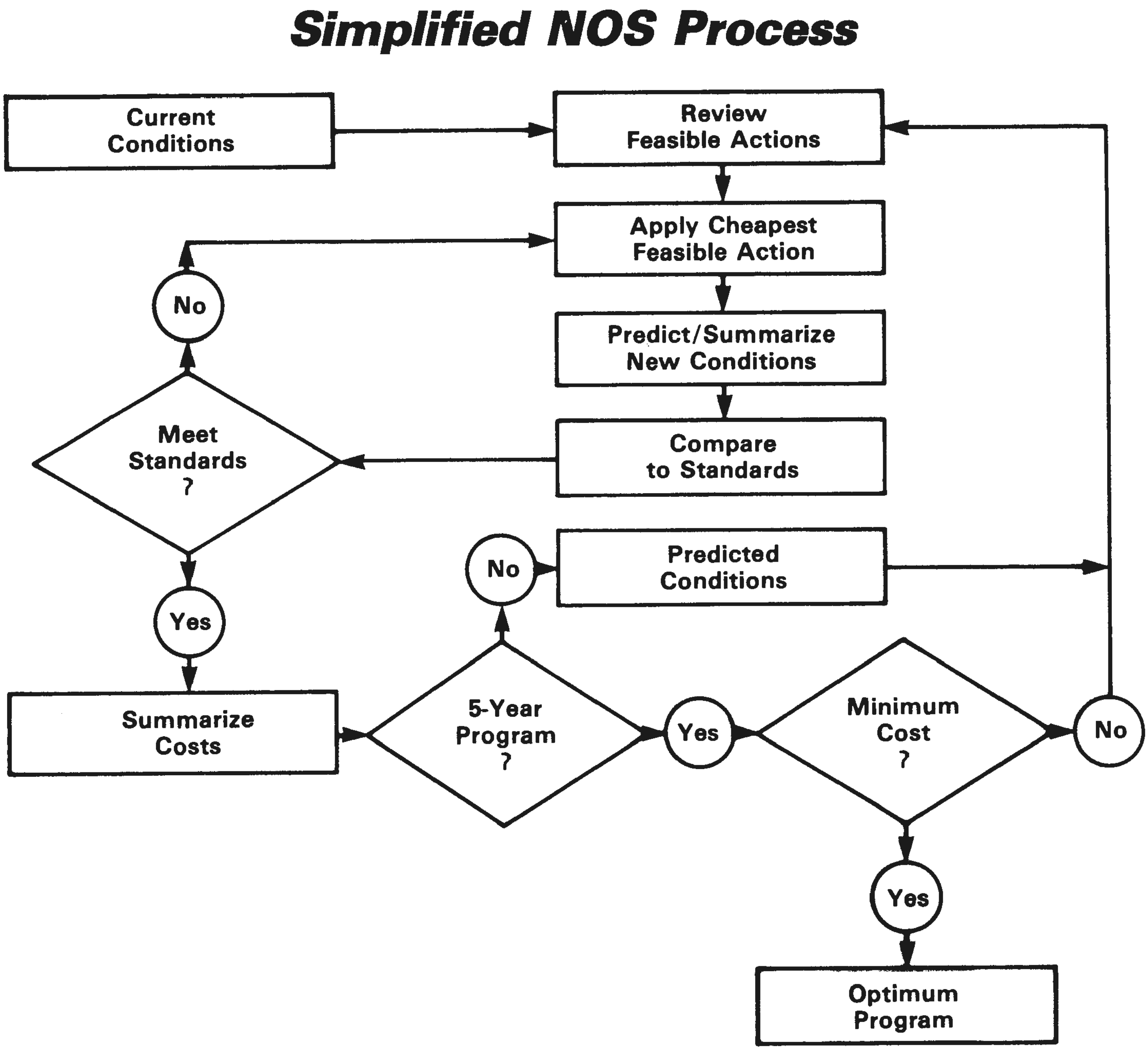
Figure 8

Current Performance Standards for the NOS *

ADT	Roughness		Cracking	
	Minimum Proportion Acceptable	Maximum Proportion Unacceptable	Minimum Proportion Acceptable	Maximum Proportion Unacceptable
0-2,000	0.50	0.25	0.60	0.25
2,001-10,000	0.60	0.15	0.70	0.20
>10,000	0.80	0.05	0.80	0.10

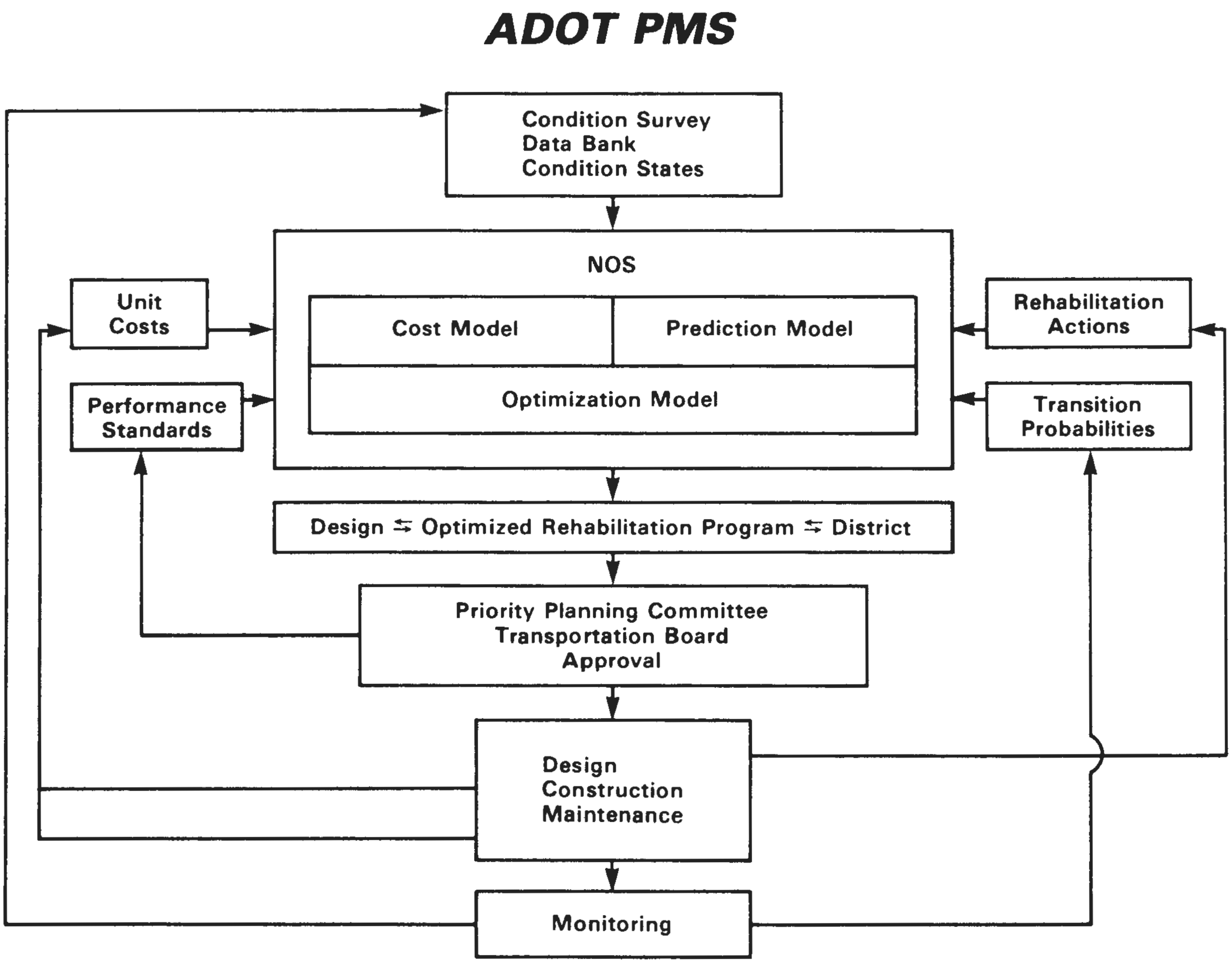
*Note: The Standard for 1980. The Standard subsequently segregated into Interstate and non-Interstate in 1981.

Figure 9



Simplified NOS Process
Current Conditions
Review Feasible Actions
Apply Cheapest Feasible Action
Predict/Summarize New Conditions
Compare to Standards
Meet Standards ?
No
Yes
Predicted Conditions
No
Summarize Costs
5-Year Program ?
Yes
Minimum Cost ?
No
Yes
Optimum Program

Figure 10


ADOT PMS
Condition Survey
Data Bank
Condition States
NOS
Unit
Costs
Cost Model
Prediction Model
Rehabilitation
Actions
Performance
Standards
Optimization Model
Transition
Probabilities
Design ⇆ Optimized Rehabilitation Program ⇆ District
Priority Planning Committee
Transportation Board
Approval
Design
Construction
Maintenance
Monitoring

Using this standard, the NOS was subjected to a test run, with the result that the standard was achievable within budget constraints. If the budget constraints were too severe to implement the NOS recommendation, then new performance standards would be set, and the process repeated. Other test runs are usually conducted and are discussed in Section IV B below. The actual output of an NOS run is a "5-Year Transportation Construction Program" (which is also discussed below), but the first part of the 5-year program presents a list of the proposed segments in need of action in year 1, the type of action recommended, and its cost.

The Pavement Management Branch in the ADOT Materials Section provides condition data to the Design Branch on all of the segments that the NOS selected for a major rehabilitation action in year 1. However, the selected fix ("action") that NOS designated is not given to the Design Branch which, instead, develops an independent fix based on condition data. The Design Branch also estimates an associated cost for each fix. The Materials Section compares the NOS and Design Branch's proposed fixes and costs and arrives at a solution (a revised NOS) satisfactory to both sections. Next, the Districts are provided with the revised NOS output, and any additional problems with the fixes/costs are noted and discussed. The Priority Planning Committee then reviews the revised NOS and is responsible for resolving differences between the pavement mangement group and the Districts. The Committee also resolves conflicts or problems that may arise between the rehabilitation and construction programs. Finally, the Committee makes formal recommendations to the Transportation Board, which approves or modifies the highway program.

Since the NOS has already selected specific segments, and since the Materials Section and the Districts have all provided input into the assignment fixes to these segments, the remaining implementation of the NOS program is mostly a formality. Essentially, the Materials Section does the design and the Districts perform the project construction.

As the projects are undertaken, rehabilitation actions are monitored and, if they do not perform as expected, the Materials Section can alter the "feasible actions" list in the NOS program. This alteration will prohibit the NOS from selecting a particular action since its performance has been unsatisfactory under specific conditions. Similarly, the cost factors in the cost model are adjusted as unit prices change.

B. Network Level

The NOS is capable of performing trial runs using various standards to reflect different policy considerations. This capability permits ADOT management to see the implications of lower minimum acceptable standards and/or higher maximum unacceptable standards. In addition, different standards can be hypothesized (and tested) for different ADT ranges. In conjunction with performing the trial runs, the NOS can produce the miles in each category (highway type by ADT), the costs of this category's rehabilitation actions, and the percentage of the preservation budget it will consume.

As indicated earlier, the ultimate output of the NOS is Arizona's "5-Year Transportation Construction Program." This publication contains: for the first year, specific segments to be rehabilitated, a recommended fix and cost; for the second year, the probable actions and costs; for the third through fifth years, the total program costs. It also provides by fiscal year a breakdown of the costs of Interstate construction, non-Interstate construction, pavement preservation, and other (see Figure 11). In Arizona, the pavement preservation costs are about 28 percent of the total construction program costs.

The NOS is thus used for budgeting, planning, and historical analysis purposes. It can provide a summarized picture of the conditions and needs of Arizona's pavements or it can break this picture down to provide a more detailed view in as many formats as ADOT management desires. As such, the NOS provides Arizona with a sophisticated and versatile tool for performing network analyses and programming.

Figure 11

5-Year Construction Program
(Millions)

	FY 83	FY 84	FY 85	FY 86	FY 87	Total
Interstate	$ 86.8	$ 82.5	$ 90.5	$ 70.3	$ 73.1	$ 403.4
Non-Interstate	43.6	104.8	37.2	57.2	51.6	294.6
Pavement Preservation	39.0	54.7	59.3	62.2	66.0	281.5
Other	8.4	7.8	7.8	7.8	7.8	39.6
Totals	$177.9	$249.9	$194.9	$197.6	$198.6	$1,019.2

Pavement Management in California

I. Introduction

In 1977, the California Department of Transportation (Caltrans) began the development of a pavement management system (PMS) in order to meet a number of needs: 1) to relate rehabilitation expenditures to actual needs rather than to the persuasive powers of District Engineers; 2) to repair the most appropriate road segments using a logically determined strategy; 3) to improve programming capabilities; and 4) to provide better service to the public. The impetus for the PMS development came from top management, the Caltrans Chief Engineer. He wanted a system which could be easily understood and which would: 1) identify rehabilitation needs and rank them on a statewide basis; 2) ensure that the most sound repair strategies were used to address these needs; and 3) be operational in 2 years (by 1979). A steering committee was formed to provide guidance and policy directions, and a task force was also created to perform the actual development and implementation of the PMS.

Several key decisions concerning the organization and operation of the PMS were made during the developmental stage. First, it was determined that if the system was to provide statewide priorities based on need, as envisioned by the Chief Engineer, the decisionmaking authority would have to be centralized. (This decision ran contrary to Caltrans' previously decentralized operations.) Second, since the PMS was designed to be used to prioritize individual projects, the system must be based on a 100% survey of the State maintained highway system. Third, in order to make decisions regarding preliminary repair strategies and their costs, the data collected for each pavement section's distress and ride could not be combined or reduced into a single number or indicator. Caltrans officials believe that the reduction of data to a single index can obscure important information which is necessary for making decisions regarding repair strategies and for estimating costs. Fourth, the frequency of the surveys was established as biennial. In California, pavements' conditions are believed to change slowly enough to permit a biennial (rather than annual) survey. Fifth, Caltrans decided it wanted a system that would make a rough estimate of repair strategies and costs as an aid in the prioritization process. To make these estimates, a program was devised which utilizes decision tree analysis to produce for each roadway segment a generalized and feasible repair strategy based on the engineering experience of Caltrans' personnel. Finally, due to the sheer volume of freeway ramps in California's highway system (over 12,000) and the time and effort required to collect, store, analyze, and retrieve data on these ramps, Caltrans decided to delay their inclusion in the PMS until an unspecified date in the future.

The California PMS has been operational since 1979 and is applied to a highway system of 15,000 centerline miles or 48,000 lane miles. Approximately 68% of the lane miles are asphalt concrete (AC), while the remainder are classified as portland concrete cement (PCC). When PCC pavements are overlaid with AC, they are reclassified as AC, and thus the AC percentage is increasing.

The following summary utilizes information contained in Caltrans' publications, Development of the California Pavement Management System, Summary Report and Volumes 1 & 2, as well as data from the Demonstration Project Study Team's notes on Caltrans' PMS. The discussion below focuses on data collection, followed by data analysis, and thirdly on the programming aspects of pavement management.

II. Data Collection

Data collection in California's PMS consists chiefly of a ride survey and a distress survey. Average daily traffic (ADT) figures are also used in the prioritization process but this data is collected separately from the ride and distress data. In addition, dynaflect data is used in project design but is not part of the systematic, network-wide PMS effort. The two major data collection undertakings - distress and ride - are described below.

A. Distress Survey

California began conducting its distress survey in 1979, having established different procedures for flexible and rigid pavements. For flexible pavements, the following distresses are examined: alligator cracking, transverse cracking, ravel, drip track ravel, shoulder condition, block cracking, longitudinal cracking, rutting, and patching. (California uses the nomenclature and definitions for these defects set forth in Highway Research Bulletin (HRB) special report 113.) Most defects are examined for severity and extent (see Figure 1). For example, for transverse cracking, the severity is rated relative to the mean width of the cracks. The extent is rated relative to the number of cracks in one lane per 100 foot section. Although some distresses (e.g., block cracking) are not rated for severity, nearly all are rated for extent of the distress, based on percentage of length or area affected, on number of occurrences, or on the length of the cracking per subsection.

For rigid pavements, Caltrans collects data on: slab breakup, faulting, lane-shoulder joint separation, lane-shoulder displacement, shoulder condition, crack spalling, and patching. (Again, Caltrans uses the nomenclature and definitions for pavement deficiencies set forth in HRB Special Report 113.) In addition, these defects are also rated for severity and extent (see Figure 2).

The conduct and completion of the condition survey is the responsibility of the headquarters (HQ) PMS staff office. A principal reason for assigning this responsibilty to the HQ staff is to ensure the uniformity and quality of the data collected. Although the PMS staff is responsible for the surveys, the raters are recruited from throughout the Caltrans' organization to collect the data. Approximately 15 raters are selected from a pool of 90-100 applicants.

A significant training effort is expended on the raters to ensure that the data collection work is of uniformly high quality. A one month classroom and field training program is provided with hands-on instruction on the road rater (for ride measurement, discussed below) and on distress survey techniques.

For the PMS survey purposes, the entire State system is divided into roadway control sections which have basically the same roadway characteristics (i.e., the same base type, same number of lanes, same functional system). The roadway control sections are divided into "subsections" for AC sections or "segments" for PCC sections. The subsections are established when a definite change in roadway condition occurs, such changes can be differences in surface type or in severity or extent of defects. A minimum length of 0.10 mile has been set for subsections, although subsections less than 0.20 miles are rare. (The average length is approximately 2 - 3 miles.) The standard length of PCC segments is 1.0 mile, with breaks set at mileposts, contract limits, cost centers, bridges, or at the beginning/end of AC pavement sections.

Figure 1

FLEXIBLE PAVEMENT CONDITION RATING SYSTEM

PROBLEM	SEVERITY		EXTENT
ALLIGATOR AND BLOCK CRACKING	TYPE		% LENGTH
	A	LONGITUDINAL CRACKING IN WHEEL PATHS ①	1
			3
	B	ALLIGATOR CRACKING IN WHEEL PATHS ①	33
	BLK	BLOCK CRACKING IN MAJORITY OF LANE WIDTH	99
	C	SPECIAL OR UNUSUAL ALLIGATOR CRACKING	DESCRIBE & EXPLAIN SEVERITY & EXTENT IN NOTES
LONGITUDINAL CRACKING	CRACK WIDTH		LENGTH/STA.
	< 1/8" (HAIRLINE)		≤ 100'
	1/8"-1/4"		200'
	> 1/4"		300'
			900'
TRANSVERSE CRACKING	CRACK WIDTH (MEAN)		NO. CRACKS/STA.
	< 1/8"		1
	1/8"-1/4"		2
	> 1/4"		3
			9
RAVEL AND WEATHERING	CONDITION	RATING	% OF LENGTH
	LOSS OF FINE AGGREGATE	FINE	1
	LOSS OF COARSE AGGREGATE	COARSE	3
			33
			99
RUTTING	DEPTH		% OF LENGTH ①
	≥ 3/4"		1
			3
			33
			99
PATCHING	QUALITY	RATING	% AREA
	SOUND	GOOD OR FAIR	1
	UNSOUND	POOR	3
			33
			99
DRIP TRACK (RAVEL)	CONDITION		OCCURRENCE/SEC.
	EXISTS		1
			2
			3
			9

① ONE WHEEL PATH CRACKED OR RUTTED THE ENTIRE LENGTH OF SEGMENT = 50% OF LENGTH

Figure 2

RIGID PAVEMENT CONDITION RATING SYSTEM

PROBLEM	SEVERITY	RATING	EXTENT	RATING
SLAB BREAKUP	STAGE CRACKING (1)		% SLABS/SEGMENT	
	1ST. STAGE		1	
	2ND. STAGE		3	
	3RD. STAGE (2)		33	
			99	
CRACK SPALLING (3RD STAGE ONLY)	AVERAGE WIDTH	RATING		
	< 1/4"	NOM		
	≥ 1/4"-1 1/2"	MOD		
	≥ 1 1/2"	SEV		
PATCHING (FULL LANE WIDTH)	CONDITION	RATING	% AREA/SEGMENT	
	GOOD	GOOD	1	
	FAIR	FAIR	3	
	POOR	POOR	33	
			99	
FAULTING (STEP OFF)	CONDITION		% SLABS/SEGMENT	RATING
	VISABLE		≥ 25	YES
LANE/SHOULDER JOINT SEPERATION (RT. EDGE)	JOINT WIDTH		% LENGTH/SEGMENT	RATING
	≥ 1/4"		≥ 10	YES
LANE/SHOULDER DISPLACEMENT (RT. EDGE)	JOINT WIDTH		% LENGTH/SEGMENT	RATING
	≥ 3/4" UP		≥ 10	UP
	≥ 3/4" DOWN		≥ 10	DOWN
RIGHT SHOULDER CONDITION	OVERALL CONDITION	RATING		
	GOOD	GOOD		
	FAIR	FAIR		
	POOR	POOR		
BRIDGE APPROACH RIDE COMFORT	PCA RIDE RATING	RATING		
	ACCEPTABLE < 17	NUMBER		
	UNACCEPTABLE ≥ 17	NUMBER		

(1) SEE FIGURE I-3.

(2) ALSO CORNER CRACKING AND FRAGMENTED SLABS. EACH SEGMENT RATED FOR ALL THREE SEVERITIES AND ACCOMPANYING EXTENT.

The field survey is generally conducted between winters, although this has not always been possible. The entire survey process including training time takes 11 months (one month of training, 7 months of surveying, and 3 months of data clean up). During the survey, the crew exits the automobile frequently, especially on PCC segments since the number of cracked slabs must be counted.

B. Ride Survey

California uses a custom manufactured Cox ultrasonic roadmeter to determine ride quality. This device measures the deflection between the vehicle body and the rear axle of the vehicle. All six of California's test vehicles are calibrated once a month on a test section of PCC pavement. The results of the ride survey measurements are expressed as a "ride score," a single numeric value, representing ride quality and computed from the sum of 1/8 inch vertical movements accumulated over a measured distance as counted by the road meter. The formula is:

$$\text{Ride score} = \frac{\sum \text{1/8" counts}}{50 \times \text{length (miles)}}$$

In order to relate the ride score to pavement serviceability, Caltrans gathered a group of engineering managers and non-technical employees and had them ride over pavements with known ride scores. The group indicated which pavements they felt needed improvements because of poor ride. This exercise resulted in a recommendation that pavements with a score of 45 or greater be considered for improvement. As will be seen in the data analysis section, this score of 45 has been established as a "trigger value" or a dividing line between good and bad ride, and is used in the prioritization process.

The ride survey is conducted in tandem with the distress survey by the same crew on a biennial basis. The entire State-maintained system is included in the survey. The estimated cost of conducting the entire survey (distress and ride) is approximately $465,000, representing less than 0.6% of the cost of a two-year rehabilitation program.

III. Data Analysis

Data analysis is designed to answer three basic questions: 1) Does the pavement need repair? 2) What general category of repair is appropriate? 3) In what priority should the pavements be repaired? These questions do not lead to a final design for rehabilitation projects, which is another process undertaken by the district design staff. Instead, the data analysis process is a management tool, providing a "first cut" solution to pavement problems, estimated costs, and priorities for establishing pavement rehabilitation projects.

A. Question #1 - Does the pavement need repair?

Trigger values are used to answer this first question. Each defect identified in the condition survey has been assigned a trigger value, which contributes to a determination of the need for pavement repairs. For example, if the ride score is equal to or exceeds 45, then the trigger value has been met and pavement repair is called for. For longitudinal and transverse cracks, if the severity level is equal to or greater than 1/4" (the trigger value), then a repair (filling cracks) is called for. All of the defects are evaluated against established trigger values, each of which is associated with a need for repairs. At this point, no priorities have been established for repairs, and no determination has been made as to the appropriate type of repair for the roadway subsection or segment. It has merely been established (from a comparison of ride score/distress survey results with trigger values) whether or not repair is warranted. If any trigger value is met, then additional analysis will be performed.

B. Question #2 - What general category of repair is appropriate?

The major analytical tool used for answering this question is the decision tree (see Figure 3). California established the preliminary repair strategies as found in the decision trees in Figure 3 after a lengthy, consultative process with the personnel in Translab (Caltrans' Transportation Laboratory), and after reviewing repair strategies used throughout California and the country. The decision trees are essentially a combination of trigger values and repair strategies. By examining the defects' trigger values and their association with repair strategies in a logical sequence, a "decision" can be made concerning what type of repair is called for regarding each segment or subsection. For example, looking at Figure 3, if Class B cracking is found, if the percentage of cracking exceeds 10% but is less than 30%, and if the area of the segment that is patched exceeds 10%, then the decision tree points to a repair strategy called, "structural analysis - overlay or reconstruction."

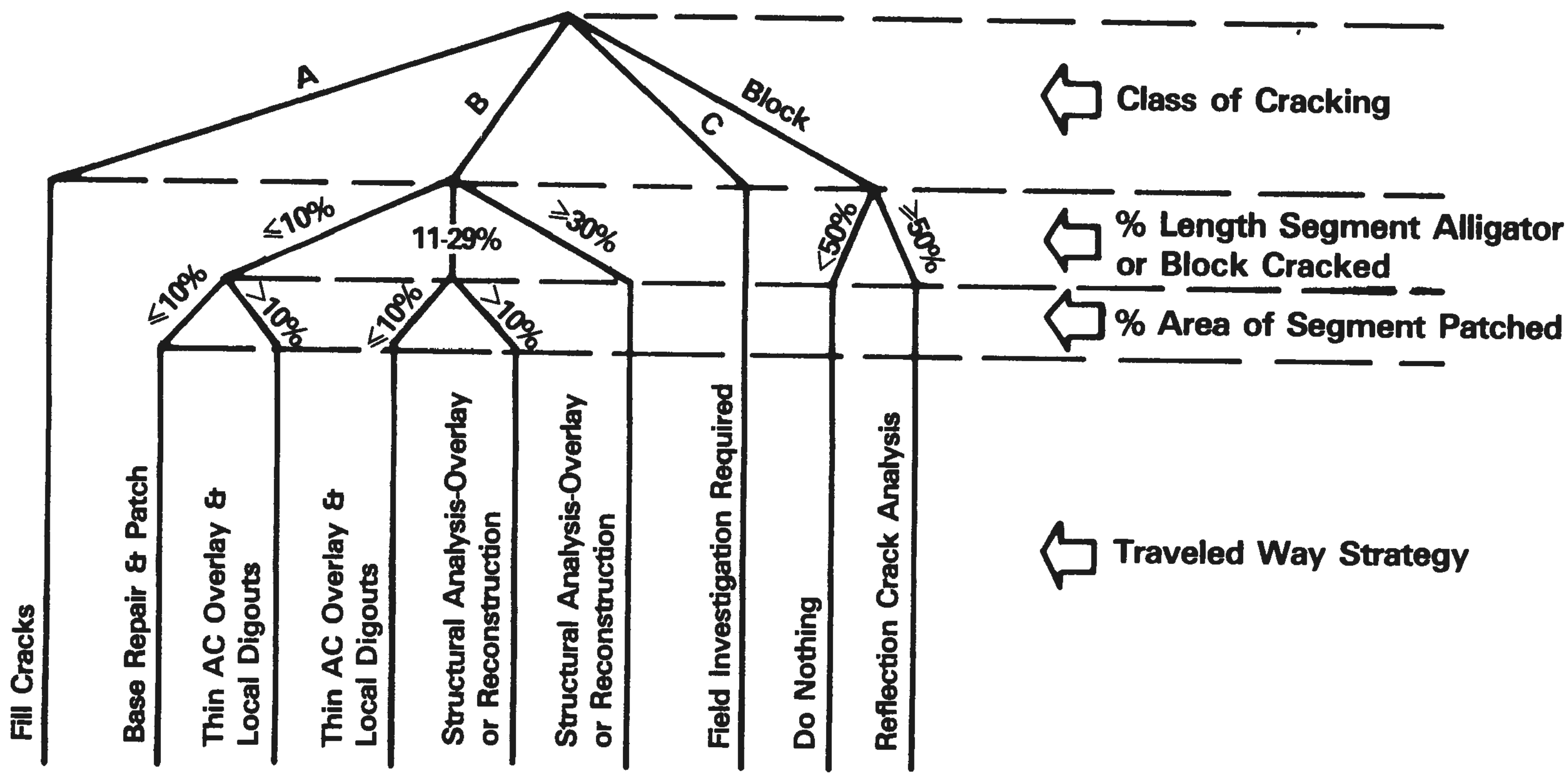
The decision tree analysis is conducted for each defect in each lane of a particular segment. Each defect may point to a different solution (see Figure 4). The individual strategies are then compared with one another to determine a strategy which will correct all of the defects in the lane. This strategy is entitled the dominant strategy. Finally, after the dominant strategies for each lane and shoulder are determined, the best or "compatible strategy" for the entire segment is found (one which will correct as many defects as possible for the entire segment) (see Figure 5). A cost and service life is then assigned to this compatible strategy.

In order to handle the large volume of calculations involved in this analysis, a computer program is used. Two automated reports are produced. A "Corrective Strategies for all Triggered Lanes" report which provides the following data for each lane: dominant strategy, location, ADT, road type, cost center, and annual maintenance cost per mile. A similar report, the "Candidate Locations Report," is produced and the data on all lanes and the shoulders are aggregated to provide a summary for each segment or subsection. These reports are used in Caltrans for developing the actual designs for individual projects.

C. Question #3 - In what priority should the pavements be repaired?

The third major component of the data analysis work is prioritization, the need for which arises from the fact that insufficient funds are available to address all of the needs identified in the ride and distress surveys. The Caltrans prioritization scheme uses three variables: ride score, distress ratings, and ADT (traffic volume). These three variables are combined in different ways to produce an array of 14 priority categories, as shown in Figure 6. Looking at this Figure, a high ride score can be seen to be a primary factor determining to which category a segment/subsection belongs. As long as ADT exceeds 1,000, a high ride score is necessary to be ranked in the first six priority categories. This ranking reflects Caltrans' commitment to improve service to as many users as possible, i.e., to provide the smoothest riding roadway to the most number of users. Structural problems (defects) are divided into major and minor categories. The distress survey must arrive at a major structural problem if the pavement unit is to be

Flexible Pavement
Alligator/Block Cracking

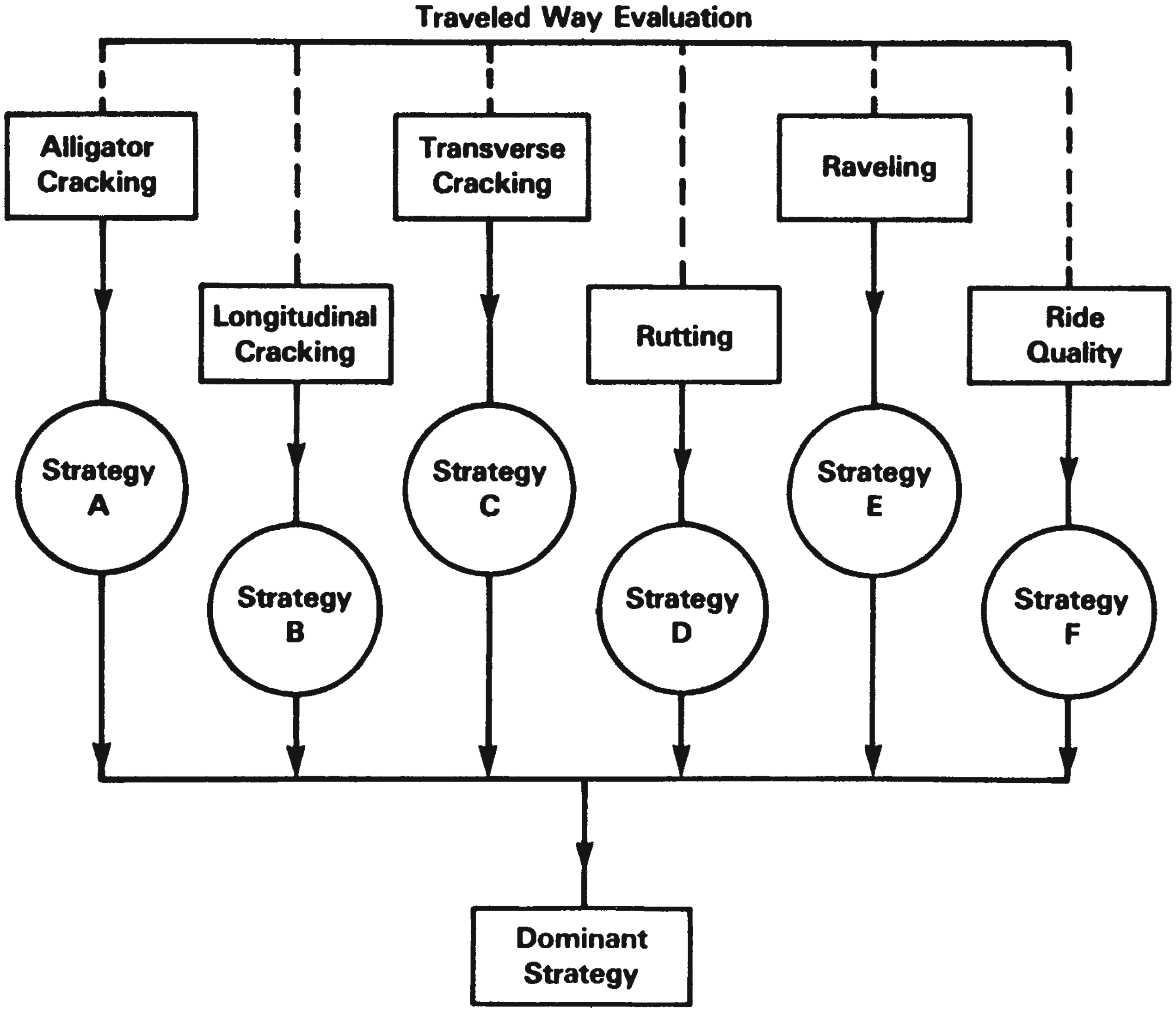


THIN AC OVERLAY = 0.10' DENSE GRADED OR OPEN GRADED MIX

A = LONGITUDINAL CRACKING IN WHEEL PATH(S)
B = ALLIGATOR CRACKING IN WHEEL PATH(S)
C = SPECIAL OR UNUSUAL ALLIGATOR CRACKING
BLOCK = BLOCK CRACKING IN MAJORITY OF LANE WIDTH

FIGURE 3

FIGURE 4



Flexible Pavement Condition Evaluation Procedure

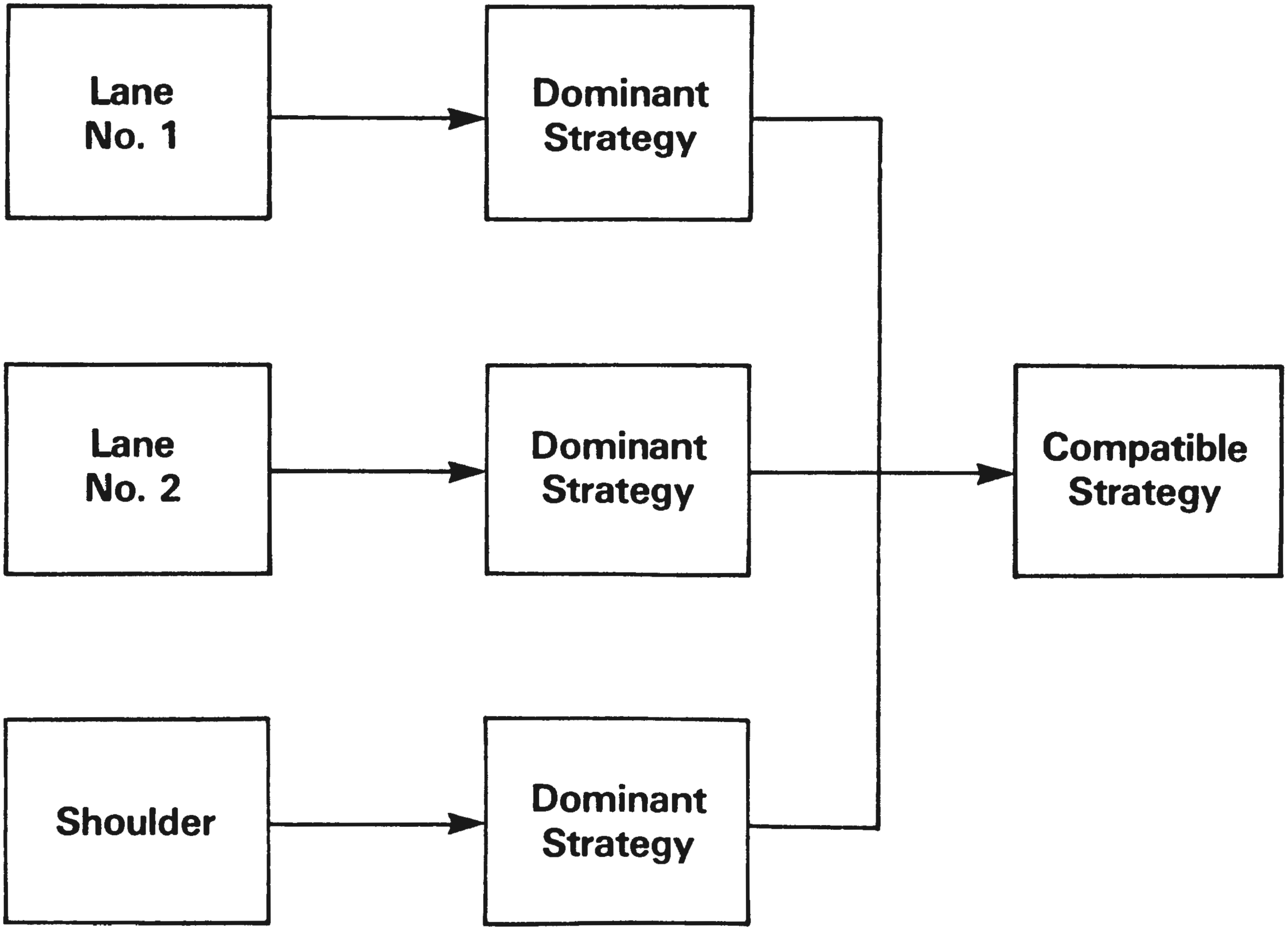


FIGURE 5

Flexible Pavement Condition Evaluation Procedure

	Pavement Problem Type	Candidate Category ADT Range >5,000	 1,000 to 5,000	 <1,000
Ride≥45	**Major Structural Problem and Unacceptable Ride** Flex: Allig.B = 11-29% & Patch>10% or Allig.B≥30% Rigid: 3rd Stg. Crk.≥10%	1	2	11
Ride≥45	**Minor Structural Problem and Unacceptable Ride** Flex: Allig.B = 11-29% & Patching≤10% Allig.B≤10% & Patching>10%	3	4	12
Ride≥45	**Unacceptable Ride Only**	5	6	X
Ride<45	**Major Structural Problem Only** Flex: Allig.B = 11-29% & Patch>10% or Allig.B≥30% Rigid: 3rd Stg. Crk.≥10%	7	8	13
Ride<45	**Minor Structural Problem Only** Flex: Allig.B = 11-29% & Patching≤10% Allig.B≤10% & Patching>10%	9	10	14

FIGURE 6

ranked in the top two priority categories. ADT is the third prioritization criteria and is divided into high (over 5,000 vehicles per day), medium (1,000 to 5,000 vehicles per day), and low (below 1,000 vehicles per day). A high ADT distinguishes the highest priority category from the second highest. Various combinations of these variables (ride, structural problems, and the three ranges of ADT) determine the order of all of the priority categories.

After performing the above analysis for each section and segment, it is possible that several candidate locations will have equal priority. In this case, a tie breaker formula is used:

$$\text{Tie breaker} = \frac{\text{cost(\$)/miles}}{\text{ADT}}$$

This tie breaker is added to the priority number of each of the tied subsections or segments. This factor essentially favors lower cost per mile projects and those with higher ADT.

An automated report, "Candidate Locations Priority List," is produced which lists all roadway segments/subsections by priority number and the PMS-determined corrective strategy. The report is distributed to both headquarters and district offices. As will be seen below, it plays a significant role in the selection and programming of projects.

IV. Programming

A. Project Level

Although the PMS is used in California to help select and program projects and involves the selection of "dominant" and "compatible" repair strategies, the system is not a design tool. Responsibility for project development and design rests with the district offices. The PMS outputs are provided to the district to assist them in performing their job better. The "Candidate Locations Priority List" is the key information source used in the district to develop a rehabilitation project. The district determines the priority number of a project by taking the weighted average of the priority numbers of the individual segments/subsections which make up the project.

The districts submit their priority list of projects to the headquarters PMS staff which reviews the submissions and compiles a statewide priority list. The districts' submittal is evaluated in light of the survey results giving consideration to special problems, errors, or changed conditions which the districts may point out. The headquarters staff will often confirm in the field any changes which the Districts have made and which may substantially alter the priority rankings. Once compiled, the statewide list is divided by funding type.

With the statewide project priority list in hand and with knowledge of the authorized funding for pavement rehabilitation work established by the legislature, the draft State Transportation Improvement Program (STIP) is developed, of which pavement rehabilitation work is only a part. The STIP is a five-year program that is updated annually. It is approved by the California Transportation Commission after holding public hearings and consultations with local governments. Few changes are typically made to the proposed rehabilitation projects. Once the STIP is approved, individual project development can proceed.

The next step in project development is for the districts to submit a project report to headquarters for approval. The PMS staff reviews the submittal to ensure that the proposed work corresponds to plan or that alternative designs are appropriate for addressing the pavement problems. If overlays are proposed, the Translab staff performs the deflection analysis. The districts' proposed design must be compatible with Translab's results or a justification is required. Once the project report is approved, the district can begin the detailed design.

B. Network Level

California's PMS provides the information for a "state of the pavement" report which identifies the program effort necessary to maintain the State highway system at a pre-determined level of service. The report serves as a basis for analysis of proposed short- and long-term funding levels and alternate funding levels. It also provides management with alternative levels of service analyses for use in evaluating program options and the cost effectiveness of maintenance and rehabilitation expenditures. The PMS also provides a continuing base for evaluating program proposals and in making project tradeoffs within districts.

The PMS also generates cost estimates for the recommended rehabilitation work. These cost estimates are used for program level budget deliberations until district estimates can be made for the actual work to be accomplished.

An essential and significant aspect of the PMS is the reports provided to operations and management personnel. These reports organize proposed projects by program and by district on a statewide basis. The designers of the system were careful to provide only the information needed by the users; however, there is enough flexibility to provide a wide range of information to both headquarters and district management on request.

The system is also designed to accommodate changes in condition evaluation criteria such as level of service trigger values. This feature allows management to evaluate options of reduced levels of service and other special study questions.

Finally, the California PMS has produced information that has been used in preparing items for legislative purposes. The PMS was helpful in obtaining legislative approval to increase funding for rehabilitation work.

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