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16. Abstract

The complex nature of highway pavements and the ever-increasing demands placed on them in the face of inflating costs and shrinking purchasing power make efficient, rational management of these assets a necessity. The Pavement Management System (PMS) methodology described herein can assist the SDHPT in allocating resources for pavements efficiently. The framework and essential characteristics of an ideal PMS are reviewed, and the current state-of-the-art of PMS development in Texas and selected other states is discussed. A simplified initial PMS for Texas is recommended, along with an implementation plan and some suggestions for future improvement of the system. This initial PMS has been termed "PMS Release 1.0" by the SDHPT.

The recommended Texas PMS Release 1.0 is based on the existing Pavement Evaluation System (PES), subject to the following modifications:

(1) it is recommended that skid resistance be omitted from the collective performance index,

(2) the current mass inventory data collection mode should be modified to allow statistical sampling, and

(3) analysis techniques for identifying the consequences of different funding levels should be added.

It is further recommended that future versions of the Texas PMS move toward long-range optimization compatible with the existing Rehabilitation and Maintenance Strategies (RAMS) computer codes.

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DEVELOPMENT OF AN INITIAL PAVEMENT MANAGEMENT SYSTEM FOR TEXAS

by

W. R. Hudson
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Research Report Number 307-1

Development of an Initial Pavement Management
System for Texas
Research Project 3-8-81-307

conducted for

Texas
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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas State Department of Highways and Public Transportation. This report does not constitute a standard, specification, or regulation.

PREFACE

This is the first report produced under Research Study 307 entitled, "Implementation of a Pavement Management System for Texas." The long-range goal of this project is to assist the Texas State Department of Highways and Public Transportation in developing a rational pavement management system for all pavement types, and to provide for updating the system with continued input of the latest research findings.

This report summarizes ~~PMS~~ development to date in Texas and across the nation, and presents recommendations for the initial release of a Texas PMS along with suggestions for future development. These recommendations were developed on the basis of the collective experience of the Texas PMS Task Force through interaction with the project staff of the Center for Transportation Research and the Texas Transportation Institute. Many people have contributed significantly to this work, and the authors are deeply grateful to them all. In particular, we would like to thank the members of the PMS Task Force and the staff of the Center for Transportation Research, especially Dr. C. S. Noble, for their valuable assistance.

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LIST OF REPORTS

Report No. 307-1, "Development of an Initial Pavement Management System for Texas," by W. R. Hudson, R. D. Pedigo, and E. G. Fernando, describes current PMS experience, presents a recommended structure for the Texas PMS Release 1.0, and suggests areas for future improvement.

ABSTRACT

The complex nature of highway pavements and the ever-increasing demands placed on them in the face of inflating costs and shrinking purchasing power make efficient, rational management of these assets a necessity. The Pavement Management System (PMS) methodology described herein can assist the SDHPT in allocating resources for pavements efficiently. The framework and essential characteristics of an ideal PMS are reviewed, and the current state-of-the-art of PMS development in Texas and selected other states is discussed. A simplified initial PMS for Texas is recommended, along with an implementation plan and some suggestions for future improvement of the system. This initial PMS has been termed "PMS Release 1.0" by the DHT.

The recommended Texas PMS Release 1.0 is based on the existing Pavement Evaluation System (PES), subject to the following modifications:

(1) it is recommended that skid resistance be omitted from the collective performance index,

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(3) analysis techniques for identifying the consequences of different funding levels should be added.

It is further recommended that future versions of the Texas PMS move toward long-range optimization compatible with the existing Rehabilitation and Maintenance Strategies (RAMS) computer codes.

KEYWORDS: Pavement management system, pavement management, pavement evaluation, rehabilitation and maintenance.

SUMMARY

A Pavement Management System (PMS) is an organized procedure intended to assist decision-makers in determining optimum strategies for providing and maintaining pavements in a serviceable condition over a given period of time. It involves an integrated, coordinated treatment of many phases of pavement management, and is a dynamic process which incorporates feedback regarding the various attributes, criteria and constraints involved in the optimization or prioritization procedure. In this report, recommendations for an initial working PMS in Texas are provided. These recommendations are in agreement with the results of a PMS Workshop held in Texas in February 1981, and the PMS Task Force Meetings involving field and Central Office personnel. A significant result of the February Workshop was the identification of the benefits and needs of a Pavement Management System in the State.

There was major agreement that a PMS could help the Department get more funds for the preservation of the highways and roads in the state highway network. In addition, it was recommended that the initial working system be kept as simple and flexible as possible in order to allow for the incorporation of suitable improvements in the future. Finally, it was emphasized that PMS is a tool to assist decision makers in the management of the roads under their jurisdiction. The recommendations resulting from the February Workshop formed the basis of the discussions for the PMS Task Force meetings and resulted in the adoption of the existing Pavement Evaluation

System (PES) as suggested PMS Release 1.0 for the state. However, minor modifications are needed to make the current PES compatible with the stated requirements of the SDHPT. These include: (1) the removal of skid in the calculation of overall pavement performance score; (2) revision of PES to accommodate statistical sampling; and (3) addition of analysis techniques for identifying consequences of different funding levels.

Some suggested approaches for improvements and modifications are provided in this report. In addition, a trial implementation period is recommended to determine areas where revisions are necessary. Finally, it is suggested that some future releases of PMS move from prioritization based on PES toward optimization based on the RAMS or other similar programs.

IMPLEMENTATION STATEMENT

The Texas PMS Release 1.0 described herein is suitable for implementation in the very near future (early 1982). The required modifications to the existing Pavement Evaluation System (PES) can be carried out relatively easily by making full use of the existing knowledge, research results and economic analysis procedures referred to in this report. The key factor is the development and implementation of a suitable data base. Recommendations in this regard have already been made, but the actual work is now expected to begin in the late Spring of 1982. It is recommended that the basic implementation plan for Release 1.0 provided in Chapter 6 of this report be undertaken by the SDHPT as soon as possible.

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CHAPTER 1. INTRODUCTION

BACKGROUND

Roads and highways are the primary assets of the Texas State Department of Highways and Public Transportation (SDHPT) and are major assets of the entire state. With construction of much of the highway system completed, existing pavements form a key portion of these assets. The complex nature of highway pavements and the ever-increasing demands placed on them in the face of inflating costs and shrinking purchasing power make efficient, rational management of these assets a necessity. Good pavement management requires careful analysis of the many factors involved, and this can best be obtained by looking at the total pavement system using systems analysis techniques. These concepts were first applied to pavements through NCHRP Project 1-10 in 1966 (Ref 1), but the application of general systems methods is widespread in industry, and the military.

During the period 1968-1975, a comprehensive flexible pavement design system (FPS) was developed for use by the SDHPT (Ref 2). This system has been implemented and used in some Districts for individual project level decision making on pavement design. Additional work has been done by Lytton on rehabilitation (RAMS) (Ref 3). More recently, the SDHPT has decided to develop a Pavement Management System (PMS) to assist in evaluating pavement information for planning and making investment decisions covering the highway network which emphasize rehabilitation and maintenance.

OBJECTIVES AND SCOPE

A PMS task group within the Texas SDHPT has outlined several general objectives for activities concerning the development of such a PMS. The purpose of this report is to describe how certain specific aspects of those general objectives have been fulfilled, to clarify other specific objectives and to recommend modifications or revisions of existing programs and procedures that may be implemented in the near future.

The list of objectives considered is shown below in terms of its treatment in this report:

(1) To establish the framework and essential characteristics for an ideal PMS (Chapter 2).

(2) To report on the current state-of-the-art concerning PMS development in Texas (Chapter 3) and throughout the United States (Chapter 4).

(3) To identify the needs and benefits associated with the developments of such a PMS for Texas highways, and to investigate the cost of implementing a suitable PMS in relation to the resources currently available within the Texas SDHPT (Chapter 5).

(4) To recommend a simplified, skeleton PMS suitable for use in the Texas SDHPT and to establish how RAMS (a candidate system being developed at TTI) would fit such a system (Chapter 6).

(5) To recommend a schedule for the implementation of PMS by the Texas SDHPT (Chapter 7).

SPECIFIC GOALS AND OBJECTIVES

The long-range goal of this project is to assist the SDHPT in developing a rational pavement management system for all pavement types and, further, to provide for updating the system with continued input of the latest research developments and findings.

Accordingly, the objective of this report is to record the development of a PMS methodology that will assist the SDHPT in allocating its resources to the maintenance, rehabilitation, and design of pavements in an efficient manner. An important output of the methodology is the identification of the policy that, within the limitations of a particular budget, maximizes the "overall benefits" over the planning horizon or funding period. Thus, the goals of this research are to:

(1) accelerate implementation of PMS in a logical progression within the Department;

(2) develop a single system for managing the pavement resources for:

(a) legislative requirements,

(b) administrative and Commission requirements,

(c) maintenance activities,

(d) RRR activities,

(e) design criteria for necessary feedback data system, and

(f) pavement materials evaluation;

(3) maximize utilization of previous research efforts;

(4) maximize utilization of existing data bases in SDHPT;

(5) integrate with the SDHPT Transportation Network Data Base;

(6) place primary emphasis on network level PMS; and

(7) promote cooperative effort of research agencies.

CHAPTER 2. FRAMEWORK AND CHARACTERISTICS FOR AN IDEAL PMS

BACKGROUND - ESSENTIAL PMS FUNCTIONS AND CONCEPTS

The process of pavement management has been developed primarily to manage a substantial investment in transportation (Ref 4). The provision of pavements involves billions of dollars, and any investment of such magnitude requires and deserves good management. In addition, substantial annual expenditures are required just to preserve and maintain this investment. Because this involves a large number of technical and economic factors, good management is needed to efficiently coordinate and carry out the work, and at the same time, insure economical results. Lastly, there is the fact that available funds for investments in pavements, and for maintenance of these investments are generally limited. Good management is, therefore, essential to obtain maximum value for limited funds. Accordingly, pavement management must be a broadly based process which incorporates the set of all activities required to provide and maintain pavements. A pavement management system consists of a comprehensive, coordinated set of activities associated with the planning, design, construction, maintenance, evaluation and research of pavements (Refs 5 and 6).

DEFINITION OF A PMS

A Pavement Management System (PMS) (Ref 8), is an organized procedure which provides decision-makers at all management levels with optimum or at least prioritized strategies derived through clearly established and defined procedures. A PMS provides an evaluation of alternative strategies over a specified analysis period on the basis of the predicted values of quantifiable pavement attributes, subject to predetermined criteria and constraints. It involves an integrated, coordinated treatment of the many phases of pavement management, and it is a dynamic process which incorporates feedback regarding the various attributes, criteria, and constraints involved in the optimization or prioritization procedure. Thus, comprehensive pavement management is accomplished through a coordinated set of activities, all directed toward achieving the best value possible for the available public funds in providing and operating smooth, safe, and economical pavements.

A comprehensive pavement management system must serve different administrative and management needs at different management levels, and it must interface with the broader highway or general transportation management system involved. Decision makers at all levels of management must be able to use information from the pavement management system in making decisions regarding both individual projects and the entire highway network. The system envisioned here has applicability for all types of decisions including those related to information needs, projected deficiencies or improvement needs for the network as a whole, as well as budgeting, programming, research, project design, construction, maintenance, resource requirements, etc.

One concept of a comprehensive pavement management system is illustrated in Fig 2.1 in terms of three major types of activities that occur. Decision making activities are characterized by their scope: (1) wide-ranging or global decisions made regarding the highway network as a whole, and (2) specific decisions required in the management of individual projects. These two decision-making levels comprise the system from the typical user's point of view. There are, however, additional activities that are vital to the proper functioning of the system. These activities provide feedback for updating the various components of the PMS used to support the decision-making process.

RECOMMENDED FRAMEWORK FOR A PMS

Figure 2.2 shows a summary framework for comprehensive pavement management and lists the key activities which occur at the two generalized management levels. An interface must exist between the management levels and between the network level and a general highway or transportation system management level. The data base is crucial for management activities at both levels as illustrated, and a feedback loop is provided to show the need for periodic revision at both levels, as well as for the periodic collection and recording of new data.

A comprehensive PMS functions at all management levels from the project engineer to the highest administrator. Different types of decisions are required at each of these levels, involving different types and amounts of information, different criteria, and constraints. Consequently, the detailed structure of the various parts of the total system could be expected to vary

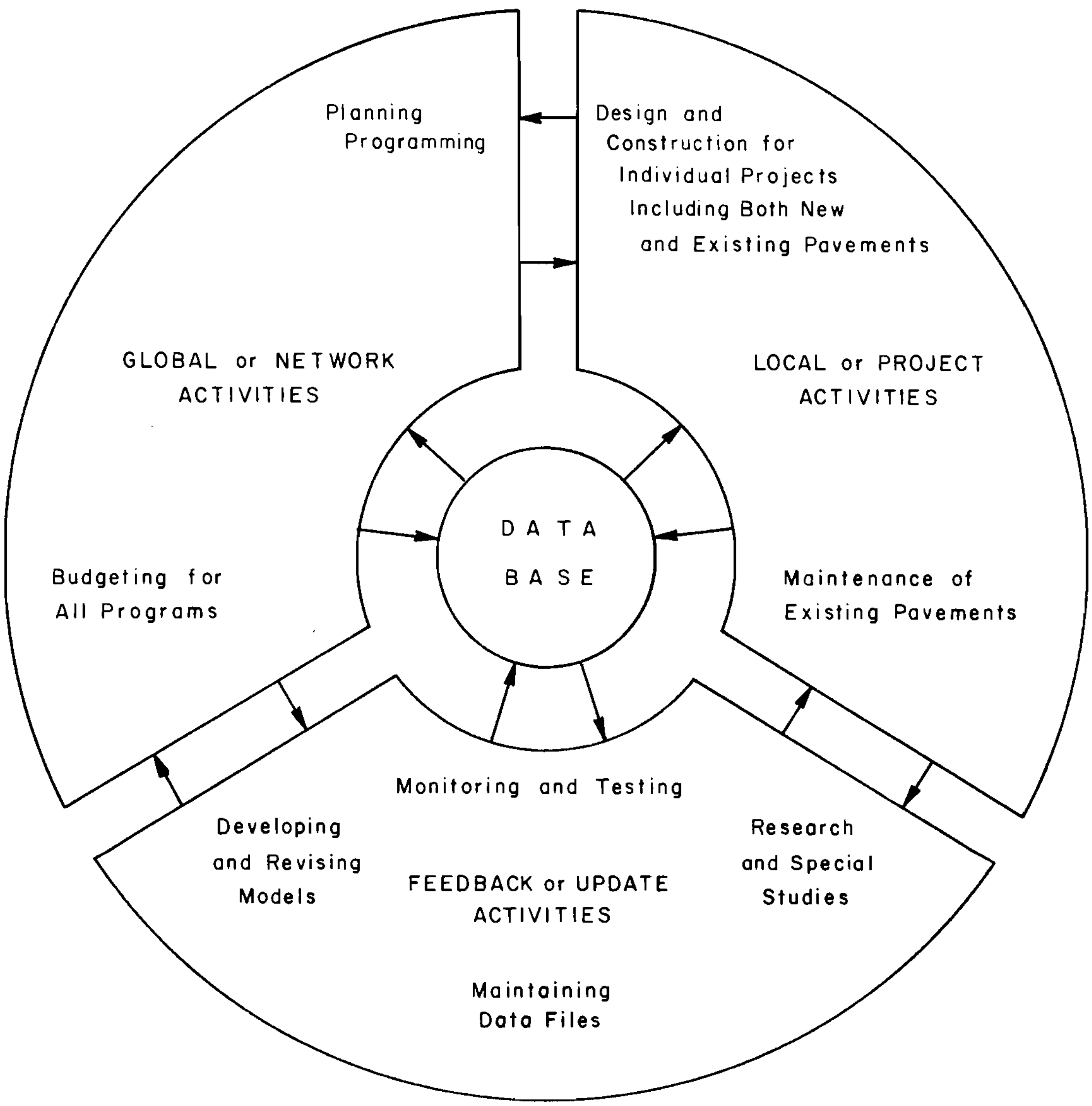

Fig 2.1. Activities of a pavement management system.

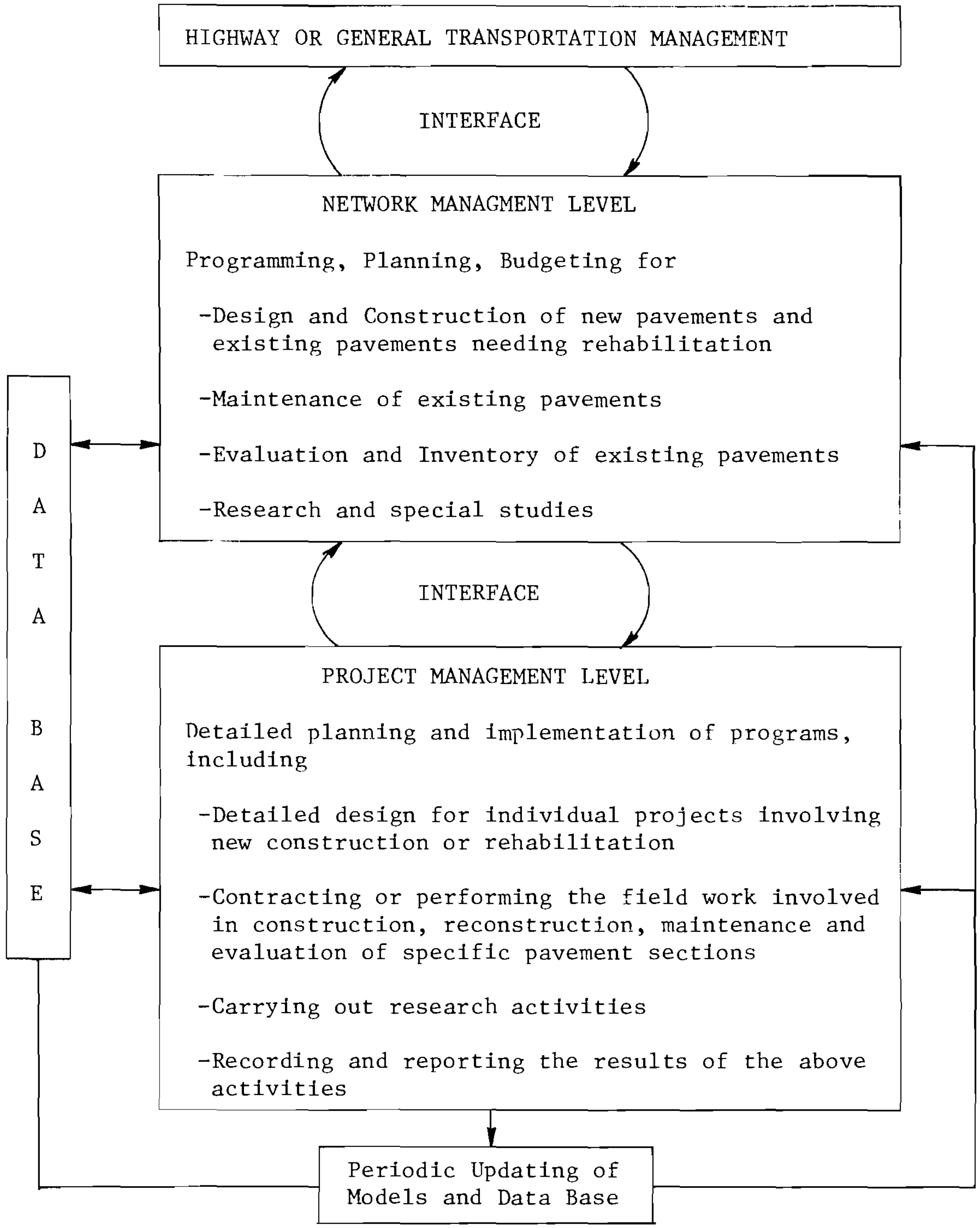

Fig 2.2. General pavement management system concept.

considerably from level to level. In addition, the different activity areas (such as maintenance, design, and construction) may involve some differences in requirements for data, criteria, and constraints within the same management level. However, the basic flow of information or sequence of actions is the same at all levels and for all activities.

The similarity in the flow of information forms the basis for a comprehensive pavement management framework. Rational decision-making follows a clear cut sequence of actions as shown in Fig 2.3. First, pertinent information is gathered and the consequences of the available choices are analyzed in the light of this information. Based on this analysis and on other non-quantifiable considerations (which may involve political and social issues), a decision is made. Then the decision is implemented, and the results of the decision are recorded in the data bank and passed on to other management levels.

RECOMMENDED SUBSYSTEMS FOR A SKELETON PMS

Three basic pavement management subsystems are involved in this process. These are identified in Fig 2.3 as "Information," "Analysis," and "Implementation." The remaining steps are not considered to be components of the PMS. The pavement management system is directly involved in the storage and retrieval of data, the performance of technical and economic analyses, the coordination and reporting of all activities, and the associated updating of records. The PMS does not, on the other hand, consider non-quantifiable factors, nor does it make decisions; these functions are handled by the decision maker using the PMS output. A more complete discussion on the

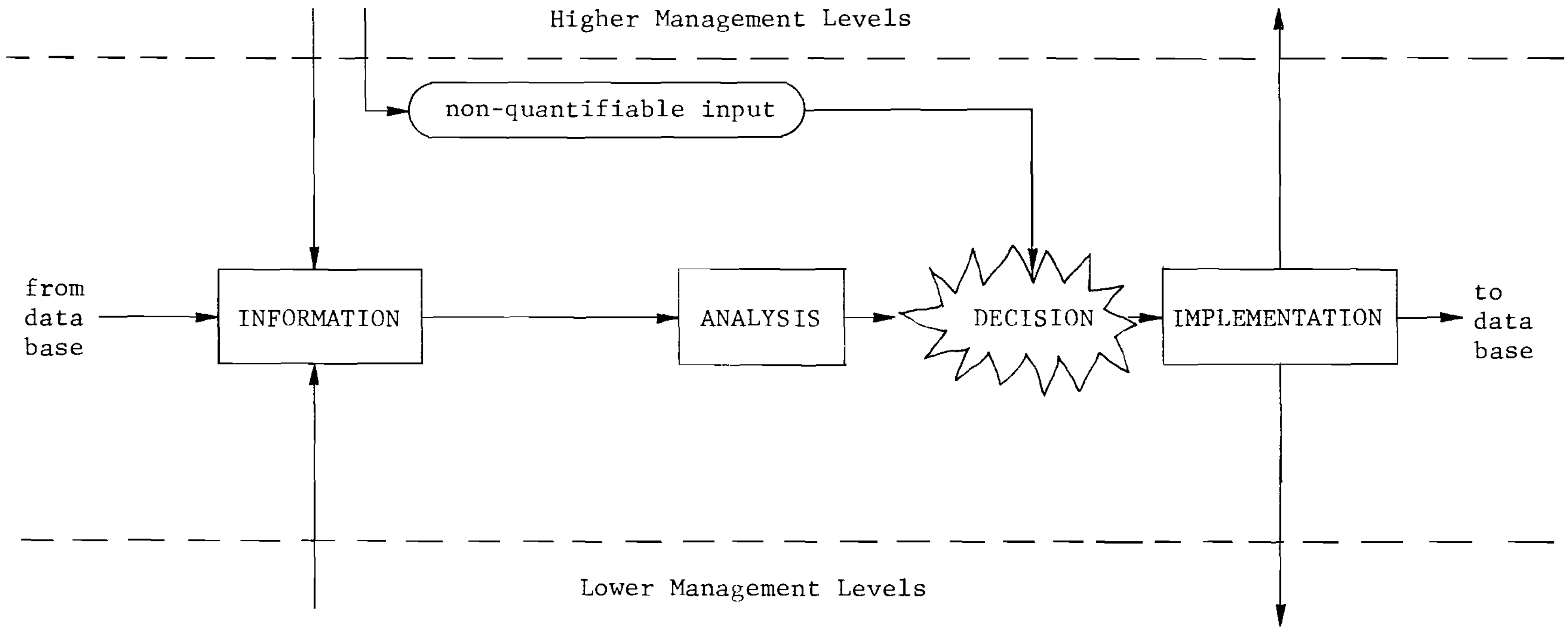

Fig 2.3. Flow of information at a typical management level within a total PMS.

characteristics of the inputs, models, and outputs for these subsystems may be obtained from Ref 5.

The interface of the pavement management system of Fig 2.2 with the higher level transportation system management occurs at the network management level; specifically, where "committed" or funded projects come forward and where the prioritized program is submitted for review and approval. Any such program and its associated costs would likely go forward to the higher level of management as a recommendation, be evaluated with respect to the overall transportation program and objectives as well as the sector (i.e., highway, airport) budget allocation, and then be suitably modified if any program revisions were required.

The remainder of the current report deals primarily with the application of the network level concerns for the Texas SDHPT, although some treatment of feedback and the interface with other management levels is also presented.

CHAPTER 3. REVIEW OF TEXAS PMS EXPERIENCE

HISTORICAL BACKGROUND

In 1968, the SDHPT undertook a Research Project 123 (Ref 2) with two main objectives:

(1) to outline a tentative master research plan for the structural design and evaluation of pavements; and

(2) to determine the feasibility of implementing the resulting plan.

This original project was concerned with the study of pavements and pavement research in a systematic manner in order that more comprehensive solutions to the problems encountered could be developed. The work was undertaken by a team of researchers from the SDHPT, the Texas Transportation Institute (TTI), and the Center for Transportation Research (CTR), to provide comprehensive coverage of the important areas of interest.

The development of comprehensive pavement systems technology began in 1966 with the initiation of Research Project NCHRP 1-10. This project developed a systems approach to pavement design (Ref 9). Similar work was being attempted by Hutchinson and Haas (Ref 10) and a basic computer program for calculation of necessary parameters had been developed in Texas by Scrivner, et al (Ref 11).

SDHPT PROJECT 123 (FPS AND RPS)

In 1968, using a systems framework, this research project proceeded to develop a series of working computer programs for the design and management of asphalt pavements (Ref 2). This series of programs is modular and may be improved as often as new information becomes available. Its designation is Flexible Pavement Systems (FPS) and an integer is placed after the FPS to designate the latest version of the program (such as FPS-13). At the present time, FPS-11 is in use by many SDHPT districts for design and management of pavements. The FPS series is dynamic, and future improvements and modifications are anticipated.

In addition to FPS, a management system was developed for rigid (portland cement concrete) pavements. It is called RPS (Rigid Pavement Systems) and has the same type of numbering system, e.g., RPS-2. This series of programs provide a set of working models which have been used by the SDHPT since implementation was begun in 1976.

In summary, this study established working systems at the project level and made only recommendations for a network level fund allocation and management system for the State as a whole.

THE TEXAS SDHPT PAVEMENT EVALUATION SYSTEM (PES)

A later series of studies at the Texas SDHPT (Ref 12) has resulted in the development of a preliminary basis for the network level PMS, known as the PES or Pavement Evaluation System. PES uses Utility Theory to combine pavement condition information into an overall pavement score, and estimates funding levels required to maintain those sections which fall below the minimum acceptable score. Only major maintenance, rehabilitation and reconstruction needs are considered; preventive maintenance is not addressed by the Pavement Evaluation System.

The objectives of the system may be summarized as follows:

(1) assist as a tool in the allocation of funds to the Districts;

(2) monitor the level of maintenance;

(3) determine total rehabilitation needs;

(4) development of work program - identify standard segments of highways as candidates for a work program which examines routine maintenance; and

(5) historical - identify trends related to design, materials, maintenance, strategies, etc.

The factors identified within the PES include:

(1) skid,

(2) ride (Mays Ride Meter), and

(3) visual distress, including

 (a) (flexible pavement) longitudinal and transverse cracking, alligator cracking, rutting, raveling, failures, flushing, and

 (b) (rigid pavement) failures, minor and severe spalling, minor and severe pumping.

The evaluation segment is standardized at two miles, beginning, where possible, at the county line or the smallest milepost on a particular highway. Exception to this will occur when there is a change in pavement type or when a short section is encountered, such as at the end of a highway.

For such cases, segments which exceed 3/4 mile shall be established as an individual segment, while those remaining segments less than or equal to 3/4 mile in length shall be included as part of the adjacent 2 mile segment where possible. By using experienced raters and proper training and monitoring, it is hoped to insure repeatability of measurements. The visual distress measurements are taken at one-half mile increments.

Under the PES, all highways are to be rated each year for the first 5 years with subsequent frequency to be determined from experience. The required frequency of evaluation will be determined from previous evaluations and various other data. Factors will be weighted by average annual rainfall, freeze thaw cycles, ADT, number of 18-k ESALS, and functional classification.

REHABILITATION AND MAINTENANCE SYSTEM (RAMS)

This system is being developed by Dr. Lytton et al at TTI (Ref 24) and appears to be a suitable long-term candidate for use in achieving the goals and objectives of this study as previously stated.

The Rehabilitation and Maintenance System (RAMS) (Fig 3.1) is a set of seven computer programs that were formulated to maximize the total effectiveness of rehabilitation and maintenance activities in Texas while remaining within established resource constraints. These resource constraints are categorized into material and supply, equipment, manpower, and available budgets. Through the combined and sequential use of the RAMS models, the optimal allocation of such resources would be achieved.

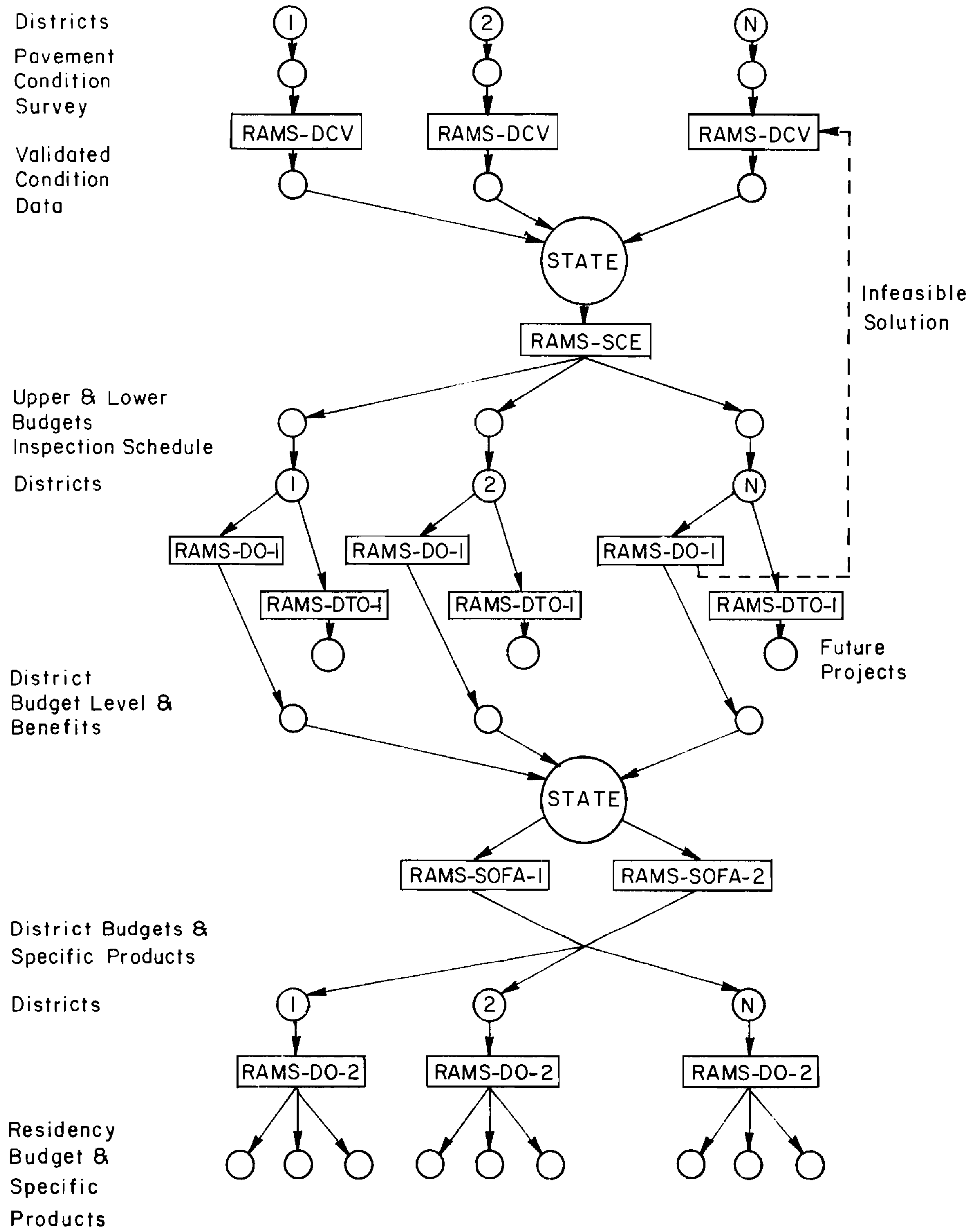

Fig 3.1. Rehabilitation and maintenance system - Texas (Ref 3).

In general, the optimization process involves two levels: the District level and the State level. The sequence of activities involved in the optimization process is as follows:

(1) At the District level, selected pavement segments are surveyed and the results are validated through the use of the RAMS-District and Check Validation (DCV) program before being sent to state authorities.

(2) The RAMS-State Cost Estimating (SCE) program is then employed to determine:

(a) the approximate rehabilitation and maintenance selection and schedule for the next pavement inspection for each district,

(b) the lower and upper limits on the District budgets,

(3) Using the RAMS-District Optimization (DO)-1 model, the optimal rehabilitation and maintenance strategies for a one-year planning horizon, and the benefits for different budget levels between the lower and upper limits established from Step 2 are determined by each district.

When infeasible solutions are obtained, a re-evaluation of the problem analysis and data collection is made. In addition, the funds required for every year of a finite planning horizon to maintain the road segments at a certain pavement quality may be determined using the RAMS-District Time Optimization (DTO)-1 program.

(4) The most promising budget level for each district is then determined using the RAMS-State Optimization Fund Allocation (SOFA)-1 model. In addition, the RAMS-SOFA-2 program is used to

determine the best rehabilitation and maintenance strategy for each section of the highway network, district by district.

(5) The information obtained from RAMS-SOFA-2 is sent back to the District which in turn utilizes the RAMS-DO-2 program to optimize fund allocation to the residences.

OTHER TEXAS EXPERIENCE (McKINSEY STUDY)

Another contribution to the available store of candidates for PMS implementation involves the results of a study completed recently by McKinsey and Company (Ref 13). A summary of the development of the forecasting model which resulted from this study is as follows.

The Highway Rehabilitation Forecasting Model (REHAB) was developed as a supplemental analysis during the intensive study conducted jointly by the State Department of Highways and Public Transportation and McKinsey and Company to determine how to respond effectively to the changing economic environment. During the diagnostic phase of the study, as the "needs/revenue gap" became more explicitly defined, it became clear that many Department commitments for rehabilitation and new construction simply could not be met with the funds available.

In light of the funds shortage, it became important that the Department be able to accurately estimate future rehabilitation requirements.

The model itself is conceptually simple. Within REHAB, each lane mile of pavement in the State is categorized by:

(1) system type (e.g., interstate, farm to market),

(2) pavement type (e.g., asphalt or concrete),

(3) region (e.g., coastal, West Texas), and

(4) rural/urban.

The model begins with an age profile in which the number of lane miles in each pavement category is distributed among 2-year age intervals. To this the model applies an expected life for each category. This gives an expected number of lane miles in each category to be rehabilitated in each 2-year period over the next 50 years. By applying the average rehabilitation cost per lane mile for each category, an expected cost can be calculated.

Although REHAB is intended primarily to project rehabilitation costs for the existing highway system, it can also be used to test the sensitivity of the statewide rehabilitation cost to variations in the model's assumptions about rehabilitation design and policy. It is important to note that the REHAB model, although developed as a supplemental analysis and therefore, not a major part of the McKinsey Study, has nevertheless begun an important analysis of obvious benefit to the Department. Through the use of REHAB, the Department has begun to systematically examine its future rehabilitation requirements.

Many other state highway agencies have carried out work on pavement management concepts in the past ten years. Appendix B presents a summary of the most important known work in other states.

CHAPTER 4. SALIENT RESULTS FROM TEXAS SDHPT PMS WORKSHOP

INTRODUCTION

In February 1981, a PMS Workshop was conducted by the Texas SDHPT. This workshop was conducted to define the relative needs for a pavement management system in the state, as well as to determine the relative benefits of such a PMS. In addition, an effort was made to examine the resources (e.g., the manpower, money, and materials) required to develop and implement the system. All of these problems were considered at the Administrative, Division, and District levels.

The Texas SDHPT also established a PMS task force composed of a wide range of representatives from both District and Division levels and headed by Mr. Byron Blaschke, the Chief Engineer of the SDHPT Safety and Maintenance Operations Division (D-18). Task Force meetings were held in May and June 1981, in order to address specific solutions to the needs and recommendations identified at the PMS Workshop. The participants divided into three groups to consider the issues of pavement management.

Researchers from the Center for Transportation Research attended all of these meetings to provide assistance to the Department in the development and implementation of the desired PMS. A survey of the primary results of the Texas SDHPT PMS Workshop is presented below, while a summary of the minutes of the Task Force meetings is given in Appendix A.

Relative Needs and Benefits of a Pavement Management System in Texas

There was major agreement among the three groups that a pavement management system would primarily benefit the Department at the Administrative level in the following ways:

(1) PMS would be a useful tool for justifying to the legislature the level of funding that is needed for the maintenance and rehabilitation of roads in the state;

(2) Such a system would also assist the administration in responding to legislative or public inquiries, and in identifying the consequences of various levels of funding; and

(3) PMS would provide a basis for determining rehabilitation needs, and fund allotment at the network level.

It was recognized that the relative needs and benefits of a PMS at the Division level are a combination of those identified at the Administrative and District levels, due to the role of the Division as a coordinator for Administrative and District functions. However, specific benefits were identified for the Design (D-8), and Human Resources (D-13), Divisions as follows:

(1) A pavement management system would assist D-8 in programming the completion of various projects by allowing contracts for the higher priority projects to be let first.

(2) A pavement management system would assist D-13 in allocating personnel by indicating the workload for both construction and maintenance.

There was general agreement among the District representatives that a PMS would be of less benefit in establishing project priority or rehabilitation strategies at their level. The concern was raised that a PMS may start out as a tool, but then become a fixed device for fund allocation and decision making with little or no District input involving direct experience and knowledge of conditions. This point was recognized as a possible stumbling block to the implementation of a pavement management system in the state. However, it was also brought out that such a system may be useful in confirming that the highest priority needs are indeed being addressed.

In addition, improvements in several areas were seen as desirable, although not all participants agreed. A PMS could be of benefit in improving design procedures, specification changes, construction quality control or procedures for maintenance on a short range basis. However, it was also recognized by all that the data collected through such a system would lead to improvement in these items in the long term. For example, the performance history available through a PMS would lead to a better method of predicting the life of pavements in the future.

Insofar as needs are concerned, the following items were discussed by the Districts as possible benefits of a PMS:

(1) Documentation of present highway conditions,

(2) Provide better methods of predicting the life of pavements,

(3) Provide better methods of determining alternative rehabilitation strategies,

(4) Verification that high priority projects are being addressed, and

(5) Help obtain more money.

In addition, the Districts recognized that the use of PMS to allocate funds should be directly beneficial, and that the system would provide them with a means to justify the scheduling of certain projects before others, when questioned by public groups such as County Commissioners, City Council members, local legislators or other citizens.

The suggestion was raised that PMS be identified as a Pavement Data System (PDS) instead of a management system. In any case, it is appropriate that the system to be implemented be compatible with field needs, and be only a tool to assist in answering such needs rather than a single "computer answer."

Resources and Costs for the Implementation of a PMS in Texas

Some discussion took place concerning the resources which may be needed for the implementation of a PMS. Certain Districts have indicated that sufficient resources are available to handle the present Texas Pavement Evaluation System (PES). However, the Districts would like the Central Office to finance the cost of PMS. Furthermore, at the network level, there may be a need to hire additional personnel on a part-time basis, and to seek the assistance of some consultants. However, with regards to a project level PMS, the Districts feel that sufficient manpower resources are already available.

Recommendations for the Implementation of a PMS in Texas

The Workshop participants agreed on the following items:

(1) The system to be implemented should be kept as simple and as flexible as possible in order to allow for the incorporation of suitable improvements in the future. However, it should also be capable of providing indications of pavement performance to allow for preventive as well as corrective maintenance.

(2) The system should allow for quick turnaround time for the exchange of information at all levels.

(3) An evaluation of the condition of the present network should be made. In connection with this, carefully designed sampling procedures consistent with the availability of resources and with the level of information should be established.

(4) The major benefits of a PMS would be seen at the Administrative and Division levels. In view of this, implementation should start at the network level PMS.

(5) It is important to emphasize that a pavement management system is just a tool or a gauge to aid decision-makers in the implementation of their plans or objectives.

(6) Skid data should be considered separately from other pavement scoring, and it is suggested that a separate safety program be maintained.

(7) A system which is operational by September of 1982 would be very desirable so that the needs of the Department could be conveyed to the Legislative Budget Board for inclusion in the 1983-84 budget process.

(8) There is a need to address the question of a data base and what and how much data to collect since some of the workshop participants felt that there were gaps in the existing information. Many believed that collection of data on roughness, cracking, skid, and traffic is indeed necessary, as well as data on structures (e.g., bridges), pavement age, and maintenance costs.

Duplication of data should be minimized, and to this end, most of the workshop participants recognized the need for an efficient and organized system for data collection. A majority of the workshop participants likewise recognized the need for continual up-dating of the data base. This is necessary to provide feedback as to the consequences of decisions made, and to provide for more reliable projection of pavement performance into future years.

SUMMARY: CURRENT STATUS OF PMS

The entire PMS Task Force, including research representatives, has made considerable progress in the development of the major elements necessary for a working PMS. The details of the Task Force findings are presented in Appendix A. Release 1.0 of the Texas PMS will be based on the existing PES, with modifications including the removal of skid from the rating process, revision to accommodate statistical sampling, and the addition of economic analysis routines for identifying the consequences of different funding levels. Work on the modification of PES is underway. However, it now appears there may be delay while the data base for the PMS is being developed and implemented, due to the lack of available computer programming assistance. As a consequence, the implementation timetable for the PMS Release 1.0 may be delayed until mid-1982.

CHAPTER 5. RECOMMENDED SKELETON PMS FOR TEXAS

INTRODUCTION

The framework outlined in Chapter 2 provides a basis for the delineation of requirements for the variables and modeling techniques used within a comprehensive pavement management system. Each of the three major subsystems pictured in Fig 2.3 involves the development or utilization of information in specific forms. The concepts and essential features of systematic pavement management pointed out previously can, therefore, be further refined to produce restrictions on the inputs, models, and outputs which comprise the major content of the information, analysis, and implementation subsystems, respectively. Accordingly, this chapter presents recommendations for the detailed structure of a skeleton plan for a simplified PMS (PMS-N) for implementation by the Texas SDHPT at the statewide as well as at the District level. That is, a simplified pavement management system for network level programming, for the Texas SDHPT, based on the framework and characteristics discussed above, is presented below. The system to be described represents a "bare minimum" PMS-N. However, subsequent portions of this report provide recommendations and examples for upgrading this simplified system.

MAJOR GOALS AND OBJECTIVES OF PMS-N

The major desired result for network level programming is a specified program of work to be performed for each District throughout the State. Ideally, this would be a list of projects (either new or rehabilitation) to be completed during each construction season over a period of five to twenty years for each district. The simplified version considers programs one year at a time and provides a prioritized listing only of rehabilitation projects to be completed during a single construction season. The decision criteria and constraints which would form the basis for this prioritization, and the associated data collection, are described in the later sections of this chapter. In summary, these specific goals have been listed in Table 5.1.

PRIORITIZATION ALGORITHM - DECISION CRITERIA AND BUDGET CONSTRAINTS

As described in the original proposal for this study (Ref 3), the first step in the development of PMS-N is the selection of specific decision criteria and constraints to be used in the system. These criteria and constraints must be thorough, yet not so comprehensive as to require excessive data collection or analysis, as this would defeat the overall purpose of developing a simplified system. This choice will also dictate a significant portion of the data requirements for PMS-N.

State Level

The decision criteria and budget constraints to be applied at the state level and accordingly, to the network analysis subsystem involve, simply, a

TABLE 5.1. SPECIFIC GOALS FOR APPLICATION AND USE OF PAVEMENT MANAGEMENT PRACTICES, USING CURRENTLY AVAILABLE TECHNOLOGY

NETWORK MANAGEMENT LEVEL	PROJECT MANAGEMENT LEVEL
Short Term	
Specifically identify the various user agencies and their decision making needs at both the network and project management levels. Focus on rehabilitation management within the State Department of Highways and Public Transportation.	
1. Select procedures for efficient information acquisition, use and updating on road networks.	1. Select procedures for information acquisition as related to various types and sizes of project.
2. Define procedures for objectively identifying overall network needs and considering alternative programs and funding levels.	2. Adapt simple models for various classes of highway and sizes of project that produce alternative strategies such as FPS, RPS.
3. Use efficient, simple procedures for arriving at programs. Consideration may initially be limited to analysis periods of one or two years.	3. Define procedures for efficient implementation and periodic monitoring of selected alternatives.
Long Term	
Incorporate additional management activity areas by repeating the above steps for new construction, routine maintenance, etc.	
1. Develop better a interface with one all transportation system management.	1. Develop better a interface method with network management level, including "upward" flow.
2. Develop models for true optimization at network management level, for analysis periods involving a complete pavement life cycle.	2. Develop better interface between subsystems, such as maintenance and design.

selection from the data bank of those projects and that work schedule which would give maximum overall benefit within the total State budget. The value of the benefit factor(s) assigned to any project would be determined through its relation to an overall pavement section rating factor such as "utility." The benefits and costs associated with bringing this utility up to a predetermined, acceptable level, for each section would be calculated. The value of the actual economic benefit could then be determined. Figure 5.1 illustrates this prioritization process.

The State budget would be determined by legislative appropriation. Ideally, several alternative budget levels should be considered, since, clearly, the size of the budget to be awarded would be dependent upon the state's needs. Projects, or parts of the maintenance program, which fall below the budget cut-off should then be returned to the candidate list for the ensuing year. The authors feel that the set of RAMS algorithms (SCE, SOFA-1 and SOFA-2) recently developed at TTI (Ref 11) could form a suitable candidate software package for achieving this prioritization. In particular, the economic analysis routines which calculate budget levels for desired levels of service (and vice-versa) could be relatively easily modified for use with PES for PMS Release 1.0.

Further, the RAMS programs offer considerable promise for future improvements to the initial Texas PMS. Not only does it have the capacity to search a statewide data bank in a comprehensive way, but SCE also outputs a classification of the prioritized list of projects according to District, along with suitable upper and lower limits for the budget levels for each District, as well as a schedule for the completion of all the projects and a schedule for subsequent pavement inspection. SOFA-1 and SOFA-2 determine optimal budget levels for each district as well as the best rehabilitation

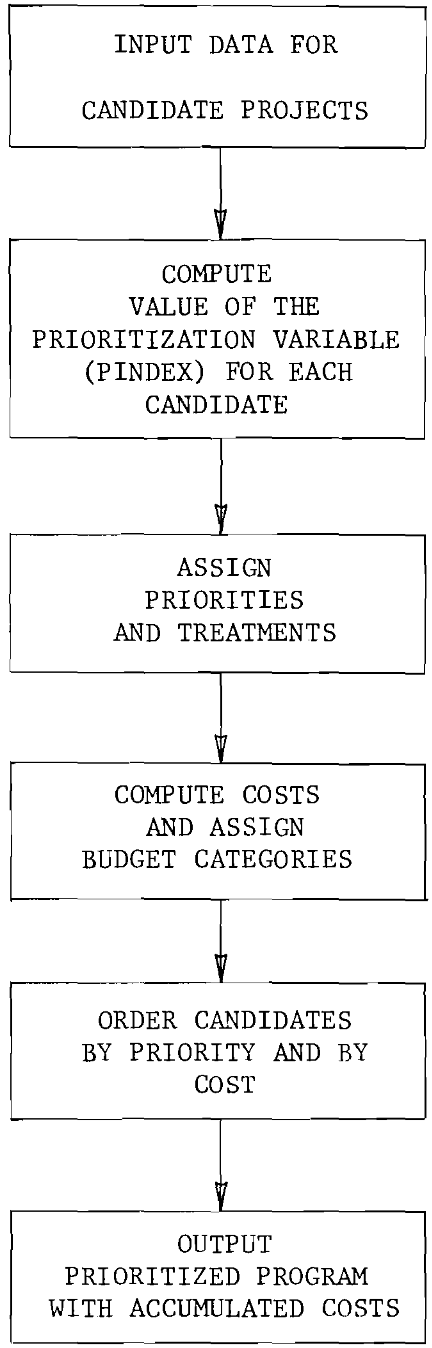

Fig 5.1. Basic steps in rehabilitation programming.

and maintenance strategy for each pavement section from each district based on the results of initial prioritizations performed by the districts.

District Level

The overall budget constraints for each district would be determined at the network level as mentioned above. Each district, in turn, would determine a most suitable strategy for the completion of the projects for which it was allocated funds by the State. The decision criteria applied to the choice of alternative strategies within each district must include both the quantitative benefit-cost factors used at the network level, and appropriate qualitative factors, such as the results of experience or the effect of local political variations. In other words, although decision criteria used at this level would involve a prioritization process such as used at the network level, the output from this procedure should be used as a guide only to the final project level decisions to be made by the district engineer.

Thus, the same analysis packages developed for the statewide system could be used as a basis for the initial district level system, with a modified PES used as the starting point for future improvements. Again, the RAMS sub-programs DO-1, DTO-1 could fulfill the major needs for the next few years, with DO-2 performing a similar optimization for final fund allocation within each district to the residences.

PAVEMENT ATTRIBUTES AND PERFORMANCE INDICATORS

In order to establish data requirements and select techniques for evaluating strategies, it is necessary to define the performance indicators and pavement attributes that will be used for evaluation. These performance indicators should be quantifiable measures of the performance of the roadway and should include measures of ride quality, physical distress, structural adequacy, and some combination of the above as an overall measure. In addition, the levels for these performance indicators that differentiate between acceptable and unacceptable roadway condition must be established. These levels should be determined for each functional class of roadway (primary, secondary, IH) and for volume categories.

Ride Quality

Traditionally, "pavement roughness" (R) and "Serviceability Index" (SI) have been variously used as measures of ride quality in the U. S. and worldwide. However, owing to a lack of standardization of roughness measures and measuring techniques, no single measure has emerged as being superior to all others. Alternately, Present Serviceability Index (PSI) offers an inexpensive, reasonable, overall assessment of the adequacy of a pavement to serve traffic, and that in conjunction with structural and/or condition survey variables, may be used to prioritize and derive generalized rehabilitation strategies for programming purposes. The Texas SDHPT should select a set of variables which is appropriate to its purpose and experience. The initial PMS (Release 1.0) should use a combination of serviceability and condition survey variables, according to the consensus developed by the PMS

Task Force. Future releases could incorporate skid number or other variables if deemed important. For example, some agencies feel that deflection information is essential for such purposes, and this choice certainly could be added to the PMS-N at a later time.

Physical Distress Measurement

Suitable physical distress measurements must be made for incorporation (along with PSI) into a comprehensive, combined overall performance indicator. These would all be measured for each pavement section as part of a visual condition survey and a roughness survey. These should include some or all of the variables used in the current SDHPT PES system:

(1) (for flexible pavements) longitudinal and transverse cracking, alligator cracking, rutting, raveling, patches, and flushing; and

(2) (for rigid pavements) punchouts, patches, minor and severe spalling, minor and severe pumping.

The combination of these individual measures into an overall performance indicator may be achieved using utility functions as described in the PES User's Manual (Ref 10). This could be done either with interview techniques and the collected engineering judgment of an appropriate group of experienced Texas Engineers (Ref 21), or by using perhaps a more rational technique, discriminant analysis. Based on actual data as described in Ref 22. By either procedure, a distress utility for each pavement section would be calculated, which could then be combined with another utility for serviceability into an overall pavement utility.

Safety Measures

Measures - Measures of skid resistance could be obtained, since they are currently included in PES, and an appropriate utility due to skid resistance may also be calculated for combination with utilities for ride and distress as mentioned above. However, at least for Release 1.0, it is recommended, based on Task Force discussions, that skid should be treated separately. In addition, the current PES utility curve for skid number should be revised before this variable is incorporated into a prioritization index in any future modification.

Structural Capacity

Deflection measurements (using available technology) could be combined with knowledge of the pavement's structural characteristics to obtain a utility for structural adequacy for combination into an overall pavement utility. Pavement characteristics or attributes such as overall thickness, individual layer thicknesses and strengths (e.g., elastic moduli), could also be combined into an overall structural capacity utility along with the deflection measurements; however, the desirability of such future modifications must be weighed against their cost.

Other characteristics which must be considered in developing the overall utility are a regional environmental factor, rainfall, freeze-thaw cycles, traffic volume (AADT), traffic breakdown according to vehicle size (number of 18-k ESALs) and direction, routine maintenance needs, geometric features and finally, the functional classification of the highway.

Finally, for each performance indicator, levels which differentiate between acceptable and unacceptable roadway conditions should be established.

Reference 10 summarizes typical values for Texas which the SDHPT has already incorporated into the PES as part of their preparation for the implementation of a comprehensive PMS.

COST AND BENEFIT FACTORS

The selection of the program analysis period and discount rate must be an essential part of the network optimization process for both technical and economic analyses. For Release 1.0, it is suggested that the programming period be fixed at one year for simplicity, subject to future modification. The basis for deciding on a final prioritized schedule should be primarily economic. Initially, this should involve simple prioritization, but future improvements should be geared toward optimization. For example, after several rounds of improvement to PMS Release 1.0, dollar benefits could be maximized or dollar costs could be minimized. The maximization of a benefit/cost ratio would be preferable, if resources within the Texas SDHPT permit, since it is felt that this ratio appropriately represents the overall concerns of the SDHPT and yet is a conceptually simple, easy to use parameter.

DATA BASE CHARACTERISTICS

For the performance indicators and economic factors that have been listed above, it is necessary to select variables for measurement and storage. One of the first considerations in establishing the "available" data base is that the types and amounts of data required must be consistent with the resources of the SDHPT. Also the use, frequency and intensity of collection, processing, and updating procedures required must be reasonable. Considerable work has been done recently on this element by various SDHPT groups and consultants (Ref 23), and the authors recommend that the SDHPT adopt the integrated results of this effort. This will involve a considerable revision of the existing hardware and software to produce a unified algorithm for the collection, storage, processing, analysis, and updating of information on potentially all highway sections throughout Texas.

The information required for the technical, non-technical, and economic analyses to be carried out in subsequent steps must be provided for those projects which are candidates for rehabilitation during the programming period. Also, it should be noted that candidate projects must be selected before prioritization can be carried out. For a small highway network, it may be convenient to consider all pavement sections as candidates, whereas for a larger network, such as in Texas, a screening process may be necessary to reduce the data collection and analysis efforts. One possible screening method involves the routine monitoring of a simple variable, such as serviceability, for all roadway sections. Then, based on the value of this variable, the "worst" 25-50 percent of the existing pavements may be chosen for further analysis. For Release 1.0, it is recommended that the current process be used, wherein each District is charged with selecting initial candidates. In any event, it is desirable that the candidate selection process be compatible with the prioritization analysis. For example, if roughness is to play a large part in determining rehabilitation priorities, then the selection process must insure that all very rough pavements are considered for inclusion as candidates.

Once candidates have been selected, the project identifiers and project characteristics required for the analysis must be recorded in the PMS data base. This data base may be a separate computer file or set of data records exclusively for the PMS function, or it may be simply a master list indicating where all of the necessary individual data elements may be found. In either case, the information must be readily accessible to the PMS staff, and such access is efficiently provided in a computerized data management system of the type envisioned in the TTI study (Refs 23 and 24).

The same type of location information must be provided for all projects. For example, either milepost limits or control-section numbers could be used to identify a project, but it is unacceptable to use only milepost identifiers for some projects and only control-section numbers for others. In addition, all data in the set must be keyed to the same location identifier. Thus, if construction information is currently reported by milepost and engineering data are reported by milepost, it will be necessary to convert to one system or the other in setting up the PMS data base. This can be a troublesome undertaking, but some states (e.g., Washington) have already accomplished such a conversion. Once this has been done the basic evaluation frequency and segment length for measurement should be chosen. The PES system, as described earlier, includes suitable procedures. The evaluation segment is standardized at two miles, where possible, beginning at the county line or the smallest milepost on a particular highway. When a change in pavement type occurs or when a short section is encountered a segment which exceeds 3/4 mile in length will constitute a new evaluation segment. Those remaining segments less than or equal to 3/4 mile are included as part of the adjacent two mile segment where possible. The visual distress measurements are taken at one-half mile increments.

As originally conceived, a total mass inventory of roadways would be performed, with all highways rated each year for the first 5 years with the subsequent frequency to be determined from history. This future frequency of evaluation would be determined from previous evaluations and various other data. This requirement could be relaxed to allow data collection every other year or every third year on pavements that are known to be in good condition (and hence not likely to be in need of rehabilitation). Such decisions would be made on the basis of budget, manpower, and equipment constraints, and it is preferable to carry out a limited monitoring program accurately and completely, rather than to hastily and partially perform a more wide spread survey. However, it should also be remembered that these data are to be used for overall judgments only, and that those candidates which appear in the final program of work will, in general, require further scrutiny before any rehabilitation activity is performed.

It now appears, however, that any mass inventory proposal will be rejected because of data collection resources and costs, and that statistical sampling will be employed. This will affect some potential future modifications of the PMS, such as the use of historical trends for performance prediction. On the other hand, it is useless to attempt to implement a data collection effort which cannot be carried out or paid for because of pre-existing constraints. Consequently, work is underway to develop an acceptable sampling plan.

TEXAS PMS RELEASE 1.0

On the basis of the foregoing discussions and in accordance with the consensus of the Texas PMS Task Force, it is recommended that the initial Texas PMS be based on the existing PES, with some modifications. These modifications include the removal of skid in the calculation of the overall utility score, revision of PES to accommodate statistical sampling as well as mass inventory, and the addition of economic analysis elements for identifying the consequences of different levels of funding for rehabilitation. These modifications are discussed below.

Removal of Skid in Calculating Pavement Score

Presently, PES includes four utility factors which are combined into a single numerical rating (known as the pavement score) with a value lying within the range of 0 to 1.0. The utility factors considered are for visual distress, serviceability, skid and routine maintenance costs, and they are combined together through the use of a multiplicative model shown below:

$$PSC = (AVU)^{a_1} \cdot (SIU)^{a_2} \cdot (SKU)^{a_3} \cdot (RMCU)^{a_4} \quad (1)$$

where

PSC = pavement score representative of the current condition of a highway segment;

AVU = adjusted visual defect utility;

SIU = serviceability index utility;

SKU = skid utility;

RMCU = routine maintenance cost utility; and

a_1, a_2, a_3, a_4 = weighting factors which are dependent on the average daily traffic and the 18-kip equivalent axle loads.

Currently, the adjusted visual utility is taken as a function of utilities for rutting, raveling, flushing, number of failures per mile, alligator cracking, longitudinal cracking and transverse cracking. Utility curves for this list of distress types have been developed by SDHPT personnel (Refs 12 and 24), and an example illustrating the construction of a utility curve is given in Appendix D. In addition, utility equations for serviceability, skid and routine maintenance cost have been formulated. The curves for serviceability are constructed for several highway categories defined by multiplying the ADT/lane by the posted speed limit for each highway segment. Those for skid are taken as a function of the product of ADT/lane and rainfall. In addition, utility equations for routine maintenance cost are defined by the pavement type, depending on whether the highway segment is a bituminous surface treated pavement, an ACP, or a concrete pavement.

The utility factors discussed above are then combined into a single pavement score using Eq 1. Since only ride quality and visual distress will be used in evaluation and analysis of rehabilitation needs in PMS Release 1.0, it is necessary to modify the overall PSC equation by simply eliminating the skid utility and routine maintenance cost utility, and reflecting this change in the PES set of programs. This does not mean, however, that skid would be entirely deleted from the initial PMS. It could still be considered, but kept separate from the initial determination of rehabilitation needs and the budget to meet those needs. However, PES will have the capability to provide a listing of skid deficient sections to District engineers if they so desire. This could be used to apportion separate "safety" funds sources. For this purpose, the present skid utility equations may still be used, or even actual skid numbers themselves. In either case, a minimum requirement for skid may have to be specified. In addition, the SDHPT will eventually have to consider merging safety programs into the overall PMS.

Revision of PES to Accommodate Statistical Sampling

During the June 15, 1981 meeting of the PMS Task Force, there was considerable discussion on the sampling method to be adopted by the Texas State Department of Highways and Public Transportation. However, at the end of the discussions, it was unanimously agreed that stratified random sampling should be used for the initial PMS. In the following sections, this method of sampling is discussed and an approach for modifying PES in order to accommodate statistical sampling is presented.

Stratified Sampling. A stratified sample is a probability sample that is distinguished by the following two-step procedure (Ref 25):

(1) The parent population is divided into mutually exclusive and exhaustive subsets based on important characteristic differences.

(2) A simple random sample of elements is chosen independently from each group or subset.

The subsets into which the population elements (e.g., pavement segments) are divided are called strata or subpopulations. Note that the division is mutually exclusive and exhaustive. This means that every population element must be assigned to one and only one stratum and that no population elements are omitted in the assignment procedure. To illustrate the process, suppose that the parent population is composed of the total number of pavement segments within a district. For purposes of stratified sampling, these highway segments may be divided into groups or "strata" on the basis of functional class, from which simple random samples may be drawn independently. This stratification of the various elements of a population may be especially advantageous for the investigation of characteristics of particular subgroups. However, criteria may have to be drawn up in order to partition the elements in such a way as to be useful for purposes of the investigation. In particular, the stratification should be selected in such a way that the variability within each stratum is minimized in order to obtain results that are as precise as possible. This may involve stratification over such factors as traffic, environment, pavement type, and functional class. In addition, a decision may have to be made on whether to select a proportionate stratified sample, or a disproportionate one.

With a proportionate stratified sample, the number of observations in the total sample is allocated among the strata in proportion to the relative number of elements in each stratum in the population. A stratum containing one-fifth of all the population elements would account for one-fifth of the total sample observation, and a stratum containing one-eighth of all the population elements would account for one-eighth of the sample observations, etc.

On the other hand, disproportionate stratified sampling requires that the variances of the individual strata be taken into account when allocating the sample observations among strata. With a fixed sample size, strata exhibiting more variability are sampled more often, and conversely those strata that are very homogeneous are sampled less than proportionately. Although this scheme will produce more efficient estimates, it requires information on strata variances which may not be available. For the previous example therefore, the use of disproportionate stratified sampling would perhaps require that variances of pavement scores for each of the functional classes be known. It is possible in such cases for estimates to be made from past records, and the experience and judgment of the district engineers would certainly be useful for problems of this nature.

An Approach for Accommodating Statistical Sampling in PES

One way of accommodating statistical sampling in PES would be to utilize descriptive measures of some characteristics of a particular sample. This would involve providing measures of central tendency and dispersion. As such, PES reports may include, for example, the mean of pavement scores, their variance and standard deviation. In addition, confidence interval estimates and frequency distribution plots of particular parameters may be useful in establishing estimates of the overall condition of the pavement network and the extent of rehabilitation work that should be done. The statistical study reported in Ref 26 may be particularly useful in accommodating statistical sampling in PES.

Addition of Techniques for Identifying Consequences of Different Funding Levels

A possible approach towards making this modification is schematically presented in Table 5.2. One significant feature of the suggested approach is that it allows for inputs from the District Engineer, especially his

TABLE 5.2. SCHEME FOR IDENTIFICATION OF VARIOUS FUNDING LEVELS IN PES

PES OUTPUT	OUTPUT EVALUATION	BUDGET ESTIMATES
1. Statistical summaries a. means of pavement scores, serviceability index utilities, and adjusted visual utilities, b. standard deviations of the parameters calculated, and c. frequency distribution plots and confidence interval estimates. 2. List of deficient segements sampled. 3. List of extreme value cases or "hot spots".	1. Examines statistical summaries from PES. 2. Defines <u>k</u> desirable levels of pavement score for each functional class. 3. Examines list of deficient segments sampled and "hot spots". 4. Assigns priorities. 5. Prepares approximate rehabilitation program for each of the <u>k</u> levels.	1. PES calculates cost of <u>k</u> rehabilitation programs. 2. PES prints out <u>k</u> budget levels, and the expected overall condition of the network for each rehabilitation program.

experience and judgment in the specification of appropriate rehabilitation strategies. Under the scheme presented, the processed information available through PES would be used by the district engineer to evaluate the condition of the roads under his jurisdiction. In the process, he may select a number of desirable pavement score (PSC) levels which would, for example, keep the roads at (1) a bare minimum, (2) a satisfactory,and (3) an above satisfactory level of service, and specify for each the approximate rehabilitation program on the basis of his judgment and experience. This information would be fed into the system, which would then calculate the cost of each rehabilitation program and print out the budget levels and the corresponding expected overall condition of the network for each budget level.

Also, the economic analysis routines already available in the RAMS programs could conceivably be easily modified for incorporation into the PES-based PMS Release 1.0, so that new software development would be minimized.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS FOR THE IMPLEMENTATION OF A SIMPLIFIED PMS

BASIC STEPS - KEY ASPECTS

Based on the information presented in the previous chapters, it can be said that Texas has several candidate procedures and algorithms for a workable pavement management system, and that efforts should be made towards a trial implementation in 1982 and 1983. In this regard, the basic steps in pavement management system implementation are summarized in Table 6.1. Several key aspects worth mentioning are as follows:

(1) A decision to implement, or at least to study the feasibility of implementing a pavement management system, is a necessary first step. This has already been carried out in Texas. However, this decision to implement, together with the plan and schedule for implementation are not sufficient by themselves. Responsibility for implementation is likewise an essential ingredient.

(2) Pavement management implementation goes hand in hand with development. It does not require that a complete and comprehensive PMS be established first before implementation. This is best explained by Fig 6.1, which shows pavement management system development as a staged process with implementation plateaus existing between successive improvements or updates.

TABLE 6.1. MAJOR STEPS IN IMPLEMENTING A PAVEMENT MANAGEMENT SYSTEM

1. Decision to implement; assign responsibilities, set objectives.
2. Inventory existing methods and communications links within PMS framework.
3. Identify deficiencies; improve where necessary.
4. Develop an implementation plan and schedule.
5. Carry out implementation; document the results.
6. Periodically assess and update the PMS.

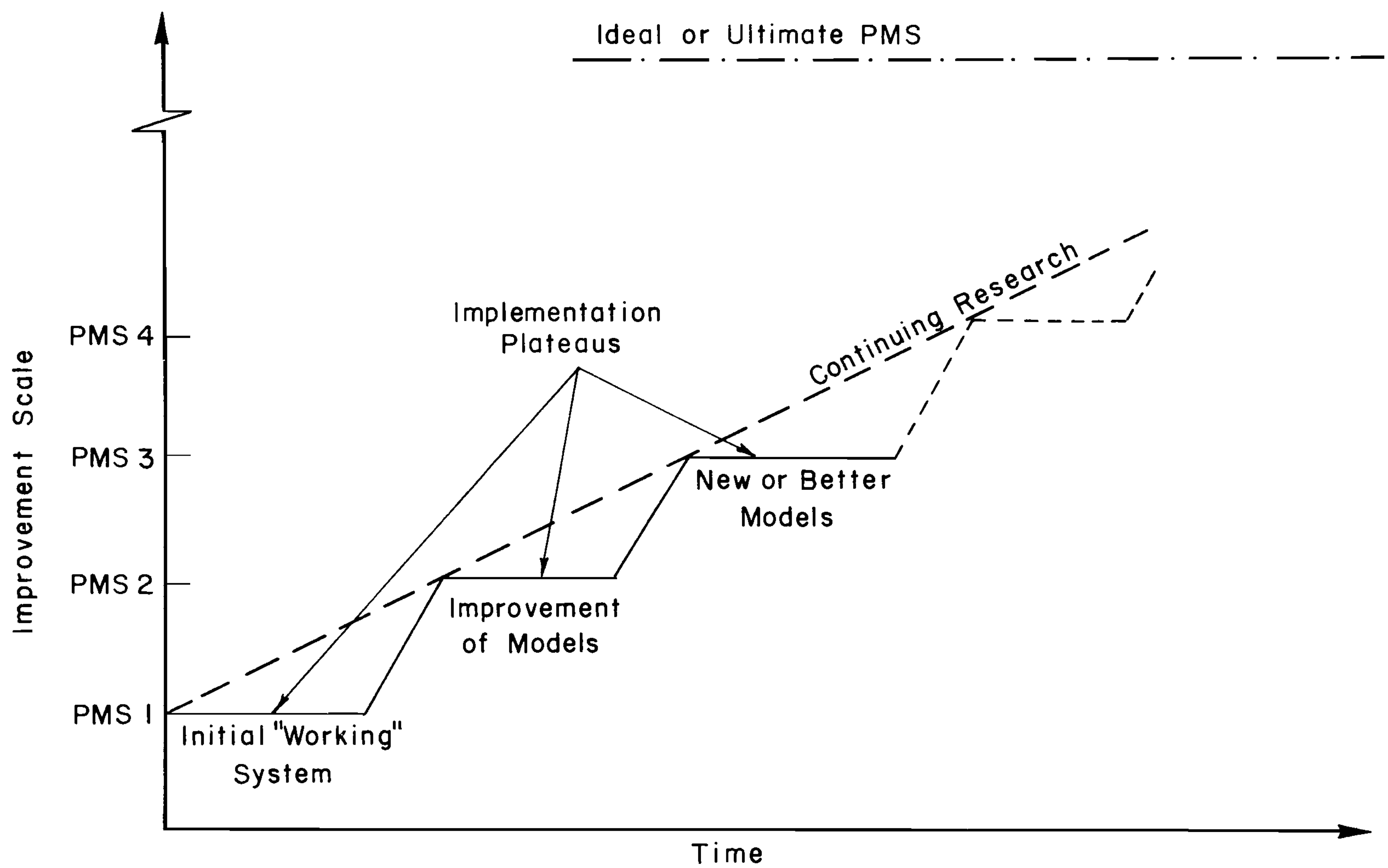

Fig 6.1. Schematic representation of progressive improvements in PMS development and implementation (Ref 10).

(3) Personnel to take charge of the system should be oriented on key PMS concepts, and necessary materials such as user manuals would be very useful and should be prepared.

(4) Cooperation, commitment, careful coordination, and communication between all levels of management in the agency are essential to the success of pavement management implementation.

(5) Documentation of work that is being done is vital for updating, carrying out improvements, and providing a record for others in the department as well as in outside agencies.

IMPLEMENTATION OF PMS RELEASE 1.0

Release 1.0 of the Texas PMS, as described in the previous chapter, should be implementable in the near future. The basic steps remaining to be done are:

Complete the Development of Release 1.0

The modifications to the existing PES must be carried out. Of these, the incorporation of statistical sampling will likely require the most time and effort. At least one and possibly two more meetings of the Task Force will be required to agree on a sampling plan which should be based on the stratified random sample methodology discussed in Chapter 5.

It should be stressed that the initial sampling plan can be modified at a later date if it is found to be inadequate. Implementation of PMS Release 1.0 should not be delayed for further research into appropriate sample sizes, etc.; rather, current knowledge (see for example Ref 26) should be used to construct a trial sample plan, and the first round of implementation should be undertaken as soon as possible.

The modification of the calculation of overall utility can be carried out quickly by simply eliminating the terms for skid number and maintenance cost, and, if necessary, revising the exponents in Eq 1 of Chapter 5. Similarly, the required economic analysis additions can be lifted almost intact from the existing RAMS programs with comparatively little effort.

Conduct a Trial Implementation

Once the required changes to PES have been made, the PMS must be tried out using actual field data. Data collection is obviously the first step, but this cannot begin until the sampling plan is fixed and the sample segments are identified. Actual data collection should take about two to three months, depending on the sample size. The analysis of the data may take an additional month or two, barring complications in the de-bugging of the computer codes.

A more serious problem will be the storage and retrieval of these data. The data base system to be used with the PMS has been reviewed and found wanting, as discussed previously in this report. Current estimates are that programming of the new data system cannot begin before late Spring of 1982, and that roughly 60 man-months of effort (minimum) will be involved in setting up the data base. A true trial implementation cannot be completed until the data base is operational. Work on the data system is crucial to further PMS development, and that this work will set the final timetable for implementation of Release 1.0.

If significant delays are encountered in obtaining a working data system, it is suggested that a trial run of PMS Release 1.0 be performed using "mocked-up" data values rather than actual field data. Such "mocked-up" data values may be pieced together from existing historical records and from the judgment of experienced engineers in the Department.

Revise the Initial PMS and Schedule Further Implementation

Based on the experience gained in the trial implementation phase, the most essential revision for the second release of the Texas PMS may be determined. Some potential areas for revision are presented in the next section, in order to stimulate current thinking toward future needs.

SUBSEQUENT MODIFICATIONS TO PMS RELEASE 1.0

In general, it is recommended that future releases of PMS move from prioritization based on PES toward optimization based on the RAMS programs. The considerable effort that has gone into the development of the RAMS programs can be very effectively utilized in this fashion. Several intermediate steps may be necessary in order to arrive at a totally revised PMS, and the precise order in which such modifications are carried out will depend upon Departmental decisions regarding most immediate needs. Several possible first steps are presented here.

Fine Tuning of PES Models

Both the economic and technical analyses of PES must be revised following trial implementation. How essential this step is will depend on how well these models work during this trial. Since the existing PES has not yet been fully tested, both the original models and utility curves as well as the PMS Release 1.0 modifications may require substantial revision. It is anticipated that the initial utility curves in particular will require considerable fine tuning.

Revise Output Reports

PES was not originally developed for use as a PMS; hence, it may be necessary to revise the types and formats of output that can be generated by the system. Brief descriptions of the kinds of reports presently available through PES are given in Appendix C. Some revision may, of course, be performed with little effort as part of Release 1.0. However, additional desirable outputs will doubtless be identified during trial implementation. For example, if traffic levels are found to be crucial for rehabilitation decision, output of overall utility versus traffic level for any stratum of pavements in the sample could be useful.

Develop Improved Financial Planning Model

The economic analysis suggested for Release 1.0 (assessment of consequences of various levels of funding) is fairly elementary, so that improved economic models may be highly desirable for future releases. Improvements might include revisions to the cost estimating model as well as the incorporation of more sophisticated rules for choosing rehabilitation actions for candidate projects.

Incorporation of Safety Program

At some point, the Department may want to integrate the safety and rehabilitation programs. Some key questions in this regard are:

(1) How shall skid data be sampled? Will it be the same as for visual distress data?

(2) How will the listing of skid deficient sections interface with the main priority list?

(3) How will the safety budget and the rehabilitation budget interface with each other? Will there be a provision allowing unused funds from one budget to be used for other purposes?

Extension of Analysis Period

Optimization of the rehabilitation program can only be achieved by comparing the consequences of alternative actions over time periods on the order of ten to twenty years, and preparing tentative programs several years in advance. Such analysis is beyond the scope of Release 1.0, but within the realm of achievability for subsequent Releases. Concurrently with the extension of the analysis period, it will be necessary to develop prediction models which can be validated using the data collected over several years of PMS operation (as well as with other existing data). The RAMS programs can provide trial models for use in this regard.

SUMMARY

In summary, it is felt that systematic efforts should proceed with vigor to develop and implement a Pavement Management System for the Texas SDHPT. If possible, discussions and briefings should be held with key administrative officials to discuss PMS benefits and to outline the feelings of the Task Force. It remains important that the SDHPT Task Force function and provide guidance to the work of PMS development.

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APPENDIX A

SUMMARY OF TASK FORCE FINDINGS

APPENDIX A. SUMMARY OF TASK FORCE FINDINGS

FIRST PMS TASK FORCE MEETING - May 6, 1981

Review of Objectives

The general functions of the pavement management system task force are to provide policy guidelines to the administration for the development and implementation of a PMS, and to closely coordinate with MIPR the work of identifying the needs of such a system as well as establishing the basic design and elements. At the first Task Force meeting, a four-step process of PMS development was outlined as follows:

(1) identification of the needs of the system - one task would be to confirm such needs;

(2) the PMS to be implemented should relate to what is available and necessary;

(3) a detailed benefit/cost analysis should be made; and

(4) administration approval of proposals should be obtained.

The results of the PMS Workshop were also reviewed. On this matter, the primary motivating factors for the development and implementation of a PMS were identified. These were primarily related to the following needs of the department:

(1) the need for a tool to effectively answer public inquiries on whether the Department is properly addressing the interests of the riding public; for example, PMS can assist in showing the public that decisions are being made on our high-priority needs;

(2) the need for a tool to communicate to the legislature the consequences of various funding levels; and

(3) the need for a tool to assist in equitably allocating highway funds.

In addition to the above, it was again emphasized that the system to be developed and implemented should be simple and easy to understand, and should be capable of providing data into a useable form in a short period of time. Finally, it was likewise stressed that PMS is only a tool which would provide decision makers with information to assist them in effectively managing the highways in the state.

Pavement Evaluation System

A presentation on the Pavement Evaluation System was made by Mr. Ed Davis. During the course of the presentation, questions were raised that primarily related to the relatively greater importance that the system places on highly trafficked roads; specifically, the concern was raised that because of the subjective way in which weighting factors may be assigned, not enough attention may be given to farm-to-market roads. It may, therefore, be relevant to come up with a consensus on whether the districts want to have a separate consideration of each of the functional road classes, i.e., separate priority lists for urban freeways, farm-to-market roads, etc. However, it was also pointed out that the results of PES are not intended to be sacredly followed, but are merely designed to provide consistent, up-to-date information which the decision maker should use with judgement and discretion to assist him in managing the roads under his jurisdiction.

The district engineers were likewise interested in knowing when PES can be operational. In answer to their question, Mr. Bob Guinn stated that the existing system could be implemented by October 1981, and that production of reports can start by January of next year. Modifications in the system are still necessary, specifically, with respect to the utility curves. In addition, there is a need to refresh the raters in pavement condition evaluation.

Overview of RAMS Programs

Dr. Robert Lytton presented a general overview of the RAMS programs which are primarily intended to assist in the establishment of district and statewide budgets, and to provide the decision-maker with information on the optimum rehabilitation and maintenance strategies. The RAMS programs are reviewed elsewhere in this report.

Presentation on Data Base Project

Ms. Barbara Hilger indicated that the Roadway Information System as it is now used is somewhat outdated, and that starting over in the data base may be easier than revising what is currently in use and would provide more future flexibility. She also pointed out that because of changes in technology, there is some problem associated with making final decisions about using the data base. She indicated that it would require a minimum of 12 calendar months to get a new system going and that she has already submitted a preliminary plan to MIPR. There was considerable discussion on this topic. Some people thought that more progress had been made in the data base than is now apparent. Others felt we should encourage MIPR to take some consideration on the request as soon as possible in order that things could move ahead. Everyone felt that the data base was essential to the proper development of a PMS.

Decision Criteria

Dr. Ronald Hudson presented a discussion of decision criteria which must be selected. It was pointed out that a common ground is needed for District, Division, and State level consideration. It was also pointed out that we must decide how simple "simple" is going to be for this system. The simplest system, for example, is the New York system which uses ride only. This system has worked well in New York and they have been able to increase their funding by using it. In an effort to deal with some of the issues on decision criteria, the following questions were covered.

(1) Do we include skid in our decision criteria? - There was unanimous consent among all members present that skid should be kept separate from other decision criteria in the prioritization index (PINDEX) for the Texas PMS. In connection with this, a separate budget may have to be established to fund safety-related projects, and a separate priority list of skid deficient sections may have to be made.

(2) Should deflection be included in PINDEX? - It was pointed out that deflection is three times as expensive as roughness measurements, and that deflection is used only at the project level, but that we

might need some sampling of deflection at the network level to evaluate structural condition of the network. No districts are currently using deflection for selecting their projects.

(3) Should we include serviceability index - performance? - Everyone was unanimous in agreeing that ride quality or serviceability index should be included. Since condition surveys are no longer included in the serviceability index, it was felt that the use of the term ride quality alone might be satisfactory.

(4) Should we include condition surveys or some condition index in the performance index? - There was considerable discussion relative to this question and no decision could be made. Therefore, the following question was asked.

(5) If you went into your district tomorrow to select five or ten pavements to rehabilitate, what would you consider as the most important factors? - The answers were as follows:

 (a) Ride and looks - take the ones with the weakest section, base failures and roughness.

 (b) Maintenance costs - surface condition.

 (c) Serviceability.

 (d) Traffic must be considered.

(6) What are your criteria for choosing projects, once you have a fixed budget? - The answers were as follows:

 (a) Recommendation from my maintenance foreman.

 (b) Serviceability first, then traffic.

 (c) For concrete pavements, I look at the condition - serviceability is not as critical.

In response to this question, it was agreed that at the state level there was a broader need for objective comparison than was necessary in a district where the district engineer and his staff could keep close watch.

As a result of these questions, there was general consensus that both riding quality and condition information are needed in the overall performance index.

Sampling Problems

There was a general discussion about the need for sampling and how it should be considered. It was pointed out that stratification of pavements will sometimes be made so that random sampling alone is not the total answer. A general discussion on sampling was held in a succeeding meeting.

Rigid Versus Flexible

There was some discussion among the district engineers with particular emphasis from Bill Ward that it was absolutely essential that we give some attention to integrating the analysis of rigid and flexible pavements. Gerald Peck indicated that the models needed in each case might be different, but it was generally agreed that the system will ultimately have to integrate them for funding purposes.

SECOND PMS TASK FORCE MEETING - June 15, 1981

Introduction

The objectives of this meeting were: (1) to define release 1.0 of PMS and schedule its implementation; (2) to identify future improvements; (3) to evaluate data base needs; and (4) to select the method of sampling for pavement condition surveys. Significant decisions were made during the meeting and they are highlighted herein.

Decision Criteria

The initial PMS shall combine ride quality and pavement condition into a single numerical score using utility theory. Skid is to be a separate consideration since it is a measure of safety rather than of pavement performance and rehabilitation needs. However, the point was raised that the Department eventually may have to consider merging safety programs into PMS.

In addition, a questionnaire was prepared by CTR for the purpose of obtaining input from PMS Task Force members concerning the relative importance of pavement condition variables. It was agreed that the questionnaire would be distributed to the PMS Task Force members at a later date, pending review by selected Task Force representatives.

Sampling

(1) Dr. Robert Lytton presented two sampling procedures which may form the basis for the selection of the most suitable sample size for the pavement condition surveys in the state. The first procedure

is the one that is currently used in the Highway Pavement Monitoring System (HPMS), while the other is based on research work performed at TTI.

(2) Following considerable discussion, a vote was taken to determine the sampling method to adopt for the PMS. There was unanimous agreement that a stratified random sampling method be used, with the stratification to be primarily by district and also by either highway system or functional class. However, it was also pointed out that other factors may influence the stratification, such as geographic factors (e.g., the Balconies Fault) or intensive truck traffic. In addition, it was agreed that each District would have the option to do a complete survey, and that, as a minimum, sampling of extreme values ("hot spots") shall be required in addition to the stratified random sample.

Data Needs

(1) Data collection will be done in the Fall, beginning as early as September in areas which are subject to early onset of winter.

(2) For multilane facilities, data shall be gathered for one lane (i.e., the worst lane). Also, each roadway will be sampled; thus divided highways with frontage roads on either side shall be counted as 4 separate roadways.

(3) Data other than pavement condition data will also be required, but can generally be supplied by other sources.

(4) Several possibilities as to how the evaluation team(s) can be formed were identified. The alternatives are:

(a) a centralized evaluation team based in Austin;

(b) separate evaluation teams for each region (mix district and state people), and

(c) separate evaluation teams for each district.

(5) Assignment of priorities for the data collection effort shall be in decreasing order by system or functional class, with the interstate system receiving 1st priority.

(6) The data base needs to be flexible in order to allow other data (such as skid numbers) to be stored. In addition, there was general agreement that road shoulders be included in the data base as the data will be useful for future work, including prediction of the future condition of specific roadway segments. However, it was recognized that this objective may not be realized if the sample size is not large enough.

Release 1.0 Implementation

(1) The current PES with minor modifications shall be release 1.0 for the Texas PMS. Dr. Robert Lytton has indicated that the modifications could probably be done within the time constraints for release 1.0, with the cooperation of D-19. The modifications include:

(a) removal of skid;

(b) revision of PES to accommodate statistical sampling; however, the system should also allow for the district option to do a mass inventory; and

(c) addition of analysis techniques for identifying consequences of different funding levels.

(2) The development schedule also calls for data collection this Fall.

Other System Features

(1) The rigid pavement data which CTR presently has may be useful in bringing rigid pavements into the picture.

(2) It is desirable to tie skid data with the PMS data, and to set up the data base in such a fashion that geometrics, accident rates and capacity data can be tied in as well.

(3) The system should allow for ease of comparison of separate listings of pavement scores, safety, geometry and capacity, etc., by providing compatible information and easy access.

(4) It may also be desirable to expand the existing TTI and CTR data bases (e.g., by including maintenance data especially on costs and on the activities which are actually carried out).

APPENDIX B

REVIEW OF PRESENT NATIONAL PMS EXPERIENCE

APPENDIX B. REVIEW OF PRESENT NATIONAL PMS EXPERIENCE

INTRODUCTION

The main focus of this appendix is on PMS developments in states other than Texas. Specifically, models developed in Arizona, Florida, California, Idaho, New York, and Washington are discussed. It is apparent from these discussions that a lack of common terminology and also a lack of agreement on what really constitutes a PMS, are two of the major problems facing pavement system designers in the United States today. In addition, a comparison of these models with each other and with the Texas RAMS model (in terms of how each fulfills PMS needs) is included at the end of this appendix.

ARIZONA NETWORK OPTIMIZATION SYSTEM

A network optimization system (Ref 14) was developed to assist in the establishment of statewide cost-effective pavement rehabilitation policies in Arizona. The system can be used to prepare 1-year, 5-year, and 10-year pavement rehabilitation budgets for the achievement or maintenance of desired performance standards. Such standards are specified in terms of the minimum proportion of the network required to be in acceptable condition states, and the maximum proportion allowed to be in unacceptable condition states. Cost and performance prediction models were developed from a large amount of real data collected annually by the ADOT staff. The overall system methodology involved: (1) selection of functional criteria and performance variables; (2) selection of influence variables for each performance variable; (3) selection of road categories and condition states; (4) specification of rehabilitation actions and policies; and (5) development of the optimization model. For the Arizona NOS, the set of variables relevant to the evaluation of pavement performance are average daily traffic, a regional factor (which takes into account the influence of the environment), cracking, and pavement roughness. For purposes of the optimization algorithm, each variable is divided into various levels and combinations of such levels from what are known as condition states. The set of variables considered, including the various ranges for each are shown in Table B.1.

A basic feature of the optimization model is the assumption of a stationary rehabilitation policy. This implies that the selection of rehabilitation actions will be a function of the pavement condition state and will not be affected by time, and that the effects of inflation are assumed to be uniform for all rehabilitation actions. Another implication is that if a stationary policy is followed, the roads in the network will achieve steady state conditions only after some length of time has elapsed. The period in which the pavements are not yet in steady state has been called the transition period. Consequently, the Arizona NOS determines rehabilitation policies for a short-term (transition) period and a long-term (steady-state) period. The length of the transition period, or the length of time the network takes to achieve steady-state conditions is to be specified by ADOT management.

The primary output of the NOS is in terms of the proportion of roads which move from a condition state i to a condition state j after some

TABLE B.1. RANGES SELECTED FOR DIFFERENT VARIABLES - ARIZONA NOS (REF 13)

Variable	Range of Variable
ADT	1. 0 - 2,000
	2. 2,001 - 10,000
	3. Greater Than 10,000
Regional Factor	1. 0 - 1.7
	2. 1.8 - 2.7
	3. Greater Than 2.7
Index To First Crack	1. 16.1 - 20
	2. 0 - 4
	3. 4.1 - 8
	4. 8.1 - 12
	5. 12.1 - 16
Present Roughness	1. 0 - 165
	2. 166 - 255
	3. Greater Than 255
Present Amount of Cracking	1. 0 - 10%
	2. 11 - 30%
	3. Greater Than 30%
Change in Amount of Cracking During Previous Year	1. 0 - 5%
	2. 6 - 15%
	3. Greater Than 15%

rehabilitation k is applied at the beginning of the 1st year. The results obtained are for all condition states i , rehabilitation actions k and time periods 1 = 1, 2, . . ., T. The system also determines the most cost effective rehabilitation action. By combining the results of the NOS with the findings of the annual condition surveys, the appropriate rehabilitation strategy for each portion of the pavement network can be determined.

Initial trial runs of the NOS have been assessed and indicate that the system is ready for trial implementation by ADOT. Because Arizona conducts condition surveys on an annual basis, the results of the NOS are based on the most current information, and can be monitored against observed pavement conditions on a yearly basis.

FLORIDA PMS

The PMS developed in Florida is aimed basically at assigning priorities for reconstruction and rehabilitation (Refs 15 and 16). It functions primarily at the project level, and consists of three main divisions: pavement design, monitoring, and materials characterization. Priorities are assigned to projects based on Engineering Rating (ER), expected improvement in Engineering Rating due to the proposed improvement, and cost effectiveness. The Engineering Rating is composed of operational rating (OR), which is a measure of the roadway's ability to adequately handle traffic, and the structural rating (SR) which is a measure of the roadway's structural condition. These two ratings are combined to provide an overall measure of performance through the equation

$$ER = \sqrt{OR \times SR}$$

Data to compute the structural rating of all flexible state highways in Florida are collected annually by the Maintenance Office. In addition, pavement condition surveys for the evaluation of concrete pavement structures were initiated in 1979. The current condition of a pavement is calculated by measuring the rideability (Ride Rating -- RR) on a scale from 0-100 with a calibrated Maysmeter equipped automobile. More recently however, the Department has started using a trailer Maysmeter that is towed by a vehicle. In addition, defects in a pavement structure are recorded by taking measurements of pavement cracking, rutting, and patching, from which a Defect Rating (DR) is calculated. Structural Rating is then computed for each highway segment through the equation

$$SR = \sqrt{RR \times DR}$$

This parameter may be projected to future years by application of procedures that are similar to those in the AASHTO Interim Guide. By combining the projected values of SR and OR, a predicted value for ER can be calculated for use in planning.

In addition to the above, a separate system has been developed to identify and investigate Safety Improvement Projects, including skid, high accident, and roadside obstacle problems. A parameter (known as the Safety Ratio) is calculated for each accident section or spot location. The 20-30 pavements with the highest Safety Ratio not otherwise scheduled for improvement within two years are chosen as candidates. All sections with skid numbers (SN) less than 36 are chosen as well as those with SN less than 41 which have greater than average accident rates. All sections with reports of vehicles striking roadside objects are investigated for possible improvements. A benefit-cost analysis is done for programming safety improvement projects.

CALIFORNIA PAVEMENT MANAGEMENT SYSTEM

The California Pavement Management System (Ref 17), has been developed and implemented by the California Department of Transportation (CALTRANS) to effectively manage pavement resurfacing and rehabilitation. The system relies on pavement condition surveys to determine the nature, severity and extent of pavement problems such as cracking, raveling, rutting, patching, skid, and ride quality. Ratings made on each of these problem types are separately evaluated and no attempt is made to produce an overall single numerical index. Instead, a "decision-tree" structure is used to determine appropriate rehabilitation strategies for each pavement section.

Pavement condition surveys are made every two years and total system coverage is required, i.e., statistical sampling for the survey was dismissed. However, consideration was given to the possibility of surveying certain select portions of the State Highway System on a less frequent scale in order to reduce survey costs. It is envisioned that as more data is gathered to permit performance and trend analyses, the manner of reducing the extent and frequency of condition surveys would be better studied.

Results of the survey are analyzed using decision trees to evaluate the pavement conditions and identify problems and appropriate rehabilitation strategies. The general approach followed considers each problem type independently, with separate repair strategies or alternatives being formulated for each. The solutions for all triggered problems are compared and the strategy that will correct all problems and provide an acceptable level of service is identified. Such strategy is defined as the dominant strategy. Because of the characteristic differences in flexible and rigid pavement problems and remedies, each pavement type is treated separately in the PMS. The evaluation procedures for both flexible and rigid pavements are shown conceptually in Figs B.1 and B.2. In addition, formulae for estimating rehabilitation costs are available for rigid and flexible pavements, and each branch of a decision tree identifying a specific repair strategy has a separate cost formula. Factors used in the formulation of cost include geographic factors (that take into account the geographical variances in costs), traffic handling factors, flexible and rigid pavement repair factors (such as those for overlay thicknesses) and shoulder factors.

The end product of the preceding processes is a series of reports describing pavement condition, rehabilitation strategy, and cost; candidate projects for various highway programs; and alternative repair strategies. The selection of an appropriate repair strategy is based on an evaluation of feasible alternatives. In this regard, the PMS includes a research of the state-of-the-art of pavement repair strategies in California -- the functions of each, applications, approximate costs and estimated service lives -- as a further aid in the selection of appropriate strategies by the decision maker.

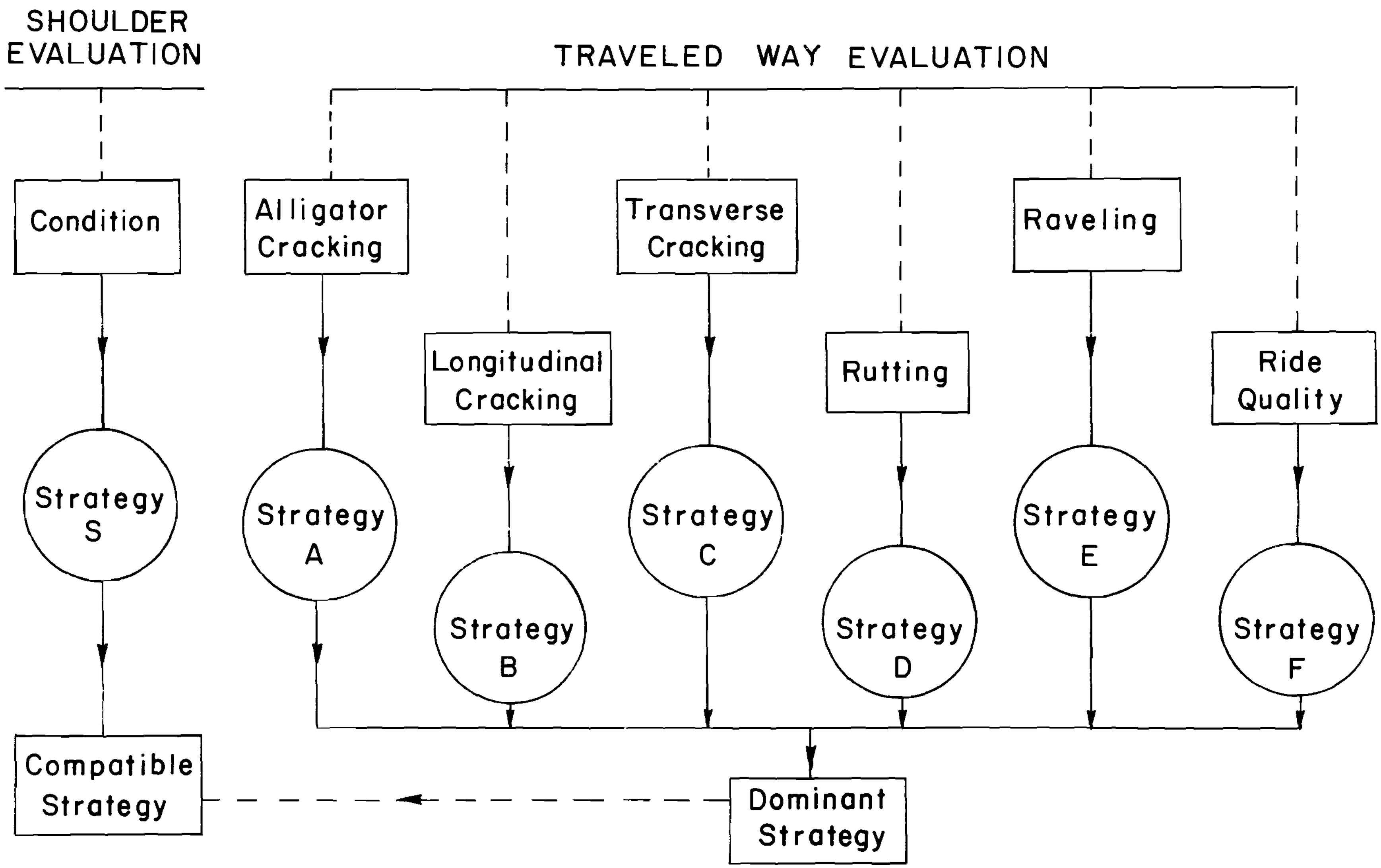

Fig B.1. Flexible pavement condition evaluation procedure - California PMS (Ref 18).

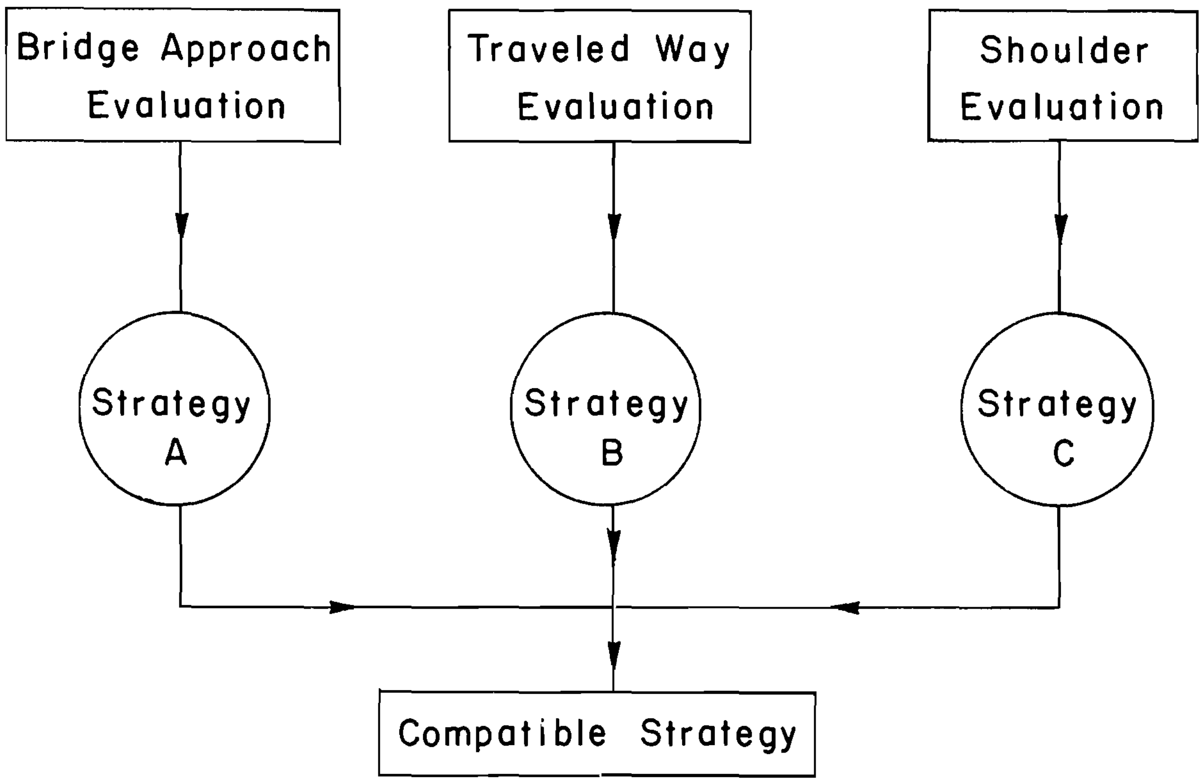

Fig B.2. Rigid pavement condition survey procedures (Ref 18).

IDAHO PAVEMENT PERFORMANCE MANAGEMENT INFORMATION SYSTEM

The basis for the development of the Idaho Pavement Performance Management Information System (PPMIS) (Ref 18), is the system developed by the State of Utah. Acquired by the Idaho Transportation Department in 1978, the system has undergone certain modifications to adapt to Idaho conditions. Such improvements or changes were based from the application of the Utah PPMIS to flexible pavements in Idaho. An overview of the system is shown in Fig B.3.

Basically, PPMIS begins with a comprehensive inventory of structural adequacy, pavement riding quality, surface condition and skid resistance. The inventory data, together with other data on traffic, are then analyzed to produce a ranked set of needs in tabular and graphical format. Two major programs, SYSTDY and SUMMARY, are used for this purpose. A third major program, POD (Pavement Overlay Design) can be used for overlay design. The first two programs are directed to assisting in decisions at the network level while the third one, POD, assists in decisions at the individual project level. A tabular summary of these three major programs is presented in Table B.2.

Following initial development and a trial implementation study of the Idaho PPMIS, two significant modifications to the system were recommended. First of all, an economic analysis package will be incorporated in the system. The goal of pavement management in general is to provide the highest possible level of service to highway users at the least possible cost. To this end, the programming of improvements a pavement network should take into account not only the relative needs of each pavement section but also the economic implications of alternative improvement strategies and the project

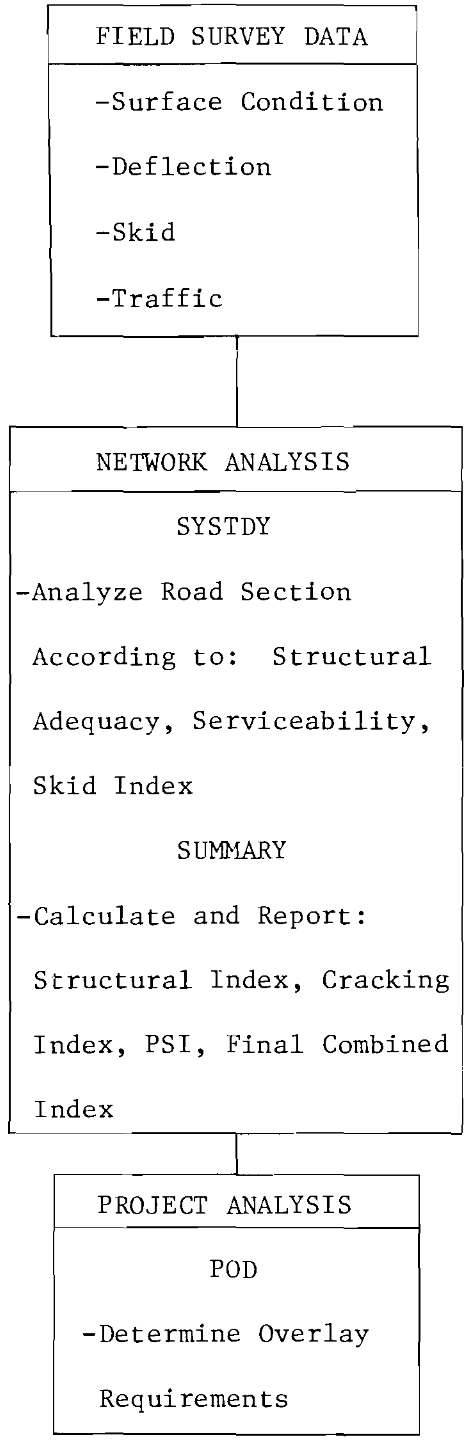

Fig B.3. Overview of Idaho PPMIS (Ref 19).

TABLE B.2. TABULAR SUMMARY - IDAHO PPMIS (REF 19)

PROGRAM	INPUT(S)	FUNCTIONS(S)	OUTPUT(S)
SYSTDY	1. Dynaflect Inventory 2. Serviceability Data 3. Skid Data 4. Traffic Data	Evaluates Road Section According to Structural Adequacy, Serviceability, Skid Index - Calculates the Number of Years Before the Pavement Becomes Structurally Inadequate - Determines the Remaining Number of Years Before a Section's PSI Drops Below the Specified Terminal Serviceability Level - Determines Skid Index Values	Brief Printed Report Showing: - Dynaflect Readings and Summary - Serviceability Summary - Skid Meter Summary - Histograms - Cracking Info.
SUMMARY	Output From SYSTDY	- Calculates Structural and Distress Indices - Determines Final, Overall Index of Each Section - Lists Sections Analyzed in Ascending Order of Some Specified Parameter - Develops an Overall List of Priorities	- Final Ranked List of Pavement Needs - Histograms
POD	- List of Sections For Further Analysis - Detailed Condition Survey Data	- Performs More Detailed Structural Analysis - Determines Overlay Requirements	- Description of Structural Condition of Each Pavement Section - Overlay Thicknesses (If Required)

timing over a programming period. Secondly, due to the significant mileage of rigid pavements in the state, the system will be further improved to include the capability to analyze such pavements. To this end, pavement behavior models for rigid pavements have been established, but specific rehabilitation strategies have not been agreed on as of this time.

NEW YORK PAVEMENT SERVICEABILITY SYSTEM

New York's Pavement Serviceability System (PSS) (Ref 19) is basically an engineering data system for the annual evaluation of pavements throughout the state's network. The evaluation is made in terms of the functionality of pavements or how well they function for their purpose, which is to provide an adequate travelling surface for the highway user (a concept that evolved from the AASHO Road Test). The degree of functionality is quantified by means of a present rideability index, PRI, which takes into account psychophysical scaling factors. Figure B.4 shows the relationship of PRI to how the user feels in riding a particular pavement, and also what the implications are for restoration or correction of that pavement. As seen from the figure, a PRI of 2.40 has been adopted as a boundary between an adequate pavement and an inadequate one.

In its planned ultimate design, the engineering utility of the PSS has been pointed toward effectively solving the following inherent problems encountered in pavement management:

(1) Locating less-than-adequate (PRI 2.40) pavements.

(2) Establishing functional condition priorities between all less-than-adequate pavement so found.

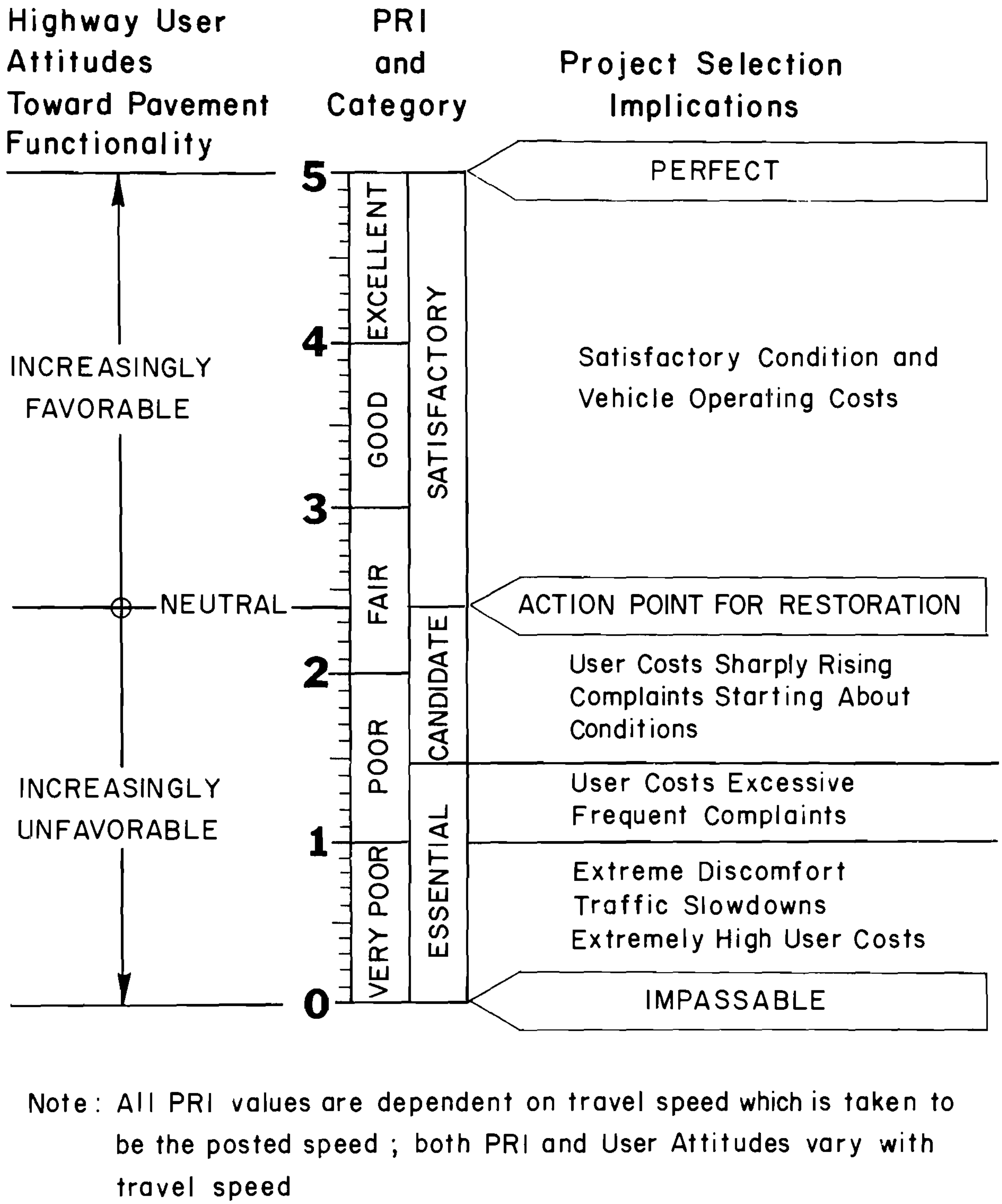

Fig B.4. Significance of the present rideability index - New York (Ref 20).

(3) Predicting several years in advance the future PRI of a pavement based on details of its composition, physical environment and past performance trend.

(4) Predicting life expectancy of various proposed corrective treatments to pavement restoration problems, based on the results of similar situations elsewhere in the real world of pavement performance history compiled by PSS.

(5) Refining pavement design methods to achieve specified predicted lives of reasonable accuracy, permitting alternatives to be compared by total cost-per-year of useful life, rather than first cost alone.

At present, the first two objectives have already been realized. In addition, projection of a pavement's PRI into the future is (at this stage) done graphically using available data on past performance. No prediction models have been developed for both flexible and rigid pavements, although development of such models is a long-range goal. It is also felt that consolidating maintenance and pavement performance data, and expanding present computer resources would contribute significantly to the realization of the last two objectives.

WASHINGTON PAVEMENT MANAGEMENT SYSTEM

Similar to the Texas PMS, the system developed by Washington (Ref 20), consists of several computer programs which are utilized sequentially to come up with a listing of the optimum rehabilitation strategies for each project segment in the state. A flow chart of the programs utilized is shown in

Fig B.5, and a tabular summary is provided in Table B.3. In general, the first four programs BUILD1, EQUATE, BUILD2, and BUILD3 are utilized for summarizing the existing information available on each project segment of the roadway system while the last two, INTERPRET and OPTIMIZE, are used for generating alternatives and for evaluating the optimum strategies. The details on how the system operates are discussed in the following paragraphs.

As shown in the flow chart, there are two programs and two data files involved in building the Master Index Listing. The first program, BUILD1, reads a current data file known as the Roadlife History and generates a file with the state system broken into project lengths by beginning and ending control section mileposts. The second program, EQUATE, reads the current State Route Log and equates all control section mileposts to current state route mileposts. The product of these first two programs is the Master Index Listing which is a breakdown of the state system into project lengths with information regarding type of facility, number of lanes, highway type, roadway and shoulder width, construction history, surfacing type and thickness, and base type.

The next data listing produced in the PMS is a Master File Listing. There are two programs and two data files (as well as the Master Index Listing) which are involved in producing the Master File. Program BUILD2 reads data from the annual traffic report and inserts ADT, growth factors, single unit truck percentages, and combination truck percentages into the Master Index Listing within the proper milepost limits while program BUILD3 matches pavement condition ratings from each year with the beginning and ending milepost limits defined in the Master Index. The product of BUILD2 and BUILD3 is the Master File which is a collection of all rating, traffic, and construction history data for each project segment on the state system.

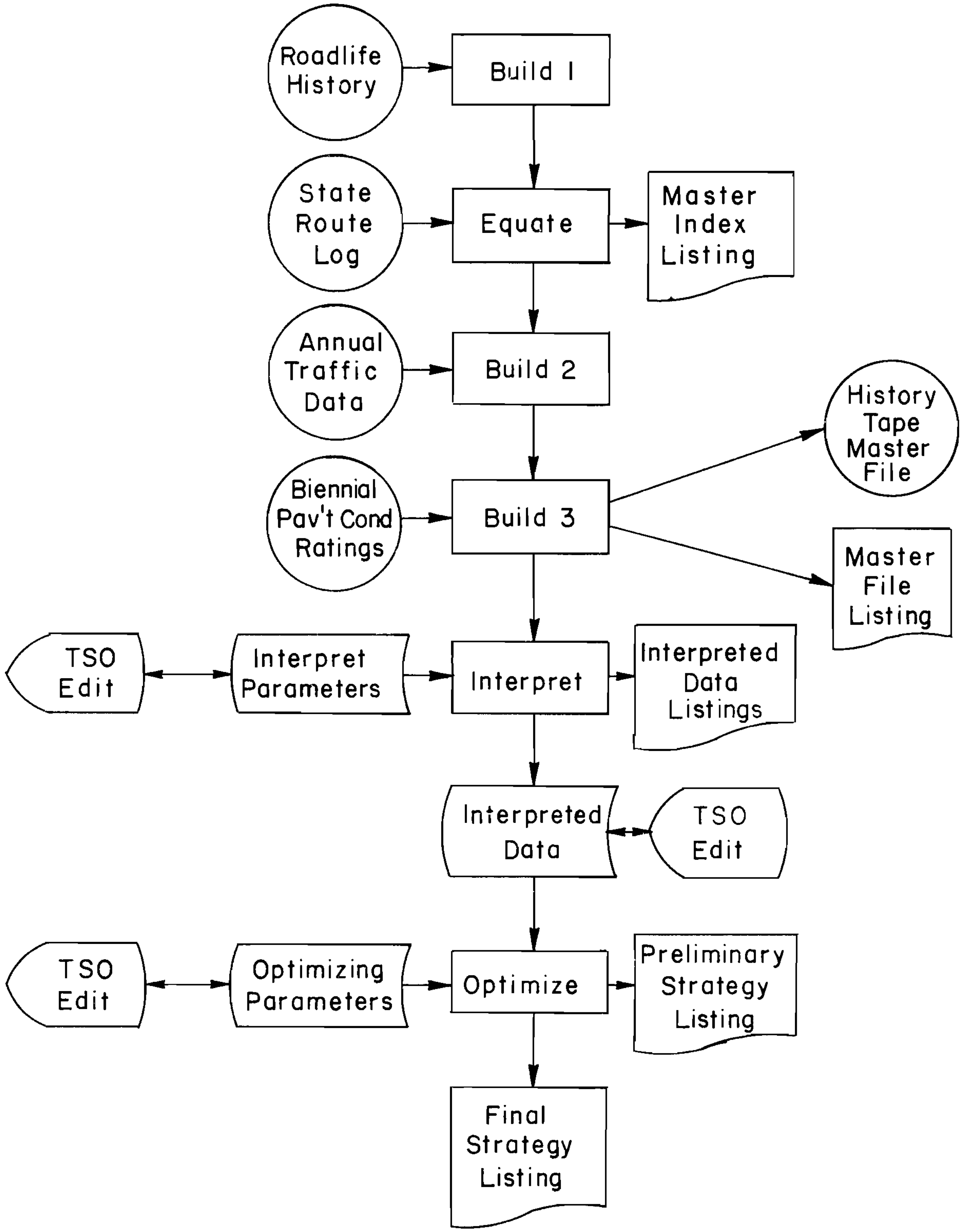

Fig B.5. Flow chart of Washington PMS (Ref 21).

TABLE B.3. TABULAR SUMMARY - WASHINGTON PMS

Program	Input(s)	Function(s)	Output(s)
BUILD1	Roadlife history	- Reads roalife history file - Generates a file of most recent surfacing contracts for each project segment defined by beginning and ending control section mileposts	Master Index Listing
EQUATE	State route log	- Equates control section mileposting to state route mileposting - Inserts data on roadway Configurations	- Product of BUILD1 and EQUATE - Includes data from both BUILD1 and EQUATE programs
BUILD2	Annual Traffic Data	- Inserts most recent traffic data into master index	MASTER FILE
BUILD3	Pavement Condition Ratings	- Matches pavement condition ratings with the corresponding project segments	- Collection of all raw rating data, traffic data and construction history for each project segment
INTERPRET	INTERPRET PARAMETERS - Defect weightings - Transformations for use in regression analysis - Traffic index scale - Master file	- Interprets data into something that can be used to measure and predict pavement performance of project	INTERPRETED DATA LISTING - Performance equations - Statistical data - Performance history - Recommended alternatives

(Continued)

TABLE B.3. Continued

Program	Input(s)	Function(s)	Output(s)
OPTIMIZE	OPTIMIZATION PARAMETERS - Cost model constants - Should and must level - Rehabilitation alternatives - Interest rate - Interpreted data	- Generates a strategy listing for each project	STRATEGY LISTING - 30 best strategies per project - Sequence of rehabilitation actions and time of each - Description of alternatives

The next step involves interpreting the data in the Master File into something that can be used to measure and predict the pavement performance of each project segment. Previously, performance prediction models based on subjectively determined probability transition matrices were used. However, as more performance data became available, the move was made to switch to analysis of historical trends as a basis for predicting pavement performance in the interpreting program known as INTERPRET. This program generates for each project segment recommended rehabilitation alternatives. Finally, the last program (OPTIMIZE) determines the sequence of rehabilitation actions and the particular timing of each, and generates a ranked list of the 30 least costly rehabilitation strategies for each project segment in the state.

SUMMARY AND COMPARISON OF CURRENT PMS PRACTICES

A tabular summary of the developments in PMS practices at the network level is provided in Table B.4. The research work indicates that considerable progress has been made especially in the analysis phase of pavement management at the network level. Although there are differences in PMS methods among different states, the general activity of collecting information and processing it to make it more usable for highway agencies is characteristic of all methods. The differences are mainly in the approaches followed in the formulation of the optimization problem, and in the methods of arriving at a measure of system adequacy. For example, Arizona, Idaho, Texas and Washington combine several pavement attributes into a single number for ranking or evaluation purposes, while California considers each attribute individually. On the other hand, New York utilizes a single index known as

TABLE B.4. SUMMARY OF PMS PRACTICES AT THE NETWORK LEVEL

PMS Feature	Agency: Arizona	California	Florida	Idaho	New York	Texas	Washington
A. Primary Inputs							
1. Pavement Condition Data	Yes	Yes	Yes	Yes	No	Yes	Yes
2. Ride Quality	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3. Traffic	Yes	Yes	Yes	Yes	No	Yes	Yes
4. Cost Variables	Yes	Yes	Yes	No	No	Yes	Yes
5. Environmental Variables	Yes	No	No	No	No	Yes	No
B. Analysis Phase							
1. Identify Needs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Measure of System Adequacy	Combined	Multiple	Combined	Combined	Single	Combined	Combined
3. Pavement Types Considered:							
a. Flexible	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b. Rigid	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4. Performance Prediction	Yes	No	Yes	No	Yes	Yes	Yes
5. Generate Rehabilitation Alternatives	Yes	Yes	No	No	No	Yes	Yes

Continued

TABLE B.4. Continued

PMS Feature	Agency						
	Arizona	California	Florida	Idaho	New York	Texas	Washington
6. Cost Analysis of Each Alternative	Yes	Yes	No	No	No	Yes	Yes
7. Determine Optimum Strategies	Yes	B	No	No	No	Yes	Yes
8. Outputs	A	C	F	I	N	T	W
C. Implementation Phase							
1. Monitor PMS Activities	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Update Data Base	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Legend: See Next Page

TABLE B.4. LEGEND

YES	included to some reasonable degree
NO	not included or not reported in references
B	California's PMS chooses a dominant strategy which would correct all triggered problems
A	the primary output of the Arizona NOS is in terms of the proportion of roads that move from one condition state to another following a rehabilitation action
C	the end product of California's PMS is a series of reports describing pavement condition, appropriate repair strategies and their costs, and candidate projects for various highway programs
F	Florida's PMS provides highway evaluation and priority listings of project segments in the state
I	the primary output of Idaho's PMS is a ranked list of sections in the network with corresponding overall indices which can be used for programming improvements
T	Texas' PMS determines the optimum budget levels for each district and the appropriate rehabilitation strategies which will make the best use of the available budget
N	New York's PMS identifies deficient pavement sections using a modified pavement riding index
W	Washington's PMS determines the appropriate rehabilitation strategies for each project segment in the state network, and provides a ranked list of such based on cost

the pavement riding index to measure how well a pavement has fulfilled its function. In addition, differences exist in the primary outputs of the different pavement management systems. The systems developed in Arizona, Texas and Washington provide the decision maker with optimum rehabilitation strategies, while that for California determines a dominant strategy as discussed previously. As for the states of Idaho and New York, the existing systems identify deficient pavement sections through the use of a combined index, and one measuring pavement functionality, respectively. In addition, the ride data collected in New York is used for identifying past and future performance trends.

Although the systems for Arizona, Texas, and Washington provide optimum rehabilitation strategies, the approaches followed in the determination of such strategies vary. As mentioned previously, the Arizona PMS determines a long-term and short-term rehabilitation policy in terms of estimates of the proportion of roads that move from one condition state to another following a rehabilitation action. When such estimates are combined with the results of the annual condition surveys, the optimum rehabilitation strategies can be determined. The Texas PMS, on the other hand, considers the optimum budget levels for each highway district in the network and determines the rehabilitation and maintenance strategies which will make the best use of the available funds. Finally, Washington's PMS generates appropriate rehabilitation alternatives for each pavement section in the network from an evaluation of pavement condition, traffic and construction history data, and determines the sequence and particular timing of such alternatives to produce optimum rehabilitation strategies.

APPENDIX C

PAVEMENT EVALUATION SYSTEM OUTPUTS

APPENDIX C. PAVEMENT EVALUATION SYSTEM OUTPUTS

Currently, there are two major types of reports available through PES, namely, the district request reports and the annual priority reports (Ref 12). The first category includes six reports which deal with different levels of detail, but which are all intended to serve as tools to help pavement managers with the investigation of problems in the road network. These six reports, together with brief descriptions of each are (Ref 12):

(1) Report R01: Valuation segments - lists all the pavement evaluation segments in a district, their location in terms of beginning and ending mileposts, the pavement type and functional class, and the particular lane evaluated in the segment.

(2) Report R02: Unweighted Evaluation Data - displays the unweighted data collected from a particular lane of an evaluation segment such as the unweighted visual utility and pavement score. In addition, information on the average daily traffic volume, 18-kip equivalent axle loads, average annual rainfall, average number of freeze-thaw cycles and functional classification are provided.

(3) Report R03: Evaluation Segment Scores - provides the district manager with a listing of pavement conditions in terms of the extent of distress types included in the pavement evaluation form in addition to the weighted pavement scores.

(4) Report R04: Omitted Evaluation Data - lists those evaluation segments that do not contain the data necessary to calculate a pavement evaluation score. For each evaluation segment listed, it indicates the number of skid and roughness readings collected and a "yes" or "no" to indicate whether a visual evaluation has been performed.

(5) Report R05: Data Plot - provides plots of the various data collected for a specified section of highway, such as data plots of serviceability indices, skid numbers and surface curvature indices over the length of a particular segment.

(6) Report R06: Pavement Rehabilitation Cost Estimate - provides a priority list of pavement evaluation segments whose pavement scores fall below the minimum allowable score, and the corresponding cost of pavement rehabilitation strategies selected by the system.

In addition to the six district request reports described above, there are annual priority reports available through PES. The programs that produce these reports will merge the detailed readings from all system files and calculate a pavement evaluation score for each pre-defined evaluation segment. Based on the pavement scores, the reports prioritize evaluation areas to help management identify segments in need of rehabilitation and provide defensible documentation for decisions concerning the allocation of funds and establishment of maintenance and rehabilitation projects. The reports in general provide listings of average pavement scores for each highway type and functional classification. They are identified by the following report numbers and titles (Ref 12):

(1) Report A01 - Annual Statewide Average Pavement Scores

(2) Report A02 - Annual District Average Pavement Scores

(3) Report A03 - Annual District Pavement Scores by Section

(4) Report A04 - Annual Pavement Scores by County

(5) Report A05 - Annual Pavement Scores by District, County, and Highway.

APPENDIX D

UTILITY CURVE CONSTRUCTION

APPENDIX D. UTILITY CURVE CONSTRUCTION

The present utility curves were constructed using the deduct values established in Project 151, and presented in Table D-1 (Ref 28). To illustrate how the curves were drawn, the utility curve for ravelling is discussed herein. From Table D-1, the deduct points for this distress type are as shown below:

Degree of Distress	Extent or Amount of Distress		
	1 (2 - 30%)	2 (32 - 60%)	3 (>60%)
Slight	5	8	10
Moderate	10	12	15
Severe	15	18	20

It has been agreed upon within the department that a pavement rating score of 50 indicates that rehabilitation work is required. Because the maximum number of points which can be deducted as a result of any one visual defect is 25 (from Table D-1), the deduct points are doubled in order to construct the utility curve for each distress type (Ref 29). Consequently, for ravelling, if the degree of distress is moderate and if the extent lies within 32% - 60% of the wheelpath area, then the number of points to be deducted is twice the value given above or 24. Curves of these deduct points

TABLE D-1. DEDUCT VALUES USED FOR RATING FLEXIBLE PAVEMENTS (REF 28)

Types of Distress	Degrees of Distress	Extent or Amount of Distress (1)	(2)	(3)
Rutting	Slight	0	2	5
	Moderate	5	7	10
	Severe	10	12	15
Raveling	Slight	5	8	10
	Moderate	10	12	15
	Severe	15	18	20
Flushing	Slight	5	8	10
	Moderate	10	12	15
	Severe	15	18	20
Corrugations	Slight	5	8	10
	Moderate	10	12	15
	Severe	15	18	20
Alligator Cracking	Slight	5	10	15
	Moderate	10	15	20
	Severe	15	20	25
Patching	Good	0	2	5
	Fair	5	7	10
	Poor	7	15	20

Deduct Points for Cracking

Longitudinal Cracking

	Sealed (1)	Sealed (2)	Sealed (3)	Partially Sealed (1)	Partially Sealed (2)	Partially Sealed (3)	Not Sealed (1)	Not Sealed (2)	Not Sealed (3)
Slight	2	5	8	3	7	12	5	10	15
Moderate	5	8	10	7	12	15	10	15	20
Severe	8	10	15	12	15	20	15	20	25

Transverse Cracking

	Sealed (1)	Sealed (2)	Sealed (3)	Partially Sealed (1)	Partially Sealed (2)	Partially Sealed (3)	Not Sealed (1)	Not Sealed (2)	Not Sealed (3)
Slight	2	5	8	3	7	10	3	7	12
Moderate	5	8	10	7	10	15	7	12	15
Severe	8	10	15	10	15	20	12	15	20

Failures						20	30		40
Maysmeter	Deduct Points	50	40	30	20	10	5	0	
	SI	2.4	2.7	2.9	3.1	3.3	3.5	4.7	

can be then constructed as shown in Fig D-1. The data points used for plotting these curves are shown below:

Degree of Distress	Extent (%)	Representative Value for Extent of Distress (%)	Deduct Points	Rating Score
	2 - 30	16	10	90
Slight	32 - 60	46	16	84
	> 60	80	20	80
	2 - 30	16	20	80
Moderate	32 - 60	46	24	76
	> 60	80	30	70
	2 - 30	16	30	70
Severe	32 - 60	46	36	64
	> 60	80	40	60

A composite utility curve is then constructed which correlates with the "severe degree" curve as follows (Ref 29):

Extent of Distress (%)	Representative Value for Extent of Distress (%)	PES Score
2 - 30	16	97/100 = 0.97
32 - 60	46	69/100 = 0.69
> 60	80	60/100 = 0.60

In a similar manner, utility curves for the other visual distresses have been constructed.

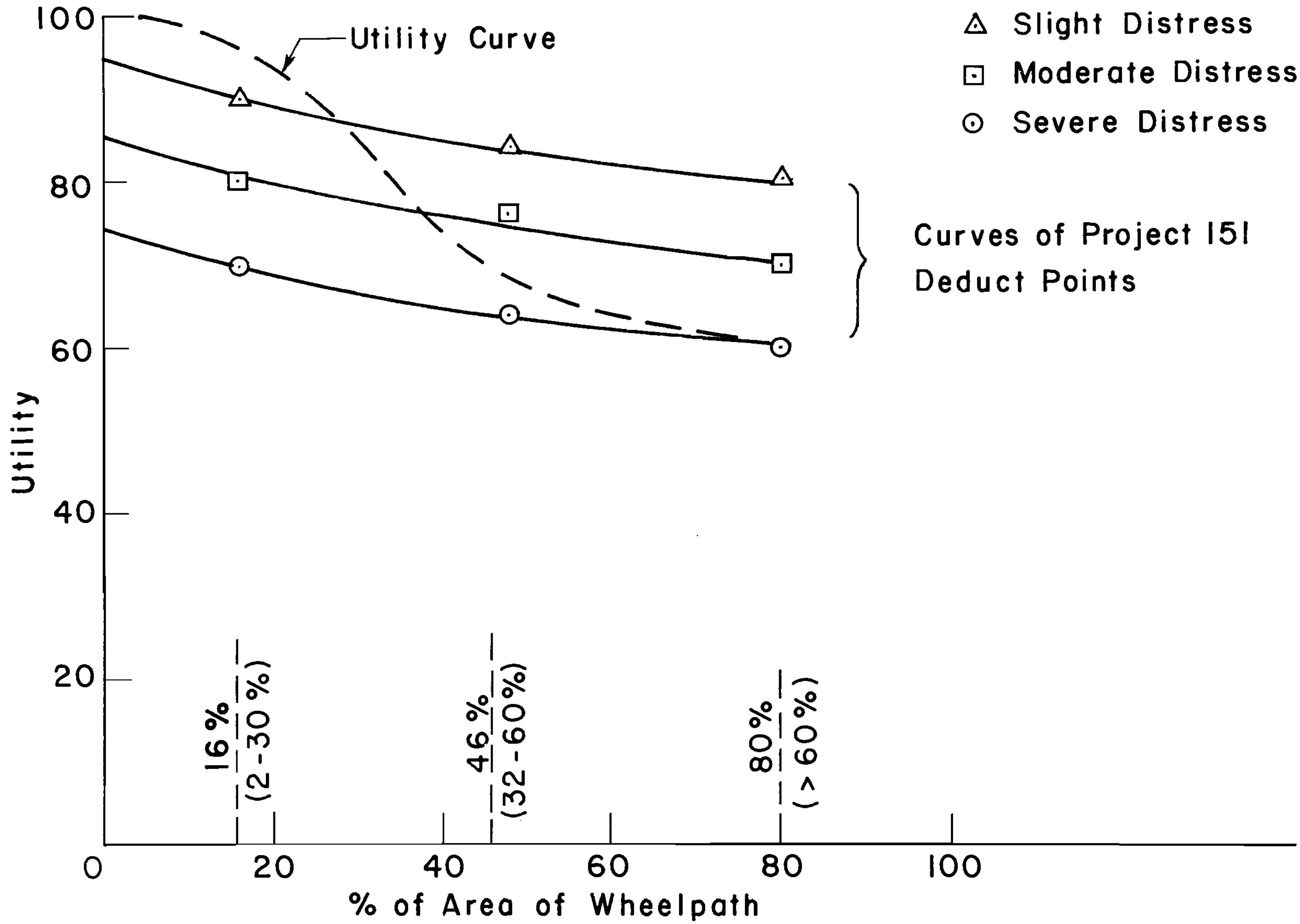

Fig D-1. Utility curve for ravelling.

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