NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT **223**

# MAINTENANCE LEVELS-OF-SERVICE GUIDELINES



TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT **223**

# MAINTENANCE LEVELS-OF-SERVICE GUIDELINES

R. KULKARNI, F. FINN, K. GOLABI,
R. JOHNSON, AND E. ALVITI
Woodward-Clyde Consultants
San Francisco, California

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:
MAINTENANCE
(HIGHWAY TRANSPORTATION)

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. JUNE 1980

## NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

**NCHRP Report 223**

Project 14-5 FY '78
ISSN 0077-5614
ISBN 0-309-03028-5

L. C. Catalog Card No. 80-52034

**Price: $8.80**

### Notice

The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the National Academy of Sciences, or the program sponsors.

Each report is reviewed and processed according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved by the President of the Academy upon satisfactory completion of the review process.

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering, serving government and other organizations. The Transportation Research Board evolved from the 54-year-old Highway Research Board. The TRB incorporates all former HRB activities but also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

### Special Notice

The Transportation Research Board, the National Academy of Sciences, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

Published reports of the

**NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM**

are available from:

Transportation Research Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America.

# FOREWORD

*By Staff*
*Transportation*
*Research Board*

Highway maintenance managers, at state and district levels, will find this report helpful in the difficult task of establishing levels of service for different elements of a highway that are consistent with regard to multiple and often conflicting considerations such as safety, riding comfort, economics, environmental impact, protection of investment, and aesthetics. Systems analysts will find the report helpful in explaining the application of decision analysis principles to maintenance planning. The report provides a procedure that allows for different levels of service to be established for various maintenance conditions, road classifications, and local values. Local values are reflected in the levels of service through systematic assessment of tradeoffs between different considerations.

---

A given road or system of roads provides varying levels of service to the road user. Maintenance levels of service influence the magnitude of the maintenance work (e.g., pavement patching, mowing, paint striping) and, therefore, the work scheduling requirements, work priorities, and resource allocations. Selection of the maintenance level of service is influenced by a number of considerations that include safety, rideability, economics, environmental impact, protection of investment, and aesthetics. To optimize the expenditure of maintenance resources, there has been a need to develop a systematic and objective method to establish maintenance levels of service guidelines for all maintenance elements of the highway (such as pavement surface, shoulder, vegetation, signs, structure, drainage ditches). Such a method has been successfully developed and demonstrated in two states for pavement edge drop-off and vegetation control. This report describes the method and the procedures to follow in applying the method. Users of the method will find it useful in the following ways:

1. The method assists in determining a set of levels of service that maximizes highway user benefits subject to the constraints of available resources (dollars, personnel, etc.). This will assure the most efficient allocation of limited resources.
2. The method allows levels of service to be systematically adjusted for changes in available resources. The method also allows differing levels of service to be established for various road classifications.
3. The policy decisions to implement various levels of service will be defensible because the rationale can be well documented.
4. The method provides a machanism for combining effects of alternative levels of service on multiple considerations (e.g., safety, user comfort, protection of investment, and aesthetics) in a logical and theoretically sound manner. The procedures will allow the agency to establish acceptable tradeoffs between different considerations based on collective inputs from a group of people that may include maintenance engineers, field supervisors, legislators, and highway users.
5. The method allows the decision-maker to establish explicit levels of service that clearly communicate to field personnel when maintenance of different highway

elements should be scheduled. The explicit levels of service will also permit an objective evaluation of whether the intended levels of service are, in fact, being achieved in the field.

Application of the method requires six steps described in Chapter Two of the report. The appendixes provide documentation of the method, comprehensive evaluations of existing practice, and guidelines for citizen participation in establishing maintenance levels of service. All appendixes except Appendix A, a user's manual for the computer program, are contained in the report. A computer program package including Appendix A is available on a loan basis, or may be purchased for $6.00, plus $1.00 for postage and handling, by writing to the Program Director, NCHRP, and supplying an EBCDIC 9-track tape, or equivalent, with a density of 1600 BPI.

# CONTENTS

**ACKNOWLEDGMENTS**

The research reported herein was conducted under NCHRP Project 14-5 by Woodward-Clyde Consultants (WCC). Dr. Ram B. Kulkarni was the principal investigator. Overall administration and technical supervision of the project for WCC was provided by Dr. Keshavan Nair.

Representatives of each state who assisted in arranging meetings with their staff members, and who provided inputs to the documentation of existing practice, were Mr. Ray Wilson, California; Mr. William Wright, Kansas; Mr. Gerald Ray, Louisiana; Mr. Ronald Zook, Ohio; and Mr. Louis O'Brien, Pennsylvania. Special acknowledgment is extended to Mr. Gerald Ray of Louisiana and Mr. Louis O'Brien of Pennsylvania for their assistance in the demonstration of the method. Mr. Travis Smith, former State Maintenance Engineer for CALTRANS, provided evaluations and comments necessary to orient the method for implementation by state agencies. Mr. Gordon Baca, a senior attorney at CALTRANS, provided discussions regarding the legal implications of maintenance levels of service.

# Maintenance Levels-of-Service Guidelines


## SUMMARY

Highway maintenance managers face the difficult task of establishing levels of service for different parts of highways that are consistent with regard to multiple and often conflicting considerations such as safety, riding comfort, economics, environmental impact, protection of investment, and aesthetics. A method was developed to assist in formulating policy decisions on optimum levels of service for those highway elements that are subject to the constraints of available resources (e.g., dollars and personnel). This summary was prepared specifically for maintenance managers to describe concisely the significance of the project's results to their decision-making responsibilities.

*Why Do We Need a New Method to Establish Levels of Service*

Currently, those decisions made by maintenance personnel (e.g., field supervisors) about levels of service are generally informal, intuitive, and based on subjective information gained through experience. Tradeoffs between different considerations (e.g., safety versus user convenience, protection of investment versus riding comfort) are considered but not in any systematic manner. Consequently, the existing practice may produce inconsistent levels of service that result in an inefficient use of limited available resources.

A formal and systematic method is necessary to establish levels of service that are optimum and consistent for given amounts of resources. Such a method was developed in this project.

*What Makes This Method Formal and Systematic*

The method is formal because it is based on theoretically sound principles of decision analysis, and it provides a mechanism for analyzing information in a logical and consistent manner. The method is systematic because it consists of a well-defined, step-by-step procedure. The method uses both objective data and the subjective judgments of knowledgeable individuals. Subjective judgments are formally assessed by consensus opinions of a large group of individuals; this group might include maintenance engineers, field supervisors, legislators, and highway users. Because balancing viewpoints are incorporated, this process helps to reduce bias in subjective judgments.

*What Benefits Will the Agency Derive From Using the Method to Establish Levels of Service*

The major benefits include the following:

1. The method assists in determining a set of levels of service that maximizes highway user benefits subject to the constraints of available resources (dollars, personnel, etc.). This will assure the most efficient allocation of limited resources.

2. The method allows levels of service to be systematically adjusted for changes in available resources. The method also allows differing levels of service to be established for various road classifications.

3. The policy decisions to implement various levels of service will be defensible because the rationale can be well documented.

4. The method provides a mechanism for combining effects of alternative levels of service on multiple considerations (e.g., safety, user comfort, protection of investment, and aesthetics) in a logical and theoretically sound manner. The procedure will allow the agency to establish acceptable tradeoffs between different considerations based on collective inputs from a group of people that may include maintenance engineers, field supervisors, legislators, and highway users.

5. The method allows the decision-maker to establish explicit levels of service that clearly communicate to field personnel when maintenance of different highway elements should be scheduled. The explicit levels of service will also permit an objective evaluation of whether the intended levels of service are, in fact, being achieved in the field.

*Was the Method Tested*

The method was tested in two States, Louisiana and Pennsylvania, for two maintenance problems—edge of traveled-way drop-off and control of roadside vegetation growth. The results of these tests showed that (1) it was practical to implement the method in a reasonable amount of time and effort, (2) an adequate data base for the method could be developed with the resources currently available to state highway agencies, and (3) with proper inputs, levels of service consistent with the experience of maintenance personnel could be produced.

*What Are the Staffing and Other Requirements Necessary to Implement the Method*

The method was coded as a computer program for which a user manual was prepared that provided detailed instructions on use of the program. Thus, to implement the method, user agencies need only generate the input data necessary for running the computer program; no additional theoretical or analytical development is necessary.

A one-time effort to generate the necessary input data will require that an investigator from the user agency become familiar with certain technical aspects of the method. This should be possible by reading the appendixes to this report, which describe the necessary theoretical background and provide illustrative examples. The investigator will have to organize meetings with (1) department specialists to estimate the effects of alternative levels of service on considerations such as safety, user comfort, protection of investment, environmental impact, and aesthetics; and (2) a group of individuals representing different viewpoints to assess value tradeoffs between different considerations.

It is estimated that this one-time effort to generate input data will require 1.5 to 2 person-years. Updating of certain portions of the input data may become necessary if new field data become available, or department policies or user expectations change significantly. It is expected that such updating will not be required frequently (e.g., only once in 5 or so years).

Once the input data are generated, the subsequent staffing requirements will be substantially less. The computer program will need to be run only once a year when the annual maintenance budget is appropriated. This can be managed routinely by a person responsible for the maintenance management system. The computer facilities available to highway agencies will be adequate to run the computer program developed for this study.

To reduce the initial implementation effort the method can be implemented in stages. In this staged-approach, the complete system can be divided into three or four groups of maintenance conditions (according to some criteria of priorities), and the method can then be implemented successively for each group.

*What Are the Potential Problem Areas for the Method*

The method will require specification of explicit levels of service. This may be of concern to state agencies because of legal implications—namely, effect on tort lawsuits involving roadway conditions and maintenance responsibility. However, a review of relevant literature and discussions with a senior attorney in a state transportation department suggest that neither the frequency of tort suits nor their outcomes would be significantly influenced by whether the levels of service were explicitly stated. The procedures developed in this study provide a systematic and structured method for establishing levels of service which would be a favorable consideration in tort suits. Another potential problem is that implementation of the method would be difficult without having access to a maintenance management system.

CHAPTER ONE

# INTRODUCTION AND RESEARCH APPROACH

State highway agencies are responsible for maintaining highways so that users are provided with a safe and comfortable product and the investment in the facility is protected. To assist field supervisors in maintaining desired conditions, guidelines that describe recommended levels of service for various highway elements (such as pavement, shoulder, vegetation, drainage structure) are prepared by maintenance engineers. Selection of levels of service is influenced by a number of considerations that include safety, riding comfort, economics, environmental impact, protection of investment, and aesthetics.

Constraints on available resources (money, personnel, equipment, and materials) may preclude maintenance of every highway element in its most desired condition. Consequently, it may be necessary to make tradeoffs between different maintenance elements. For example, if both activities cannot be accomplished with the available funds, should money be spent on either improving a deficiency of the traveled-way or reshaping obstructed drainage ditches? Which elements should be maintained at a desired level of service and which should be allowed to regress to lower than desired levels? In most cases, these decisions are made informally by maintenance personnel (e.g., field supervisors). However, because the issues involved are complex, inconsistent decisions may be made that result in less than optimum levels of service.

A systematic and formal method should be developed that can be used when making policy decisions of optimum levels of service for highway maintenance elements for given amounts of resources. The method should consider each component of quality and weigh those components to reflect different user evaluations. It should also allow different levels of service to be established for various maintenance elements, road classifications, and local values.

## RESEARCH OBJECTIVES

The objectives of this project were:

1. To document existing practices used to establish levels of service.
2. To formulate a method to establish levels of service that consider user values and tradeoffs among safety, riding comfort, economics, environmental impact, protection of investment, and aesthetics.
3. To develop the method in the form of a manual containing guidelines for transportation maintenance organizations when establishing levels of service.
4. To demonstrate and document how the method would be used to develop the levels of service for two diverse maintenance problems—traveled-way drop-off and control of roadside vegetation growth.

## SCOPE OF STUDY

The study was primarily concerned with developing and testing a method to establish optimum levels of service. Levels of service that were developed during testing of the method were only for demonstration purposes and are not recommended levels of service.

## RESEARCH APPROACH

The research approach to accomplish the four specific objectives of this project was as follows.

### Documentation of Existing Practice

Meetings with maintenance engineers of five States active in the development of maintenance management systems were arranged to obtain a representative sample of procedures used by highway maintenance organizations to establish levels of service. The five States were: California, Kansas, Louisiana, Ohio, and Pennsylvania. The information obtained from these meetings was supplemented by a literature review.

### Development of a Method

Decision analysis techniques were used to develop a rational and consistent basis for choosing among alternatives, and a nonlinear integer program was developed to determine an optimum set of levels of service. Decision analysis approach has proven effective with problems involving multiple considerations and uncertain consequences. (The works of Raiffa (*1*), Schlaifer (*2*), Keeney and Raiffa (*3*), and Fishburn (*4*) discuss the theoretical basis of the decision analysis approach and its applications to practical problems.) Complex problems in many diverse disciplines have been analyzed using this approach. The problems include nuclear power plant siting in Keeney and Nair (*5*), environmental impact assessment in Nair et al. (*6*), seeding of hurricanes in Howard et al. (*7*), and development of a pavement management system in Kulkarni et al. (*8*)). The nonlinear zero-one algorithm was developed by Woodward Clyde Consultants (WCC) and is an effective tool for maximizing nonlinear functions when one of several alternative levels of service is to be chosen.

The method was developed as a stepwise procedure that could be implemented within the data base of information currently available to state highway agencies.

### Preparation of a User Manual

The method was coded in a computer program for which a user manual was prepared that describes the stepwise procedure necessary to determine optimum levels of service. The user manual also contains sufficient details of the computer program to enable computer personnel within state agencies to run the program.

### Demonstration of the Method

In demonstrating the method, the stepwise procedure described in the user manual was followed.

## GUIDE TO DOCUMENTATION

The report consists of a summary, the main body, and 7 appendixes. The summary concisely describes the significance of the method to highway maintenance organizations in making policy decisions on levels of service. The main body of the report contains a narrative of the development, testing, and appraisal of the method, and a discussion of the feasibility of implementing the method. All technical details are included in Appendixes A through G, as submitted by the research agency.

### Appendix A—User Manual for Computer Program ASOP

The user manual contains detailed instructions for using the computer program ASOP (acronym for *A*lgorithm for *S*election of *O*ptimum *P*olicy). The program is designed to facilitate implementation of the method to determine optimum maintenance levels of service. The user manual is organized in six sections: (1) description of the method, (2) organization of the input data, (3) description and interpretation of the program output, (4) applications of the program, (5) assessment of the program capabilities and limitations, and (6) program documentation.

### Appendix B—Documentation of Existing Practice for Establishing Levels of Service

This appendix documents the existing practice of establishing maintenance levels of service. The criteria used, and the common procedures followed, in establishing levels of service are described.

### Appendix C—Demonstration of the Method in Louisiana and Pennsylvania

The details of demonstrating the method developed in this project in Louisiana and Pennsylvania are described. Assessment of input data and interpretation of results in each state are discussed.

### Appendix D—Description of Delphi Technique

This appendix briefly describes the origin and characteristics of a conventional Delphi procedure. The application of this procedure to assess consensus value judgments of decision-makers that can be used in establishing optimum maintenance levels of service is discussed in detail. A stepwise procedure for conducting a Delphi experiment is provided.

### Appendix E—Review of Information Regarding the Effects of Edge of Traveled-Way Drop-Off on Various Considerations

Information available in the literature is reviewed relevant to estimating the effect of different amounts of drop-off at edge of traveled-way on protection of investment and safety. Limitations of the available information are also discussed.

### Appendix F—Literature Review of Roadside Vegetation Maintentance

This appendix contains a detailed review of the recent publications including journal articles, technical reports,

and maintenance manuals relative to current practices and considerations in roadside vegetation maintenance.

**Appendix G—Guidelines for Citizen Participation in Establishing Maintenance Levels of Service**

The intent of this appendix is to familiarize briefly the reader with some of the issues involved in encouraging citizen participation and the pitfalls that are often overlooked, and suggest some practical ideas on how citizen participation can be applied successfully in establishing maintenance levels of service.

### TERMINOLOGY

To facilitate the reading of this report, the following terms are defined:

MAINTENANCE ELEMENT—A part of the highway system that requires maintenance (e.g., traveled-way, roadside, drainage, traffic services).

MAINTENANCE CONDITION—A deficient condition of a maintenance element that needs to be repaired or corrected (e.g., cracking and rutting—for traveled-way; grass growth and litter and debris—for roadside).

MAINTENANCE ACTIVITY—The work required to repair or correct a maintenance condition (e.g., filling—for cracking; mowing—for grass growth).

LEVEL OF SERVICE (*quality standard*)—The threshold deficiency level of a maintenance condition that should trigger an appropriate maintenance activity (e.g., grass should be mowed when it is 12 in. high; a drainage ditch should be cleaned when 50 percent of its area is blocked).

CONSIDERATIONS—The factors used in evaluating the performance of maintenance elements (e.g., safety, riding comfort, economics, aesthetics).

ATTRIBUTE—A numerical scale for measuring the effect on a given consideration (e.g., frequency of accidents—for safety; roughness—for riding comfort).

CHAPTER TWO

# FINDINGS

The findings of this study are organized in the categories that reflect the accomplishment of the four research objectives.

### DOCUMENTATION OF EXISTING PRACTICE

A detailed review of current practices used for establishing maintenance levels of service is contained in Appendix B. The purpose of this section is to provide a brief summary of these practices as a basis for comparison with the methods developed in this investigation.

Every agency responsible for the maintenance of a roadway has established its own levels of service. These levels may be extremely subjective and somewhat variable depending primarily on the day-to-day decisions of the maintenance superintendent and the resources available at that time. For those agencies that have adopted maintenance management systems, a more organized set of maintenance levels of service will be established.

Information provided in the *NCHRP Report 131* (*9*) is pertinent to this investigation. This summary includes quotations from the referenced report that are considered applicable, as follows:

> In those highway agencies investigated, there was little evidence of objective evaluation and consideration of criteria in the determination of a desired level of maintenance (p. 9).
>
> Statements (in operating manuals) were encountered with regard to safety, comfort, convenience, economy, aesthetics, and serviceability—but usually these were in generalized terms that were of little use in determining the appropriate level of maintenance of a specific roadway condition (p. 9).
>
> When levels-of-service were defined adequately, considerable variation was found in the expression and interpretation of levels-of-service for the same deficiency condition (pp. 9, 10).
>
> There is almost a complete absence of objective evaluation and systematization in the area of criteria for maintenance levels. None of the highway agencies investigated had proceeded much beyond implicit consideration of criteria in the determination of maintenance levels. Indeed, little information exists anywhere on which objective decisions may be based (p. 37).

On the basis of the literature review conducted for this study and visits to five state DOT's, it can be concluded that: (1) since 1972, the major emphasis of highway engineers has been to systematize procedures for budget preparation, and (2) very little useful objective data have been developed for specific application to establishing levels of service.

Interviews with the participants from various state DOT's as well as a literature review indicated that a combination of factors is considered in establishing levels of service. These factors are:

1. Safety.
2. Preservation of public investment in the highway system.
3. Comfort and convenience of user.
4. Aesthetics.
5. Legal implications.
6. Traffic volume and route classification.
7. Political and social considerations.

Further discussion of these items is contained in Appendix B.

The current method used to establish levels of service is predominantly based on subjective experience that is converted into consensus of opinion through informal discussions and interviews or structured panel-type meetings.

There is very little indication from the literature or direct contacts with the five state agencies included in this investigation that procedures to accommodate tradeoffs between different considerations have been included in establishing levels of service. There is an implicit recognition that such tradeoffs are necessary, but there is no apparent structured procedure for evaluation.

As in the case of tradeoffs, monitoring of maintenance levels of service and feedback of such information are implied in most maintenance management systems but are not formally included in current methods. The Ohio DOT has developed monitoring procedures to evaluate the quality of maintenance levels of service (*10, 11*), and other states have indicated interest in such procedures.

Major deficiencies of present methods are as follows:

1. There is no standard procedure for systematically establishing maintenance levels of service.
2. Current procedures do not provide for systematic tradeoffs between levels of service for various roadway conditions (e.g., shoulder drop-off and vegetation control).
3. Current procedures do not provide a systematic method for adjusting levels of service as a function of available resources (money, personnel, and equipment).

## DESCRIPTION OF METHOD

### Simplified Overview of the Method (See Fig. 1)

In this method combinations of alternative levels of service for different maintenance conditions are examined, and those combinations that satisfy constraints of available resources are identified. For each combination that satisfies such constraints, the effects on relevant considerations are quantified and the individual value of each effect is assessed on a scale of 0 (worst effect) to 1 (best effect). Next, the relative weights of various effects are determined based on assessed tradeoffs between pairs of different effects. An overall weighted value of each combination is calculated ranging from 0 (all worst effects) to 1 (all best effects). The final stage of the analysis identifies the combination of alternative levels of service with maximum overall value. This is the optimum combination of levels of service in the sense that it maximizes overall value subject to the constraints of available resources.

### Detailed Steps of the Method

The method to determine optimum maintenance levels of service involves the following successive steps.

1. Structure the problem of selecting optimum levels of service.
2. Estimate the effects of alternative levels of service on various considerations (e.g., safety, aesthetics).
3. Assess the individual value functions of different attributes and their tradeoffs.
4. Determine the optimum combination of levels of service.
5. Conduct sensitivity analyses.
6. Formulate recommendations.

*Step 1—Structure the Problem of Selecting Optimum Levels of Service*

Structuring the problem of selecting optimum levels of service for various maintenance conditions included in the system involves the following tasks.

1. Select maintenance elements (e.g., shoulders).
2. Select maintenance conditions (e.g., edge of traveled-way drop-off) for each maintenance element (e.g., shoulders).
3. Specify alternative levels of service for each maintenance condition (e.g., repair when edge of traveled-way drop-off is 1 in., 2 in., or 3 in.).
4. Select considerations (e.g., safety) relevant to evaluating performance of each maintenance element (e.g., shoulders).
5. Select attributes (e.g., frequency of accidents) that can be used to quantify effects on various considerations e.g., safety).
6. Identify the maintenance conditions (e.g., edge of traveled-way drop-off) that affect each attribute (e.g., frequency of accidents).

A brief description of each task follows.

*Select Maintenance Elements.* The agency prepares a list of maintenance elements (e.g., shoulders, roadside) by identifying all the major parts of the highway system within the full right-of-way that an agency is responsible for maintaining.

*Select Maintenance Conditions for Each Maintenance Element.* Since factors such as climatic conditions, maintenance practices, and the existing condition of a highway network are different for different states, a single list of maintenance conditions for various maintenance elements may not be applicable to all states. The method requires that state agencies prepare a list of maintenance conditions that are appropriate for its environment and highway network.

*Specify Alternative Levels of Service for Each Maintenance Condition.* A general procedure that can be used to generate alternative levels of service is as follows.

The department specialists for a given maintenance condition are first asked to assume that there are no resource constraints (dollars, personnel, etc.) for the particular maintenance condition under consideration. How would the specialists improve the levels of service for that condition? The response to this question would generally produce a level of service somewhat higher than the current level of service used by the agency. Next, the specialists are asked to consider the implications of moderate and severe budget cuts, successively, for the maintenance condition. To accommodate the budget cuts, a reduced level of service would have to be adopted. How would the agency reduce the level of service in each case? Responses to this question would generate two levels of service generally lower than the current level of service. If they are mean-

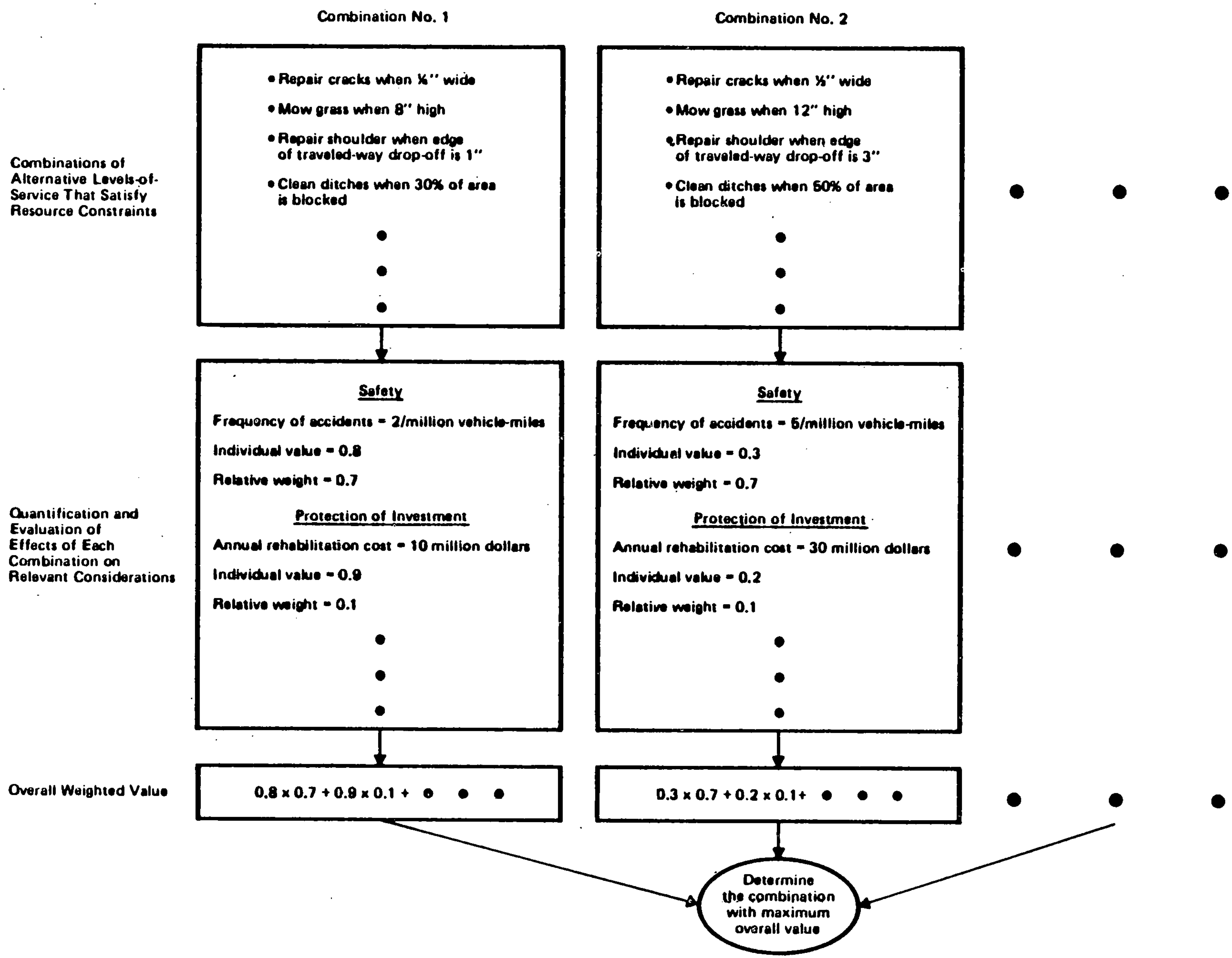



*Figure 1. Simplified overview of method.*

ingful in practice, additional intermediate levels of service may also be considered.

At the conclusion of this step, a spectrum of alternative levels of service ranging from the highest (ideal) to the lowest (barely tolerable) would be generated. Some guidelines pertinent to the selection of alternative levels of service include:

1. The specification of each level of service should be explicit (i.e., it should clearly communicate to field personnel when they are expected to work on a given maintenance condition).

2. The specification of a level of service should not involve complicated measurements on the part of the field supervisors because they would be difficult to make in the field and most likely would be ignored. Ideally, the specification of levels of service should involve visual inspections and/or some simple measurements that can be made quickly while driving.

3. The resource requirements (dollars, personnel) of the levels of service should be significantly different from each other so that discernable options are represented. If two levels of service differ only slightly with respect to their maintenance costs, it may be best to combine them to represent a single level of service.

4. Each of the selected alternative levels of service must be viable; that is, if the analysis selects the lowest level of service for a particular maintenance condition, the agency should be willing to adopt that level of service.

A checklist of maintenance elements, maintenance conditions, and possible parameters for specifying alternative levels of service is given in Appendix A (Table A-1). Information obtained from both a literature review and meetings with maintenance engineers of the states visited were used to prepare the checklist.

*Select Considerations for Each Maintenance Element.* A checklist of considerations and attributes for various maintenance elements is given in Appendix A (Table A-2).

*Select Attributes for Various Considerations.* Two types of attributes are appropriate to consider.

1. *Natural attribute.* This is an attribute whose levels are physically measurable. For example, "dollar cost" is an objective attribute of the consideration "economics." For the safety consideration of traveled-way drop-off, an appropriate objective attribute may be "percentage of drivers who cannot recover normally if their vehicles accidentally go over the edge of traveled-way."

2. *Constructed attribute.* This is an attribute for which a physical measurement is impractical or inappropriate. A subjective scale or index must be constructed to define various degrees of impact for this attribute. For example, "aesthetics" cannot be measured objectively; a subjective scale of 1 to 5 could be defined that described the degree of pleasing appearance. Each number on the subjective scale should be described in sufficient detail so that the associated level of impact is communicated unambiguously. When appropriate and practical, pictures should be provided to give visual images of the conditions defined by each number on the subjective scale.

*Identify the Maintenance Conditions That Affect Each Attribute.* An attribute (e.g., index of pleasing appearance) may be affected by a number of maintenance conditions (e.g., grass growth, weed growth, litter, and debris). In this task, the maintenance conditions affecting each attribute are identified.

### *Step 2—Estimate the Effects of Alternative Levels of Service on Various Considerations*

The effect of alternative levels of service on a given consideration (e.g., safety) is estimated in terms of the attribute of that consideration (e.g., frequency of accidents). Ideally, the procedure for estimating the effects should be based on objective data (e.g., field measurements). However, a review of available literature and discussions with maintenance engineers of five state agencies indicated that available data would not be adequate to estimate directly the effects of alternative maintenance levels of service. Consequently, the procedure used in this study involved structured interviews with specialists in which available objective data were presented to them and the effects of alternative maintenance levels of service on various attributes were estimated based on both available data and subjective opinions. The implementation of this procedure is described in Appendix C.

### *Step 3—Assess Individual Value Functions of Different Attributes and Their Tradeoffs*

In this step, the relative desirability (value) of a set of effects on various considerations (e.g., safety, aesthetics) is assessed. The effects on the considerations are measured in terms of the selected attributes.

The assessment of a value function over multiple attributes can be completed in two steps: (1) assess individual value functions of different attributes, and (2) assess value tradeoffs between different attributes to determine their relative weights.

*Assess Individual Value Functions of Different Attributes.* An individual value function determines the relative values of different levels of an attribute; that is, how much better or worse one level of an attribute (e.g., percentage of drivers who cannot recover = 5) is relative to another (e.g., percentage of drivers who cannot recover = 10).

The assessment of individual value functions can be done by interviewing the specialists in a user agency who are most knowledgeable about a given attribute. Two assessment techniques can be used: (1) assess midvalue points, and (2) assess "willingness to pay." Descriptions and examples of these techniques are given in Appendix C.

*Assess Value Tradeoffs Between Different Attributes to Determine the Relative Weights.* The assessment of value tradeoffs between different attributes is made using a Delphi procedure. This procedure involves a group session in which individuals representing different viewpoints participate (e.g., maintenance engineers, field supervisors, legislators, and highway users). An attempt is made to obtain group consensus on tradeoffs between pairs of competing attributes. However, there is no need to force a group con-

sensus, because decision analysis allows one to assess the significance of differences in value judgments when selecting policies. Participation of individuals with balancing viewpoints generally helps reduce the bias and arbitrariness of subjective judgments. The background and implementation of the Delphi procedure, as well as a discussion of how to analyze situations in which a clear group concensus is not identified, are described in Appendix D.

### *Step 4—Determine the Optimum Combination of Levels of Service*

The objective of this step is to find the optimum combination of levels of service for all the maintenance conditions in the system. The criterion used for optimization is to maximize the overall value of highway user benefits subject to the constraints of available resources (dollars, person-days, etc.). User benefits are expressed in terms of the effects of levels of service on various considerations (e.g., safety, aesthetics, and protection of investment).

To formulate the resource constraints, the resources required for implementation of each level of service need to be estimated. If available to the user agency, a maintenance management system can be of significant help in estimating resource requirements. Some of the alternative levels of service may not have been previously used. Because hard data necessary to estimate the resource requirements for such levels of service will not be available, judgmental estimates will be necessary. With time, more information should become available to provide more reliable estimates of resource requirements.

### *Step 5—Conduct Sensitivity Analyses*

The objective of this step is to assess the impact of changes in major inputs and assumptions on selection of the optimum levels of service. The output of this analysis would identify the parameters to which the selection of optimum levels of service is very sensitive. These parameters should be carefully assessed.

### *Step 6—Formulate Recommendations*

Recommendations are formulated after the results of the base case and the sensitivity analyses are evaluated. The recommendations should include the following:

1. The optimum level of service for each maintenance condition in the system.
2. Resources that would be required to implement the optimum levels of service.
3. Situations (e.g., budget cuts) that would require significant changes in the optimum levels of service.

## USER MANUAL FOR THE COMPUTER PROGRAM

The method developed for this study was coded in the computer program ASOP (acronym for *A*lgorithm for the *S*election of *O*ptimum *P*olicy). A user manual with detailed instructions about the proper use of the computer program is provided in Appendix A. This program has been tested and debugged.

The computer program ASOP facilitates the use of the method significantly. The program was designed such that the assessed data could be directly input and all parameters (such as value coefficients, relative weights, and regression coefficients) are computed internally. Thus, the user does not need to make external calculations that require experience with decision analysis techniques.

The program was designed to perform various types of sensitivity analyses when requested by the user. This feature of the program simplifies the task of finding the sensitivity of results to factors such as changes in available resources and value tradeoffs.

The program can be run on different computer systems provided that the systems can compile ANSI (American National Standard Institute) FORTRAN language. The storage requirements and computation times for running typical problems are reasonable (see App. A).

## DEMONSTRATION OF THE METHOD

The method developed for this study was demonstrated in two States, Louisiana and Pennsylvania, for two maintenance problems—edge of traveled-way drop-off and control of roadside vegetation. In demonstrating the use of the method, the six steps described in the previous section were implemented. A schematic representation of the implementation procedure is shown in Figure 2; details of the procedure are given in Appendix C. The major findings of the demonstration exercise include the following:

1. It was practical to complete the six steps in both States. In each State this was accomplished in about 10 days; 5 days were required to obtain input data and 5 days to run the computer program and analyze its output.
2. The inputs required to run the computer program were generated from the data base of information currently available to the State agencies. The data base included information from literature surveys, studies conducted within the departments, information from maintenance management systems, and experience and judgments of knowledgeable individuals within the department.
3. Previous knowledge of decision analysis or the Delphi procedure was not required of the individuals who estimated the effects of alternative levels of service and assessed value tradeoffs in the group session.
4. The experience in both States indicated that it would be desirable to spend more time with department specialists to obtain relevant objective data, particularly those being collected by the State. Examples of such data include statistics on accidents resulting from driving over the edge of traveled-way with various amounts of drop-off, numbers of different types of animals killed on highways in auto–animal collisions, and number of days of ice and snow on the road for different "daylighting" conditions that result from brush and tree growth. Data on some of these factors may be available for a sample of the highway network in a state. It would be desirable to provide these kinds of data to the participants in the Delphi exercise to increase the confidence in, and consistency of, the value tradeoffs assessed by the participants.

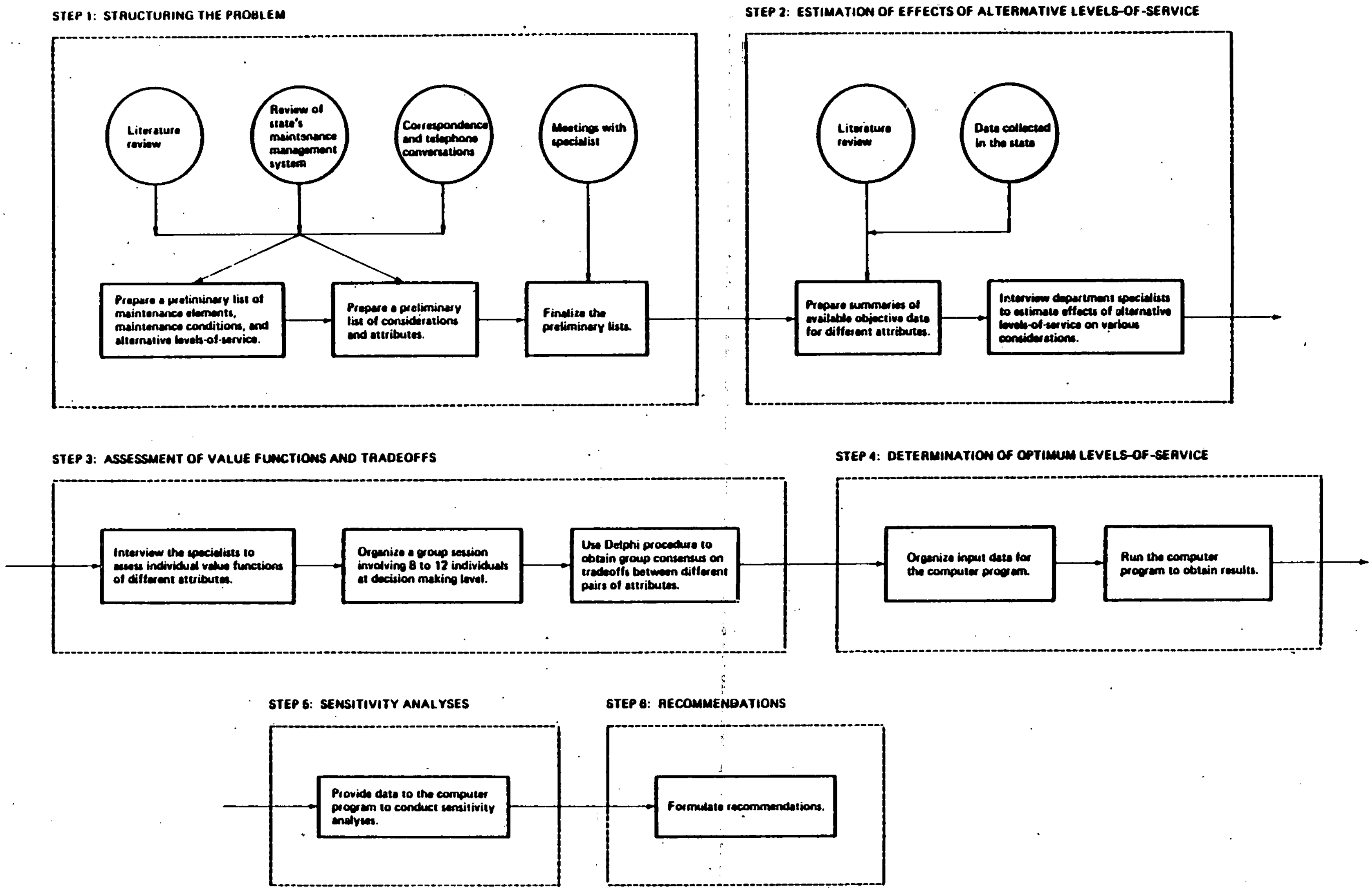



*Figure 2. Procedure used for demonstration of method.*

5. The concept of quantifying a tradeoff between two attributes (e.g., pavement rehabilitation costs versus index of pleasing appearance) is relatively difficult to understand. The response of participants in the first iteration of tradeoff assessments showed a wide scatter that was caused most likely by misunderstanding of the assessment questions rather than genuine differences of opinions. The discussions of possible inconsistencies in the first iteration responses helped the participant understand the implications of their responses. The responses in the second iteration typically showed much better convergence of group opinions. This trend was encouraging because it showed that assessing tradeoffs with a group of decision-makers, although difficult, was viable.

CHAPTER THREE

# INTERPRETATION, APPRAISAL, AND APPLICATION

The most important result of this study was development of the method for selecting optimum levels of service for different maintenance conditions as a function of available resources (dollars, personnel, etc.). This chapter examines the significance of the method to highway maintenance organizations when policy decisions on levels of service are made.

## INTERPRETATION AND APPRAISAL

This section discusses the following aspects of the method:

1. Advantages offered by the method in establishing levels of service.
2. Feasibility of implementing the method by state highway agencies.
3. Limitations of the method.

### Advantages of the Method

The information about existing practice obtained through visits with state DOT's and literature reviews indicates a general lack of systematic and formal procedures for establishing levels of service for highway maintenance. Such a procedure is provided by the method developed in this study. Major advantages of the method include the following:

1. The method allows one to estimate and evaluate the effects of alternative levels of service on multiple considerations (e.g., safety, user comfort and convenience, protection of investment and aesthetics) in determining the optimum set of levels of service. This procedure involves a formal assessment of tradeoffs between different considerations. In general, such tradeoffs are not considered in any systematic manner in the establishment of levels of service.

2. It is generally accepted that any decision-making problem of choosing between alternatives requires the subjective value judgments of the decision-maker(s). For example, even if the effects of alternative levels of service on various considerations are estimated from extensive field measurements, one would still be required to assess the relative weights of different considerations. The strength of the method developed for this project lies in the formal and systematic assessment of value judgments that will produce nonarbitrary, unbiased, and consistent relative weights of different considerations.

3. The method allows different levels of service to be established for various maintenance conditions, road classifications, and local values.

4. The policy decisions about levels of service would be more defensible because the basis of making the decisions is derived from the theoretically sound principles of decision analysis and can be well documented.

5. The method is based on a systems approach (i.e., it analyzes the complete system of maintenance conditions together rather than individually). This produces a consistent set of levels of service that take into account the interactions between various maintenance conditions.

6. The method provides a mechanism for incorporating value judgments of maintenance engineers, field supervisors, legislators, and highway users. Because of constraints on time and budget, judgments of only state maintenance personnel were used in demonstrating the method. However, legislators, highway users, and others can be included in the group meetings to assess value tradeoffs between different considerations. Additional effort will be required to obtain a representative, unbiased sample of participants from these groups and to train the nontechnical individuals in the highway maintenance terminology. Appendix G contains a discussion of issues relevant to citizen participation in transportation planning programs.

7. The specification of explicit levels of service would permit an objective evaluation of highway conditions to check whether the intended levels of service are in fact achieved in the field.

8. The method is modular in the sense that one part of the method can be changed without having to change any other part. For example, models for estimating the effects of alternative levels of service can be modified without changing value judgment models. This feature simplifies

updating of the method if and when new data become available.

**Feasibility of Implementing the Method**

Implementation of the method by state highway agencies is greatly simplified because the method is coded in the form of a tested and debugged computer program. The implementation effort involves generation of input data necessary to run the computer program. Even though the method is based on sophisticated techniques of decision analysis and mathematical programming, the user is not required to have a detailed knowledge of these techniques. Those analytical calculations that require experience in the mathematical aspects of decision analysis are handled internally in the computer program. Thus, the user does not need to make external calculations on the assessed data.

The user manual provides a step-by-step procedure for implementation of the method. Blank assessment forms and tables that need to be filled in to generate necessary input data are also included in the manual.

Major factors in evaluating the feasibility of implementing the method are: (1) data requirements, (2) staffing requirements, (3) implementation in stages, and (4) legal implications.

*Data Requirements*

Data are required to complete three components of the method: (1) estimating effects of alternative levels of service on various considerations (e.g., safety, aesthetics), (2) assessing value tradeoffs between different considerations, and (3) estimating resources required to implement alternative levels of service.

Adequate field data are currently not available for directly estimating the effects of alternative levels of service. The procedures developed for this project enable field data to be supplemented with professional judgments in a systematic manner. The experience accumulated by department specialists over a number of years provides an important source of information.

The value tradeoffs between different considerations (e.g., safety and aesthetics( should be assessed using subjective judgments of individuals representing different viewpoints (e.g., maintenance engineers, field supervisors, legislators, highway users). The Delphi procedure adapted for this study uses a formal structure to obtain group consensus regarding value tradeoffs.

Our experience in demonstrating the method in two states indicates that it is desirable to provide the participants in the Delphi procedure with field data pertinent to the conditions of the state. The availability of these data will increase the confidence in, and consistency of, the value tradeoffs assessed by the participants. Although all desired types of field data are generally not collected by state agencies because of time and budget constraints, some of the desired data may be available on a sample of the highway network in the state. The department specialists should assist in identifying the sources of relevant data being collected by various departments and compiling the available data. The specialists may also be able to indicate relatively minor modifications to the data collection procedures that will significantly improve the usefulness of the data for establishing levels of service. For example, in recording accident data it may be useful to note the existing level of service for that part of the highway relevant to the accident (e.g., edge of traveled-way drop-off).

The method requires estimates of resources required for the implementation of each alternative level of service being evaluated. The task of estimating resource requirements is facilitated significantly by the availability of a maintenance management system. Such a system incorporates statewide data on productivity for different maintenance activities and unit costs of material, equipment, and manpower. One only needs to estimate annual work quantities for alternative levels of service; the maintenance management system can calculate the corresponding resource requirements.

Demonstration of the method in two states shows that an adequate data base for the three parts previously described can be developed with the resources currently available to state agencies. The data base will include information available in the literature, studies conducted within the department, data collected by different agencies in the state, information available from maintenance management systems, and the experience and judgments of knowledgeable individuals within and outside the department.

*Staffing Requirements*

The short-term and long-term staffing requirements necessary to implement the method are different.

Over the short-term, successful implementation of the method will require a significant amount of effort by the user agency. A typical highway system would probably involve some 20 to 25 maintenance conditions and 10 to 15 attributes of practical significance. The method will require that (1) the effects of alternative levels of service of relevant maintenance conditions on each of the 10 to 15 attributes be estimated, and (2) value tradeoffs between 10 to 15 different pairs of attributes be assessed.

To efficiently manage the implementation of the method, it would be best for an individual to assume the role of a principal investigator (PI). The PI should become familiar with all aspects of the method, including the assessment of value functions and trade-offs, and implementation of the Delphi procedure. A person with this type of background may not be available within the maintenance department. However, a person with some analytical capability can train one by studying this report and its appendixes in detail and consulting the references if necessary. The possibility of hiring a consultant to perform the duties of the PI may also be considered. The PI will be responsible for conducting interviews with selected department specialists for given attributes and implementing a Delphi procedure in a group session with some 8 to 12 decision-makers.

An approximate estimate of the level of effort required for the initial phase is as follows:

1. Training of the PI to become familiar with the methodology—15 to 20 person-days.
2. Meetings with specialists to structure the problem

and to identify sources of relevant data—50 to 80 person-days.
3. Collection and compilation of objective data by department staff—50 to 80 person-days.
4. Interviews with specialists to estimate effects of alternative levels of service and to assess individual value functions—40 to 60 person-days.
5. Implementation of a Delphi procedure in a group session involving 8 to 12 decision-makers—80 to 100 person-days.
6. Organizing assessed data and running computer program—20 to 30 person-days.

Although the personnel requirements for the initial phase are substantial, this effort will not have to be repeated unless a substantial amount of new data become available, or department policies or user attitudes change significantly.

The existing practice of establishing levels of service also requires a significant number of person-days, since the practice is to hold group meetings and panel-type discussions to select levels of service. The method developed for this study is different in that it involves structured and formal interviews and group meetings.

To spread out the effort required in the initial implementation of the method over a longer period of time, the possibility of implementation in stages can be considered. This topic is discussed later in this section.

Once all the input data for the computer program are obtained, the long-term staffing requirements for the program will be substantially less. The computer program can be routinely managed by a person currently responsible for the maintenance management system. The computer facilities used for the maintenance management system will also be adequate for the computer program developed for this study.

*Implementation in Stages*

The possibility of implementing the method in stages may be considered in order to spread out the intensive effort required in the initial implementation phase. A possible approach is to consider implementation in 3 or 4 stages. At each stage, 8 to 10 maintenance conditions may be included in the system. This procedure, of course, will consider tradeoffs between only those maintenance activities that are included in the system and, in this sense, a suboptimal set of levels of service may be produced. However, if the personnel requirements to implement the entire system cannot be met, the staged implementation offers a practical alternative. The effort required at any stage will be significantly less than that required for the entire system. In addition, each stage builds on the previous stage; hence, the effort in any one stage is not wasted. The implementation of a portion of the complete system will also provide training for the principal investigator, department specialists, and participants in the Delphi procedure and will improve the reliability of the assessments made in subsequent stages.

Two criteria can be considered when dividing the system into stages. One criterion is based on the list of maintenance conditions in the order of the percentage of maintenance budget currently spent on each maintenance condition. For example, the maintenace conditions requiring 30 to 40 percent of the budget may be included in the first stage and the maintenance conditions requiring the next 25 to 30 percent of the maintenance budget in the second stage; the remaining maintenance conditions can be included in the final stage.

The second criterion considers the functional importance of different maintenance conditions. Those maintenance conditions that perform more critical functions can be included in the first stage. This will probably include all maintenance conditions that affect safety and some of the maintenance conditions that influence user comfort or preservation of investment. The second stage can consider maintenance conditions that influence user comfort, preservation of investment, and user costs. The maintenance conditions that affect user convenience, aesthetics, and ecology may be included in the final stage. Examples of maintenance conditions considered in various stages are:

*Stage 1*—Edge of traveled-way drop-off, snow and ice buildup, traffic signals, pavement skid resistance, pavement rutting, bridge structures.

*Stage 2*—Present serviceability index, pavement cracking, traffic delineators, pavement markings, drainage structures (in addition to those in Stage 1).

*Stage 3*—Roadside vegetation, litter and debris, snow fences, rest areas (in addition to those previously noted).

*Legal Implications*

The legal implications of establishing maintenance levels of service are a major concern of maintenance managers and will be addressed briefly in this report. The cause for concern is the increasing frequency of tort suits involving roadway conditions and maintenance responsibility.

It is not necessary to substantiate the validity or degree of concern associated with the legal implications of establishing maintenance levels of service. The strong consensus of maintenance engineers interviewed for this project, together with pertinent references (*12, 13*), has adequately established the fact that public agencies are being sued with increasing frequency, and that at least one consideration included in these tort suits is the condition of the roadway.

The procedures proposed by this investigation require that specific definitions or descriptions of levels of service be provided. This is necessary so that the relative desirability of different levels of service for each condition can be assessed and the tradeoffs between levels of service for different conditions can be determined. It is also desirable so that clear and definitive instructions can be given to field personnel to interpret and comply with published levels of service.

It was generally acknowledged by maintenance personnel that, from an operational viewpoint, specific descriptions of levels of service are preferable to nonspecific or generalized descriptions of levels of service. However, it was also indicated that a greater responsibility would be

incurred by the use of specific levels of service because failure to meet such levels could be established more easily.

There was no clear consensus on the issue of levels of service and legal implications. For example, at the 1970 Maintenance Management Workshop (*14*) it was proposed that:

> . . . lawyers should be included in the process of setting levels and, while it may still be desirable to set these levels, they should be well-planned and documented as to rationale. We should be prepared to meet them or face lawsuits due to negligence.

During the same workshop, some participants expressed the feeling that

> . . . we must set aside our fears of standards. We need them because we can't effectively conduct maintenance without them. If this briefly faces us with lawsuits, then perhaps it is the price we must pay for progress.

It is clear that there is an overall concern regarding the legal implications associated with how maintenance levels of service should be described. It is not clear what role maintenance levels of service play in tort suits against public agencies.

To provide a better perspective on the subject of legal implications it was considered useful to obtain input from a legal expert experienced in tort suits against state agencies. For this purpose an interview was held with a senior lawyer from the California DOT. The results of that interview are summarized briefly as follows. The summary has been prepared by the engineers conducting this study.

1. If levels of service are specific and conditions are not met, there would be an unfavorable impact.
2. If levels of service are specific and conditions are in compliance, there may be a favorable impact.
3. If a particular element of the roadway can be shown to be unsafe, there will be a negative impact regardless of level of service provided by the maintenance manual.
4. Maintenance levels of service are a minor factor in affecting the frequency of tort suits. So-called "hair-trigger" mentality, i.e., increasing tendency of injured parties to sue, and "deep pocket" attitude, i.e., compensation of the injured by public agencies regardless of fault, are more significant in the increasing number of suits. Levels of service may be involved in 25 percent of tort suits; however, few if any suits are ever based on negligent maintenance alone. Other factors are almost always involved or claimed by lawyers for the plaintiff.
5. The existence of specific levels of service for use in courtroom arguments can be beneficial in establishing good management standards.
6. Compelte (100 percent) compliance with level of service is not necessary providing a high level of compliance can be established.
7. Substantiation of established levels of service by systematic and structured procedures would be useful in tort suits.
8. Preventive law is not considered particularly helpful. The use of knowledgeable witnesses to document adequacy of maintenance is more beneficial.
9. Maintenance levels of service are not high on the list of concerns for CALTRANS relative to tort suits against the state.
10. Engineers should employ those procedures that are most appropriate to their task providing they have solid reasons for such procedures.
11. Regardless of the manner in which levels of service are to be described, a major consideration in tort suits is the indication that all reasonable effort is being made to comply with established standards.
12. Specific standards for level of service are coming whether considered desirable or not, and agencies will need to deal with this eventually.

In summary, it would appear that there could be some marginal benefits associated with nonspecific descriptions of levels of service. However, a more important consideration is the adequacy with which maintenance is accomplished. If an unsafe condition exists, it will have a negative influence on a tort suit regardless of how the level of service is described. The procedures proposed by this investigation provide a systematic and structured method for establishing levels of service that would be favorable considerations in tort suits.

### Limitations of the Method

A potential limitation of the method may be its requirement of explicit levels of service. Maintenance engineers are generally concerned about the impact of explicit levels of service on tort lawsuits. The limited information obtained in this study indicates that, among those factors affecting the frequency of tort suits and their outcomes, the specification of explicit levels of service is not a significant one. Further investigation of this issue in consultation with the agency's legal staff would be desirable.

Another limitation is the substantial one-time effort (about 1.5 to 2 person-years) required for the implementation of the method. However, the subsequent use of the method can be handled routinely by the staff currently available to a state agency. The possibility of implementation in stages can be considered to reduce the initial effort.

To keep the computing time within reasonable limits, the size of the program will have to be limited to some 20 to 25 maintenance conditions with an average of 3 or 4 alternative levels of service per maintenance condition. This size should be sufficient to include all maintenance conditions of practical significance.

## APPLICATION OF THE METHOD

The computer program is specifically designed to simplify use of the method and can be applied in the following situations.

### Selection of Optimum Levels of Service for Given Amounts of Available Resources

This is the routine use of the program. The user provides the necessary input data and the program displays the optimum levels of service for all maintenance conditions included in the system. The levels of service are optimum in the sense that they maximize user benefits subject to resource constraints.

#### Assessment of Effects of Maintenance Budget Changes on Levels of Service

With the sensitivity analysis options included in the program, the user can determine the optimum levels of service for different sets of available resources in one run of the program. Of particular significance are those situations (e.g., budget reductions) that would result in significantly lower levels of service. This is useful information to communicate to legislators who are responsible for approving maintenance budgets. Adverse effects of proposed budget costs, if any, can be identified explicitly.

#### Evaluation of the Significance of Differences of Opinions of Decision-Makers Regarding Tradeoffs Between Attributes

One of the important inputs in selecting optimum levels of service is the set of tradeoffs between different attributes. These tradeoffs are assessed in a Delphi procedure involving individuals responsible for setting and implementing levels of service. These assessments may reveal certain differences of opinion. It is important to discover how critical these differences are. This can be done by running the program with different sets of tradeoffs—an option provided in the sensitivity analysis. If little change in the optimum levels of service is produced, the differences of opinion would not be of consequence in selecting levels of service. On the other hand, a significant effect on the optimum levels of service would indicate that the differences of opinion regarding the tradeoffs are critical and need to be resolved for proper selection of levels of service.

CHAPTER FOUR

# CONCLUSIONS AND SUGGESTED RESEARCH

## CONCLUSIONS

A formal and systematic method has been developed to establish maintenance levels of service that maximize the user benefits subject to the constraints of available resources. Implementation of the method by state agencies appears feasible. Continuing use of the method will provide the most efficient allocation of limited resources among various parts of a highway system. Other potential advantages of the method include: (1) objective evaluation of field conditions; (2) uniform and consistent highway conditions across various parts of a state and classes of roads; (3) defensible policy decisions on levels of service; and (4) the capability to incorporate value judgments of maintenance engineers, field supervisors, legislators, and highway users.

A potential limitation of the method may be the legal implications of explicit levels of service that are required by the method. The limited information obtained in this study indicates that the specification of explicit levels of service is not a significant factor in the frequency or outcome of tort lawsuits. Discussion of this issue between maintenance engineers of a state agency and the agency's legal staff would be desirable.

The Delphi procedure adapted for this study appears to provide a useful communication tool between individuals at various management and supervisory levels. The Delphi procedure opens a dialogue between managerial and field personnel regarding the critical issues in making policy decisions and priorities of such issues. The experience in demonstrating the method shows that such a dialogue can be extremely helpful for managers to appreciate concerns of field personnel and vice versa.

## SUGGESTED RESEARCH

Results of this project indicate that a practical and implementable method has been developed for selecting levels of service in a systematic and objective manner. Further research will be desirable in actually implementing the method in some states. The following options may be considered for the additional research:

1. *Demonstrate the implementation of the method for a complete system consisting of 20 to 25 maintenance conditions in one or two states.* Specific objectives of such research should be to: (1) generate the data necessary to run the computer program, (2) use the results of the computer program to select optimum levels of service for various maintenance conditions, and (3) train a person within a state agency in implementation of the method.

The generation of data will require five to six 1-week visits to a state agency by the research team. A significant amount of work will have to be performed by state agency personnel particularly to collect and compile available objective data.

This should be the preferred option for further research, because it will identify difficulties and their solutions in implementing the complete system. Tradeoffs between all aspects of highway maintenance will be considered and hence a truly optimum set of levels of service will be produced.

2. *Demonstrate staged implementation of the procedure in two or three states.* The complete highway system can be divided into three or four groups of maintenance conditions according to selected criteria. The method may be implemented for the top priority group of maintenance conditions in two or three states. Necessary data should be generated for determining optimum levels of service for the selected maintenance conditions, guidelines for the implementation of subsequent stages should be prepared, and one or two persons in the user agency should be trained in the procedures that are to be used. However, tradeoffs between only a limited set of maintenance activities can be included.

3. *Present the method in 5-day workshops organized in appropriate subdivisions of AASHTO.* Each workshop should involve participation of two to three individuals from each state in the selected subdivision. The workshop should concentrate on (1) description of the step-by-step procedure involved in implementing the method, (2) use of the computer program, (3) discussion of data assessment procedures, and (4) description of staged implementation.

The workshop should provide general familiarity with the method and the computer program. This should help state agencies move toward implementation of the method. However, the workshop cannot be expected to provide detailed training for the participants in actual implementation of the method. For example, conducting a group session for the assessment of value tradeoffs using a Delphi procedure may not be practical or meaningful.

# REFERENCES


1. RAIFFA, H., *Decision Analysis.* Addison Wesley, Reading, Mass. (1968).
2. SCHLAIFER, R. O., *Analysis of Decisions Under Certainty.* McGraw-Hill, New York (1969).
3. KEENEY, R., and RAIFFA, H., *Decisions With Multiple Objectives: Preferences and Value Tradeoffs.* John Wiley and Sons, New York (1976).
4. FISHBURN, P. C., *Utility Theory for Decision Making.* John Wiley and Sons, New York (1970).
5. KEENEY, R. L., and NAIR, K, "Decision Analysis for the Siting of Nuclear Power Plants: The Relevance of Multiattribute Utility Theory." *Proceedings of the IEEE,* Vol. 63 (1975) pp. 494-501.
6. NAIR, K., SICHERMAN, A., and MERINO, J., "Environmental Impact Assessment Methodology for Energy Conversion Systems." Woodward-Clyde Consultants (1976).
7. HOWARD, R. A., Matheson, J. E., and NORTH, D. W., "The Decision to Seed Hurricanes." *Science,* Vol. 176 (1972) pp. 1191-1202.
8. KULKARNI, R., PETERS, R., MORRIS, G., and FINN, F., "Developing a Pavement Management System Framework." Annual Meeting of the Association of Pavement Technologists, *Proc.* (1978).
9. ROY JORGENSEN ASSOCIATES, "Performance Budgeting System for Highway Maintenance Management." *NCHRP Report 131* (1972) 213 pp.
10. ZOOK, R. L., "Ohio's Highway Maintenance Quality System." 63rd Annual Meeting of AASHTO, Committee on Operations and Maintenance (Nov. 1977).
11. MILLER, E. L., "A Method of Measuring the Quality of Highway Maintenance." *TRB Record No. 506* (1974) pp. 1-14.
12. TRANSPORTATION RESEARCH BOARD, "Liability of State Highway Departments for Design, Construction, and Maintenance Defects." *NCHRP Digest 80* (Sept. 1975) 49 pp.
13. JONES, R. O., "Sovereign Immunity: Where We've Been, Where We Are Now, and Where We're Going." 64th Annual Meeting of AASHTO, Louisville, Ky. (1978).
14. TRANSPORTATION RESEARCH BOARD, "Maintenance Planning and Supervision." *HRR No. 347* (1971).


# APPENDIX A

## USER MANUAL FOR COMPUTER PROGRAM ASOP

The user manual contains detailed instructions for using the computer program *A*lgorithm for *S*election of *O*ptimum *P*olicy (ASOP). The program is designed to facilitate implementation of the method to determine optimum maintenance levels of service. The user manual is organized in six sections: (1) description of the method, (2) organization of the input data, (3) description and interpretation of the program output, (4) applications of the program, (5) assessment of the program capabilities and limitations, and (6) program documentation. The contents of this appendix are not published herein. A computer package including Appendix A as submitted by the research agency, however, is available on a loan basis, or may be purchased for $6.00, plus $1.00 for postage and handling, by writing to the Program Director of NCHRP and supplying a blank computer tape for a copy of the computer program.

# APPENDIX B

## DOCUMENTATION OF EXISTING PRACTICE FOR ESTABLISHING LEVELS OF SERVICE

INTRODUCTION

The purpose of this appendix is to summarize procedures that are currently used by transportation maintenance organizations to establish maintenance levels-of-service. Two sources of information have been used for this summary: (1) review of the literature, and (2) visits to five states active in the development of maintenance management systems, specifically, California, Kansas, Louisiana, Ohio, and Pennsylvania. The summary is organized into the following parts:

1. Considerations for establishing levels-of-service
2. Procedures used to establish levels-of-service
3. Methods for describing levels-of-service
4. Tradeoffs between conflicting levels-of-service
5. Monitoring and feedback.

NCHRP Report 131 (1) provides a comprehensive state-of-the-art review of performance budgeting for highway maintenance management systems through 1971. Two of the factors discussed in the report were: (1) criteria for the establishment of maintenance levels, and (2) levels of maintenance desired for various functions.

The term "level-of-service" used here refers to the quality standard of the maintenance work and is synonymous to the terms "maintenance level" and "quality standard" that are widely used in the literature. According to the AASHTO Manual (2) "Quality standards define the physical



conditions that indicate a need for maintenance and repair activities and prescribe the character of workmanship and properties of the completed product."

Most states specify only the minimum level-of-service necessary, i.e., the poorest condition that can be tolerated before maintenance is required. Ohio has established two components for quality standards as follows:

- <u>Threshold condition</u>. This is the condition to which the physical element (roadway, shoulders, ditch, etc.) is permitted to deteriorate before maintenance is performed in order to prevent further deterioration of the element. The threshold conditions are reviewed annually to keep maintenance expenditures within the imposed budget. Some activities are expressed as a frequency rather than a threshold condition indicating how often maintenance should be performed.

- <u>Maintenance Level</u>. This is the level to which the physical element must be restored to adequately perserve the physical integrity of the element and render safe and satisfactory service to the user.

This definition of quality standards or levels-of-service covers most of the objectives served under any maintenance management system. Levels-of-service are used to specify how well the maintenance is to be done. When levels-of-service are combined with other features of a

maintenance management system, (e.g., performance and quality standards) it is possible to plan for equipment, personnel, and materials and develop a maintenance budget. Thus, levels-of-service are an essential part of any maintenance management program that uses performance budgeting systems (1).

Under a performance budgeting system the levels-of-service serve the following purposes (3):

- Provide a measure of district and statewide uniformity in maintenance practice
- Provide a basis for work planning guides
- Assist in controlling the budget by helping to reduce the instances of too frequent and unnecessary maintenance or too little maintenance which may result in emergency work and unplanned expenditure of funds.

Since the information provided in NCHRP Report 131 (1) is pertinent to this investigation, it is useful to summarize their findings about procedures used in establishing maintenance levels-of-service. The following summary quotes from the referenced report:

> "In those highway agencies investigated, there was little evidence of objective evaluation and consideration of criteria in the determination of a desired level of maintenance" (page 9).





> "Statements (in operating manuals) were encountered with regard to safety, comfort, convenience, economy, aesthetics, and serviceability—but usually these were in generalized terms that were of little use in determining the appropriate level of maintenance for a specific roadway condition" (page 9).

> "When levels-of-service were defined adequately, considerable variation was found in the expression and interpretation of levels-of-service for the same deficiency condition" (pages 9, 10).

> "There is almost a complete absence of objective evaluation and systematization in the area of criteria for maintenance levels. None of the highway agencies investigated had proceeded much beyond implicit consideration of criteria in the determination of maintenance levels. Indeed, little information exists anywhere on which objective decisions may be based" (page 37).

On the basis of the literature review conducted for this study and visits to five state DOT's it can be concluded that: (1) the major emphasis of highway engineers since 1972 has been to systematize procedures for budget preparation, and (2) very little useful objective data has been developed for specific application to the establishment of levels-of-service.

## CONSIDERATIONS FOR ESTABLISHING LEVELS-OF-SERVICE

Interviews with the participants from cooperating state DOT's as well as a literature review indicated that a combination of factors are

considered in establishing levels-of-service, including:

- Safety
- Preservation of public investment in the highway system
- Comfort and convenience of user
- Aesthetics
- Legal implications
- Traffic volume and route classification
- Political and social.

Safety

Without exception, engineers in the five states indicated that the first consideration in establishing levels-of-service was safety. In this instance, safety relates to the potential for accidents or a history of accidents along a specific route or at a specific location.

The specific conditions that would be included under safety are: (1) pavement slipperiness, (2) rutting, (3) sight distance as affected by vegetation or alignment, (4) shoulder drop-off, and (5) excessive pavement deterioration (e.g., potholes or spalling). Factors such as pavement roughness, signing, and lighting would also fall into this general category. Snow and ice removal policies could be classified as a safety consideration (4) as well as a user convenience. Mowing is sometimes related to safety based on potential fire hazard (5, 6). Specific interpretations about what is to be included in the safety consideration will vary from agency to agency depending on experience and engineering



evaluation. For example, CALTRANS considers that shoulder drop-off should be evaluated under preservation of investment rather than safety, i.e., it is more important to pavement performance than it is to accident potential. In some situations, drainage could be a safety consideration if an inadequate level-of-service were to result in flooding of the pavement surface.

Preservation of Investment

The consensus of agency personnel interviewed was that preservation of investment was the second priority in establishing levels-of-service. There is no clear definition or criteria to use as an attribute for preservation of investment. In general, it is understood that those activities should be included which, if properly implemented, will obtain the full potential service life of each highway element for which such considerations are appropriate. A reverse evaluation would be the occurrence of premature distress in a given element of the roadway as a result of untimely maintenance.

Additional types of standards that would be affected by consideration of preservation of investment are physical maintenance of the pavement, cleaning of ditches (drainage), cleaning and painting of bridge structures, shoulder maintenance, and proper cleaning of signs that can be adversely affected by chemical deposits.

The literature has not provided documented information pertinent to the benefits associated with timely maintenance although most highway

engineers believe it is effective and beneficial; discussions with maintenance personnel will strongly support this position.

Most maintenance performed by state forces is corrective maintenance in that it is triggered by some visible deterioration in a particular element, i.e., pavement, shoulder, drainage ditch, signs, or lighting. In the view of many maintenance people this is preventive maintenance. For example, patching a cracked area of asphalt pavement will prevent the cracking from spreading at an accelerated rate.

## User Comfort and Convenience

User comfort and convenience were considered very close in priority to the preservation of investment discussed previously. In actual practice (in the field) user comfort may take precedence over preservation of investment due to societal and political influences.

User comfort and convenience include conditions such as riding comfort, snow and ice removal, lighting and signing, comfort stations and width and condition of the shoulder.

A desirable way to evaluate user considerations would be in terms of user costs. That is, what are the user costs associated with pavement roughness, snow and ice removal (7), etc. A comparison between the cost of maintaining various levels-of-service and user benefits could be used to determine the optimum level-of-service.





Unfortunately, there is no reliable information to assess the excess user costs associated with the various levels of roughness or delays related to snow and ice removal.

Recent interest in the design and construction of maintenance-free pavements has resulted in inquiries concerning the relationship between user costs and pavement condition (8, 9, 10, 11, 12, 13, 14, 15, 16). The indications from references 8-16 suggest that user costs due to delays of any kind can be very expensive. Based on such information, a high level of service for pavement smoothness or a "bare pavement" policy could easily be justified on main roads. Such a conclusion may be fairly obvious for snow and ice removal but requires further study regarding smoothness requirements.

## Aesthetics

Aesthetics is a major consideration in planning, constructing, and maintaining a highway. The objective of roadside development, as described in NCHRP Report 137 (17) is "to provide an appropriate integration of the highway with the rural or urban landscape; to conserve, enhance, and display the natural beauty or compatible man-made developments of the landscape through which the highway passes, and to improve the aesthetic qualities of the highway and its structure..."

Mowing, vegetation control, landscaping, litter control, etc., are some of the activities included in the maintenance work that may contribute to the aesthetics of the system (2). Decisions to establish levels-of-service for such activities are sometimes complicated by the fact that

ecologists consider roadside development from another point of view. For example, a reduction in the frequency of mowing may result in a substantial increase in the acreage of nesting cover along the highway roadside for song birds and game birds (18). However, increased roadside growth may result in more accidents involving deer and birds (18).

Legal Implications

The legal implications of establishing levels-of-service were understood by the promoters of maintenance management systems. During the 1970 Maintenance Management Workshop (19) it was proposed that:

> "...lawyers should be included in the process of setting levels and, while it may still be desirable to set these levels, they should be well-planned and documented as to rationale. We should be prepared to meet them or face lawsuits due to negligence."

During the same workshop it was expressed by the participants that:

> "...we must set aside our fears of standards. We need them because we can't effectively conduct maintenance without them. If this briefly faces us with lawsuits, then perhaps it is the price we must pay for progress."

Until recently, state highway departments had little fear of tort suits against them for injury to person or property caused by negligence in highway maintenance because they were either immune from suits or from tort liability (20). However, recent trends in tort laws indicate that negligent maintenance is least likely to be immune from liability (20).



Possible legal complications were a dominant concern for state personnel in their approach to establishing levels-of-service for maintenance, specifically those activities related to the pavement and shoulder areas. If quantitative levels-of-service are established it could be interpreted that no section of the roadway should ever fall below such levels. Highway engineers recognize that such an interpretation is virtually impossible to achieve without increasing surveillance and personnel requirements to an unacceptable level.

Considering the concern expressed by state personnel, it may be difficult to establish quantitative descriptions for levels-of-service or items such as shoulder drop-off, pavement roughness, pavement distress, or potholes, until some future time when legal criteria make it possible to do so.

Traffic Volume and Route Classification

Highway agencies responsible for maintenance of the roadway system may be involved with the maintenance of different classifications of roads (urban, rural, primary, secondary, etc.) that handle varying amounts of traffic. The levels-of-service under these conditions may depend upon their classifications and/or volume (3); for example, many highway agencies specify bare pavement policy for all major highways and streets that carry high traffic volume (9), but specify a different level-of-service for snow and ice removal for other road classifications (5).

Mowing and vegetation control was another area in which route or location factors were considered. Levels-of-service for mowing is

sometimes a function of the amount of development; for example, for rural or urban areas, or for multi-lane and two-lane highways. In addition, mowing policies in some agencies are responsive to the mowing patterns of private property adjacent to the right-of-way. That is, if farm land is maintained clear of grass or vegetation, mowing standards for the highway will be reasonably compatible.

There is no clear consensus with regard to establishing different levels-of-service for the majority of maintenance activities as a function of road classification or traffic. California, for example, does not consider either factor in establishing levels-of-service. This can be justified by the facts that: (1) users are entitled to an adequate level-of-service regardless of the route location, etc., and (2) the more heavily traveled roadways will receive the greatest attention (frequency) by virtue of the effects of traffic.

Pennsylvania has attempted to recognize road classifications by establishing Maintenance Functional Classifications (MFC) for their very large and complex system. Different levels-of-service would be set in consideration of the MFC; however, in practice there are relatively few activities that are affected.

The fact that maintenance responsibility by road classification is different in California and Pennsylvania may account for the different policies. For example, California does not maintain the county road system, whereas Pennsylvania does. Thus, for states with such a wide spectrum





of roads to maintain as in Pennsylvania, functional classifications would seem useful; however, if only the state system is involved a single policy may be adequate.

<u>Political and Social</u>

Maintenance levels-of-service can be significantly influenced by legislative decisions (e.g., increase or decrease in budget) (<u>21</u>). Pennsylvania has established five levels-of-service that reflect the monies available.

There is no clear evidence that societal considerations directly affect levels-of-service. It is generally believed that transportation department officials can act as a proxy for public input. This conclusion is based on the fact that maintenance department personnel are in close contact with the public by virtue of their presence in the field on a day to day basis. Mail and telephone contacts also offer a means of input from the public.

Those contacted in the five state DOT's indicated that it would be desirable to obtain more public information from a broad cross-section of users. No direct technique for obtaining such information has been developed; however, techniques are available and will be discussed in another part of this report.

PROCEDURES USED TO ESTABLISH LEVELS-OF-SERVICE

The method used to establish levels-of-service is predominantly based on subjective experience. This experience is converted into

consensus of opinion based on informal discussions and interviews or structured panel-type meetings.

An alternative method for establishing levels-of-service would be to use objective data obtained from data acquisition programs. However, at the present time there is no indication that objective data have been used to establish levels-of-service. It is generally conceded that the use of objective data would be a much preferred technique for establishing levels-of-service.

Use of Objective Information

There is extensive information in the literature concerning the performance of various elements of the highway; for example, pavement roughness can be related to riding comfort, pavement features to safety, and mowing practices to the nesting habits of birds.

There are a number of areas for which virtually no reliable or useful information is available; for example, pavement roughness to vehicle operating cost, pavement roughness to accidents, lighting to accidents, skid number to accidents, or physical maintenance to pavement life cycle. Some maintenance considerations defy the use of measurements, i.e., aesthetics or political factors.

In view of the large amount of information that has been collected for various maintenance considerations--safety, comfort, pavement performance--it is surprising and certainly disappointing that none of this information can be used <u>directly</u> to establish levels-of-service. The



main reason for this is that research objectives have not been directed toward establishing levels-of-service.

To meet the needs for establishing levels-of-service, the information must relate to one or more of the maintenance considerations, i.e., safety, preservation of investment, user cost, etc. Consider, for example, studies by CALTRANS concerning shoulder drop-off. In these studies, professional drivers were asked to drive over pavements with various magnitudes of shoulder drop-off. The objective was to determine the limit at which the driver could maintain control of the vehicle. The results indicated that, under the conditions of the experiment, the drivers could maintain control for a shoulder drop-off of up to 4-1/2 inches. However, to suggest that under all conditions a safe drop-off is 4-1/2 inches would be extending the inference beyond the constraints of the study. For example, in that study the drivers were aware that a shoulder drop-off was present, and anticipated this condition. In addition, the study did not involve tests under a variety of driving conditions, i.e., day <u>and</u> night, dry <u>and</u> wet weather, at various speeds. Finally, the experiment did not attempt to relate shoulder drop-off to preservation of investment, which is a major consideration for some agencies regarding this particular condition.

Even with their limitations, studies such as the one for shoulder drop-off are useful in establishing levels-of-service. By providing such information to an assessor, more realistic and valid judgements can be

made regarding appropriate levels-of-service. Since safety is considered to have the highest priority, information concerning the relationship of maintenance to accidents is useful for establishing levels-of-service.

A great deal of information about accidents is available. A number of references are cited in Attachment 1 (list of references not cited). Reference 22 is a summary of accident information.

Table B-1 (taken from Reference 22) summarizes the benefit/cost ratios of various counter-measures (improvements), i.e., shoulder widening or improvement yielded the highest benefit/cost ratio of 28.83. The benefits shown in Table B-1 are annual benefits and were calculated with the Report of Societal Costs of Motor Vehicle Accidents (25).

Unfortunately, the improvements cited in Table B-1 do not specifically relate to levels-of-service for highway maintenance. Rather, they are more concerned with betterment or new installations, i.e., shoulder widening or improvement (betterment), traffic signals installed or improved. However, some information can be obtained from this table that is pertinent to establishing levels-of-service.

The improvement which has the highest benefit/cost ratio is shoulder widening or improvement. Based on this finding, activities related to the shoulder condition should be considered eligible for relatively high levels-of-service. Next on the list would be striping and signing, i.e., proper maintenance and frequent inspection of stripes, delineators, and traffic signs.



Table B-1. SAFETY BENEFITS OF COUNTERMEASURES

| Risk (1) | Improvement (2) | Service life (3) | Number of projects (4) | Reductions Accident (5) | Injuries (6) | Fatalities (7) | Benefit in dollars (8) | Cost Per project (9) | Benefit/cost ratio (10) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Shoulder widening or improvement | 20 | 46 | 29 | 20 | 41 | 4,745,088 | 35,200 | 28.83 |
| 2 | Installation of striping, delineators, or both | 4 | 2,000 | 13 | 20 | 46 | 17,493,150 | 1,094 | 26.49 |
| 3 | Skid treatment/grooving | 20 | 96 | 48 | 20 | 74 | 6,372,399 | 32,385 | 20.12 |
| 4 | Installation or upgrading of traffic signs | 4 | 775 | 23 | 33 | 27 | 8,031,275 | 2,278 | 15.03 |
| 5 | Siging or marking or both | 10 | 3,046 | 0 | 42 | 35 | 3,638,462 | 536 | 14.94 |
| 6 | Installation or improvment of median barrier | 10 | 23 | 3 | 6 | 91 | 12,712,361 | 270,070 | 13.73 |
| 7 | Roadway lighting installation | 10 | 115 | 9 | 9 | 73 | 4,393,559 | 19,363 | 13.24 |
| 8 | Installation or improvment of raod edge guardrail | 10 | 1,651 | 13 | 15 | 59 | 12,273,743 | 4,546 | 10.97 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 9 | Flashing lights replacing signs only—railroad | 10 | 56 | 94 | 93 | 99 | 2,014,682 | 25,655 | 9.41 |
| 10 | Signs/striping combinations | 4 | 465 | 24 | 26 | 27 | 9,982,024 | 8,270 | 8.60 |
| 11 | Breakaway signs or ligthing supports | 4 | 527 | 35 | 44 | 100 | 656,538 | 569 | 7.25 |
| 12 | Traffic signals, installed or improved | 10 | 699 | 18 | 32 | 49 | 17,688,205 | 26,650 | 6.36 |
| 13 | Skid treatment/overlay | 20 | 126 | 17 | 27 | 30 | 4,747,692 | 60,796 | 6.09 |
| 14 | Automatic gates replacing signs only | 10 | 101 | 99 | 99 | 100 | 3,100,704 | 37,872 | 5.44 |
| 15 | Cannelization, including left turn bays | 10 | 612 | 34 | 39 | 65 | 17,982,781 | 50,091 | 3.94 |
| 16 | Pavement widening, no lanes added | 20 | 241 | 25 | 38 | 87 | 7,238,024 | 80,188 | 3.68 |
| 17 | Sight distance improved | 10 | 142 | 31 | 38 | 36 | 859,826 | 13,696 | 2.97 |
| 18 | Combination of 10 and 11 | 10 | 36 | 31 | 35 | 50 | 620,449 | 64,846 | 1.78 |
| 19 | Automatic gates replacing active devices | 10 | 166 | 81 | 75 | 96 | 948,528 | 33,921 | 1.13 |
| 20 | Combination of 40 and 41 | 20 | 69 | 21 | 32 | 69 | 1,350,900 | 211,055 | 0.91 |
| 21 | Replacement of bridge or other major structures | 30 | 163 | 44 | 60 | 47 | 1,548,658 | 118,475 | 0.90 |
| 22 | Lanes added, without new median | 20 | 96 | 17 | 11 | 31 | 900,544 | 114,937 | 0.80 |
| 23 | Widening existing bridge or other major structures | 20 | 354 | 65 | 74 | 33 | 1,103,632 | 75,440 | 0.41 |

Many of the items shown in Table B-1 are not within the purview of maintenance departments, i.e., skid treatment/grooving, installaton and upgrading of traffic signs, installation of median barrier, etc. These improvements are generally initiated by departments concerned with safety, traffic, planning, or design and their sources of information and funding are generated by agency policies. In some cases maintenance forces can be contracted to carry out improvements under specific fiscal policy; however, the action policy is not related to levels-of-service.

## METHODS FOR DESCRIBING LEVELS-OF-SERVICE

A comprehensive summary of levels-of-service adopted by various highway agencies is available in NCHRP Report 131 (1). Recommendations of levels-of-service for various highway conditions are contained in the AASHTO Maintenance Manual (2) and can be used as guidelines for developing such standards for existing conditions.

In reviewing levels-of-service it was observed that different agencies use different formats for expressing levels of service. In addition, the levels-of-service may be expressed in qualitative or quantitative terminology.

Most maintenance management systems rely on simple statements in their maintenance manuals to describe levels-of-service. For example, California, in describing levels-of-service for the flexible roadbed-maintenance of the traveled way, includes the following.



### Cracks

"Cracked pavement allows water and foreign material to enter the structural section and may cause ultimate failure. Individual cracks 1/4 (one quarter) inch wide or wider and any other areas with extensive cracking should be repaired before the rainy season to protect the structural section."

In this description of level-of-service, three items are covered: (1) why cracks need to be sealed, (2) when they should be filled (1/4-inch or wider), and (3) the time of year. Thus, a rather specific description or guideline for field personnel is made available.

### Raveling

"Raveling is an indication of failure of the binder or aggregate and extensive pavement loss or a traffic hazard may occur in a short period of time. Raveling should be corrected before safety is impaired or extensive pavement loss occurs."

Note that in this case a considerable leeway is given in judging when corrective action should be taken. Experience and judgement plus headquarters coordination is considered adequate to assure uniform interpretation of this level-of-service.

Louisiana uses a similar approach to describe levels-of-service. However, in this state the level-of-service is tied to a maintenance activity; for example, maintenance standards for premix leveling include the following.

"Road Condition. General distortion including minor depressions. Large areas of severe depressions and distortions (more than two (2) depressions in 25 feet or depressions more than 50 feet in length)."

"Description (photo included). Minor settlement or rutting of the surface. Normally these are not serious enough to be repaired except before the road is seal coated."

"Quality Standard. More than two (2) depressions in 25 feet or depressions more than 50 feet in length. General distortion including minor depressions." The description includes a discussion of need for repair, how to repair, and helpful hints.

Performance standards for the Ohio DOT maintenance management system provide crew sizes, numbers and types of equipment, amount of material per work unit, productivity methods, techniques for performing the work, reporting procedures, and a quality guide. The quality guide lists two conditions--a threshold condition to which the highway component is permitted to deteriorate before maintenance is performed, and the level or condition to which the component is to be restored upon completion of the maintenance activity. An example of the Ohio description for performance standard is shown in Figure B-1.

Pennsylvania uses a system for setting levels-of-service which is responsive to budgetary constraints. Five general guidelines are used to adjust specific levels-of-service. A general description of these levels is given in Table B-2.



STATE OF OHIO
DEPARTMENT OF TRANSPORTATION

**PERFORMANCE STANDARD**

MAINTENANCE MANAGEMENT SYSTEM

| ACTIVITY NAME | WORK UNIT | ACTIVITY NUMBER |
|---|---|---|
| POTHOLE PATCHING | Tons of Bituminous Mixture | |

**DESCRIPTION AND PURPOSE**

Hand patching small areas of pavement and berm surfaces with a bituminous mixture to correct abrupt depressions, potholes, edge failures and other surface defects. This includes crossovers, drives and mailbox turnouts and any type of surface.

**MAINTENANCE CRITERIA**

| CONDITION | LEVEL |
|---|---|
| Potholes greater than one square foot and 3/4 inch deep | Restore loss of surface to level of existing surface |

**RECOMMENDED CREW SIZE**

NUMBER

**RECOMMENDED MATERIAL**

| QUANTITY (PER WORK UNIT) | DESCRIPTION | CODE |
|---|---|---|
| | | |

**RECOMMENDED EQUIPMENT**

| NUMBER | DESCRIPTION | CODE |
|---|---|---|
| | | |

**AVERAGE DAILY PRODUCTION**

**PRODUCTIVITY RATE**

| APPROVED BY | DATE |
|---|---|
| | |

Figure B-1. DESCRIPTION OF PERFORMANCE STANDARDS

Table B-2. LEVELS OF HIGHWAY MAINTENANCE FOR PENNSYLVANIA DEPARTMENT OF TRANSPORTATION

| | |
|---|---|
| M1 | Maintain all roads, shoulders, bridges, guardrails, etc. at normal recommended standards. Do catch-up work at a rate that would eliminate backlogs on resurfacing, bridge upgrading and narrow-road widening in 12 years. Replace substandard guardrail over 25 years. Keep all roadways generally free of ice and snow 95 percent of the time and have limited access roads bare within two hours after a storm. Maintain sign and line painting and vegetation control at normal standards. |
| M2 | Maintain roads, bridges, etc. at M1 level on limited access and primary highways, but reduce maintenance on secondary and rural roads. Eliminate work affecting aesthetics only. Do catch-up work to eliminate backlog of resurfacing, bridge upgrading, guardrail replacement and road-widening over 25 years. Permit snow accumulations of three inches on secondary roads and five inches on rural roads. Remove half of picnic tables from roadside rests. Do cleanup services only for safety reasons. |
| M3 | Do only 2,200 miles of resurfacing and surface treatment. This will increase backlog by 500 miles per year. Otherwise keep maintenance at M2 level. Do catch-up work on widening, guardrail replacement and roadwidening on 30 year schedule. Reduce snow removal during non-peak hours from 9 p.m. to 4 a.m. Reduce grading, restabilization and dust control work on unpaved roads by 10 percent and on shoulders by 25 percent. Do only 50 percent of required public service facility work. |
| M4 | Keep highways in M3 condition but permit deterioration that will significantly affect capital investment. Put major emphasis on roadway maintenance with little or none on shoulders, service facilities, etc. Reduce preventive maintenance by 85 percent. Upgrade serious bridge deficiencies on 50-year schedule. Replace no guardrails. Eliminate snow removal from 9 p.m. to 4 a.m. Discontinue maintenance of route markers and other signs, and do only 80 percent of required line painting. Reduce mechanized patching by 50 percent. Clean drainages only when completely clogged. |
| M5 | Keep highways open but in a very poor state. Deficiencies will affect highway safety. Patch and surface treat roads only on priority basis with emphasis on alleviating structural damage. Do 25 percent of required bridge maintenance and repair structural damage to bridges. Put up no snow fences and do all snow removal with department forces. Paint center line only on interstate, primary and secondary roads. Paint no rural roads. Warning signs and regulatory signs not maintained for night visibility. Do cleanup and vegetation control work only for safety. Replace guardrail only in hazardous situations. |





Based on this review it would appear that a variety of descriptions and guidelines can be used to assist in establishing levels-of-service. The purpose of this project is to develop a systematic procedure to assist in the determination of the levels-of-service to be used within these frameworks.

TRADEOFFS BETWEEN CONFLICTING LEVELS-OF-SERVICE

The levels-of-service guidelines used by Pennsylvania recognize the need for tradeoff in establishing maintenance policy. In evaluating alternative levels-of-service, the effect of each on multiple considerations such as safety, riding comfort, economics, and environmental impact must be taken into account. Many of the considerations conflict with each other, i.e., improvement on one may come only at the expense of another. Consider, for example, shoulder drop-offs. By maintaining a lower drop-off, the accident potential to users may be reduced. This is a desirable effect as far as safety is concerned. However, a lower drop-off may be maintained only by more maintenance work resulting in high expenditure. Thus, an increase in public safety, in this instance, also means an increase in the cost. Another example of conflicting considerations could be the effect of vegetation control on safety, environment, and aesthetics. A particular level-of-service may provide a more pleasing highway appearance, but it may also result in more adverse impacts to the environment or safety.

There is very little indication from the literature or direct contacts with the five states cooperating on the project, that procedures

to accommodate tradeoffs have been formally included in establishing levels-of-service. There is an implicit recognition that such tradeoffs occur as noted in Figure B-2. This figure illustrates that maintenance levels are a variable that can be influenced by consideration of the alternatives, benefits, costs, constraints, and policy studies (5). One of the objectives of this project is to develop systematic procedures for evaluating tradeoffs and selecting levels-of-service that consider the tradeoff preferences.

MONITORING AND FEEDBACK

As in the case of tradeoffs, monitoring and feedback is implied in most maintenance management systems but is not formally included in the procedures. It is generally considered that supervisory personnel will be able to provide the necessary quality control to assure that policy guidelines are being uniformly adhered to.

The Ohio DOT has for some time been using a monitoring technique to evaluate the quality of maintenance on their highway network. Zook (23) and Miller (24) have described the Ohio procedures. Briefly, the system summarizes observations of field conditions for each highway element or activity as a direct measure of the quality of maintenance.

The approach taken by Ohio was to identify those conditions that indicate deterioration of the physical intergrity or reduction in the operational characteristics of the highway. This is accomplished through the selection and definition of a series of highway conditions referred



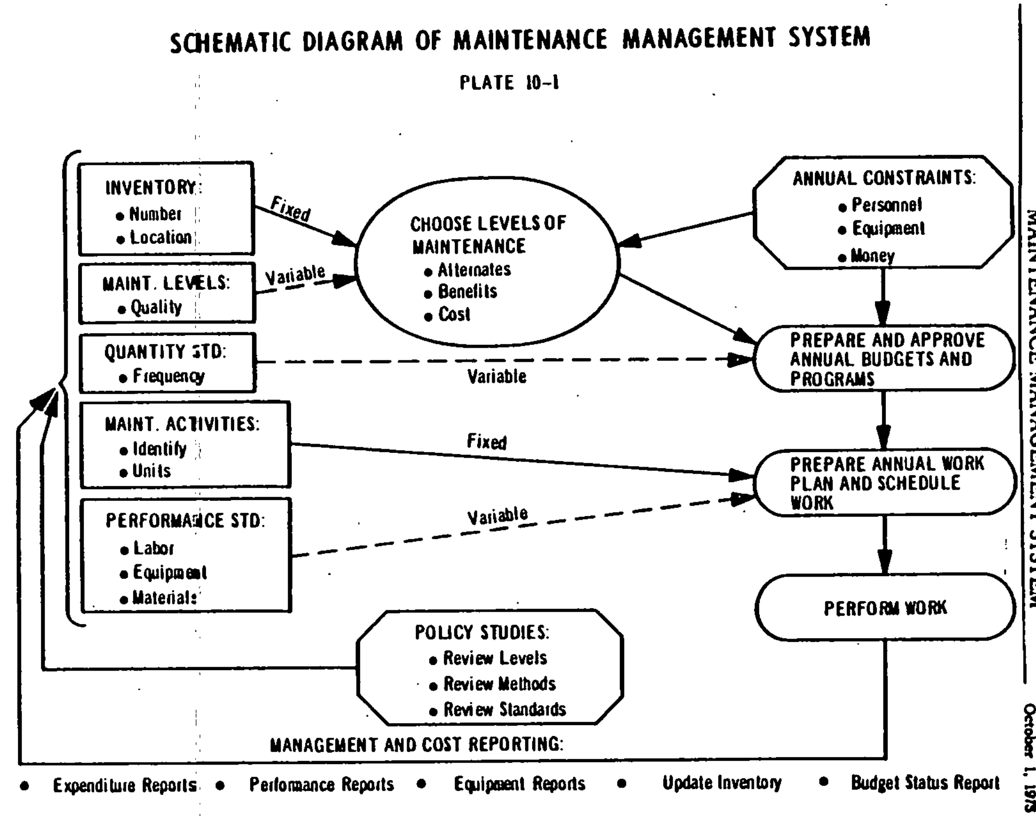



Figure B-2. CHOOSING LEVELS OF MAINTENANCE FOR CALIFORNIA (From Reference 5)

to as "recordable conditions." Table B-3 summarizes the recordable conditions used by Ohio. Figure B-3 shows a summary bar graph of recordable conditions for the pavement surface in seven counties. Note that the summary also shows the amount of maintenance money spent per lane-mile to maintain the surface. Louisiana is now experimenting with a procedure similar to that used in Ohio as a means of monitoring maintenance.

The Ohio procedure provides a basis for monitoring maintenance and comparing it with levels-of-service established for each activity. The information obtained from the Ohio system has not been designed to evaluate compliance with maintenance levels-of-service; however, only minor modifications in programming and field sampling procedures would be necessary to provide such information.

## Summary

The previous sections of this appendix have attempted to summarize procedures currently being used to establish levels-of-service for highways.

Based on the information from the literature and interviews with agency personnel in five states, it is concluded that maintenance levels-of-service are established on the basis of subjective information that is obtained through experience.

There is a strong desire on the part of agency personnel to use more objective measurements in establishing levels-of-service. Many authorities feel that sufficient information for use in establishing levels-of-



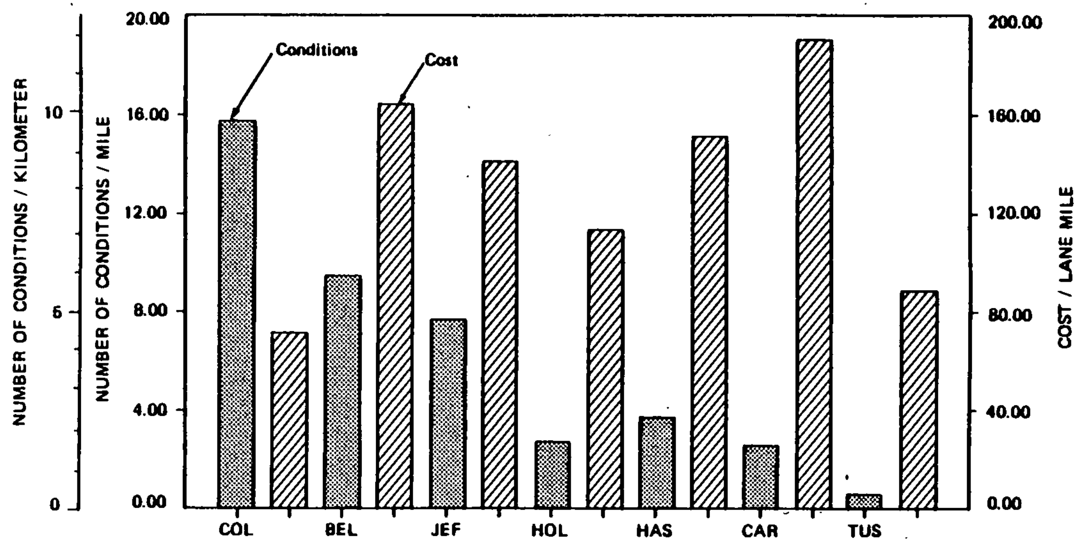



Figure B-3 RECORDABLE CONDITIONS AND MAINTENANCE COSTS FOR PAVEMENT SURFACE (Source: Maintenance Management System for Ohio DOT)

Table B-3. RECORDABLE MAINTENANCE CONDITION FOR OHIO

STATE OF OHIO RECORDABLE CONDITION REPORT DEPARTMENT OF TRANSPORTATION

DATE______ COUNTY______ ROUTE______
OBSERVERS HUGHES AND STEWART SECTION NO.______

| CONDITION | ONE UNIT COUNT FOR EACH | UNITS | TOTAL |
|---|---|---|---|
| PAVEMENT | | | |
| Surface | | | |
| Deterioration | 2 Sq. Yd. | | |
| Obstruction | Location | | |
| Flushing | 100 Lin.Ft. | | |
| Striping | | | |
| Deterioration | 1/10 mile | | |
| Auxiliary Marking | | | |
| Deterioration | Location | | |
| SHOULDERS (Surface) | | | |
| Drop Off | 100 Lin.Ft. | | |
| Obstruction | Location | | |
| APPURTENANCES | | | |
| Guardrail | | | |
| Appearance | 100 Lin.Ft. | | |
| Deterioration | 100 Lin.Ft. | | |
| Signing | | | |
| Deterioration | Sign | | |
| ROADWAY (Appearance) | | | |
| Vegetation | 1/5 mile | | |
| Litter | 1/10 mile | | |
| DRAINAGE (Obstruction) | | | |
| Ditches | 100 Lin.Ft. | | |
| Structures | Structure | | |
| STRUCTURES | | | |
| Deterioration | 2 Sq. Yd. | | |

ODOMETER LOG
Control Point______
Section Start 0.00
Guardrail (end of 6th run)______
Drainage (6th structure)______
Section end______
Length of section 2 miles



service can be found in the literature. However, the information available in the literature cannot be used directly in establishing levels-of-service. Much of this information can be used as a reference for formulating subjective opinions which in turn can be used for establishing levels-of-service.

## REFERENCES


1. Transportation Research Board, "Performance Budgeting System for Highway Maintenance Management." NCHRP Report No. 91, 1970.

2. American Association of State Highway and Transportation Officials. AASHTO Maintenance Manual 1976. AASHTO, 1976.

3. Katz, J.S., "Performance Standards as a Tool in Preparing the Maintenance Program Budget." Transportation Research Board, HRR No. 347, 1971.

4. Keefe, R.A., "A Framework for a Maintenance Management System for Massachusetts." MA Thesis, M.I.T., 1975.

5. California Dept. of Transportation. Maintenance Manual, 1975.

6. Gomez, J.F. and C.H. Oglesby, "A Proposed Approach to Setting Road Maintenance Levels for Forest Roads." TRB Special Report No. 160, 1976.

7. Lockwood, R.K. (ed.), "Snow Removal and Ice Control in Urban Areas," APWA Research Foundation Project No. 114, Vol. I, August 1975.

8. Butler, B.C., Jr., "Economic Analysis of Roadway Occupancy for Freeway Pavement Maintenance and Rehabilitation." Federal Highway Administration, Washington, D.C., October 1974.

9. Winfrey, R., "Highway Engineering Economy Analysis." Highway Research Board Special Report No. 108, 1970.

10. Winfrey, R., Economic Analysis for Highways. International Textbook Co., Scranton, Pennsylvania, 1969.

11. Karan, M.A., and Hass, R.C.G., "User Delay Cost Model for Highway Rehabilitation." Univ. of Waterloo, Ontario Joint Transportation and Communications Research Program, Project W-30, 1974.

12. McFarland, W.F., "Benefit Analysis for Pavement Design Systems." Research Report No. 123-13, Texas Transportation Inst., Texas A&M University, April 1972.

13. Karan, M.A., Haas, R., and Kher, R., "Speed-Roughness Relationships for Rural Highways." Presented to Transportation Research Board, Washington, D.C., January 1976.

14. Claffey, P.J., and P.L. Claffey and Associates, "Running Costs of Motor Vehicles as Affected by Road Design and Traffic." NCHRP Report No. 111, 1971.





15. Lytton, R.L., McFarland, W.F., and Schafer, D.C., "Flexible Pavement Design and Management Systems Approach Implementation." NCHRP Report No. 160, 1975.

16. Darter, M.I., and Barenberg, J., "Zero-Maintenance Pavements: Results of Field Studies on the Performance Requirements and Capabilities of Conventional Pavement Systems." Volumes I and II, Federal Highway Administration, Washington, D.C., 1977.

17. Transportation Research Board. "Roadside Development—Evaluation of Research" NCHRP Report No. 137, 1972.

18. Joselyn, G.B., "Wildlife—An Essential Consideration Determining Future Highway Roadside Maintenance Policy." Transportation Research Board, HRR No. 280, 1969.

19. Transportation Research Board, "Maintenance Planning and Supervision," HRR No. 347, 1971.

20. Transportation Research Board, "Liability of State Highway Departments for Design, Construction, and Maintenance Defects." NCHRP Digest No. 80, Sept. 1975.

21. Washington State Dept. of Highways. "Quality Standards for Highway Maintenance," 1968.

22. Hall, T.A., "National Highway Safety Program Effectiveness," ASCE Transportation Eng. Journal, July 1978, pp. 449-456.

23. Zook, R.L., "Ohio's Highway Maintenance Quality System." 63rd Ann. Meeting of AASHTO, Committee on Operations and Maintenance, November 1977.

24. Miller, E.L., "A Method of Measuring the Quality of Highway Maintenance." TRB Record No. 506, 1974.

25. Department of Transportation "1975 Societal Costs of Motor Vehicle Accidents." National Highway Traffic Safety Administration, Washington, D.C., December 1976.

ATTACHMENT 1

## REFERENCES NOT CITED IN TEXT


1. Alexander, J.A., "Application of Maintainability and Expected Cost Decision Analysis to Highway Design." TRB Special Report No. 148, 1974.

2. Alexander, J.A. and F. Moavenzadeh, "Highway Maintenance," Urban System Laboratory, MIT Repport No. TR-70-38, Sept. 1970.

3. Beggs, J. and Young, J.C.L., "An Economic Analysis of Factors Influencing Road Maintenance Costs." Australian Road Research Board Conf. No. 8, August 1976.

4. Butler, B.C., "Economics of Ice and Snow Removal in Urban Areas," American Public Works Association Spec. Rep., APWA Research Foundation Project 114, Vol. I (Aug. 1965), pp 67-118.

5. Byrd, L.G., "Introduction Remarks - External Influences on Management." Transportation Research Board, HRR No. 347, 1971.

6. Byrd, L.G. and B.C. Butler, "Maintenance Management Concepts," Public Works, Aug. 1974.

7. California Dept. of Transportation, "1976 Accident Data on California State Highways." A report prepared in cooperation with the U.S. Dept. of Transportation and FHWA.

8. Childs, J.M., "Highway Maintenance Service Levels." Transportation Research Board, HRR, No. 241, 1967.

9. Cox, B.E., "U.K. Developments in Highway Maintenance Since the Marshall Report," TRR No. 554, 1975.

10. Crawford, F.E., "Planning and Programming Highway Maintenance." Transportation Research Board, HRR No. 241, 1967.

11. Currey, D.A. and D.G. Anderson, "Procedures for Estimating Highway User Costs, Air Pollution and Noise Effects." NCHRP Report No. 133, 1972.

12. EPPS, J.A., "Developing Decision-Making Maintenance Management Tools." Public Works, Febraury 1976.

13. Federal Highway Administration, "Evaluation of the Highway-Related Safety Program Standards," U.S. DOT, FHWA, 1977.

14. Federal Highway Administration, "Highway Maintenance Research Needs: Report of a workshop held Oct. 8-10, 1974," Report No. FHWA-RD-75-511, March 1975, 152 pp.

15. Federal Highway Administration, "Unit Costs and Productivity Standards for Various Highway and Bridge Maintenance Activities." U.S. DOT, FHWA, June 1977.

16. Federal Highway Administration and Federal Energy Administration, "Effectiveness of Highway Arterial Lighting." Report No. FHWA-RD-77-37 and FHWA-RD-77-38, July 1977.

17. Grietzer, M.S., "Role of and need for Maintenance Feedback," TRR No. 613, 1976.

18. Haas, Ralph and R.W. Hudson, "Pavement Management System," McGraw Hill Book Co., 1978.

19. Keefe, R.A., "Proposed Framework for a Maintenance Management System," Public Works, Jan. 1976.

20. Mann, L. Jr., D.G. Modlin, and S. Mukhopadhyay, "Further Refinement of Louisianan Maintenance Cost Formulas," TRR No. 598, 1976, pp. 26-28.

21. McCAskill, G.A. and C.F. Crumpton, "Paint Stripe and Glass Bead Study," Study," Reports 1 and 2, State Highway Commission of Kansas, 1969.

22. McManus, P.F. and Barenberg, E.F., "Impact of Subgrade Variability on Pavement Construction-Maintenance Cost Trade-offs." TRB Special Report No. 148, 1974.

23. Oglesby, C.H., Highway Engineering. 3rd ed., John Wiley and Sons, New York, 1975.

24. Oglesby, C.H., "Dilemmas in the Administration, Planning, Designing, construction, and Maintenance of Low-Volume Roads," TRB Special Report No. 160, 1976.

25. Ohio Dept. of Highways. "A Study of Highway Maintenance Quality Levels in Ohio." Byrd, Tallamy, and McDonald.

26. Oliver, D.C., "Legal Liability and Highway Design and Maintenance," ASCE Journal of Transp. Engr. Proc., Vol. 101, TE3, Aug. 1975, pp. 425-435.

27. Pigman, J.G., et al., "Optimal Highway Safety Improvement Investments by Dynamic Programming." TRR No. 585, 1976.

28. Records, W.N., "An Overview of the Highway Maintenance Management Research Program in the United States." HRB Special Report No. 100, 1968.

29. Roy Jorgensen Assciates, Inc., "Arizona Highway Maintenance Management Research and Development Project," Prepared for FHWA, June 1972.

30. Sabey, Barbara, "Accidents: Their Cost and Relation to Surface Characteristics." Symposium of Safety and Concrete Roads Surface-design, Specification and Construction, Cement and Concrete Association, Warwickshire County Cricket Club, Birmingham, Nov. 1973.

31. Sheer, H.O., "An Approach to Performance Rating." Transportation Research Board, HRR No. 241, 1967.

32. Shofner, G.N., "Cost Effectiveness Maintenance-Management Systems." ASCE Journal of Transp. Engr., Proc. Vol. 102, No. TE2, May 1976, pp. 331-346.

33. Smith, T.G. and Oppenlander, J.C., "Economic Model for the Maintenance of Traffic Signals." Transportation Research Bord, HRR No. 254, 1967.

34. Transportation Research Board, "Liability of State and Local Governments for Snow and Ice Control." NCHRP Digest No. 83, Feb. 1976.

35. Transportation Research Board, "Interstate Highway Maintenance Requirements and Unit Maintenance Expenditure Index." NCHRP Report No. 42, 1967.

36. Transportation Research Board, "Motorists' Needs and Services on Interstate Highways." NCHRP Report No. 64, 1969.

37. Transportation Research Board, "Effects of Deicing Salts on Water Quality and Biota." NCHRP Report No. 91, 1970.

38. Transportation Research Board," Procedures for Esitmating Highway User Costs, Air Pollution, and Noise Effects." NCHRP Report No. 133, 1972.

39. Transportation Research Board, "Recording and Reporting Methods for Highway Maintenance Expenditures," NCHRP Synthesis of Highway Practice, Nov. 1976.

40. Transportation Research Board, "Maintenance Management." Special Report 100, 1968.

41. Transportatin Research Board, "Progress Report on Maintenance and Operations Personnel," Transportation Research Circular No. 188, Jan. 1978.





42. Transportation Research Board, "Maintenance Management, The Federal Role, Unionization, Pavement Maintenance, and Ice Control," TRR No. 598, 1976.

43. Turner, O.D., "Management by Objectives Program of the Florida Department of Transportation." Transportation Research Board, TRR No. 585, TRB, 1976.

44. Webster, J.T., "The Value of Vehicle Time." State of California, Business and Transportation Agency, DOT, Div. of Highways, Nov. 1974.

45. Winfrey, R., Economic Analysis for Highways. International Textbook Co. (1969).

46. Winfrey, R. and Others, "Economics of the Maximum Limits of Motor Vehicle Dimensions and Weights," Vols. I and II, Report No. FHWA-RD-73-69, FHWA Final Report, Sept. 1968.

# APPENDIX C

## DEMONSTRATION OF THE METHOD IN LOUISIANA AND PENNSYLVANIA

### INTRODUCTION

The methodology for selecting optimum levels-of-service was demonstrated in two states, Louisiana and Pennsylvania, for two maintenance problems—edge of traveled-way drop-off, and control of roadside vegetation. The procedure used to demonstrate the methodology followed the steps that were described in the User Manual (Appendix A). A schematic representation of the procedure is shown in Figure C-1. This appendix describes the implementation of the six steps in Louisiana and Pennsylvania.

A major portion of the input data for the computer program was obtained during a 5-day visit to each state. A typical schedule for such a visit is presented in Table C-1. The participants of meetings in the two states are presented in Table C-2.

### STEP 1. STRUCTURE THE PROBLEM

This step involves the preparation of two lists:

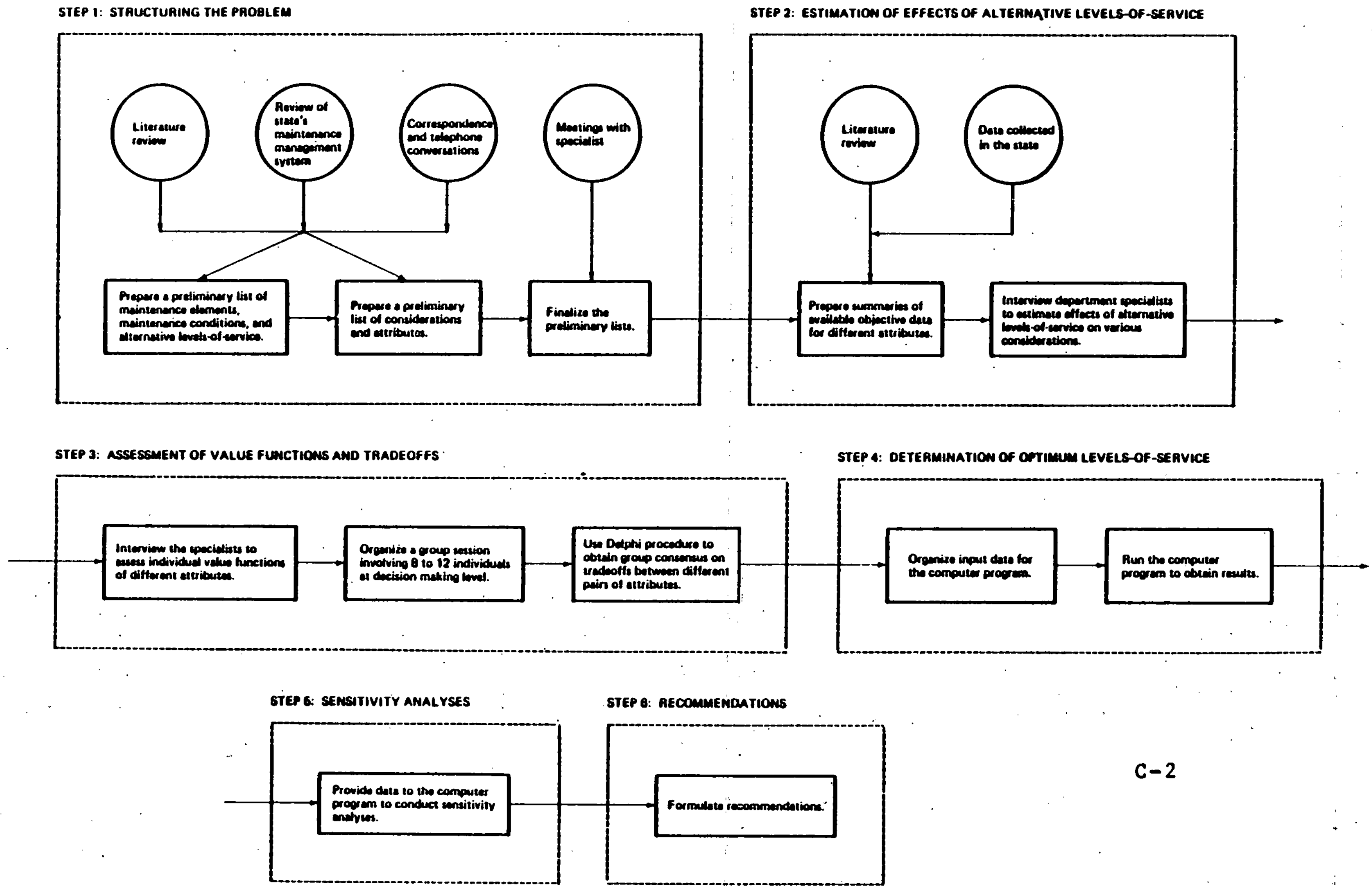
(1) a list of maintenance elements, maintenance conditions, and alternative levels-of-service

(2) a list of considerations and attributes.



Table C-1. A TYPICAL SCHEDULE FOR THE STATE VISITS

| Time | Activity |
|---|---|
| Morning (1 hour) of first day | Meeting with state maintenance engineer and his staff; orientation and preparation for scheduled meetings |
| Morning and afternoon of first day | Meeting with roadside vegetation maintenance specialists |
| Morning and afternoon of second day | Meeting with specialists with regard to edge of traveled-way drop-off |
| Morning and afternoon of third day | Group session with 6 to 12 participants at decision-making level; use of Delphi procedure to assess consensus value tradeoffs |
| Morning of fourth day | Continuation of group session |
| Afternoon of fourth day | Meeting with maintenance department staff; review procedures for estimatting resource requirements |
| Morning of fifth day | Meeting with state maintenance engineer; review and summarize the activities of the week |




C-2

**Figure C-1. PROCEDURE USE FOR DEMONSTRATION OF THE METHODOLOGY**

Table C-2. PARTICIPANTS IN VARIOUS MEETINGS IN LOUISIANA AND PENNSYLVANIA*

| Type of Meeting | Participants: Louisiana | Participants: Pennsylvania |
|---|---|---|
| Meeting with specialists regarding edge of traveled-way drop-off | Road maintenance engineer and assistant road maintenance engineer | Chief of research and studies division, and traffic safety engineers (2) |
| Meeting with specialists regarding vegetation maintenance | Road maintenance engineer and roadside development supervisor | Chief of research and studies division, chief of roadside division, and supervisor of roadside |
| Group session for the assessment of tradeoffs using a Delphi procedure | Road maintenance engineer, assistant road maintenance engineers (2), roadside development supervisor, district maintenance engineers (3), and assistant district maintenance engineer | Director of maintenance, division maintenance engineer, chief of research and studies division, chief of roadside division, district maintenance engineer, assistant district maintenance engineers (3), and county superintendents (3) |

*Co-principal investigators of the project conducted all the meetings.



The preliminary lists that were prepared were based on information from literature surveys, review of the state's maintenance management system, and correspondence and telephone conversations with the state maintenance engineer and staff members. These preliminary lists were finalized during meetings with department specialists. The final lists used in demonstration of the methodology are presented in Tables C-3 and C-4 (Louisiana) and Tables C-5 and C-6 (Pennsylvania). A brief description of the various attributes used in the two states is given below.

## ATTRIBUTES USED IN LOUISIANA

### Percentage of Drivers Who Cannot Recover

The concern here is about drivers who accidentally drive over the edge of the traveled-way and, because of a drop-off at the edge, cannot recover in a normal manner. The failure of a driver to recover does not necessarily result in an accident. The occurrence of an accident would depend on several other factors such as volume of traffic, reaction of other drivers, and encroachment of the non-recovering vehicle on other traffic lanes. However, non-recovery of the driver does represent a potential for an accident and can be used as proxy attribute for safety.

### Percent Increase in Pavement Rehabilitation Cost

This is an attribute of preservation of investment in the pavement. Because shoulders provide lateral support to the pavement, a

Table C-3. ALTERNATIVE LEVELS-OF-SERVICE FOR MAINTENANCE CONDITIONS OF GIVEN MAINTENANCE ELEMENTS IN LOUISIANA

| Maintenance Element | Maintenance Conditions | Alternative Levels-of-Service |
|---|---|---|
| Shoulders | 1. Edge of traveled-way drop-off | 1. Repair when drop-off is 1-inch.<br>2. Repair when drop-off is 2 inches.<br>3. Repair when drop-off is 3 inches.<br>4. Repair when drop-off is 4 inches.<br>5. Repair when drop-off is 5 inches. |
| Roadside Vegetation | 2. Vegetation growth | 1. Mow 500,000 acres and spray 150,000 acres annually. (Mow full right-of-way before grass reaches 8 inches.)<br>2. Mow 300,000 acres and spray 120,000 acres annually. (Urban area: mow full width before grass reaches 8 inches. Rural area: mow 30 feet from edge of traveled surface after grass exceeds 12 inches.)<br>3. Mow 200,000 acres and spray 60,000 acres annually. (Urban area: mow full width after grass exceeds 18 inches. Rural area: mow one machine pass after the grass exceeds 18 inches.)<br>4. Mow 150,000 acres and spray 60,000 acres annually. (Mow for safety only.) |



Table C-4. CONSIDERATIONS, ATTRIBUTES, AND MAINTENANCE CONDITIONS AFFECTING EACH ATTRIBUTE IN LOUISIANA

| Maintenance Element | Considerations | Attributes | Maintenance Conditions Affecting the Attribute |
|---|---|---|---|
| Shoulders | Safety | 1. Percentage of drivers who cannot recover | Edge of traveled-way drop-off |
| | Protection of investment | 2. Percent increase in pavement rehabilitation cost | Edge of traveled-way drop-off |
| Roadside Vegetation | Aesthetics | 3. Index of pleasing appearance | Vegetation growth |
| | Ecology | 4. Index of environmental pollution | Vegetation growth |

Table C-5. ALTERNATIVE LEVELS-OF-SERVICE FOR MAINTENANCE CONDITIONS OF GIVEN MAINTENANCE ELEMENTS IN PENNSYLVANIA

| Maintenance Element | Maintenance Conditions | Alternative Levels-Of-Service |
|---|---|---|
| Shoulders | 1. Edge of traveled-way | 1. All roads: repair when drop-off is 1-inch.<br><br>2. Interstate and Limited Access Highways<br>MFC* - A&B roads: repair when drop-off is 1-inch.<br>Non-interstate or Limited Access Highways<br>MFC - C,D,&E roads: repair when drop-off is 2 inches.<br><br>3. MFC - A,B,&C roads: repair when drop-off is 2 inches.<br>MFC - D&E roads: repair when drop-off is 3 inches.<br><br>4. MFC - A,B,&C roads: repair when drop-off is 3 inches.<br>MFC - D&E roads: repair when drop-off is 4 inches. |
| Roadside Vegetation | 2. Grass Growth | 1. MFC-A&B roads<br>(a) Urban areas: Mow when grass height reaches 6 inches to the full limits of mowable grass areas. Mow about four times a year.<br>(b) Rural areas: Mow when grass height reaches 8 inches to the ditch line. Mow about four times a year.<br><br>MFC-C,D&E roads<br>(a) Urban areas: Mow when grass height reaches 12 inches to the ditch line. Mow about three times a year.<br>(b) Rural areas: Mow when grass height reaches 18 inches to the ditch line or one mower swath from edge of paved roadway. Mow about twice a year.<br><br>2. MFC A & B roads<br>(a) Urban areas: Mow when grass height reaches 12 inches to the ditch line or maximum width of 15 feet. Mow three times a year.<br>(b) Rural areas: Mow when grass height reaches 18 inches to the ditch line or maximum width of 15 feet. Mow twice a year.<br><br>MFC-C, D & E roads<br>(a) Urban areas: Mow when grass height reaches 18 inches to the ditch line or one mower swath from edge of shoulder. Mow twice a year.<br>(b) Rural areas: Mow when grass height reaches 24 inches or constitutes a visual hazard. Mow only at critical areas. Mow once a year.<br><br>3. MFC-A & B roads<br>(a) Urban areas: Mow when grass height reaches 18 inches to ditch line or maximum width of 15 feet. Mow twice a year.<br>(b) Rural areas: Mow when grass height reaches 24 inches to ditch line or one mower swath. Mow once a year. |

*MFC stands for Maintenance Functional Code which denotes relative importance of different roads. MFC ranges from A (most important) to E (least important).

Table C-5. LEVELS-OF-SERVICE FOR MAINTENANCE CONDITIONS OF GIVEN MAINTENANCE ELEMENTS (Continued)

| Maintenance Element | Maintenance Conditions | Alternative Levels-Of-Service |
|---|---|---|
| | | MFC-C, D, & E roads<br>(a) Urban areas: Mow only for adequate sight distance.<br>(b) Rural areas: Mow only for adequate sight distance. |
| | 3. Weed Growth | 1. MFC-A & B roads: Apply herbicides three times a year.<br>(a) Non-Selective - once a year<br>(b) Selective - twice a year.<br>MFC-C, D, & E roads: Apply herbicides twice a year.<br>(a) Non-Selective - once a year<br>(b) Selective - once a year |
| | | 2. MFC-A & B roads: Apply herbicides twice a year.<br>(a) Non-Selective - once a year<br>(b) Selective - once a year<br>MFC-C, D, & E roads: Apply selective and non-selective herbicides as required at problem areas on a 2-year cycle. |
| | | 3. MFC-A & B roads: Apply non-selective and selective herbicides on a 2-year cycle.<br>MFC-C, D & E roads: Apply selective herbicide as required at problem areas on a 2-year cycle. |
| | | 4. MFC-A & B roads: Apply herbicides as required at problem areas on a 2-year cycle. |
| | 4. Brush and Tree Growth | 1. All roads: Control brush and tree on a 4-year cycle |
| | | 2. All roads: Control brush and tree on a 15-year cycle. |
| | | 3. All roads: Remove brush and tree only to maintain proper clearances. |

Table C-6. CONSIDERATIONS, ATTRIBUTES, AND MAINTENANCE CONDITIONS AFFECTING EACH ATTRIBUTE IN PENNSYLVANIA

| Maintenance Element | Considerations | Attributes | Maintenance Conditions Affecting an Attribute |
|---|---|---|---|
| Shoulders | Safety | 1. Probability of recovery | Edge of traveled-way drop-off |
| | Protection of Investment | 2. Percent increase in pavement rehabilitation cost | Edge of traveled-way drop-off |
| Roadside Vegetation | Aesthetics | 3. Index of pleasing appearances | Grass growth, weed growth |
| | Ecology | 4. Index of environmental pollution | Grass growth, weed growth |
| | Safety | 5. Percent reduction in number of auto-animal collisions | Grass growth, brush and tree growth |
| | Safety | 6. Percent reduction in number of days of ice and snow on road | Brush and tree growth |



high amount of drop-off at the edge of the traveled-way results in a loss of lateral support. This may produce cracking, rutting, and/or potholes along the edge of the pavement. These defects may not be serious enough to warrant pavement rehabilitation earlier than scheduled; however, when rehabilitation does take place, certain preparatory work would be necessary to correct the defects before an overlay could be put on the pavement.

A reasonable assumption is that the higher the amount of allowable drop-off, the higher would be the cost of preparation before pavement rehabilitation. It is assumed that the highest level-of-service (i.e., shoulder repair when drop-off reaches 1-inch) does not incur these preparation costs. Increase in preparation cost per lane-mile is computed as a function of amount of allowable drop-off and expressed as a percentage of typical rehabilitation cost per lane-mile assuming a 4-inch overlay.

Index of Pleasing Appearance

This attribute is a measure of the aesthetics (pleasing views) of roadside vegetation. The index of pleasing appearance is a 4-point scale on which each point is associated with one of the four alternative levels-of-service for vegetation growth shown in Table C-3. The higher levels-of-service in Table C-3 specify more work quantities for mowing and spraying and consequently can be assumed to provide more pleasing appearances.

## Index of Environmental Pollution

This attribute measures the adverse effects of herbicide spraying on the environment. It is possible, though very unlikely, that some of the chemicals used in spraying reach bodies of water and affect the fish and cows that drink the water. Alternatively, berries on roadside bushes may be sprayed, posing a potential hazard to individuals (particularly children) who may eat the berries.

The potential for such pollution would increase as the number of acres sprayed with herbicides increased. Again, the index of environmental pollution is a 4-point scale corresponding to the four alternative levels-of-service for vegetation growth in Table C-3.

## ATTRIBUTES USED IN PENNSYLVANIA

In addition to those attributes used in Louisiana, two attributes were relevant in Pennsylvania — percent reduction in number of auto-animal collisions and percent reduction in number of days of ice and snow on roads. In addition, the attributes of safety and environmental pollution were also defined differently in Pennsylvania. These attributes are described below.

### Percent Reduction in Number of Auto-Animal Collisions

Animals such as deer and rabbits may be attracted to the potential food sources found in roadside vegetation. Some of the animals may venture out on the traveled-way. In trying to avoid an animal on the road,





particularly a large one (e.g., a deer), a driver may suddenly change the course of the vehicle and cause an accident.

### Percent Reduction in Number of Days of Ice and Snow on Roads

Branches of trees overhanging roads may prevent sunshine from reaching pavement surfaces. This may prolong icy conditions on roads during the winter season. Proper brush and tree control promotes "daylighting," i.e., allows sun to shine on pavement surfaces and reduces the number of days of ice and snow on roads.

### Probability of Recovery

This attribute considers the safety aspect of accidentally driving over the edge of traveled-way drop-off. The specialists and the Delphi group participants related better to "probability of normal recovery of a motorist" than to "percentage of drivers who cannot recover" used in Louisiana.

### Index of Environmental Pollution

The concern here was primarily about uncontrolled growth of undesirable weeds. Such weeds would pose a threat to the growth of desirable species of vegetation. Some of the weeds might also be hazardous to the health of people and animals.

STEP 2. ESTIMATE EFFECTS OF ALTERNATIVE LEVELS-OF-SERVICE ON VARIOUS CONSIDERATIONS

The effect of alternative levels-of-service on a given consideration (e.g., protection of investment) was estimated in terms of the attribute of the consideration (e.g., percent change in cost of pavement rehabilitation). Meetings with department specialists were arranged to review available objective data. The effects were estimated by the specialists based on both available data and subjective opinions. The estimation of effects for the various attributes in the two states is described below.

ESTIMATION OF EFFECTS IN LOUISIANA

Percentage of Drivers Who Cannot Recover

Three specific sources of information that relate edge of traveled-way drop-off to safety were reviewed with the two specialists who participated in the meetings in Louisiana. These sources were the following:

1. DOT/FHWA report, "Evaluation of Highway Safety Program Standards." (1)
2. California DOT investigation, "The Effect of Longitudinal Edge of Paved Surface Drop-Off on Vehicle Stability." (2)
3. Klein, Johnson, and Szostak investigation, "Influence of Roadway Disturbances on Vehicle Handling." (3)



These reports provided useful information regarding the effects of various amounts of drop-off on a driver's ability to recover safely. However, these studies have limitations that must be considered. The experiments were conducted under controlled conditions so that the drivers participating in the tests would not be harmed. Factors such as adverse weather, traffic conditions, and driver inexperience or unpreparedness could not be included.

Because of these limitations, the results of the studies could not be directly used to estimate the percentage of drivers who would not be able to recover normally after driving over different amounts of edge of traveled-way drop-off. One use of the studies might be to indicate limiting amounts of drop-off under ideal driving conditions.

Accident reports prepared by the highway patrol and compiled by the traffic safety division usually have information regarding causes of accidents; however, this information is very general and does not include specifics such as whether the edge of traveled-way drop-off was a primary cause of an accident and if it was, what the amount of the drop-off was.

Because of the limited data, the specialists were asked to extrapolate the available information to real-world situations, based on their experience and judgment. To assist the specialists in their assessments, slides of roads with different amounts of drop-off at the edge of traveled-way were shown. Some of the slides also displayed

the relative rotation of a vehicle with one side over the edge of traveled-way drop-off.

Assessment of the percentage of drivers who cannot recover for given amounts of edge of traveled-way drop-off was done in two steps:

1. What percentage of drivers would encounter the drop-off problem (i.e., accidentally drive over the edge of the traveled-way)?
2. Of the drivers who encounter the problem, what percentage would not be able to recover normally?

Breaking down the overall assessment into two parts seemed to help the specialists estimate the required numbers. The results of the assessments are presented in Table C-7.

There could be some question about the accuracy of the numbers in Table C-7. However, for the evaluation of alternative levels-of-service, relative magnitudes -- rather than the absolute numbers -- were more important. The relative magnitudes of the numbers appeared reasonable.

<u>Percent Increase in Pavement Rehabilitation Cost</u>

As explained earlier, high amounts of allowable drop-off at the edge of the traveled-way may require preparatory work on the edge of the pavement at the time an overlay is applied. No quantitative information was found to indicate the influence of edge of traveled-way drop-off on the change in pavement rehabilitation costs. Therefore,





Table C-7. EFFECTS OF ALTERNATIVE LEVELS-OF-SERVICE OF EDGE OF TRAVELED-WAY DROP-OFF ON PERCENTAGE OF DRIVERS WHO CANNOT RECOVER IN LOUISIANA

| Threshold Amount of Edge of Traveled-Way Drop-Off | Percentage of Drivers Who Drive Over the Edge of Traveled-Way | Percentage of Drivers Who Cannot Recover if They Drive Over the Edge of Traveled-Way | Percentage of Drivers Who Cannot Recover |
|---|---|---|---|
| | (a) | (b) | (c = ab/100) |
| 1-inch | 15 | 0.01 | 0.0015 |
| 2 inches | 14 | 0.5 | 0.07 |
| 3 inches | 13 | 15 | 1.95 |
| 4 inches | 12 | 55 | 6.60 |
| 5 inches | 10 | 90 | 9.0 |

Table C-8. EFFECTS OF ALTERNATIVE LEVELS-OF-SERVICE OF EDGE OF TRAVELED-WAY DROP-OFF ON PERCENT INCREASE IN PAVEMENT REHABILITATION COST IN LOUISIANA

| Threshold Amount of Edge of Traveled-Way Drop-Off | Percent Change in Pavement Rehabilitation Cost |
|---|---|
| 1-inch | 0 |
| 2 inches | 1 |
| 3 inches | 5 |
| 4 inches | 12 |
| 5 inches | 15 |

the specialists had to rely on their experience and judgment to estimate the amount of additional pavement work required prior to an overlay as a function of the amount of edge of traveled-way drop-off. Once the amounts of additional work are estimated, typical unit costs in the state can be used to calculate the percent change in pavement rehabilitation. The base cost was assumed to be that of a 4-inch asphalt overlay per lane-mile without any extra preparation work.

The assessment of percent change in pavement rehabilitation costs for various amounts of edge of traveled-way drop-off is presented in Table C-8.

Index of Pleasing Appearance and Environmental Pollution

As noted previously, the alternative levels-of-service for roadside vegetation define a 4-point scale for these two attributes.

## ESTIMATION OF EFFECTS IN PENNSYLVANIA

### Probability of Recovery

The department specialists believed that, for the same amount of edge of traveled-way drop-off, the probability of recovery would vary according to the class of roads. The Pennsylvania DOT has defined maintenance functional codes (MFC) of roads based on the traffic volume and type of service provided. The five MFC in order of their importance are A, B, C, D, and E. The probability of recovery for roads of each MFC was estimated for different amounts of edge of traveled-way drop-off,



and was generally considered better for more important roads because they are usually designed to better standards.

Alternative levels-of-service for edge of traveled-way drop-off (Table C-4) specified combinations of amounts of drop-off for different MFC roads. A sum of weighted probabilities of recovery was calculated for each alternative level-of-service where the weights were the proportions of roads in the state in different MFC. For example, the assessed probability of recovery was 0.98 for C roads for a drop-off of 1-inch, and 10 percent of the total roads were C; hence, the weighted probability for this drop-off and MFC was (0.98 x 0.1) = 0.098. Weighted probabilities were summed to obtain the probability of recovery on any road in the state for each alternative level-of-service. The probabilities of recovery are presented in Table C-9.

### Percent Increase in Pavement Rehabilitation Cost

The reasoning used in Pennsylvania to estimate this attribute was similar to that used in Louisiana. A higher amount of drop-off at the edge of traveled-way would cause more pavement deficiencies and require more preparatory work on the pavement itself before an overlay. It was estimated that a level-of-service of less than 1-inch drop-off would require very little additional work. Increases in pavement rehabilitation costs were estimated for other amounts of drop-off for various MFC roads. A sum of percent increase in pavement rehabilitation costs for various MFC roads weighted by proportion of roads in each MFC was

Table C-9. EFFECTS OF ALTERNATIVE LEVELS-OF-SERVICE FOR EDGE OF TRAVELED-WAY DROP-OFF ON PROBABILITY OF RECOVERY IN PENNSYLVANIA

| Alternative Level-of-Service for Edge of Traveled-Way Drop-Off | Probability of Recovery |
|---|---|
| 1 | 0.96 |
| 2 | 0.76 |
| 3 | 0.54 |
| 4 | 0.25 |

Table C-10. EFFECTS OF ALTERNATIVE LEVELS-OF-SERVICE FOR EDGE OF TRAVELED-WAY DROP-OFF ON PERCENT INCREASE IN PAVEMENT REHABILITATION COST IN PENNSYLVANIA

| Alternative Level-of Service for Edge of Traveled-Way Drop-Off | Percent Increase in Pavement Rehabilitation Cost |
|---|---|
| 1 | 0 |
| 2 | 2.84 |
| 3 | 9.1 |
| 4 | 22.8 |





calculated for each alternative level-of-service. The results are presented in Table C-10.

### Index of Pleasing Appearance

The combinations of alternative levels-of-service for grass growth and weed growth were ranked from 1 (best) to 11 (worst) from the view-point of pleasing roadside appearance. The results are presented in Table C-11.

### Index of Environmental Pollution

Table C-12 shows the ranking of various combinations of alternative levels-of-service for grass growth and weed growth from the view point of environmental pollution due to growth of undesirable weeds. The scale ranges from 1 (best) to 12 (worst).

### Percent Reduction in Number of Auto-Animal Collisions

Better control of grass and brush and tree growth on the roadside would reduce the number of animals that are attracted to the roadside and venture on the traveled-way. Table C-13 shows the estimates of percent reduction in number of auto-animal collisions in the state for different combinations of alternative levels-of-service for grass growth and brush and tree growth. Primarily large animals (e.g., deers) were considered because small animals (e.g., rabbits) on a traveled-way generally would not create an accident potential.

Table C-11. INDEX OF PLEASING APPEARANCE FOR DIFFERENT COMBINATIONS OF LEVELS-OF-SERVICE FOR GRASS GROWTH AND WEED GROWTH IN PENNSYLVANIA

| Grass Growth Level-of-Service | Weed Growth Level-of-Service | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 1 | 1 | 3 | 4 | 9 |
| 2 | 2 | 4 | 5 | 10 |
| 3 | 6 | 7 | 8 | 11 |



Table C-12. INDEX OF ENVIRONMENTAL POLLUTION FOR DIFFERENT COMBINATIONS OF LEVELS-OF-SERVICE FOR GRASS GROWTH AND WEED GROWTH

| Grass Growth Level-of-Service | Weed Growth Level-of-Service | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 1 | 1 | 4 | 7 | 10 |
| 2 | 2 | 5 | 8 | 11 |
| 3 | 3 | 6 | 9 | 12 |



Table C-13. PERCENT REDUCTION IN NUMBER OF AUTO-ANIMAL COLLISONS FOR DIFFERENT COMBINATIONS OF LEVELS-OF-SERVICE FOR GRASS GROWTH AND BRUSH AND TREE GROWTH IN PENNSYLVANIA

| Grass Growth Level-of-Service | Brush and Tree Growth Level-of-Service | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 1 | 30 | 20 | 5 |
| 2 | 23 | 13 | 3 |
| 3 | 20 | 10 | 0 |



The Pennsylvania DOT has conducted a study (4) to evaluate the effectiveness of fences to deter animals from coming to the roadside and consequently reduce the number of animals killed on the highway. This study provided useful background information in estimating the reduction in the number of auto-animal collisions.

Percent Reduction in Number of Days of Ice and Snow on Roads

An average number of storms that deposit ice and snow on roads was estimated for those parts of the state susceptible to cold weather. This information was used to estimate the number of days of ice and snow on a road assuming worst "daylighting" conditions, i.e., very little control of brush and tree growth (level-of-service = 3).

Considering this to be the base case, percent reduction in the number of days of ice and snow on a road was estimated for the other two levels-of-service for brush and tree maintenance. The results are presented in Table C-14.

STEP 3. ASSESS INDIVIDUAL VALUE FUNCTIONS AND TRADEOFFS

Two tasks were involved in the completion of this step.

1. Assessing individual value functions of different attributes. The objective of this task was to assess relative values of different levels of each attribute. The assessments were made during meetings with specialists regarding edge of traveled-way drop-off and roadside vegetation control.

Table C-14. EFFECTS OF ALTERNATIVE LEVELS-OF-SERVICE FOR BRUSH AND TREE GROWTH ON PERCENT REDUCTION IN NUMBER OF DAYS OF ICE AND SNOW ON ROADS IN PENNSYLVANIA

| Brush and Tree Growth Level-of-Service | Percent Reduction in Number of Days of Ice and Snow on Roads |
|---|---|
| 1 | 12.5 |
| 2 | 3 |
| 3 | 0 |





2. <u>Assessing value tradeoffs between different attributes.</u> The value tradeoffs were assessed during a group session using a Delphi procedure.

Since the same procedures were used in both states, the assessments are described in detail for Louisiana only; for Pennsylvania, only a summary of the results is given.

ASSESSMENT OF INDIVIDUAL VALUE FUNCTIONS OF DIFFERENT ATTRIBUTES

<u>Assessment of Value Functions of Attributes Related to Edge of Traveled-Way Drop-Off in Louisiana</u>

The attributes related to edge of traveled-way drop-off were: (1) percentage of drivers who cannot recover, and (2) increase in pavement rehabilitation costs. The technique of assessing a midvalue point of a value function described in the user manual (Appendix A) was used. This involved selecting a range for an attribute that contained the highest and lowest assessed levels of the attribute and asking the assessor to select a level of the attribute which divided the range into two equal value parts.

To illustrate the procedure that was used, consider the attribute $\theta_1$ = percentage of drivers who cannot recover. A range of 0 to 10 was selected for $\theta_1$ based on the assessed levels of $\theta_1$ shown in Table C-7. Different levels of $\theta_1$ were successively proposed to the specialist. The specialist was asked to examine a given level of $\theta_1$ and judge whether

that level divided the total range of $\theta_1$ into two parts, each having the same value. An attempt was made to approach it from both ends. A level of $\theta_1=1$ was first suggested. The specialist was asked: "Which is better -- decreasing the percentage of drivers who cannot recover from 10 to 1 or decreasing it from 1 to 0?" The specialist indicated that decreasing the attribute from 10 to 1 was better. Next, $\theta_1 = 9$ was proposed. The question was asked: "Which is better -- decreasing percentage of drivers who cannot recover from 10 to 9 or decreasing it from 9 to 0?" The specialist considered it better to decrease the attribute from 9 to 0. By systematically varying the proposed levels of the attribute, $\theta_1 = 5$ was arrived at as the midvalue point. Since $\theta_1 = 5$ is the average of the end points of $\theta_1$ a linear value function was indicated. This implied that a change of the same magnitude in the attribute anywhere in its range had the same value. For example, decreasing the percentage of drivers who cannot recover from 10 to 9 was as valuable as decreasing it from 2 to 1. This implication seemed reasonable to the specialist.

Assessment of Value Functions of Attributes Related to Roadside Vegetation Growth in Louisiana

The attributes related to roadside vegetation growth were: (1) index of pleasing appearance, and (2) index of environmental pollution. The alternative levels-of-service for the maintenance of roadside vegetation defined a 4-point discrete scale for each of the two attributes. The procedure of assessing a midvalue point was not practical in the case



of these attributes because it was possible that none of the points on the discrete scale would provide a midvalue point. An alternative procedure was used, based on the concept of willingness-to-pay.

To illustrate this procedure, consider the index of pleasing appearance. The participants were asked how much more they would be willing to pay to improve the index of pleasing appearance from its lowest level (number of acres mowed = 150,000; number of acres sprayed = 60,000) to each of the other levels. After some discussion, the response was that they would be willing to pay 50 percent more to move to Level 3 and 200 percent more to move to Level 2. With respect to Level 1, the specialists did not see much benefit in moving from Level 2 to Level 1, and were willing to pay very little to move from Level 2 to Level 1. However, other individuals in the department, particularly those at the district level, might have responded differently about moving from Level 2 to Level 1. Consequently, group consensus was sought for this question. In the group session, which is discussed in the next section, the participants indicated that they would be willing to pay about 8 percent more to move from Level 2 to Level 1.

With respect to the index of environmental pollution, the specialists were asked how much it would be worth to reduce the number of acres sprayed from 150,000 to 120,000 and 60,000? Assuming the cost of spraying 150,000 acres to be 100 units, the response of the specialists was that, from the viewpoint of reducing pollution, it would be worth 15 and 30 units, respectively, to reduce the number of acres sprayed

from 150,000 to 120,000 and 60,000. Since the fourth level (see Table C-3) involves the same number of acres sprayed as the third level, it followed that both of these levels had the same value with regard to environmental pollution.

Results of Assessment of Individual Value Functions

No additional calculations were required for the attributes for which midvalue points were assessed. The computer program is designed to accept midvalue points directly. The discrete attributes for which the willingness-to-pay approach was used required additional calculations to obtain values of various levels of an attribute. The necessary calculations are described below.

Let $V_3$ (i) be the value of $i^{th}$ level of the attribute "index of pleasing appearance" denoted by $\theta_3$. The assessments of how much one would be willing to pay to move from one level of the attribute to another yielded the following relative values:

$$V_3(3) = 1.5\ V_3(4)$$

$$V_3(2) = 3\ V_3(4)$$

$$V_3(1) = 3.08\ V_3(4).$$

If $V_3(4)$ is set to 1, the following value is obtained:

$$V_3(3) = 1.5,\ V_3(2) = 3,\ V_3(1) = 3.08.$$

Since the end points of a value function were assumed to be 0 and 1, a linear transformation of the above numbers was made by subtracting





the minimum value (i.e., 1) from each number and dividing by the range (i.e., 3.08-1). The following values were then obtained:

$$V_3(1) = 1,\ V_3(4) = 0$$

$$V_3(2) = \frac{3-1}{3.08-1} = 0.96$$

and $$V_3(3) = \frac{1.5-1}{3.08-1} = 0.24.$$

Similar calculations were made for the index of environmental pollution.

The results of assessment of individual value functions are summarized in Table C-15 (Louisiana) and Table C-16 (Pennsylvania).

ASSESSMENT OF VALUE TRADEOFFS BETWEEN DIFFERENT ATTRIBUTES IN LOUISIANA

The value tradeoffs were assessed in a group session using a Delphi procedure. Appendix D provides a detailed description of the Delphi procedure and its implementation for the assessment of value tradeoffs. The following steps were involved in completion of the Delphi procedure:

1. Arrangements for group session
2. Presentation of the background of the project and the Delphi procedure
3. Description of attributes required to obtain group responses
4. Description of assessment forms
5. Filling in assessment forms
6. First iteration results

C-34

Table C-15. ASSESSMENT OF VALUE FUNCTIONS OF VARIOUS ATTRIBUTES IN LOUISIANA

| Attribute | Best Level | Worst Level | Midvalue Point for a Continuous Attribute | Values of Intermediate Levels for a Discrete Attribute |
|---|---|---|---|---|
| 1. Percentage of drivers who cannot recover | 0 | 10 | 5 | — |
| 2. Percent increase in pavement rehabilitation cost | 0 | 35 | 17.5 | -- |
| 3. Index of pleasing appearance | 1 | 4 | -- | Value of Level 2 = 0.96<br>Value of Level 3 = 0.24 |
| 4. Index of environmental pollution | 4 | 1 | -- | Value of Level 2 = 0.5<br>Value of Level 3 = 1.0 |

Table C-16. ASSESSMENT OF VALUE FUNCTIONS OF VARIOUS ATTRIBUTES IN PENNSYLVANIA

| Attribute | Range of the Attribute in the Value Function | Midvalue Point |
|---|---|---|
| 1. Probability of recovery | 0.2 to 1.0 | 0.55 |
| 2. Percent increase in pavement rehabilitation cost | 0 to 30 | 15 |
| 3. Index of pleasing appearance | 1 to 11 | 6.5 |
| 4. Index of environmental pollution | 1 to 12 | 6.5 |
| 5. Percent reduction in number of auto-animal collisions | 0 to 30 | 12 |
| 6. Percent reduction in number of days of ice and snow on road | 0 to 12.5 | 4.5 |

7. Statistical feedback and second iteration results.

The details of each step are described below.

Arrangements for Group Session

The group sessions were organized in a conference room that was equipped with a blackboard, and overhead and slide projectors.

Presentation of the Project Background and the Delphi Procedure

A presentation was made about the general background of the project. The primary objective of the project was to develop and demonstrate a methodology for selecting maintenance levels-of-service. The purpose of the state visit was to demonstrate how the methodology could be used in Louisiana to select maintenance levels-of-service for two specific maintenance problems -- edge of traveled-way drop-off and roadside vegetation.

It was explained that the evaluation of alternative maintenance levels-of-service requires value judgments of a policy maker(s) regarding the relative desirability or undesirability of various consequences of alternative levels-of-service. Because value judgments are subjective, it is desirable to obtain a group consensus about these judgments rather than rely on individual opinions. One technique used to obtain group consensus is the Delphi procedure, which was used for the group sessions. A brief background of the Delphi procedure was presented to the participants.





Description of Attributes Required to Obtain Group Responses

The attributes that were selected with the agency specialists were described to the group participants. These attributes were:

- Percentage of drivers who cannot recover
- Percent increase in pavement rehabilitation cost
- Index of pleasing appearance
- Index of environmental pollution.

A summary of the discussions with the specialists on these attributes was presented. Visual aids, such as viewgraphs and slides of edge of traveled-way drop-off and roadside vegetation under different maintenance levels-of-service were used in this presentation.

Description of Assessment Forms

Three assessment forms were used to obtain responses from the group participants. These were:

- Form A: assessment of tradeoff between percentage of drivers who cannot recover and index of pleasing appearance
- Form B: assessment of tradeoff between percent increase in pavement rehabilitation cost and index of pleasing appearance
- Form C: assessment of tradeoff between percentage of drivers who cannot recover and index of environmental pollution.

Figure C-2 shows a typical tradeoff assessment form used in Louisiana.

TRADEOFF ASSESSMENT USING DELPHI PROCEDURE

FORM A

Date: ____________________

Iteration Number: ____________________

You have the choice between the following options:

| | Percentage of Drivers Who Will Encounter Drop-off and Not Recover | Acres Mowed | Acres Sprayed | Index of Pleasing Appearances: Urban | Index of Pleasing Appearances: Rural |
|---|---|---|---|---|---|
| Option A | 10 | 300,000 | 120,000 | Mow when 8"-Full width | Mow when 12"-30' width |
| Option B | X | 150,000 | 80,000 | Mow only for safety | |

At what level of X, would you be indifferent beween the two options?

X = ____________________

Figure C-2. A TYPICAL FORMAT USED IN LOUISIANA FOR A TRADEOFF ASSESSMENT FORM



Filling in Assessment Forms. Copies of the first assessment form (Form A) were distributed to the group participants. The purpose of the form was explained and a hypothetical assessment was made by one of the research investigators to illustrate the types of considerations pertinent to responding to the questions on the form.

It was pointed out that to be consistent with one's preferences, the responses should follow certain trends. These trends were explained and are discussed below. The participants were then asked to consider each question, formulate their responses, and record them in the appropriate spaces on the form. The participants were encouraged to ask questions if they did not understand parts of the form or were not sure about the response that was expected of them. The completed forms were collected and subsequently analyzed for statistical summaries. This procedure was repeated succesively for Form B and Form C.

To explain the trends expected in a tradeoff assessment, let us consider Form A. As one moves from Option A to Option B, there is a penalty in terms of reduced pleasing appearance and a reward in terms of a reduced number of drivers who cannot recover. The response X should be such that the reward just balances the penalty.

To assess X, it is best to start with points on either end of the scale of percentage of drivers who cannot recover. For example, if X = 0 one would prefer Option B; if X = 9.5, Option A might be preferred. The idea is to successively narrow down the choice of X until a point is reached where both options are equally preferred.

For example, assume that X = 6 (for Option B) represents the indifference point. The following consistency check should be made to verify that this choice of X represents an indifference point. Increase X by a small amount, let us say to X = 7. Since the reward is now less than that in the indifference situation, Option A should be preferred. Next, reduce X by a small amount, let us say to X = 5. The reward is now more than that in the indifference situation and Option B should be preferred. If the switch in preference from Option A to Option B does not occur in the above situations, the original indifference point (X = 6) is not the correct one and a reassessment would be necessary.

The participants were asked to apply this consistency check before they finalized the response X on each form.

<u>First Iteration Results</u>

First iteration responses for each of the three forms are presented as histograms in Figures C-3 and C-4. In addition, these figures also show the number of respondents, sample mean, standard deviation, and coefficient of variation of the responses.

Identification of a group consensus is a subjective process, particularly because there is no fixed criterion for such a concept. However, two parameters are considered important for such evaluation: (1) the range of responses recorded, and (2) their spread around the mean. In cases where responses are widely scattered, the relative significance of small deviations from the mean is less than the significance of equally small deviations when the responses are closely grouped.





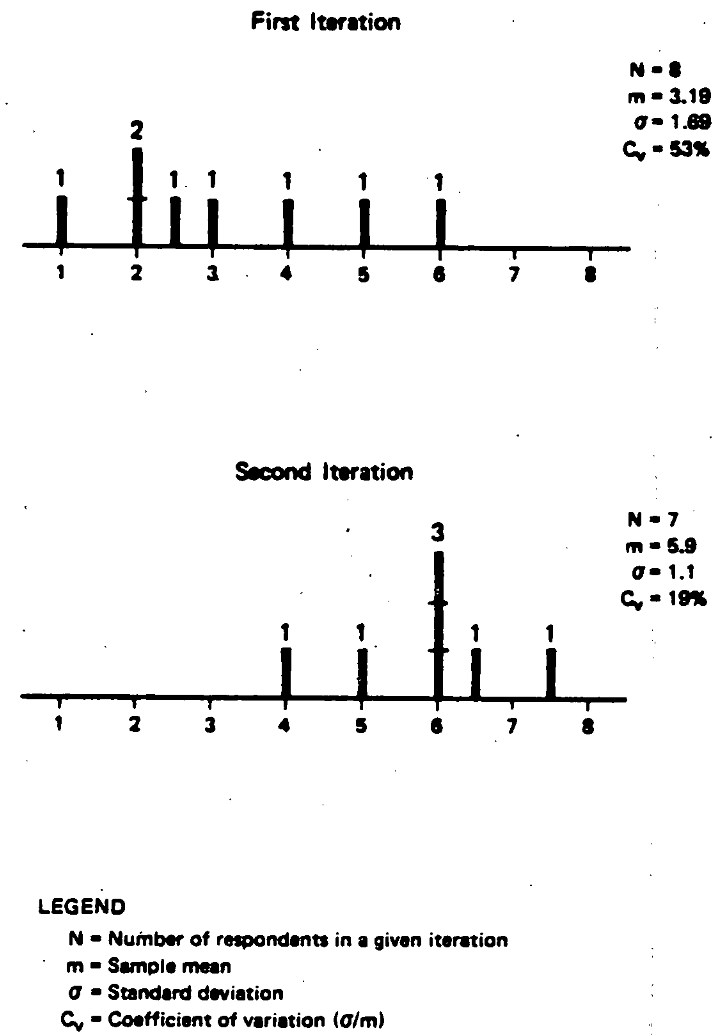
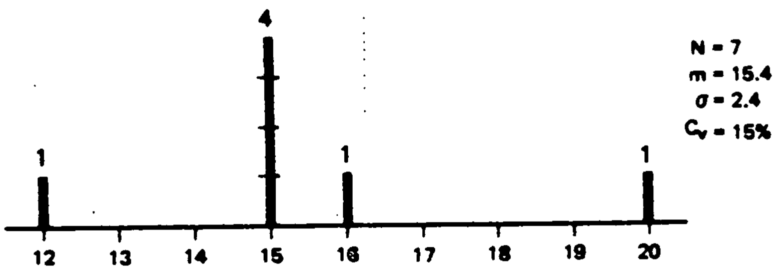


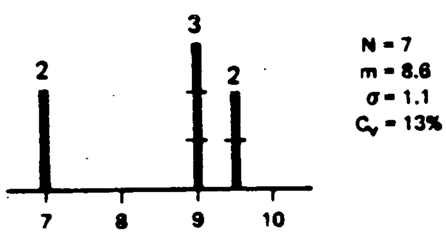

Figure C-3. FIRST AND SECOND ITERATION RESPONSES TO FORM A IN LOUISIANA

First Iteration




First Iteration Responses to Form B

First Iteration




First Iteration Responses to Form C

LEGEND

N = Number of respondents in a given iteration
m = Sample mean
σ = Standard deviation
$C_v$ = Coefficient of variation (σ/m)

**Figure C-4. FIRST ITERATION RESPONSES TO FORMS B FORMS B AND C IN LOUISIANA**



Coefficient of variation (ratio of standard deviation to the sample mean) is a good measure of the spread as well as the central tendency of the responses and can be used as a proxy to decide when reasonable group consensus is reached. Since the number of respondents was small and the range of variables relatively large, it was decided that a coefficient of variation greater than 25 percent should necessitate a second iteration.

Using the above criterion, first iteration responses to Form B and Form C are considered sufficiently close (hence, not requiring a second iteration). In these cases, the sample means can be used as a proxy for group consensus.

Statistical Feedback and Second Iteration Results

With Form A, the first iteration coefficient of variation exceeded 25 percent and a second iteration was repeated the following day. In accordance with Delphi criteria, the participants were presented with first iteration statistical feedback in the form of histograms (similar to Figure C-3) and statistical summaries of mean, standard deviation, and coefficient of variation. The implications of the extreme responses were discussed to make sure that there was no misunderstanding about the original question. Discussion among the participants was encouraged to provide an opportunity for an exchange of views and opinions.

The participants were then presented with copies of Form A and were asked to reassess their responses. The objective here was simply

to point out that there were diverse opinions on the same issue and to make sure that no significant factors had been neglected in responding to the question.

The second iteration responses to Form A are shown in Figure C-3. Clearly, group consensus converged around the mean of 5.9 and the coefficient of variation was reduced from 53 to 19 percent. A third iteration is not necessary and the mean value can be used as a proxy for group consensus.

The results of the Delphi procedure in Louisiana are summarized in Table C-17.

## ASSESSMENT OF VALUE TRADEOFFS BETWEEN DIFFERENT ATTRIBUTES IN PENNSYLVANIA

Implementation of the Delphi technique in Pennsylvania followed the same stepwise procedure that was used in Louisiana. The results of the procedure in Pennsylvania are summarized in this section.

Five assessment forms were used to obtain responses from the participants:

Form A: assessment of tradeoff between percent increase in pavement rehabilitation cost and index of pleasing appearance

Form B: assessment of tradeoff between probability of recovery and index of pleasing appearance





Table C-17. CONSENSUS VALUE TRADEOFFS BETWEEN DIFFERENT PAIRS OF ATTRIBUTES IN LOUISIANA

| | Percentage of Drivers Who Cannot Recover | | Index of Pleasing Appearances | |
|---|---|---|---|---|
| Option A | 10 | Balancing Reward | 1 | Penalty |
| Option B | 5.9 | | 4 | |
| | **Percent Increase in Pavement Rehabilitation Cost** | | **Index of Pleasing Appearance** | |
| Option A | 35 | | 1 | |
| Option B | 15.4 | | 4 | |
| | **Percentage of Drivers Who Cannot Recover** | | **Index of Environmental Pollution** | |
| Option A | 10 | | 4 | |
| Option B | 8.6 | | 1 | |

Form C: assessment of tradeoff between percent increase in pavement rehabilitation cost and index of environmental pollution

Form D: assessment of tradeoff between probability of recovery and percent reduction in number of auto-animal collisions

Form E: assessment of tradeoff between probability of recovery and percent reduction in number of days of ice and snow.

The tradeoff assessment form was improved after the experience in Louisiana and initial difficulties encountered in Pennsylvania. A typical format for the revised tradeoff assessment form is shown in Figure C-5.

The results of the first and second iterations on various forms are shown in Figures C-6 through C-10. The number of respondents, mean, standard deviation, and coefficient of variation of the responses are noted on each figure.

With Form A (Figure C-6), the second iteration responses converged rapidly around a mean of 23.9 and the coefficient of variation dropped from a first iteration of 37 percent to 14 percent. The sample mean of the second iteration was used as a proxy for group consensus.

With Form B (Figure C-7) convergence was slow and the coefficient of variation, although smaller than that in the first iteration, was still relatively high. It was not clear if a third iteration would have been useful. In the absence of such data, the second iteration



DELPHI PROCEDURE FOR TRADEOFF ASSESSMENT

FORM A

Date:________________

Iteration Number:________________

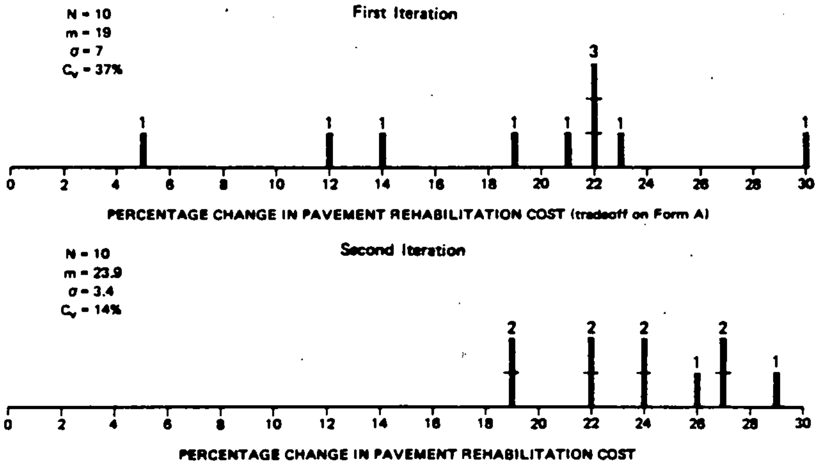
1. Assume that you start with Option A and are offered the choice of switching to one of the B options. Indicate for each B option whether you would stay with Option A or switch to Option B.

| | Percent Increase in Pavement Rehabilitation Cost | Index of Pleasing Appearance | Prefered Option |
|---|---|---|---|
| Option A | 30 | 1 | |
| Option $B_1$ | 25 | 11 | ______ |
| Option $B_2$ | 20 | 11 | ______ |
| Option $B_3$ | 10 | 11 | ______ |
| Option $B_4$ | 0 | 11 | ______ |

2. Indicate the level (X) of the percent increase in pavement rehabilitation cost at which the reward (reduced pavement rehabilitation cost) just balances the penalty (less pleasing appearance).

X = ________________

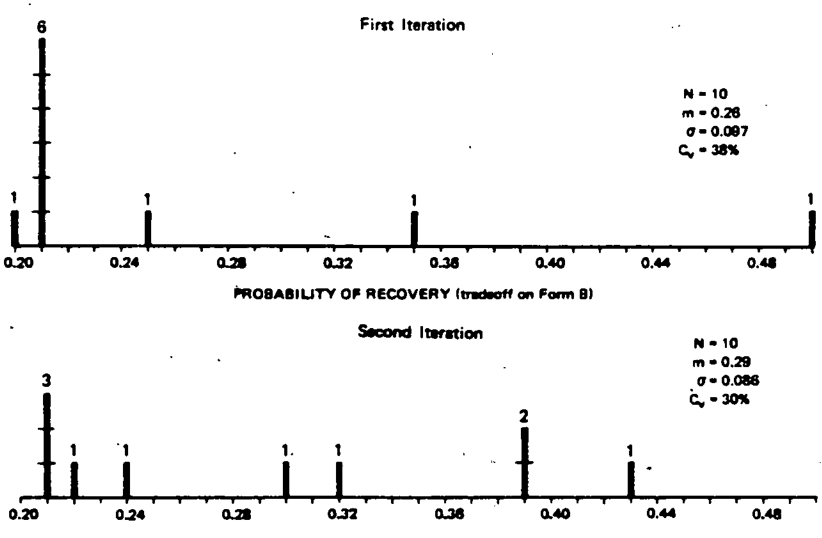
Figure C-5. TYPICAL TRADEOFF ASSESSMENT FORM USED IN PENNSYLVANIA




LEGEND
N = Number of participants in the exercise
m = Sample mean
σ = Sample standard deviation
$C_v$ = Coefficient of variation (σ/m)

Figure C-6. FIRST AND SECOND ITERATION RESPONSES TO FORM A

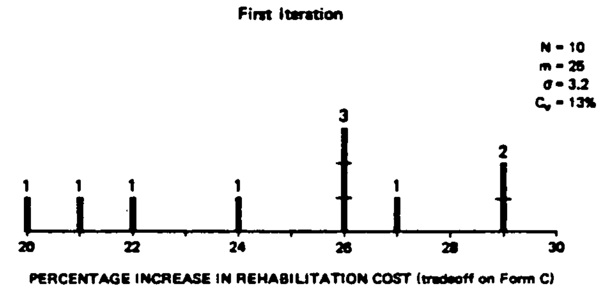
C-48




LEGEND
N = Number of participants in the exercise
m = Sample mean
σ = Sample standard deviation
$C_v$ = Coefficient of variation (σ/m)

Figure C-7. FIRST AND SECOND ITERATION RESPONSES TO FORM B

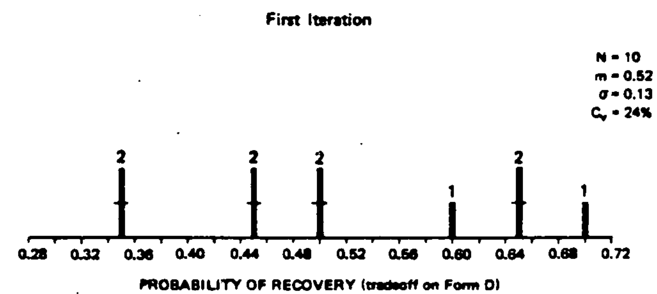
C-49




LEGEND
N = Number of participants in the exercise
m = Sample mean
σ = Sample standard deviation
$C_v$ = Coefficient of variation (σ/m)

Figure C-8. FIRST ITERATION RESPONSES TO FORM C

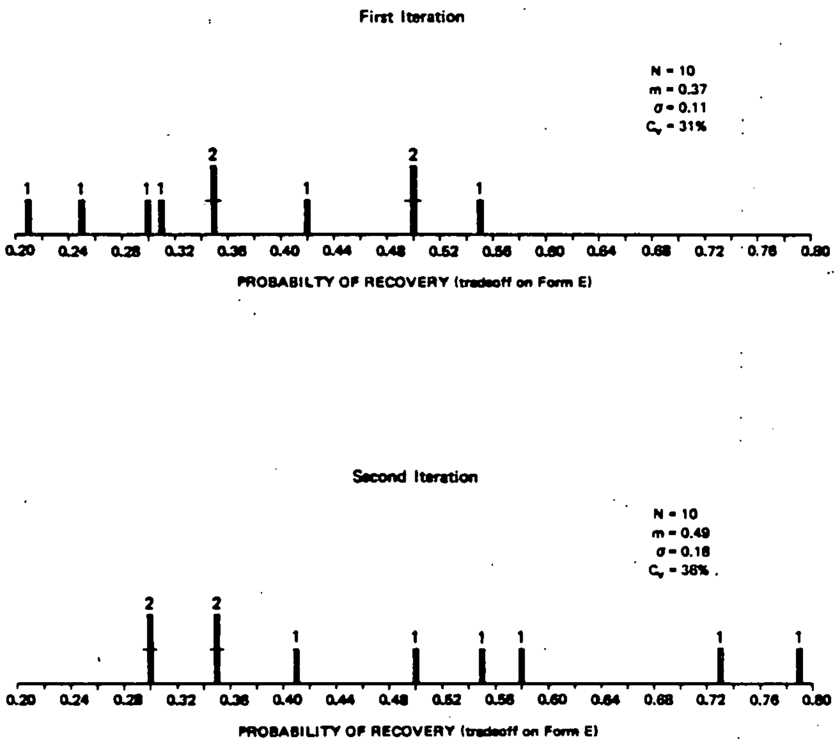
C-50




LEGEND
N = Number of participants in the exercise
m = Sample mean
σ = Sample standard deviation
$C_v$ = Coefficient of variation (σ/m)

Figure C-9. FIRST ITERATION RESPONSES TO FORM D

C-51




LEGEND
N = Number of participants in the exercise
m = Sample mean
σ = Sample standard deviation
$C_v$ = Coefficient of variation (σ/m)

Figure C-10. FIRST AND SECOND ITERATION RESPONSES TO FORM E



sample mean was used as the best measure of group consensus. During the sensitivity analysis (described later in this report), the responses on this form were divided in two groups and corresponding sample means were used as tradeoffs.

Forms C and D showed good convergence in the first iteration. The sample means in the first iteration were used as consensus tradeoffs.

No convergence of opinion was apparent in Figure C-10 (Form E). In fact, it appeared that the group was more divided in the second iteration than they were in the first (as reflected in an increase in the coefficient of variation). Indeed, there was obvious disagreement between the participants on the relative benefits of brush and tree control in terms of reducing number of days and ice and snow on the road. The sample mean from the second iteration was used as the consensus tradeoff in the base case analysis. However, the significance of assuming different tradeoffs implied by clustering of opinions was also examined during the sensitivity analysis (described later).

The results of the Delphi exercise in Pennsylvania are presented in Table C-18.

STEP 4. DETERMINE THE OPTIMUM COMBINATION OF LEVELS-OF-SERVICE

The assessed data were arranged in the formats necessary for the computer program using the instructions in the user manual (Appendix A). The results of the base case analysis obtained from the program output are described below.

Table C-18. CONSENSUS VALUE TRADEOFFS BETWEEN DIFFERENT PAIRS OF ATTRIBUTES IN PENNSYLVANIA

| | Percent Increase in Pavement Rehabilitation Cost | | Index of Pleasing Appearance | |
|---|---|---|---|---|
| Option A | 30 | Balancing Reward | 1 | Penalty |
| Option B | 23 | | 11 | |

| | Probability of Recovery | Index of Pleasing Appearance |
|---|---|---|
| Option A | 0.20 | 1 |
| Option B | 0.29 | 11 |

| | Percent Increase in Pavement Rehabilitation Cost | Index of Environmental Pollution |
|---|---|---|
| Option A | 30 | 1 |
| Option B | 25 | 12 |

| | Probability of Recovery | Percent Reduction in Number of Auto-Animal Collisions |
|---|---|---|
| Option A | 0.20 | 30 |
| Option B | 0.52 | 0 |

| | Probability of Recovery | Percent Reduction in Number of Days of Ice and Snow on Road |
|---|---|---|
| Option A | 0.20 | 12.5 |
| Option B | 0.49 | 0 |





Results of Base Case Analysis for Louisiana

The estimates of resources required to implement alternative levels-of-service of various maintenance conditions are presented in Table C-19. These estimates were made by assessing the annual work quantities for different levels-of-service and then converting work quantities into resource requirements. The maintenance management systems provided information on unit costs and productivity rates of different maintenance activities.

For the base case analysis the available resources were assumed to be those required for the current levels-of-service that were (1) repair when edge of traveled-way drop-off is 1-inch, and (2) mow 300,000 acres and spray 120,000 acres annually.

The results of the base case analysis as they appeared in the computer printout are presented in Figure C-11. The levels-of-service currently used in Louisiana for the two maintenance conditions are also the optimum levels-of-service selected by the program. This was to be expected because the analysis assumed the resources currently used for the two maintenance conditions, and the value judgments of those involved in setting the current levels-of-service were used. In fact, any other result would have required a reexamination of the data assessment procedures. The strength of the methodology is that it will consistently select optimum levels-of-service when a large number of maintenance conditions are analyzed and when changes in the current maintenance budget become necessary.

Table C-19. ESTIMATION OF RESOURCES FOR ALTERNATIVE LEVELS-OF-SERVICE FOR A GIVEN MAINTENANCE CONDITION IN LOUISIANA

| Maintenance Condition | | Maintenance Levels-of-Service | Type 1 Materials (dollars) | Type 2 Labor-Hours | Type 3 Equipment (dollars) |
|---|---|---|---|---|---|
| Edge of Traveled-Way Drop-Off | 1. | Repair when drop-off is 1-inch. | 4,730,000 | 256,000 | 1,092,000 |
| | 2. | Repair when drop-off is 2 inches. | 4,000,000 | 217,000 | 923,000 |
| | 3. | Repair when drop-off is 3 inches. | 3,000,000 | 163,000 | 693,000 |
| | 4. | Repair when drop-off is 4 inches. | 2,000,000 | 108,000 | 462,000 |
| | 5. | Repair when drop-off is 5 inches. | 700,000 | 38,000 | 162,000 |
| Vegetation Growth | 1. | Mow 500,000 acres and spray 150,000 acres annually. | 500,830 | 560,264 | 3,808,712 |
| | 2. | Mow 300,000 acres and spray 120,000 acres annually. | 400,664 | 388,048 | 2,285,227 |
| | 3. | Mow 200,000 acres and spray 60,000 acres annually. | 200,332 | 215,000 | 1,523,485 |
| | 4. | Mow 150,000 acres and spray 60,000 acres annually. | 200,332 | 165,000 | 1,142,613 |

BASE CASE ANALYSIS

Complete Enumeration

The selected policy is:

| | |
|---|---|
| Edge of traveled-way drop-off | Repair when drop-off is 1-inch. |
| Vegetation growth | Mow 300,000 acres and spray 120,000 acres. |

Costs of the Selected Policy

| | |
|---|---|
| Materials (thousands of dollars) | Available - 5130, used - 5130 |
| Thousands of Labor-Hours | Available - 644, used - 644 |
| Equipment (thousands of dollars) | Available - 3380, used - 3377 |

Evaluation of the Attributes

Safety--percent of drivers who cannot recover
Individual value - 1.000 Weighted value - .438

Percent change in rehabilitation costs
Individual value - 1.000 Weighted value - .321

Pleasing appearance
Individual value - 0.962 Weighted value - 0.173

Environmental pollution
Individual value - .500 Weighted value - .031

THE VALUE OF THIS POLICY IS 0.96

Figure C-11. RESULTS OF THE BASE CASE ANALYSIS IN LOUISIANA





The overall value of the optimum levels-of-service was 0.96. For the reasons explained in the next section, an improvement in the optimum levels-of-service would not be possible even if higher amounts of resources were available.

Results of Base Case Analysis for Pennsylvania

Table C-20 shows the estimates of resources required to implement alternative levels-of-service of various maintenance conditions. For the base case analysis the available resources were arbitrarily assumed to be those required for the second level-of-service of each maintenance condition. The current levels-of-service in Pennsylvania for the two maintenance conditions were not specific enough for comparison with the alternative levels-of-service used in this analysis. The influence of assuming different amounts of available resources was studied later in the sensitivity analysis.

The results of the base case analysis obtained from the computer printout are shown in Figure C-12. The program selected the highest levels-of-service for edge of traveled-way drop-off, grass growth, and weed growth, and the lowest level-of-service for brush and tree growth. The dollars and person-days required for the second level-of-service for brush and tree growth were substantially higher than those required for the lowest (the third) level-of-service. The resources saved by letting the level-of-service for brush and tree growth go to its lowest class were sufficient to improve levels-of-service for all other maintenance conditions. The overall user benefits increased

Table C-20. RESOURCE REQUIREMENTS OF ALTERNATIVE LEVELS-OF-SERVICE FOR DIFFERENT MAINTENANCE CONDITIONS IN PENNSYLVANIA

| Maintenance Condition | Alternative Level-of-Service | Resources of Given Type Required Annually: Dollars (in thousands) | Person-Days (in hundreds) |
|---|---|---|---|
| Edge of Traveled-Way Drop-Off | 1 | 9784 | 961 |
| | 2 | 8723 | 867 |
| | 3 | 7661 | 774 |
| | 4 | 6600 | 681 |
| Grass Growth | 1 | 2365 | 212 |
| | 2 | 1828 | 164 |
| | 3 | 1075 | 96 |
| Weed Growth | 1 | 1030 | 65 |
| | 2 | 751 | 48 |
| | 3 | 558 | 35 |
| | 4 | 440 | 27 |
| Brush and Tree Growth | 1 | 8085 | 670 |
| | 2 | 5558 | 460 |
| | 3 | 3067 | 260 |



## BASE CASE ANALYSIS

Complete Enumeration

The selected policy is:

Maintenance Element - Shoulders

| Maintenance Condition | Alternative Selected |
|---|---|
| Edge of Traveled-Way Drop-off | Repair When Drop-off is 1-inch |

Maintenance Element - Roadside Vegetation

| Maintenance Condition | Alternative Selected |
|---|---|
| Grass Growth | Mow full width when 6 in. 4 times/yr |
| Weed Growth | Apply herbicides nonselective-1/yr selective-2/yr |
| Brush and Tree Growth | Remove only to maintain proper clearance |

COST OF THE SELECTED POLICY

Thousands of dollars — Available - 16860.0000, Used - 16246.0000
Hundreds of person-hours — Available - 1539.0000, Used - 1498.0000

EVALUATION OF THE ATTRIBUTES

Probability of recovery — Weighted value - .351
individual value - .950

Percent increase in pavement rehab. cost — Weighted value - .218
individual value - 1.000

Index of pleasing appearance — Weighted value - .049
individual value - .958

Index of environmental pollution — Weighted value - .036
individual value - 1.000

Percent fewer auto-animal collisions — Weighted value - .041
individual value - .241

Percent fewer days of ice and snow on road — Weighted value - .000
individual value - .000

THE VALUE OF THIS POLICY IS 0.70

Figure C-12. RESULTS OF THE BASE CASE ANALYSIS IN PENNSYLVANIA

because the improved levels-of-service were more than the decrease in benefits from the worst level-of-service. This caused the program to select levels-of-service different from those initially assumed. Actually, the contributions of the highest levels-of-service for grass growth and weed growth to the overall value were very small. However, the resources saved by lowering the levels-of-service for these two maintenance conditions were not enough to increase the level-of-service for brush and tree growth from the third (worst) level to the second level. As in the sensitivity analysis (described later), if enough resources were available to increase the level-of-service for brush and tree growth, the program would do so even at the expense of lowering the level-of-service for grass growth.

STEP 5. SENSITIVITY ANALYSES

The objective of this step was to assess the influence of changes in some of the major inputs and assumptions on the selection of the optimum levels-of-service.

<u>Sensitivity Analysis in Louisiana</u>

The demonstration example in Louisiana included two maintenance conditions. In the sensitivity analysis, advantage was taken of the fact that none of the attributes were affected by both maintenance conditions. It was possible to determine the complete contribution of a given level-of-service of each maintenance condition to the overall value. The results are shown in Table C-21.



Table C-21. CONTRIBUTIONS OF INDIVIDUAL LEVELS-OF-SERVICE TO THE OVERALL VALUE

| Maintenance Condition | Level-of-Service | Contribution to Overall Value | Change in Value from the Lower Level-of-Service |
|---|---|---|---|
| Edge of Traveled-Way Drop-Off | 1. Repair when drop-off is 1-inch. | 0.759 | 0.012 |
| | 2. Repair when drop-off is 2 inches. | 0.747 | 0.119 |
| | 3. Repair when drop-off is 3 inches. | 0.628 | 0.268 |
| | 4. Repair when drop-off is 4 inches. | 0.360 | 0.133 |
| | 5. Repair when drop-off is 5 inches. | 0.227 | -- |
| Roadside Vegetation Growth | 1. Mow 500,000 acres, spray 150,000 acres annually. | 0.180 | -0.024 |
| | 2. Mow 300,000 acres, spray 120,000 acres annually. | 0.204 | 0.10 |
| | 3. Mow 200,000 acres, spray 60,000 acres annually. | 0.104 | 0.043 |
| | 4. Mow 150,000 acres, spray 60,000 acres annually. | 0.061 | -- |

It is interesting that the first level-of-service for roadside vegetation growth would always be inferior to the second level-of-service, irrespective of available resources. This is the case because of the conflict between aesthetics and environmental pollution. The slight improvement in aesthetics provided by the first level-of-service over the second is more than offset by the penalty of increased environmental pollution of the first level-of-service (resulting from a higher amount of herbicide spraying). The net effect is that the second level-of-service uses less resources and yet provides higher overall value than the first level-of-service. This conclusion is valid over a wide range of relative weights of aesthetics and environmental pollution. For example, keeping the tradeoff between safety (percentage of drivers who cannot recover) and environmental pollution constant, the first level-of-service for vegetation growth would be inferior to the second even if aesthetics is made as important as safety. This indicates that the differences in individual opinions observed in group sessions regarding tradeoffs are of little consequence to the superiority of the second roadside vegetation level-of-service over the first.

Results in Table C-21 enable one to determine the optimum levels-of-service for any amount of available resources. For example, assume that we start with the worst level-of-service for both edge of traveled-way drop-off and roadside vegetation growth. If available resources are just enough to increase the level-of-service for only one of the maintenance conditions by one notch, the level-of-service for edge of



traveled-way drop-off should be improved. On the other hand, if the choice is between improving the level-of-service from the fifth to the fourth for edge of traveled-way drop-off (increase in overall value of 0.133) or improving the level-of-service from the fourth to the second for roadside vegetation growth (increase in overall value of 0.143), the latter improvement should be made.

## Sensitivity Analysis in Pennsylvania

Since some of the attributes were affected by multiple maintenance conditions, the analysis of individual contributions to the overall value conducted in Louisiana was not possible in Pennsylvania. Instead, the effect of changes in available resources and tradeoffs on the selection of optimum levels-of-service was examined. The results are discussed next.

Changes in Available Resources. The effects of a 20 percent increase and a 20 percent decrease in both the resources (dollars and person-days) were studied. With a 20 percent increase in resources the program selected the highest levels-of-service for edge of traveled-way drop-off, weed growth, and brush and tree growth, and the third (lowest) level-of-service for grass growth. Thus, with more resources, a higher level-of-service for brush and tree growth was selected at the expense of a lower level-of-service for grass growth. The reason for this selection was that improving the level-of-service for brush and tree growth contributed more to the overall value than improving the level-of-service for grass growth. Alternatively, the aesthetic value of

mowing grass was less important than the safety value (in terms of reducing number of days of ice and snow on road) of controlling brush and tree growth. The overall value of the optimum solution was 0.92, significantly higher than the 0.70 value obtained for the base case.

A 20 percent decrease in both available resources required the program to reduce levels-of-service in order to satisfy resource constraints. The third level-of-service was selected for edge of traveled-way drop-off and the third (lowest) level-of-service for both grass growth, and brush and tree growth. It was still possible to select the highest level-of-service for weed growth because of its relatively modest resource requirements. The overall value of the optimum solution was 0.38, significantly lower than the 0.70 value obtained for the base case.

Changes in Tradeoffs. As was discussed earlier, the Delphi exercise showed significant differences of opinions with regard to the relative importance of index of pleasing appearance and percent reduction in number of days of ice and snow on roads. Value judgments of some of the participants implied higher weights for these attributes than others. Two computer runs were made for the sets of tradeoffs shown in Table C-22. The program selected the same levels-of-service as being optimum in both the runs. This showed that the differences of opinions identified in the Delphi procedure were not significant factors in the choice of optimum levels-of-service.





Table C-22. SETS OF TRADEOFFS USED IN SENSITIVITY ANALYSIS IN PENNSYLVANIA

Set 1. LOWER WEIGHTS ON VEGETATION CONTROL ATTRIBUTES

| | Probability of Recovery | | Index of Pleasing Appearance | |
|---|---|---|---|---|
| Option A | 0.2 | Balancing Reward | 1 | Penalty |
| Option B | 0.244 | | 11 | |

| | Probability of Recovery | Percentage Reduction in Number of Days of Ice and Snow on Road |
|---|---|---|
| Option A | 0.2 | 12.5 |
| Option B | 0.368 | 0 |

Set 2. HIGHER WEIGHTS ON VEGETATION CONTROL ATTRIBUTES

| | Probability of Recovery | Index of Pleasing Appearance |
|---|---|---|
| Option A | 0.2 | 1 |
| Option B | 0.4 | 11 |

| | Probability of Recovery | Percentage Reduction in Number of Days of Ice and Snow on Road |
|---|---|---|
| Option A | 0.2 | 12.5 |
| Option B | 0.66 | 0 |

STEP 6. FORMULATE RECOMMENDATIONS

The recommendations discussed here are only for illustrative purposes; they should not be taken as the basis for establishing levels-of-service in either Louisiana or Pennsylvania.

Illustrative Recommendations for Louisiana

1. The optimum levels-of-service for edge of traveled-way drop-off and control of roadside vegetation, assuming current resources used for these conditions, are:
   - Repair when the drop-off is 1-inch
   - Mow 300,000 acres and spray 120,000 acres annually.

   These, in fact, are the current levels-of-service used in Louisiana.

2. Resources required for implementing the optimum levels-of-service and available resources are shown below.

| Resource Type | Amount Required | Amount Available |
|---|---|---|
| Materials (in thousands) | 5130 | 5130 |
| Labor-hours (in hundreds) | 644 | 644 |
| Equipment (in thousands) | 3377 | 3380 |

3. The current levels-of-service for edge of traveled-way drop-off and control of roadside vegetation provide the highest user benefits possible. No improvement in these levels-of-service would be possible even if more resources were available.



Illustrative Recommendations for Pennsylvania

1. Assuming that 16.9 million dollars and 0.154 million person-hours are available for the maintenance of edge of traveled-way drop-off and control of roadside vegetation, the optimum levels-of-service for these conditions are as shown in Figure C-11.

2. The value of user benefits derived from the maintenance conditions would increase significantly if dollars and person-hours allocated to these conditions were increased by 20 percent. On the other hand, a 20 percent reduction in the allocated resources would significantly reduce the value of user benefits and should be avoided.

3. Resources required for implementing the optimum levels-of-service for the base case and the assumed available resources are shown below.

| Resource Type | Amount Required | Amount Available |
|---|---|---|
| Dollars (in thousands) | 16,246 | 16,860 |
| Person-hours (in hundreds) | 1,498 | 1,539 |

CONCLUSIONS

1. It was practical to complete the six steps involved in the use of the methodology in both states. This was accomplished within a reasonable amount of time and effort (about 5 days for assessing

input data and 5 days for running the computer program and analyzing results in each state).

2. The inputs required for running the computer program were generated from the data base of information currently available to the state agencies. The data base included information available from literature reviews, studies conducted within the department, information available from maintenance management systems, and the experience and judgment of knowledgeable individuals within the department.

3. No prior knowledge of decision analysis or the Delphi procedure was required of the individuals who estimated the effects of alternative levels-of-service and assessed the value of tradeoffs in the group session.

4. The experience in both states indicated that it would be desirable to spend more time with department specialists to obtain relevant objective data, particularly those being collected by the state. Examples of such data include statistics on accidents resulting from driving over the edge of traveled-way with various amounts of drop-off, number of different types of animals killed on highways in auto-animal collisions, and number of days of ice and snow on the road for different "daylighting" conditions resulting from brush and tree growth. Data on some of these factors may be available for a sample of the highway network in a state.



It would be desirable to provide these kinds of data to the participants in the Delphi exercise to increase the confidence in and consistency of the value tradeoffs assessed by the participants.

5. The concept of quantifying a tradeoff between two attributes is relatively difficult to understand. The responses of participants in the first iteration of tradeoff assessments showed a wide scatter that was most likely caused by misunderstanding of the assessment question rather than genuine differences of opinions. The discussions of possible inconsistencies in the first iteration responses helped the participants understand the implications of their responses. The responses in the second iteration typically showed much better convergence of group opinions. This was an encouraging trend because it showed that assessing tradeoffs with a group of decision makers, although difficult, was feasible.



REFERENCES


1. Federal Highway Administration, "Evaluation of the Highway-Related Safety Program Standards," U.S. DOT, FHWA, 1977.

2. E.F. Nordlin, D.M. Parks, R.L. Stoughton, and J.R. Stoker, "The Effect of Longitudinal Edge of Paved Surface Drop-Off on Vehicle Stability," Final Report CA-DOT-TL-6783-1-76-22, Cal Trans, March 1976.

3. R.H. Klein, W.A. Johnson, and H.T. Szostak, "Influence of Roadway Disturbances on Vehicle Handling," Vol. II, Technical Report, U.S. Department of Commerce, NTIS, Feb. 1977.

4. Bellis, E.D. and H.B. Graves. "Highway Fences as Deterrents to Vehicle-Deer Collisions." Transportation Research Board Record 674, National Academy of Sciences, Washington, D.C., 1978, pp. 53-58.

# APPENDIX D

## DESCRIPTION OF DELPHI TECHNIQUE

### INTRODUCTION

In many problems of practical importance it is necessary to make decisions based on the subjective opinions of a group of decision makers. Difficulty arises because individuals have different backgrounds and objectives and often hold divergent opinions on the issues under consideration. Furthermore, if each individual has expertise in a particular field, it would seem desirable to have their expertise "pooled" into a "group consensus," that could be used instead of any one individual's opinion. It is a generally held (but as yet unproven) belief that group opinion is superior to individual opinion; this is the fundamental assumption of the Delphi technique (explained in more detail in the next section).

In the context of establishing maintenance levels-of-service, individual value functions $V_i(\theta_i)$; $i = 1, 2, \ldots$ can be assessed using the opinion(s) of one or more "experts" who are most familiar with attributes $\theta_i$. For example, relative values of different levels of ecological impact can be assessed by a biologist, while relative values of different levels of pavement life cycles can be assessed by a pavement engineer. Scaling of the multiattribute value function, however, requires specific comparisons of the relative importance of various attributes. As already noted, experts are likely to hold different opinions with respect to the value tradeoffs between various attributes. For example,



even though highway maintenance experts and transportation planning experts may agree among themselves on the shape of value functions, the opinions of the two groups may be quite different with respect to the relative importance of one attribute in comparison with another.

For these reasons, and to obtain and incorporate the diverse opinions of various experts on different attributes in an objective and systematic manner, it is suggested that the Delphi technique be used. In the context of establishing maintenance levels-of-service guidelines, the objective of the Delphi technique is to systematically arrive at a group consensus on the tradeoffs between different attributes. This objective can be achieved in a group session involving representatives from supervisory, maintenance, management, and decision-making ranks of the state transportation department, as described in the following sections.

## BACKGROUND

### Origin

The Delphi technique originated at the Rand Corporation in the late 1940s as a systematic method for eliciting expert opinion on a variety of topics. Early Delphi studies at Rand were primarily concerned with scientific and technological forecasting. Those studies were initially viewed "as experiments with what was thought to be an interesting, and possibly useful, new technique" (1, p. 3).

From these humble beginnings, Delphi has grown into a widely practiced technique in diverse areas. Furthermore, the scope of "conventional" Delphi has been altered and its applications have expanded. At the same time, questions have been raised about the validity of some of the claimed advantages of the Delphi technique, particularly in applications that clearly exceed the intended scope of the technique and in situations where the quality of the experiments has been questionable.

### "Conventional" Delphi Technique

The objective of the "conventional" Delphi technique (as opposed to its variants) is to forecast specific long- or short-term events through generation of quantitative estimates or qualitative evaluations from a set of participants who are supposed to be knowledgeable "experts" in a given field. "The consensus intent of Delphi is typically



orientated toward controlled and rational exchange of iterated opinion leading toward optimal convergence of opinion achievable within the framework of the technique" (1, p. 6).

The Delphi technique developed at Rand has three basic characteristics: (1) an iterative questionnaire format, (2) anonymous response, and (3) statistical feedback. Later variants of Delphi have eliminated one or more of these fundamental requirements,* and there is some debate about whether such techniques qualify as Delphi.

Although difficult to define in one paragraph, the basic characteristics of the "conventional" Delphi method are the following:

- The format is usually (but not necessarily) a written questionnaire that is administered in an interactive way.**
- The questionnaire (which is usually prepared by the director or principal investigator) consists of a set of questions that elicit quantitative or qualitative responses from the participants.

---

* For example, SPRITE (Sequential Polling and Review of Interacting Teams of Experts), developed by Bedford (2), eliminates anonymity and statistical feedback.

** It can be administered by mail.

- The questionnaire is generally accompanied by a set of instructions (these may be verbal), and different scales may be provided for responding to various questions.

- The participants (who are presumably acknowledged "experts" in the subject area) are asked to participate in two or more rounds (or iterations) of questions and answers.

- After each iteration, the respondents are provided with some form of statistical feedback (which usually involves a measure of central tendency, some measure of dispersion, or perhaps the entire frequency distribution of responses for each item).

- Individual responses to questions are kept anonymous.

- Each iteration may or may not be accompanied by some form of controlled discussion. Respondents may be given the opportunity to exchange views in face-to-face conversations.

- Iterations are continued until convergence of opinions, or "consensus," as determined by the director, is reached.*

---

* From a practical point of view, three iterations are generally considered more than sufficent (in terms of reaching the point of diminishing marginal returns).



Advantages of Delphi Procedure and Its Limitations

When used properly, the Delphi method is a systematic, fast, and inexpensive way to pool opinion on a host of issues from a group of participants who are familiar with the subject matter. The Delphi technique can be particularly useful in applications where no one opinion is clearly superior to another or where individuals are experts in various aspects of a complex issue and their fragmentary expertise must be combined into an agreed-upon overall objective.

Many of the criticisms directed at the Delphi method are, in fact, criticisms about inappropriate use of the technique or questionable conclusions drawn from the results of the experiment. It has been argued, for instance, that if Delphi questions are ambiguous, then the responses are likely to be amorphous (i.e., nonspecific). This is a valid criticism and suggests that the questions (or questionnaires) must be carefully prepared and the use of the technique must be limited to cases where fairly direct questions can be asked to obtain specific responses.

Some other major limitations and pitfalls of the Delphi technique,* that should be avoided are the following:

---

* The reader is referred to Sackman's (1) incisive critique of the Delphi technique for further discussion of these and other issues.

- The panelists (or respondents) must be carefully selected so that they form a representative, unbiased, and impartial group of experts on the subject area.

- The participants must understand the importance and the limitations of the technique and possible applications of the results obtained.

- The tacit assumption of the Delphi technique--that the pooled opinion of experts is better than that of any subgroup of experts--has been challenged and must be carefully evaluated for each case under consideration.

- The conventional practice of taking the central tendency of pooled opinion as the best estimate of expert opinion must be evaluated in situations in which "clustering" of subgroup opinions occurs.*

---

* In practice, panel members occasionally have (or form) "clusters" of opinion, rather than a group consensus. For instance, highway maintenance specialists and safety experts may agree on certain points, while the environmental and public relations subgroups hold a different point of view. The opinions of these groups are likely to "cluster" about two divergent points and show no tendency to converge in repeated iterations of the Delphi method. Forcing group consensus is not likely to be successful, or meaningful, in such cases.



- In certain applications, better results may be obtained if "controlled conflict" between contrasting groups (as opposed to forced consensus) is used and qualitative arguments (as opposed to anonymous statistical feedback) are permitted (2).* For example, the panel participants may be allowed to discuss their disagreements and inform one another about issues likely to be unknown to or misunderstood by some of the participants. The director, however, must ensure that no individual (or group of individuals) dominates the discussion and imposes his/her (its) point of view on others.

- The "halo effect"** and the effect of the "dominant expert"*** must be avoided or reduced.

---

* This would be a "nonconventional" Delphi.

** "The tendency of respondents to be unduly influenced by any favorable or unfavorable characteristic of the questionnaire which colors and contaminates their judgment" [1, p. 34).

*** The tendency of a well-known and recognized expert to dominate the judgment of other participants. The same effect can occur if an outspoken participant (or someone with a high degree of authority) dominates the discussions, and hence the panel's views.

- Someone, preferably the director, must be responsible and accountable for the entire Delphi process. Otherwise the anonymity of the method (and the fact that the participants need not take any risks) may lead to "suspect" results.

- If respondents have various degrees of expertise, authority, or responsibility, proper use of self-rating or some other weighing procedure may be useful.

- "Outliers" (i.e., those whose responses differ substantially from the group norm) should not be forced or manipulated into the group norm but asked to explain their nonconformity. If the "outliers" still persist in their responses, other techniques, such as sensitivity analysis, may be used to examine their responses.

- The questionnaire must be carefully prepared to ensure that no ambiguities exist. When subjective and qualitative responses are elicited, appropriate scales or ranges of responses may be provided to avoid vague and amorphous responses.

- As a matter of practicality, the number of iterations should be limited to about three rounds, as determined by the director. If no consensus is reached within the first few rounds, then the questions are too ambiguous or the respondents are noncompromising in their beliefs and both should be reevaluated.



APPLICATION TO ESTABLISHING MAINTENANCE LEVELS-OF-SERVICE GUIDELINES

Having discussed at some length the Delphi technique, its advantages and pitfalls, this section will demonstrate the applicability of the method in establishing maintenance levels-of-service guidelines. In this context, the Delphi method is suggested as a systematic and relatively fast means of reaching consensus in establishing tradeoffs between various attributes of the multiattribute value function. The main body of the report contains a list of possible attributes pertinent to this problem and typical assessment procedures for obtaining tradeoffs between pairs of given attributes.

General Considerations

One of the first considerations to be addressed is the question of who and how many should participate in the Delphi study. Since an informal and spontaneous Delphi process is proposed for the problem at hand, limitations of time and resources suggest that a reasonably small group of participants participate in the experiment. A large group would be difficult to assemble and manage and might not be meaningful with respect to policy decisions. Conversely, if the group is too small, their responses may be too widespread and meaningful measures of central tendency and dispersion may not exist. A practical and reasonable number of participants for the Delphi method for this study is about 6 to 12 participants.*

---

*It appears that with smaller groups more iterations may be required to reach "consensus," and it would be difficult to define convergence in a statistically meaningful way.

As to the question of who should participate, "conventional" Delphi calls for the opinions of "experts." In this case, the experts are fairly easy to identify: included should be safety, supervisory, maintenance, and management experts in the state transportation department, preferably those with decision-making responsibilities for establishing maintenance levels-of-service and those whose experience in one or more highway-related areas is unquestionably acknowledged by other Delphi participants and the director. For example, participants may include experts from each of the following areas:

- State Transportation Safety Division
- State Highway Maintenance Department
- Field Supervisors of Highway Maintenance
- Transportation Planning Division
- Financial and Budgeting Personnel.

It would be useful if informed and interested representatives of the general public and highway users could also participate. If this is not possible, then highway public relations experts may be used as a proxy. The group must be well-rounded and include participants with different backgrounds and expertise.

The director should be familiar with the Delphi technique and be experienced as a discussion leader and group moderator. His overall familiarity with the pros and cons of the various issues involved and the expertise of each participant is essential to the successful application of the Delphi exercise. In addition, it is extremely important





that the director not bias the group's attitudes. An impartial, articulate, informed, and well-rounded director is an important factor in properly applying the Delphi exercise and in obtaining timely results.

STEP-BY-STEP PROCEDURE

Assuming that a panel of "experts" and an experienced and qualified director have been selected, the Delphi exercise can proceed. The group should be assembled in a room equiped with a blackboard or a projector and screen. The following step-by-step procedure may be followed.

Step 1

The director should first explain that the purpose of the meeting is to obtain consensus estimates of certain parameters which are required to establish maintenance levels-of-service. At this point, the methodology for establishing maintenance levels-of-service should be briefly described. The group session is primarily concerned with establishing a value function over the attributes, a list of which should be shown to the participants.

The two steps involved in establishing a value function--assessment of individual value functions, and assessment of tradeoffs between various attributes--should be briefly described. The director should explain that individual value functions have been assessed from experts who are most familiar with given attributes. It may be helpful to show the names of the individuals involved and the attributes for which they assessed value functions.

Step 2

The director should now explain that the specific purpose of the meeting is to obtain consensus estimates of tradeoffs between various attributes. The procedure for assessing tradeoffs between a given pair of attributes should be explained. It would be useful to illustrate the procedure with a simple example drawn from day-to-day life. One appropriate example might be that of buying a house, in which two attributes--price of the house and proximity to schools--are considered. The director should outline the reasoning he would use to arrive at a tradeoff between these two attributes. Next, an example applicable to the problem of establishing maintenance levels-of-service should be presented. The ranges of the two attributes selected for the example should be different from those to be used in the actual assessments so that the example will not bias the responses of the participants.

Step 3

It should be explained that it would be desirable to use group, rather than individual, consensus estimates of the tradeoffs to broaden the basis for establishing maintenance levels-of-service. One of the procedures used to obtain group consensus is the Delphi technique.

It would be helpful to provide a brief introduction to the vocabulary needed to conduct the experiment. The concepts of mean and measures of dispersion (for example, standard deviation) should be explained to the participants in a language that is compatible with



their backgrounds. A simple numerical example may be all that is needed to refresh their memories and clear up any remaining questions.

For the experiment proposed here, the only necessary statistical feedback would seem to be the mean, the standard deviation, and a diagrammatic or tabular representation of the entire frequency distribution. Use of complicated statistical jargon is not recommended, particularly if panel members are not familiar with such terminology.

Step 4

The director should present information pertinent to assessing the tradeoff between a given pair of attributes. The information may be compiled in the format shown in Figure D-1. The two attributes should be explained in some detail and the individual value functions already assessed for the attributes should be presented. To orient the participants to the tradeoff assessment procedure, extreme combinations of attributes, where the preferred combination is obvious, should be discussed first. The participants should then be asked to continue with similar reasoning until a point of indifference is obtained. Each participant should be asked to record his or her point of indifference in the blank space provided on the form.

If there is disagreement about which attribute should have higher relative weight, it will surface during this discussion. Clearly, such disagreement needs to be resolved before any consensus can be obtained.

Delphi Procedure for Tradeoff Assessment

Form ___________

Date: ___________

Iteration No.: ___________

1. Assume that you start with Option A and are offered the choice of switching to one of the B options. Indicate for each Option B whether you would stay with Option A or switch to Option B.

| Option | (Description of Attribute 1) | (Description of Attribute 2) | Preferred Option |
|---|---|---|---|
| A | (Worst level) | (Best level) | |
| $B_1$ | (Level better than the previous) | (Worst level) | ______ |
| $B_2$ | (Level better than the previous) | (Worst level) | ______ |
| $B_3$ | (Level better than the previous) | (Worst level) | ______ |
| | ⋮ | ⋮ | ⋮ |
| $B_n$ | (Best level) | (Worst level) | ______ |

2. Write the level (X) of Attribute 1 at which the reward in Attribute 1 just balances the penalty in Attribute 2.

X = _______________

Figure D-1. FORM FOR TRADEOFF ASSESSMENT USING DELPHI PROCEDURE



If the disagreement still persists, it would be best to continue with the majority opinion and treat other opinions through sensitivity analysis.

The content and organization of these forms should be based on the following criteria.

1. If n attributes are to be considered for a particular problem, tradeoffs between (n-1) pairs of attributes need to be assessed for the complete specification of an additive value function assumed for this study. Each attribute must appear at least once in the pairwise comparisons.

2. The general format of a tradeoff assessment form is as follows.

| | Attribute i | Attribute j |
|---|---|---|
| Option A | Worst level | Best level |
| Option B | Level X | Worst level |

The best and worst levels of each attribute would have been determined previously. The participants are asked to select X, which would make the value of the two options the same, i.e., the two options would be equally preferred. For this format to work, Attribute i should be more important than Attribute j, i.e., if Level X under Option B is the best level of Attribute i, Option B should be preferred to Option A.

3. Attribute i in each pairwise comparison should be on a continuous scale, e.g., percentage of drivers who cannot recover or percent change in pavement rehabilitation. If Attribute i is on a discrete scale, it is possible that no level of this attribute for X (under Option B) would make the two options equally preferred. For example, with one level of the attribute, Option A may be preferred, while with the next level of the attribute, Option B may be preferred. For this reason, both the index of pleasing appearance and index of environmental pollution would not qualify to be Attribute i in a tradeoff assessment form.

4. A pair of attributes selected for tradeoff assessment should be such that the attributes compete with—not supplement—each other. Thus, it should be physically possible to improve one attribute at the expense of degrading the other. For example, percentage of drivers who cannot recover and index of pleasing appearance would be a reasonable pair of attributes for tradeoff assessments because one can reduce the effort on control of roadside vegetation by some amount and spend that amount of effort on shoulder repairs to improve recovery of drivers. On the other hand, percentage of drivers who cannot recover and percentage change in pavement rehabilitation cost would not be a reasonable pair, because improving one attribute also improves the other; hence, no real tradeoff is possible.



Step 5

After the participants have filled in their responses, the director should collect the response forms and record them on a prepared tabular form. For example, if a question asks the respondents to provide a point of indifference on a scale of 1 to 10, the director should record the distribution of responses and calculate the mean, or average, as shown in Figure D-2.

Step 6

Next, the distribution of the panel's responses should be presented to the participants along with the original question and its suggested scale.* Depending on the question and the frequency distribution of the responses, some discussion among the panel members may be allowed. The director should explain the implications of the response distribution and serve as the discussion moderator. His/her role should be to allow each panel member an opportunity to express his/her feelings without dominating the group's discussion or biasing the views of other panelists.

Step 7

Following the discussion of the nature of group responses, if one is needed, the panel members should be asked to reevaluate their responses. The responses of the second iteration should be recorded on a blank copy of the form already mentioned.

* Two projectors may be used for this demonstration.

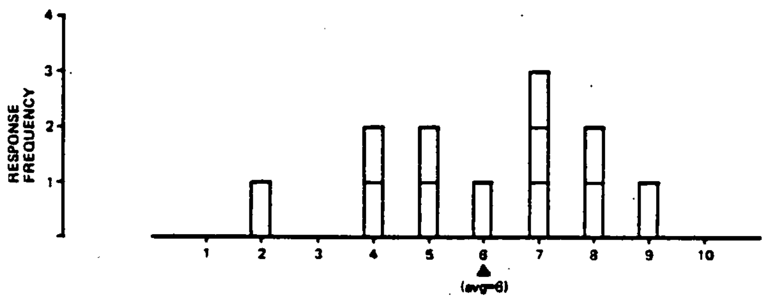



Figure D-2. HYPOTHETICAL RESPONSES RECORDED ON A SCALE OF 1 TO 10 BY A PANEL OF 12 RESPONDENTS



<u>Step 8</u>

The director should analyze the second iteration responses, compare them with those of the first iteration, and decide if a third iteration is warranted. If the group's responses were in general agreement on the first round and became further clustered about the mean (or average) on the second round, then no further iterations may be needed. If, on the other hand, the initial responses were widely spread and on the second iteration showed some tendency to converge (but no clear-cut consensus), or if they were clustered about two or more values, then a third iteration may be desirable. The director's experience and familiarity with the issues and the group's attitudes should help determine when the point of diminishing marginal returns has been reached. Except for the most unusual cases, three iterations should suffice (<u>1</u>, p. 49). Two iterations should be adequate in most instances.

<u>Step 9</u>

With the Delphi experiment completed, the director should compare the results of each iteration and decide what the group consensus is. One of the following three outcomes would normally be expected.

1. If the initial responses are fairly close and further converge in the second iteration, the mean can be used as a measure of group consensus. (See Figure D-3.)

2. If the responses are spread out in the first iteration but cluster in groups and converge on dual (or multiple)

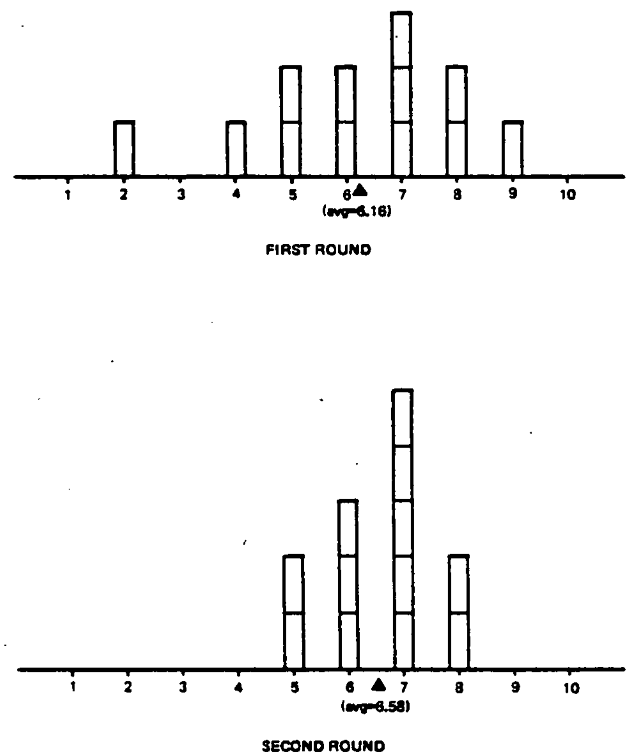



Figure D-3. HYPOTHETICAL EXAMPLE OF CONVERGENCE OF GROUP OPINION (assumes 12 panel participants - suggested response scale 1 to 10)



values, then the indications are that a dichotomy of opinions exists and forcing a group consensus is useless. (See Figure D-4.) The director should report the subgroups' consensuses.

3. If the responses are spread out initially and show no tendency to converge or cluster on the second iteration, then either no consensus exists or the results indicate a poorly phrased or ambiguous question. (See Figure D-5.)

Step 10

The above procedure is repeated for each pair of attributes for which tradeoff assessment is desired.*

OTHER POSSIBLE USES OF THE DELPHI TECHNIQUE

The most promising use of the Delphi technique for this project appears to be in the assessment of tradeoffs between different attributes. The application of Delphi to this situation was discussed in

---

* A more efficient variation of the above technique is to obtain the first iteration responses for all questions and analyze and report them before initiating the second iteration. This scheme may prove feasible if the total number of assessments is relatively small and there is no danger that the respondents will be confused by multiple questions in each iteration.

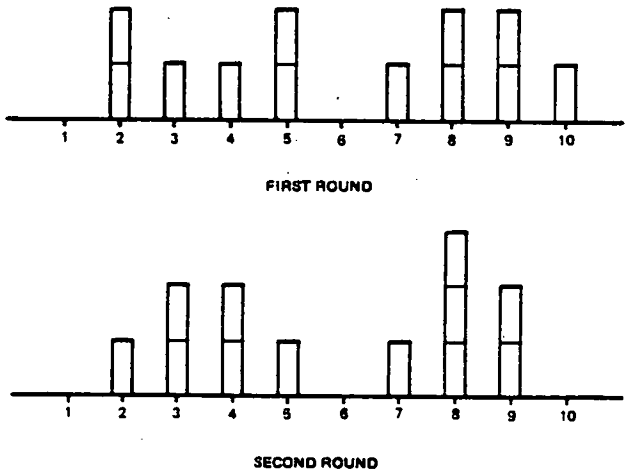



Figure D-4. HYPOTHETICAL EXAMPLE OF DUAL "CLUSTERING" OF GROUP OPINION



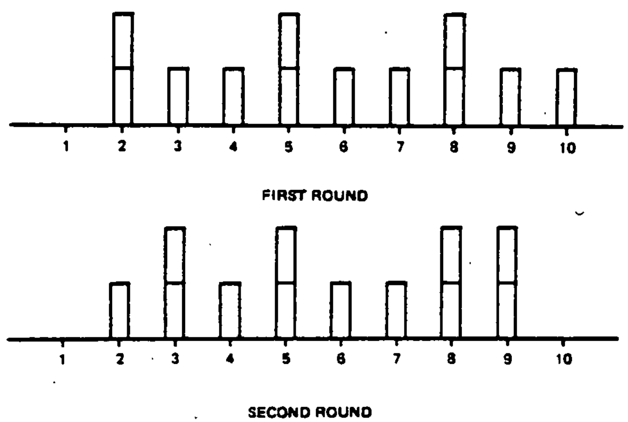



Figure D-5. HYPOTHETICAL EXAMPLE OF DISAGREEMENT OF GROUP OPINION





the previous sections. Other situations in which the Delphi technique may be of some value include the following.

<u>Assessment of Effects of Maintenance Levels-of-Service on a Given Attribute</u>

It is assumed that effects are assessed by interviewing one or two experts most knowledgeable for the given attribute. For example, for assessing effects on bird habitats of levels-of-service for vegetation control, agronomists or biologists may be interviewed. Similarly, traffic safety personnel may be asked to assess the effects of edge of traveled-way drop-off on the percentage of drivers who cannot recover if they accidentally drive over the edge. Since only one or two experts would normally be involved for each attribute, use of the Delphi technique would not be necessary. However, if several individuals are involved in the assessment of a particular attribute, group consensus regarding the effects on the attribute may be obtained by using Delphi in a manner similar to that described in the previous section.

<u>Assessment of Individual Value Functions of Various Attributes</u>

Again, the assumption is that an individual value function can be best assessed by interviewing one or two experts for the given attribute. If several individuals are involved in the assessment of individual value functions, however, use of the Delphi technique may be considered.

## A HYPOTHETICAL EXAMPLE

As an example of the Delphi technique, let us suppose one is interested in finding the group consensus on the tradeoffs between two attributes — $\theta_1$, present serviceability index (PSI), and $\theta_2$, percent change in the number of drivers who cannot recover normally from driving over the edge of a travelled-way drop-off.

An appropriate way to pose the question in this case would be to ask the respondents to choose a level of $\theta_1$ for Option A (below) which would make them indifferent between options A and B.

| Option A | Option B |
|---|---|
| $\theta_1 = ?$, $\theta_2 = 50\%$ | $\theta_1 = 1.5$, $\theta_2 = 0\%$ |

Let us suppose that there are 12 respondents and their first iteration response distribution on $\theta_1$ (which has a scale of 1.5 to 3.5) is as shown in Figure D-6.*

The director shows the first-iteration responses to the participants. This schematic presentation may be accompanied by an explanation of the implications of the responses and a brief discussion period during which the participants may ask questions or consult with one another. Then a second iteration of responses is collected. (See Figure D-6.)

*Suppose the suggested response scale is divided into intervals of 0.25 between 1.5 and 3.5.



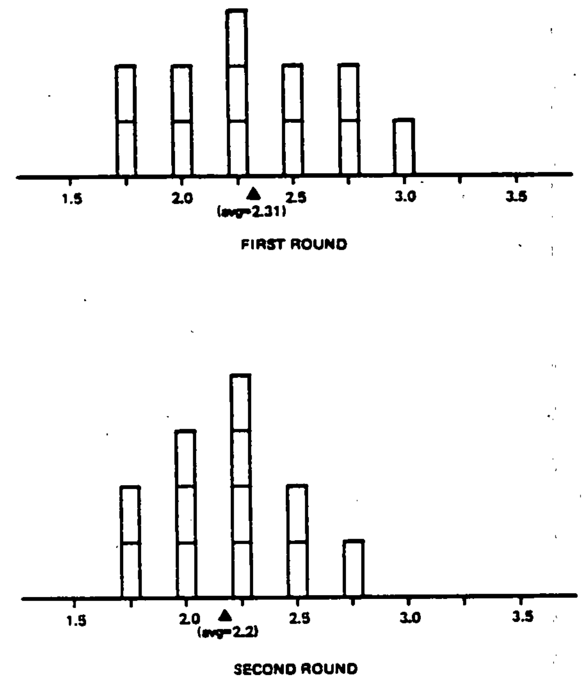



Figure D-6. HYPOTHETICAL EXAMPLE FOR DETERMINATION OF GROUP OPINION ON THE TRADEOFF BETWEEN $\theta_1$ AND $\theta_2$

The director must now compare the two iterations and decide if the group's consensus can be deduced from these results or if a third iteration is called for. In this case the first-iteration responses suggest a central tendency of about 2.25. The second iteration reinforces this idea and suggests that the "outliers" abandoned their initial positions in favor of more central responses. For this example, a third iteration may not be fruitful, as it would most likely produce a frequency response quite similar to the one already obtained. Hence, the group's second iteration average response (in this case $\theta_1 = 2.2$) can be used as the most representative opinion. As this example suggests, no complicated statistical analysis is required, nor would such techniques likely be cost effective in practical applications of small size.



REFERENCES


1. Sackman, H., "Delphi Assessment : Expert Opinion Forecasting and Group Processes," The Rand Corp., R-1282-PR, April 1974.

2. Bedford, M. T., "The Value of 'Comments' Analysis and an Analysis of SPRITE as a Planning Tool," Delphi: The Bell Canada Experience, Bell Canada, October 1972.






ADDITIONAL REFERENCES NOT CITED IN TEXT


1. Amara, R. C., and A. J. Lipinski, "Some Views on the Use of Expert Judgment," Technnological Forecasting and Social Change Vol. 3, No. 3, 1972.

2. Brown, B., "Delphi Process: A Methodology Used for the Elicitation of Opinions of Experts," The Rand Corp., P 3925, Sept. 1968.

3. ______, S. W. Cochran and N. C. Dalkey, "The Delphi Method, II: Structure of Experiments," The Rand Corp.,RM-5957-PR, June 1969.

4. Dalkey, N. C., "The Delphi Method: An Experimental Study of Group Opinion," The Rand Corp., RM-5888-PR, June 1969.

5. ______, "Delphi," The Rand Corp., P-5704, Sept. 1967.

6. ______, B. Brown and S. W. Cochran, "The Delphi Method, IV: Effect of Percentile Feedback and Feed-In of Relevant Facts," The Rand Corp., RM-6118-PR, March 1970.

7. ______, "The Delphi Method, III: The Use of Self-Rating to Improve Group Estimates," The Rand Corp., RM-6115-PR, Nov. 1969.

8. Dalkey, N. C., and D. L. Rourke, "Experimental Assessment of Delphi Procedures with Group Value Judgments," The Rand Corp., R-612-ARPA, Feb. 1971.

9. Doyon, L. R., T. V. Sheehan and H. I. Zagor, "Classroom Exercises in Applying the Delphi Method for Decision-Making," Socio-Economic Planning Sciences, Vol. 5, pp. 363-75, 1971.

10. Helmer, O., "Convergence of Expert Consensus through Feedback," The Rand Corp., P-2973, Sept. 1964.

11. Molnar, D., and M. Kammerud, "Developing Priorities for Improving the Urban Social Environment: A Use of Delphi," Socio-Economic Planning Sciences, Vol. 9, pp. 25-29, 1975.

12. Pill, J., "The Delphi Method: l Substance, Contexts, A Critique and an Annotated Bibliography," Socio-Economic Planning Sciences, Vol. 5, pp. 57-71, 1971.





13. Rescher, N., "Delphi and Values," The Rand Corp., P-4182, Sept. 1969.

14. Skutsch, M., and J. L. Schofer, "Goals-Delphis for Urban Planning: Concepts in their Design," Socio-Economic Planning Sciences, Vol. 7, pp. 305-13, 1973.

15. Weaver, W. T., "Delphi, A Critical Review," Syracuse University Research Corp., RP-7, Feb. 1972.

# APPENDIX E

## REVIEW OF INFORMATION REGARDING EFFECTS OF EDGE OF TRAVELED-WAY DROP-OFF ON VARIOUS CONSIDERATIONS

INTRODUCTION

Two considerations are relevant to assessing the effects of alternative levels-of-service on edge of traveled-way drop off--preservation of investment, and safety.

Preservation of investment can be related to the cost of pavement rehabilitation. For example, what is the required cost of rehabilitation as a function of edge of traveled-way drop-off? Other attributes such as life cycle as a function of the drop-off were considered; however, assessors can better contemplate the relative cost of rehabilitation. No quantitative information was found in the literature that indicated the influence of edge of traveled-way drop-off on preservation of investment. Therefore, the assessor is virtually "on his own" and must rely on his experience and judgment. Group discussions with other experienced personnel can be useful in establishing a subjective framework for responding to specific assessments.

Specific Sources of Information

Some useful information relating edge of traveled-way drop-off to safety is available and should be reviewed with the assessors. Three specific sources of information are summarized and reviewed in the following portion of this report.

In the report "Evaluation of Highway Safety Program Standards," DOT/FHWA (1) the investigators report on annual accident reductions for selected improvements before and after improvements were made.



The specific information provided by this investigation is not directly applicable to edge traveled-way drop-off. However, it is interesting that when shoulder improvements (width, grade, and general configuration) are made, a reduction in accident frequency can be anticipated. It is also highly significant that shoulder improvements produce benefits (reduction in accident potential) comparable to those associated with pavement widening, installation of traffic signals, or installation or upgrading of traffic signs, striping and/or delineators.

This DOT report also illustrates the type of information that would be most applicable to safety considerations, i.e., change in number of accidents with specific roadway conditions.

The investigation by the California DOT on "The Effect of Longitudinal Edge of Paved Surface Drop-Off on Vehicle Stability" (2), and the investigation "Influence of Roadway Disturbances On Vehicle Handling" (3) attempt to evaluate the effect of amount of traveled-way drop-off on vehicle response.

The primary objective of each investigation was to evaluate the vehicle response and the ability of the driver to control the vehicle while maneuvering across a drop-off at the edge of traveled-way.

The CALTRANS study involved one professional driver and four vehicles driving over three different levels of drop-off (1-1/2, 3-1/2, and 4-1/2 inches) at 60 mph. Two nonprofessional drivers participated

in a few supplementary tests and commented about driving over the drop-off heights at 40 to 45 mph.

The major conclusions reached by the CALTRANS studies, relative to the safety aspects of edge of traveled-way drop-off, suggest that no significant difficulties were encountered in redirecting a vehicle to the travel lane after driving across a drop-off of 4-1/2 inches.

The CALTRANS study did not include variables such as poor mechanical condition of the vehicle, driver inexperience or unpreparedness, adverse weather, roadway and shoulder geometry, roadside obstructions, nighttime driving conditions, or the influence of traffic operating on the same roadway. In this respect the findings are somewhat constrained. Even so, the results are informative and useful with respect to limiting values for edge of traveled-way drop-off.

The report by Klein et al. (3) provides information on driver response to driving across a drop-off as well as data pertinent to vehicle characteristics during edge of traveled-way drop-off maneuvers. These investigators conducted field studies involving 22 "naive" drivers with three vehicles: (1) compact, (2) intermediate, and (3) full size. The drivers were told to drive in a designated lane, off and back onto the pavement, at speeds ranging from 25 to 55 mph. Testing with these inexperienced drivers was limited to a 4-1/2-inch edge of traveled-way drop-off. Additional testing with instrumented vehicles over drop-off levels of 2, 2-1/2, 3-1/2, and 4-1/2 inches was also included in the study.





The results indicate that vehicle control is possible as a function of critical vehicle speed. The data and the driver response indicate that the vehicle-speed relationship for a 4-1/2-inch drop-off is as follows:

- Nova: 42 mph
- Pinto: 30 mph
- Capri (wagon): 32 mph.

While not explicitly stated in their report, it can be concluded that the critical speed would be considered a safe speed under which the vehicle could be controlled without violating driving lane restrictions. For example, the authors state:

> Below the critical speed almost all runs (85 percent) resulted in safe recoveries (no lane boundary exceedances), while above the critical speed almost all runs (83 percent) resulted in unsafe recoveries (lane boundary being exceeded).

Depending on the seriousness of the consequences, even 87 percent recovery may not be entirely acceptable.

This report also indicates a rapid rate of change in vehicle controlability between 2 inches and 4-1/2 inches, becoming extremely sensitive to drop-offs above 4 to 4-1/2 inches.

The overall evaluation of the results is limited to most of the constraints included in the CALTRANS studies particularly regarding

driving conditions, e.g., weather, preparedness, traffic, etc. Inexperienced drivers and curved sections were included in these studies.

It is significant that both studies indicate that an edge of traveled-way drop-off of 4 to 4-1/2 inches can be negotiated, under specific conditions, without losing control of the vehicle.



REFERENCES

1. Federal Highway Administration, "Evaluation of the Highway-Related Safety Program Standards," U.S. DOT, FHWA, 1977.

2. E. F. Nordlin, D. M. Parks, R. L. Stoughton, and J. R. Stoker, "The Effect of Longitudinal Edge of Paved Surface Drop-Off on Vehicle Stability," Final Report CA-DOT-TL-6783-1-76-22, Cal Trans, March 1976.

3. R. H. Klein, W. A. Johnson, and H. T. Szostak, "Influence Of Roadway Disturbances on Vehicle Handling," Vol. II, Technical Report, U. S. Department of Commerce, NTIS, Feb. 1977.



# APPENDIX F

## LITERATURE REVIEW OF ROADSIDE VEGETATION MAINTENANCE

INTRODUCTION

This appendix is a literature survey of roadside vegetation maintenance. It focuses on the control of vegetation and how various types of controls affect considerations such as safety, economic, aesthetic, and ecological impacts of roadside maintenance.

The information in this appendix is organized into the following sections:

- a list and description of information sources used in this appendix
- examples of maintenance specifications for various types and levels of service
- safety, economic, aesthetic, and ecological considerations for selecting maintenance levels-of-service
- information on the above considerations which would be useful when assessing the effects on those considerations caused by varying the types and levels-of-service*

---

*This section of the report also includes bibliographies with citations that may contain useful information (not all of the reports in the bibliographies were reviewed). The Reference Section in this appendix lists all the documents which were cited or otherwise used in this appendix.

- information on tradeoffs between conflicting considerations (e.g., mowing versus allowing vegetation to grow for animal habitat).

INFORMATION SOURCES

A variety of sources were consulted for this study including libraries, computer data bases, and staff members of several state Departments of Transportation (DOTs). A description of these sources follows.

Libraries

Several libraries on the University of California, Berkeley campus were visited. The Institute of Transportation Studies Library provided the greatest number of useful references. The California State Library in Sacramento was also contacted. A literature and computer data search was conducted by the library staff, and the pertinent information is included in this appendix.

State Departments of Transportation

Personnel specifically involved with roadside vegetation management were contacted at several state DOTs. They provided information on mowing policies, spraying programs, and (when possible) aesthetics, wildlife, and native vegetation. The following states were contacted:

- Illinois
- North Carolina
- Pennsylvania
- Wisconsin.



Computer Data Bases

A number of computer data files were accessed in an attempt to sample recent journal publications and ongoing research. The files included:

- DBI
- BIOSIS
- AGRICOLA
- COMPENDEX
- NTIS
- ENVIROLINE
- PROMPT
- SSIE
- HRIS.

The DBI (Data Base Index) file provided a listing of additional files with references that included the key words "roadside" and "vegetation" that were used in the search. Most of the data bases provided very few useful references (less than five). The NTIS, SSIE, and HRIS data bases provided the greatest number of useful references. Descriptions of these files are provided below.

NTIS.* Broad and cross-disciplinary file containing citations to U.S. government-sponsored research and development, technical reports from over 200 federal agencies and some reprints, federally-

*These informational descriptions are excerpted from a brochure provided by System Development Corporation Search Service which sells access time to these files.

sponsored translations, and foreign language reports in areas of major technical interest. Multi-disciplinary scope includes aeronautics, agriculture, astronomy and astrophysics, behavioral/social sciences, biological and medical sciences, chemistry, earth sciences, oceanography, electronics, engineering, energy, materials, mathematical sciences, military sciences, communications, space technology. Corresponds to Weekly Government Abstracts and semi-monthly Government Reports Announcements.

Prepared by: National Technical Information Service (NTIS) of the U.S. Department of Commerce

File Size: Approximately 60,000 records per year

Coverage: January 1970 to present

Updating: Bi-weekly, approximately 2,300 citations.

SSIE.* Covers ongoing and recently completed research in the agricultural sciences, behavioral sciences, biological sciences, earth sciences, chemistry and chemical engineering, electronics, engineering, materials, mathematics, medical sciences, physics, and social sciences (both basic and applied research projects). Research in progress is included from over 1,300 funding organizations, such as federal, state, and local government, non-profit associations, colleges and universities, non-affiliated investigators, and some non-U.S. organizations and private industry. Available on-line exclusively on the ORBIT system.

*These informational descriptions are excerpted from a brochure provided by System Development Corporation Search Service which sells access time to these files.



Prepared by: Smithsonian Science Information Exchange, Inc.

File Size: Approximately 108,000 projects per fiscal year

Coverage: Fiscal year 1974 to date

Updating: Monthly, approximately 9,000 records.

HRIS.* The input for Highway Research Information Service (HRIS) comes from over 4,000 domestic and foregin sources. Major contributors are the Highway Research Board, the U.S. Department of Transportation, and other information services with which the Board maintains exchange agreements, such as the International Road Federation, the International Road Research Documentation network of OECD through direct cooperation with the British Transport and Road Research Laboratory, the Smithsonian Science Information Exchange, the National Safety Council, the Roads and Transportation Association of Canada, and the Road Research Institute of Brazil. The service contains summaries of ongoing research projects and abstracts of published reports, including the abstracts of reports made available to the public by the Urban Mass Transportation Administration of all federally sponsored and completed urban mass transportation research, technical studies, university grants, and other projects.

*These informational descriptions are excerpted from a brochure provided by System Development Corporation Search Service which sells access time to these files.

Prepared by: Highway Research Board

File Size: Approximately 70,000 references to date

Coverage: 1967 to date including several thousand selected references from 1966 and earlier

Updating: Approximately 10,000 references added annually.

## Annotated Bibliographies

During this literature survey, two excellent annotated bibliographies were found that contained 500 to 600 references. They are organized by topic, many of which deal specifically with vegetation management or are tangential to the subject. Some of the most pertinent references from the bibliographies are included in this report. These bibliographies should be reviewed in conjunction with the material presented here. The titles of these documents and some of the topics they cover are listed below.

- White, D.B., and M.H. Smithberg. 1971. Methods and Materials for the Maintenance of Turf on Highway Rights-of-Way. Department of Horticultural Science, University of Minnesota. This document includes references from approximately 90 periodicals from 1959 to 1970. The topics covered include:
  - mowing
  - weed control
  - growth regulators
  - use of native plants on roadsides
  - pesticides and their effect on wildlife.





- Dailey, N.S. 1978. Environmental Aspects of Transmission Lines. A Selected, Annotated Bibliography. Oak Ridge National Laboratory. Oak Ridge, Tennessee. January, 190 pp. This bibliography includes literature reviewed from 1949 to 1977. The topics covered include:
  - road rights-of-way
  - vegetation management
  - wildlife
  - aesthetic impacts
  - herbicides.

## SPECIFICATION OF MAINTENANCE LEVELS-OF-SERVICE

### Mowing

Description. Mowing programs vary considerably from state to state and are generally influenced by climatic factors and departmental practices. Recently, there has been a trend to reduce mowing programs both for total area mowed per mile of road and frequency of mowing. This reduction is primarily economically based, but more and more it is also based on environmental considerations. (These topics are more fully discussed in this appendix.)

Where Mowing is Conducted. Rights-of-way for all classes of roads are mowed to some extent. Most of the mowing is done between the roadway and the ditch. Backslopes (of ditches) are usually mowed only in urban areas, or near public facilities such as schools and churches. Roadcuts are mowed at least one mower width to preclude brush or trees.

Narrow rights-of-way (e.g., less than 12 feet) are often mowed in their entirety. For interstates, mowing widths varied from state to state. Many states have established mowing patterns, and mowing is practiced up to the edge of these patterns. However, where these patterns do not exist, mowing is done from the roadway, 15 to 40 feet out.

When Mowing is Conducted. The timing or frequency of mowing is influenced by a variety of factors, most of which are extrinsic to the need for mowing. They include:

- mowing contracts
- holidays
- complaints
- vegetation height
- class of road.

For those DOTs which contract out their mowing, it is usually done a specified number of times around specified dates regardless of whether more or less mowing is actually necessary. Frequently, mowing is carried out just prior to major holidays (Memorial Day, Fourth of July, Labor Day) for public relations purposes. However, those DOTs contacted who follow this schedule indicated that these dates correspond well with the need for mowing (i.e., the vegetation has reached a height where mowing is considered necessary). For those DOTs that are trying to reduce the frequency of mowing, additional mowing usually takes place only after complaints have been received from the public. Mowing is often carried out only after vegetation has reached a specified height.



Finally, the frequency of mowing is sometimes based on the class of road being mowed. Some data have been compiled on the above factors and are presented in Tables F-1 through F-4.

Spraying

Description. Spraying programs are conducted throughout the United States and are used to reduce the demand for mowing, control weeds, and control or eliminate trees and shrubs. Two basic groups of herbicides are used in these programs: (1) sterilants, which eradicate vegetation, and (2) herbicides which are suppressants and growth inhibitors.

Where Spraying is Conducted. Sterilants are most commonly used along guardrails, fences, medians, graveled shoulders, and other places where vegetation is both undesirable and difficult to mow or otherwise maintain. Suppressants and inhibitors slow, stop, or direct the growth of vegetation. They are used in areas where vegetation is desirable (e.g., for erosion control) but are difficult or dangerous to mow or otherwise maintain. These areas include slopes, traffic islands, and places where sterilants may also be used. Suppresants are also used along interstates, controlled-access highways, and other frequently-mowed areas to reduce the frequency of mowing.

When Spraying is Conducted. To control growth, herbicides must be simultaneously applied with a specific biological phase of vegetation growth. Thus, herbicides are classified as pre-emergent, emergent, post-emergent, and contact. Some DOTs have indicated that: (1) because spraying is not

Table F-1. AVERAGE NUMBER OF ANNUAL MOWINGS ON HIGH TYPE ROADS FOR SELECTED STATES*

| State | Road Types** | Average Number Of Mowings |
|---|---|---|
| Louisiana | Interstate | 3.82 |
| | Primary | 2.61 |
| | Interstate | |
| | Urban | 6 |
| | Rural | 4 |
| Virginia | Major Primary | |
| | Urban | |
| | East | 6 |
| | All except East | 5 |
| | Rural | |
| | East | 6 |
| | Central | 4 |
| | West | 3 |
| Indiana | All | |
| | North | 3 |
| | South | 4 |
| Wyoming | All | |
| | Non-Irrigated | 2 - 3 |
| | Irrigated | 0 - 1 |
| Minnesota | All | 2 |
| California | All | 3 |
| North Carolina | Rights-of-way | |
| | 100 Feet | 4 |
| | Primary | |
| | 100 Feet | 4 |

* This table was excerpted from Creech 1977.

**Secondary roads are mowed once annually.



Table F-2. NUMBER OF MOWINGS PER YEAR BY ROAD CLASS

| State | Road Type | Number of Mowings per Year |
|---|---|---|
| Illinois | All Classes | 3 - 4 |
| North Carolina | All Classes* | 4 or less |
| Pennsylvania | Interstate | 1 - 2 |
| | Primary | 4 |
| | Secondary | 2 |
| Wisconsin | All Classes | 1 - 2 |

*Secondary roads are mowed more frequently than others to eliminate obstructions to school buses.

Table F-3. RANGE OF MAINTAINED HEIGHTS FOR VEGETATION ON HIGH TYPE ROADS FOR SELECTED STATES*

| | Vegetation Maintained Between Specified Heights (In Inches) | |
|---|---|---|
| State | Urban | Rural |
| Louisiana | 4 - 8 | 4 - 12 |
| Virginia | 4 - 10 | 4 - 10 |
| Indiana | 4 - 12 | 4 - 12 |
| Wyoming | 4 - 24 | 4 - 24 |
| Minnesota | 3 - 12 | 4 - 12 |
| California | No Set Height | No Set Height |
| North California | 6 - 18 | 6 - 18 |

*This table was excerpted from Creech 1977.

Table F-4. SEASONAL AND VEGETATION HEIGHT MOWING CONSIDERATIONS

| State | Vegetation Mowed at Specified Heights | Time of Year Mowing Occurs |
|---|---|---|
| Illinois | Not Specified | Before Memorial Day, Fourth of July, Labor Day, and once in fall if necessary |
| North Carolina | 12 - 18 inches | Not Specified |
| Pennsylvania | 8 - 12 inches* | Before Memorial Day, Fourth of July, and Labor Day |
| Wisconsin | Not Specified | June, late August, or early September |

*Interstate only.



more effective than mowing, and (2) the timing and other aspects of application pose significant problems, spraying programs have been discontinued or reduced (especially with respect to suppresants). However, Creech (1977) found that Louisiana was able to significantly reduce their mowing program by increased spraying.

Shrub and Tree Maintenance

Description. Shrub and tree maintenance programs are usually a combination of mowing, spraying, cutting and pruning, or removal and are conducted on an "as needed" basis. Probably the most common way of controlling this type of vegetation is by mowing the rights-of-way so the vegetation cannot establish itself. Spraying programs have also been used to stop, retard, or direct the growth of shrubs and trees. One commonly used product is Krenite. Buds sprayed with this material will not develop. Spraying the sides of the shrubs or trees nearest the road will retard growth which could otherwise obstruct views or overhang the road; the unsprayed side will continue to develop. Cutting, pruning, and removal of shrubs and trees is generally labor intensive and/or requires specialized removal equipment.

Where Programs are Conducted. Shrubs and trees are often discouraged from growing anywhere in rights-of-way because they can interfere with traffic and power lines and are costly to maintain. If they are allowed to grow, it is usually no closer than at least one mower width from the road. In wide rights-of-way (such as along the interstate system), they are usually maintained at the outer edge of the right-of-way, farthest from the road.

When Programs are Conducted. Brush and trees can be removed on a year-round basis. However, removal is influenced by a number of factors such as softness of the ground where heavy equipment must be placed, possible disturbance of wildlife, and the presence of toxic vegetation (e.g., poison ivy). Historically, brushing has been done in the winter as a make-work function to keep road crews busy (Creech 1977).

## CONSIDERATIONS FOR SELECTING MAINTENANCE LEVELS-OF-SERVICE

There are a number of factors that should be considered in the selection of maintenance levels-of-service. These include safety, ecology, economics, and aesthetics. These factors will be discussed for the following vegetation maintenance practices: mowing, spraying, brushing/trimming, and other pertinent topics.

### Safety Considerations

Mowing. A number of vegetation maintenance practices affect driver safety. Probably the principle practice of this type is mowing along roadsides to improve driver sight distances. Most DOTs mow when vegetation has reached a height between 1 and 2 feet. Mowing also helps maintain a green strip along roads to help prevent fires that start when cigarettes thrown by passing motorists land in tall, dry vegetation. Smoke from roadside fires can constitute a roadside hazard.

Spraying. Spraying programs are conducted to control the height of roadside vegetation and to direct the growth of shrubs and trees.



These programs improve sight distances and prevent vegetation from overhanging onto roads. Another safety aspect of spraying programs is that they are often carried out in areas where mowing can be dangerous to the mower operator (e.g., in meridians).

Brush/Tree Maintenance. Brush and tree trimming are conducted to improve driver sight distances. It is also an important practice in states where overhanging vegetation creates safety problems by shading road surfaces and causing ice to form.

The removal of trees that grow near the roadside will help eliminate hazards to vehicles that leave the road. However, brush growing along the roadside or in meridians provides effective crash barriers. Large trees can also be hazardous: during storms large limbs or the trees themselves either fall on the road or down utility lines.

Wildlife. Maintenance (and establishment) of vegetation can also affect roadside wildlife populations which in turn can create safety problems. Small mammals and birds that are attracted to roadside vegetation for food and/or cover are not serious safety problems for the motorist. However, large mammals (e.g., deer) have been responsible for highway fatalities. In states where this is a serious problem (e.g., Virginia, Pennsylvania), establishment and/or maintenance of plant species which attract these large animals should probably be discouraged.

Aesthetics. Vegetation maintenance and aesthetic considerations can also interact to influence safety considerations. For example, mowing

patterns and trimming programs are often designed to provide a visually pleasing and interesting roadside view. This helps reduce driver fatigue and the likelihood of falling asleep at the wheel.

## Economic Considerations

Mowing. Probably the most commonly used method of reducing maintenance costs is to reduce the frequency of mowing. Studies have been conducted to examine the effects of reduced mowing and to determine the optimum times to mow (see Economic Considerations Information beginning on page 23).

Spraying. Many DOTs have been involved in studies to reduce vegetation maintenance costs while still providing adequate control. Creech (1977) found that Louisiana was able to significantly reduce the overall costs of their spraying/mowing program by decreasing mowing and increasing spraying. However, at least one state contacted in this study indicated that it was as costly to spray (suppressants) as to mow and that they preferred to mow. Creech also states that spraying is less energy and labor intensive than is mowing.

Brush/Tree Maintenance. Brush and tree maintenance are probably the most labor intensive and, therefore, the most costly aspect of roadside vegetation maintenance programs. Mowing rights-of-way to inhibit the growth of trees and shrubs may be the least costly way of maintaining vegetation (by precluding growth). However, a brush maintenance program has been established in Wisconsin to reduce overall maintenance costs



over a period of years (Natural Resources Committee of State Agencies 1967). A description of the program is on page 29 of this appendix.

A study described in the source cited above showed that insects and mammals occupying grassy rights-of-way adjoining farmland were more serious crop threats than those residing in shrub cover. This is an example of a secondary economic consideration of roadside vegetation maintenance.

Native Vegetation. Interest has been growing in preserving and re-establishing native flora along road rights-of-way. The advantage of planting or preserving native species is that they are adapted to their environment and can survive without the special attention (e.g., watering, trimming) that many landscape exotics often demand. The disadvantage is that it is sometimes difficult and expensive to obtain native stock. Frequently, native species will voluntarily invade rights-of-way thereby providing "free" stock. Sometimes native species must be seeded or transplanted. Seedings can be thinned from other rights-of-way and transplanted to new areas. Seeds (from wild flowers, native grasses) can be gathered from existing areas. As interest in native vegetation restoration has grown, so have the number of private nurseries and seed producers which sell native stock.

Wildlife. Some states are reducing mowing/spraying programs to both reduce costs and improve the rights-of-way for wildlife habitat. In some cases, mowing is delayed until the completion of the nesting season. Other states (e.g., Illinois) are involved in food and cover enhancement and signing of roadsides for wildlife protection and enhancement. The

Illinois "Roadsides for Wildlife" program (and its costs) are described later in this appendix (see page 34).

The Utah DOT is involved in a program to encourage the growth of legumes and native vegetation along roadsides to provide food for bees (and a cash crop for beekeepers).

## Aesthetic Considerations

Mowing. In general, the literature and state DOTs indicate that the public views a mowed roadside as aesthetically pleasing. Some DOT personnel feel that the public can be persuaded that unmowed roadsides are also attractive. In some states where programs for wildflower planting or nesting habitat protection are conducted, roadsides are "signed" to inform the public of the purpose for not mowing the roadsides. This is done in an attempt to win public acceptance by showing that unmowed roadsides are beneficial.

Spraying. Spraying programs are often conducted during nongrowing seasons to avoid unsightly "brown-outs" due to vegetation kill.

Brush/Tree Maintenance. Maintaining shrubs and trees in rights-of-way provide an aesthetically pleasing and varied view to passing motorists. Trimming and removal of trees and shrubs usually only temporarily impacts the visual aspect of the roadside. However, spraying (for control or eradication) can create long-term visual impacts by killing vegetation. Programs should, therefore, be conducted in a manner that minimizes such impacts.





Native Vegetation. Some of the most aesthetically pleasing rights-of-way have been maintained or planted with native vegetation. A number of states have initiated wildflower seeding programs along their roadsides. During road construction (especially interstate) specimen trees or clumps of shrubs can often be left to improve the motorists view and complement vegetation outside the right-of-way. The native vegetation along roads often leaves motorists with lasting remembrances of new areas.

## Ecological Considerations

Mowing. Mowing can potentially disrupt the native flora and fauna growing along a roadside: it can also be conducted in a manner that minimizes any impacts. Wildflowers can survive periodic mowing (Hesse and Salac 1973). Mowing can also be delayed to allow birds to complete their nesting period along rights-of-way. In general, continuous mowing reduces both food and cover for wildlife.

Spraying. The spraying of herbicides along rights-of-way is potentially the most ecologically disruptive of all roadside maintenance practices. The application of herbicides must frequently be timed to a specific phase of plant development. If the timing is off, the target plant may not be affected. If a rainstorm closely follows a herbicide application, much of the effectiveness could be lost through herbicide wash-off. However, the herbicide does not disappear. Instead, it is incorporated into the runoff and ends up in streams or other waterways where it may remain toxic to plant and animal life for an extended time.

The quantities of herbicides dispersed during application may not always be closely regulated. This may result in an "overkill" (i.e., more herbicide is applied than is necessary to kill or otherwise control the plant). In the short-term, the target plants may be controlled. In the long-term, irreversible environmental damage may occur. (See page 38 for a discussion on herbicides.)

Brush/Tree Maintenance. The removal of all shrubs and trees along roadsides means the loss of habitat for certain species of plants and animals. However, selective removal can enhance wildlife habitat by providing better sources of food and cover.

Roadsides of predominately brush need less maintenance than those managed with grasses or herbaceous plants. Mowing a strip immediately adjacent to the road once every 2 or 3 years may be all that is necessary to control the brush (Moore 1977).

It has also been found that species of insects and mammals which reside in shrub rights-of-way are less of a threat to crops than those which live in grassy rights-of-way adjoining farmland (Natural Resources Committee of State Agencies 1967).



## INFORMATION AVAILABLE FOR ASSESSING EFFECTS OF ALTERNATIVE LEVELS-OF-SERVICE ON VARIOUS CONSIDERATIONS

The following information was taken from the literature available on roadside vegetation maintenance. It provides some background information on various considerations for vegetation maintenance (i.e., safety, economic, aesthetic, ecological). It also provides some information on the effects of a single type of maintenance (mowing, spraying, tree/brush maintenance) on the considerations.

### Safety Considerations Information

Very few publications were found which presented more than a sentence or two on the safety aspects of vegetation management. Most of the information found is presented in the Safety Considerations Section (page 14). The additional information is presented below.

Mowing. In a study in North Dakota that examined the impact of mowing on duck nesting habits it was found that leaving interstate rights-of-way unmowed for 1-year did not cause snow build-up on the driving surface.

Wildlife. Birds and small or medium-sized mammals (e.g., rabbits, woodchucks) attracted to roadside vegetation are frequently killed by vehicles. In general, they do not pose a problem to traffic. However, deer can be a safety problem. Duell (1969) reported an appreciable annual rise in deer deaths caused by cars in Virginia (from 1960 to 1965). He did not, however, provide any information on the impact to humans involved in the accidents. He also reported that a number of

states and several foreign countries have experimented with mirrors to reduce the number of deer accidents. This technique was generally successful but the mirrors were expensive and susceptible to vandalism.

Bibliography. The following documents contain information on safety and vegetation management.

Duell, R.W. 1969. Highway Vegetation: For Utility, Safety, Economy and Beauty. Rutgers University Agriculture Experiment Station. Bulletin No. 822. 30 pp.

Illinois Department of Transportation. 1978. Effects of Roadside Vegetation on Drifting Snow. Bureau of Maintenance. September, 14 pp.

Oetting, R.D., and J.F. Cassel. 1970. Effects of Interstate Right-of-Way Mowing on Wildlife, Snow Buildup, and Motorists Opinions in North Dakota. A Preliminary Report. Highway Res. Abstracts 39(12):74.

## Economic Considerations Information

Mowing. Several recent publications provide a good survey of mowing practices. Of these, one of the most comprehensive is "Deferred Maintenance-Roadside Vegetation and Drainage Facilities" (Creech 1977). In this study, field data were collected in the following states:

- California
- Wyoming
- Minnesota
- Indiana
- Virginia
- Louisiana.





The report addresses and contains field data on a variety of subjects, including:

- average number of mowings by road type
- maintained vegetation heights by road type
- mowing costs per acre
- total mowing costs and acres mowed
- mowing standards
- mowing reductions.

In addition, this report includes a summary of the maintenance philosophies of these states and a literature review summary covering deferred, reduced, or adjusted maintenance practices.

In "A Low-Cost Maintenance Program for Indiana Roadsides" (1977) Moore evaluated a 5-year study (1972 to 1977) of Indiana highway mowing practices and compared his findings to practices in other states and in Europe. Factors that influence highway mowing practices are also discussed. Weed populations in mowed and unmowed areas previously treated with 2,4-D amine were compared to determine the number of plants per acre. Major findings of uniform mowing tests are discussed. Recommendations for mowing (in conjunction with a spraying program) are made with respect to safety and/or appearance factors.

Moore found that in Indiana, one-cycle mowing conducted in the first week of August was adequate for interstates. This was especially true for areas where bluegrass was the dominant species. By that date, the

grass was approximately 2 feet tall yet the roads were not unsightly, sight distances were maintaned at intersections and inside curves, and traffic control devices were still visible. Moore also found that there were no harmful effects from not mowing grass where weed control was adequate (e.g., along interstates) and was actually superior to one or two-cycle mowing which was done poorly.

In a section of a Public Works publication (May 1979), it was found that areas established in tall grasses should only require mowing for spot weed control, and then weeds should be mowed when present but not mature. It was also found that mowing of grass plants in the fall may stimulate lush growth that makes the plants more susceptible to winter kill. Close mowing not only reduces leaf surface but also reduces the extent of the root system. This can decrease the plants' effectiveness in erosion control and make them less resistant to hot, dry weather.

"Improving Grassing Construction and Maintenance" (Whittington 1977) discusses the mowing practices in Georgia. Advantages and disadvantages of mowing standards, and recommendations to improve the standards are included in the report.

<u>Bibliography.</u> The following documents may contain pertinent information on mowing practices.

Anonymous. 1979. Turf and Roadside Maintenance. Public Works Manual. Section B-8, pp. B-62 - B-66. May.

Anonymous. 1978. Cloverleaf - More Than a Roadway Design. Public Works. December, p. 49



Borup, B. 1978. 'Bugs', Mowers and Sprays - Part 2, Roadside Maintenance. Rural and Urban Roads. February.

Creech, M.F. 1977. Deferred Maintenance: Roadside Vegetation and Drainage Facilities. Byrd, Tollamy, MacDonald and Lewis, A Division of Wilbur Smith and Associates. Prepared for Federal Highway Administration. Report Number FHWA-RD-77-502, August, 114 pp.

Dailey, N.S. 1978. Environmental Aspects of Transmission Lines - A Selected, Annotated Bibliography. Oak Ridge National Laboratory. Oak Ridge, Tennessee. January, 190 pp.

Dudeck, A.E., and J.O. Young. 1968. Establishment and Use of Turf and Other Ground Covers. Nebraska Dept. Roads. Highway Research Project No. 1. 1967 Annual Report. 25 pp.

Duell, R.W. 1969. Highway Vegetation: For Utility, Safety, Economy and Beauty. Rutgers University Agriculture Experiment Station. Bulletin No. 822. 30 pp.

Duell, R.W., and R.M. Schmit. 1975. Better Grasses for Roadsides. Rutgers University. Final Report HPR-7726. 66 pp.

Hesse, J.F., and S.S. Salac. 1973. Effects of Mowing on the Vegetative and Reproductive Development of Species of Wild Flowers. Department of Horticulture and Forestry, University of Nebraska. Lincoln, Nebraska. June, 38 pp.

Juska, F.V., and A.A. Hanson. 1961. Effects of Interval and Height of Mowing on Growth of Merion and Common Kentucky Bluegrass (<u>Poa pratensis L.</u>). Agron. Jour. 53:385-388.

Moore, D.J. 1977. A Low-Cost Maintenance Program for Indiana Roadsides. Purdue University and Indiana State Highway Commission. Joint Highway Research Project, JHRP-77-13. July, 101 pp.

Torstensson, G. 1938. Influence of the Interval of Time Between Cuts and Height of Stubble on Yield and Root Development in Grasses. Medd. Svenska Bettes-O. Vallforen 5:1-37. 1938. Herbage Abstracts, 8(4):420. 1938. Imperial Bureau of Pastures and Forage Crops Mimeo Pub. No. 2. Aberystwyth, Great Britian.

Watson, J.R., Jr. 1968. Mowing Theory and Practices. Central Plains Turfgrass Foundation. Manhattan, Kansas. March.

White, D.B., and M.H. Smithberg. 1971. Methods and Materials for the Maintenance of Turf on Highway Rights-of-Way—An Annotated Bibliography. Department of Horticultural Science, University of Minnesota. Investigation Number 619. June, 102 pp.

White, D.B., and T.B. Bailey. 1969. Vegetation Maintenance Practices, Programs, and Equipment on Minnesota Highways. Department of Horticultural Science, University of Minnesota. Investigation Number 619. February, 69 pp.

Whittington, E.L. 1977. Improving Grassing Construction and Maintenance. Georgia Department of Transportation. Departmental Research Special Report. Atlanta, Georgia. January, 72 pp.

Aesthetic Considerations Information

Discussion. Little information is available concerning the impact on the aesthetic aspects of roadsides from vegetation control. Most of the literature in this area deals with establishing vegetation (e.g., wild flowers) and landscaping roadsides to improve their visual aspect.

The DOTs that were contacted reported that they had not conducted user surveys on this type of impact. However, most cited instances of complaints about unmowed areas or indicated they would receive complaints if areas were left unmowed for an extended time. Complaints were also generated when herbicides were applied during the summer (when foliage is greatest) thus causing unsightly "brown-outs." On the positive side, the Pennsylvania DOT has received compliments on its flowering crown-vetch along roadsides.

It is possible to decrease the overall maintenance of a roadside as well as enhance its aesthetic appeal. This can be done by returning roadsides to natural landscapes by allowing native species to invade or by having them planted. Many roadsides are mowed, flat, monocultures of exotic grasses. An advantage to maintaining a natural (native) landscape



is that it helps limit mowing to areas where it is necessary to maintain sight distances or keep trees and shrubs from the edge of the road. Another advantage of a diverse (native) roadside flora is that it helps break the monotony of driving. Some DOTs have special mowing patterns just for this purpose. Others have attempted to open up a view from the road (during road construction) to a pleasing landscape or geologic formation. To save the native landscape, some DOT's have adopted policies to keep disturbances to the existing environment to a minimum during road construction. After construction, the roadside environment is reconstructed to approximately its preconstruction condition.

Bibliography. The following documents contain information on vegetation maintenance and aesthetics.

Creech, M.F. 1977. Deferred Maintenance: Roadside Vegetation and Drainage Facilities. Byrd, Tollamy, MacDonald and Lewis, A Division of Wilbur Smith and Associates. Prepared for Federal Highway Administration. Report Number FHWA-RD-77-502. August, 114 pp.

Dailey, N.S. 1978. Environmental Aspects of Transmission Lines. A Selected, Annotated Bibliography. Oak Ridge National Laboratory. Oak Ridge Tennessee. January, 190 pp.

Davidson, P., J. Tomer, and A. Waldman. 1968. The Economic Benefits Accruing from the Scenic Enhancement of Highways. Rutgers State University, Bureau of Economic Research.

Natural Resources Committee of State Agencies. 1967. Selective Brush Management Program for Wisconsin Roadsides. Madison, WI. July, 16 pp.

Vredenbregh, P. 1978. Colors Easy on the "I". Wisconsin Natural Resources. 2(4): 28-29, July-August.

Whittington, E.L., P.B. Middlebrooks, Jr., and J. Wall. 1977. Improving Grassing Construction and Maintenance. Georgia Department of Transportation. Special Departmental Research Report. Atlanta, GA. January, 72 pp.

Wisconsin Natural Resources Council of State Agencies. 1972. A Roadside Conservation and Beautification Program for Southeastern Wisconsin Watersheds. Madison, WI.

## Ecological Considerations Information

It is generally agreed that a diverse flora is healthier than a monoculture such as one species of grass, tree, or shrub. Monocultures (either native or exotic) are more susceptible to pests and disease.

The use of exotics for landscaping has drawbacks. Exotic species do not evolve in the habitat into which where they are transplanted and may not integrate very well into the new ecosystem. Exotics may also "go wild" and over-run the environment, forcing native species out. On the other hand, native species, are well-suited to their environment, are an integral and productive part of the whole ecosystem, and provide food and cover for the native fauna. Some state DOTs are working with their Departments of Conservation to use native plant species that will provide food and cover for a variety of wildlife. These same native species can be used for aesthetic purposes, low maintenance cover, erosion control, and noise, crash, or view screening barriers.

Maintenance of Native Vegetation. A major reason for using native vegetation is to reestablish the natural aspect of the landscape, thereby minimizing maintenance.



In areas of grasses and forbes, mowing could be kept to once a year (except where tall grass could cause a visual safety problem). Natural reseeding of grasses and wild flowers would occur if the areas were moved in the fall (after the seeds have matured), using the mowed material for mulch.

A study was conducted by Hesse and Salac (1973) to determine the effects of mowing on the vegetative and reproductive development of eleven species of wild flowers. Twelve mowing dates were studied. Plants were mowed within 4 inches of the ground surface. All eleven species survived mowing but, in general, plant vigor was reduced. With one exception, the height usually reached by the plant was reduced by mowing. This reduction was directly correlated to the lateness of mowing. Mowed plants reached a more uniform height later in development than unmowed plants and they showed no lodging problem.

> "In most cases, the number of lateral buds forced on mowed plants was significantly greater than those left unmowed. The peak number of lateral buds forced was generally noted from plants mowed 2 to 4 weeks before blooming was initiated on the unmowed plants of any one species." Mowing extended and delayed the blooming of all species except one. The longest period of delay was two months. "The number of flowers produced per plant was generally reduced by mowing. However, the aesthetic value of the taller species was enhanced because mowing eliminated the open type of growth associated with lodging" (Hess and Salac 1973).

In some areas where snow drifting is a problem, it may be advantageous to delay cutting until spring. Vegetation could then act as a snow trap.

In general, trees and shrubs need little maintenance except in areas where they create visual hazards. In those instances, it may be necessary to replace them with low-growing species.

An example of a brush management program can be found in Wisconsin where such a program was initiated to reduce mowing costs and (in the long run) brush and tree management costs. In this program, trees and some undesirable shrubs are selectively removed and the growth of desired shrub species is encouraged. These shrubs eventually shade out tree saplings and discourage weed species as the spread. A minimal amount of right-of-way is mowed to maintain sight distances.

In a study by Moore (1977), it was found that in Indiana test plots (where a 1-, 2-, or 3-cycle mowing program was being tested) brush was effectively controlled in plots that had been mowed only once in 2 or 3 years.

The results of the above program and study indicate that roadside vegetation maintenance can be reduced and still be effective.

Many DOTs use Krenite to direct the growth of trees and shrubs. This product inhibits the growth of sprayed buds. Unsprayed buds are unaffected and follow a normal growth pattern. The advantage of this





practice is that the direction of growth can be controlled. This makes it possible to keep trees and shrubs from overhanging roads (which could create ice conditions in winter or block a driver's view) but still allows them to grow on the unsprayed side.

Native trees and shrubs can be used for many purposes such as:

- food and cover for wildlife (including honeybees)
- wind, noise, crash, and/or visual barriers
- aesthetic enhancement
- erosion control.

However, in snow states they should be carefully placed and arranged. Often, such plantings have caused severe snow drifting across roads (Illinois DOT 1978).

Bibliography. The following publications may provide pertinent information on the maintenance of native vegetation.

Aikman, J.W. 1960. The Use of Native Midwestern Grasses for Highway Purposes. Ohio Department of Highways and Ohio State University. 19th Short Course on Roadside Development, pp. 71-79.

Anonymous. 1978. Cloverleaf - More Than a Roadway Design. Public Works. December, p. 49.

Creech, M.F. 1977. Deferred Maintenance: Roadside Vegetation and Drainage Facilities. Byrd, Tollamy, Macdonald and Lewis, A Division of Wilbur Smith and Associates. Prepared for Federal Highway Administration. Report Number FHWA-RD-77-502. August, 114 pp.

Crockett, J.J. 1967. Effect of Mowing on a Relict Tall Grass Prairie. Proceeding Oklahoma Academy Sciences. (1965) 46:1-2.

Dailey, N.S. 1978. Environmental Aspects of Transmission Lines - A Selected, Annotated Bibliography. Oak Ridge National Laboratory. Oak Ridge, Tennessee. January, 190 pp.

Ehrenreich, J.H., and J.M. Aikman. 1963. An Ecological Study of the Effect of Certain Management Practices on Native Prairie in Iowa. Col. Monogr. 33(2):113-130.

Hesse, J.F., and S.S. Salac. 1973. Effects of Mowing on the Vegetative and Reproductive Development of Species of Wild Flowers. Department of Horticulture and Foresty, University of Nebraska. Lincoln, Nebraska. June, 38 pp.

Huffine, W.W. 1969. Species Evaluation and Ecology in Roadside Stabilization. Procedures of the 1st International Turfgrass Research Conference. Harrogate, England. pp. 592-597.

Illinois Department of Transportation. 1978. Effects of Roadside Vegetation on Drifting Snow. Bureau of Maintenance. September, 14 pp.

Morrison, D.G. 1978. Native Vegetation Restoration. Department of Landscape Architecture, University of Wisconsin. Madison, Wisconsin.

Natural Resources Committee of State Agencies. 1967. Selective Brush Management Program for Wisconsin Roadsides. Madison, WI. July, 16 pp.

Owensby, C.E., G.M. Paulsen, and J.D. McKendrick. 1970. Effect of Burning and Clipping on Big Bluestem Reserve Carbohydrates. J. Range Management. 23:358-362.

Penfound, W.T. 1964. Effects of Denudation on the Productivity of Grassland. Ecology 45:838-845.

Tester, A., and W.H. Marshall. 1962. Minnesota Prairie Management Techniques and Their Wildlife Implications. Trans. North American

University of Wisconsin. 1977. Natural Roadsides. UW Extension, Environmental Resources Unit. Madison, WI. Brochure, July.

Vredenbregh, P. 1978. Colors Easy on the "I". Wisconsin Natural Resources. 2(4): 28-29, July-August. Wildlife Conference. 27:267-287.

White, D.B., and M.H. Smithberg. 1972. Turf Methods and Materials for Minnesota Highways. Final Report. Department of Horticultural Science, University of Minnesota. Investigation Number 619. November, 145 pp.



White, D.B., and M.H. Smithberg. 1971. Methods and Materials for the Maintenance of Turf on Highway Rights-of-Way - An Annotated Bibliography. Department of Horticultural Science, University cf Minnesota. Investigation Number 619. June, 102 pp.

Wisconsin Natural Resources Council of State Agencies, and Southeastern Wisconsin Regional Planning Commission. 1972. A Roadside Conservation and Beautification Program for Southeastern Wisconsin Watersheds. 26 pp.

Zak, J.M., J. Troll, S.H. Mosler, and R.S. Zak. 1977. Massachusetts Roadside Development Research - 1977. Massachusetts University, Department of Plant and Soil Sciences. Amherst, Massachusetts. December, 49 pp.

Zak, J.M, J. Troll, J.R. Havis, R.N. Carrow and S.H. Mosler. 1976. Roadside Vegetation Cover for Critical and Eroded Areas. Massachusetts University, Department of Plant and Soil Sciences. Amherst, Massachusetts. Massachusetts Department of Public Works. Wellesley Hills. Federal Highway Administration, Research and Materials Division. Washington, D.C. October, 137 pp.

Zak, J.M, J. Troll, J.R. Havis, H.M. Yegian, P.A. Kaskeski, W.W. Hamilton, and L.C. Hyde. 1972. The Use of Adaptable Plant Species for Roadside Cover in Massachusetts. University of Massachusetts, Department of Plant and Soil Sciences. February, 160 pp.

Young, W.C. 1968. Ecology of Roadside Treatments. J. Soil and Water Conservation. 23:47-50.

Wildlife. Roadside vegetation management programs for wildlife use vary considerably. In some areas, no attempt is made to encourage the use of roadsides by wildlife because of the large number of roadkills. This may be due to the nature of the surrounding habitat (i.e., rural, "wild" lands with high faunal densities). Other programs are putting forth considerable effort to encourage the use of roadsides. This is especially true in agricultural areas where little wildlife habitat remains.

In most cases, it is the state Department of Conservation or Natural Resources that initiates these programs. Together with the DOT, they attempt to use plant species that provide food and cover for wildlife as well as erosion control, snow-drift control, noise barriers, and other uses. In Wisconsin, the DOT has been working with the Department of Natural Resources for the past 16 years to develop native food and cover for wildlife. The Illinois Department of Conservation has been working for a comparable time on a roadside nesting habitat program, the first of its kind in the nation. Details of this "Roadsides for Wildlife" program (David and Warner 1978), its results, and its costs are described below.

In the past 10 to 15 years populations of both game and non-game birds have been significantly affected by farming practices and government farming policies. This is primarily due to a switch from hay fields, pastures, and small grain crops to row crops. In 1962, the Illinois Conservation Department and the Illinois Natural History Survey initiated studies on the potential of managing roadsides for pheasant nesting cover. The study involved planting roadsides with a brome/alfalfa mixture and the cooperation of the local farmers to delay their roadside mowing until August 1 (after the nesting period).

The results of these studies were good. The landowners involved in the program were highly cooperative. Nest densities in the seeded, unmowed areas were twice as high as in unseeded, unmowed control areas. The controlled seeding/mowing program not only provided pheasant and



songbird habitat, but also retarded noxious weed growth. In addition, local beekeepers commented favorably on the forage provided for honey bees. Other benefits included erosion control and reduced mowing (a saving of time, energy, and funds).

The result of these studies is the "Roadsides for Wildlife" program currently in its fifth year and the first of its kind in the nation. The Illinois DOT and some county highway departments have also reduced their mowing, with beneficial nesting results.

The costs of seeding, fertilizing, and signing roadsides is under $90 per acre. These costs are paid by revenues obtained from state hunting taxes and fees. Averaged over the 15-year life expectancy of the nesting cover, the cost is less than six dollars per acre/per year. There is some indication that the seedings will last well beyond the expected 15 years.

In a study dating back to 1929 in Wisconsin (Columbia County), it was shown that the loss of the quail population was directly related to the loss of approximately 60 percent of the hedgerows in the area. Two-thirds of the hedgerows lost were along roadsides. The study also stated that the wildlife that may be killed along roadsides would be more than compensated for by the increased production of wildlife in improved brushy areas (Natural Resources Committee of State Agencies 1967).

In 1968 and 1969, 23 miles of interstate rights-of-way in North Dakota were studied to learn how mowing affected duck nesting habits.

Approximately 74 percent of the nesting ducks choose the unmowed parcels (which consisted of alternative miles of right-of-way and half the interchange triangles). It was found that approximately one-third of the nests had not hatched by the July 4th mowing.

Bibliography. The following publications may provide pertinent information on wildlife and vegetation management.


Arner, D.H. 1977. Transmission Line Rights-of-Way Management Topical Briefs: Fish and Wildlife Resources and Electric Power Generation, Number 2. U.S. Fish and Wildlife Service. FWS/OBS-76/20.2. March.

Bramble, W.C. and W.R. Byrnes. 1974. Impact of Herbicides Upon Game Food and Cover on a Utility Right-of-Way. Purdue University, Agricultural Experiment Station. Res. Bull. No. 918. 16 pp.

Bramble, W.C. and W.R. Byrnes. 1955. Effect of Certain Common Brush Control Techniques and Materials on Game Food and Cover on a Power Line Right-of-Way, No. 1. P nn. State University Agricultural Experiment Station Program. Report No. 135. 7 pp.

Coulter, L.L. 1958. The Role of Herbicides in Wildlife Production Through Creation and Stabilization of Habitats. Down to Earth. Dow Chemical Company. Midland, MI. 13(4):4-6.

Dailey, N.S. 1978. Environmental Aspects of Transmission Lines - A Selected, Annotated Bibliography. Oak Ridge National Laboratory. Oak Ridge, Tennessee. January, 190 pp.

David, L.M., and R.E. Warner. 1978. Update: Roadsides for Wildlife. Illinois Department of Conservation. Outdoor Highlights. May 8, 4 pp.

Duell, R.W. 1969. Highway Vegetation: For Utility, Safety, Economy and Beauty. Rutgers University Agriculture Experiment Station. Bulletin No. 822. 30 pp.

Edminister, F.C. 1939. Hedge Plantings for Erosion Control and Wild-Life Management. Trans. N. Amer. Wildl. Conf. 4:534-541.

Joselyn, G.B., J.E. Warnock, and S.L. Etter. 1968. Manipulation of Roadside Cover for Nesting Pheasants - A Preliminary Report. J. Wildlife Management. 32(2):217-233.





Lawrence, W.H. 1967. Effects of Vegetation Management on Wildlife. Symposium Proceedings: Herbicides and Vegetation Management. Oregon State University. Corvallis, OR. pp. 89-93.

Moore, N.W. 1967. A Synopsis of the Pesticide Problem. Advan. Ecol. Res. 4:75-129.

Natural Resources Committee of State Agencies. 1967. Selective Brush Management Program for Wisconsin Roadsides. Madison, WI. July, 16 pp.

Oetting, R.D. 1971. Right-of-Way Resources of the Prairie Provinces. Manitoba Department of Mines. Winnipeg. Manitoba, Canada. Blue Jay, 29(4):179-183. December.

Oetting, R.D., and J.F. Cassel. 1970. Effects of Interstate Right-of-Way Mowing on Wildlife, Snow Buildup, and Motorists Opinions in North Dakota. A Preliminary Report. Highway Res. Abstracts 39(12):74.

University of Washington. 1970. A preliminary Bibliography on Rights-of-Way Management. College of Forest Resources. Seattle, WA. January.

Warner, R.E., and G.B. Joselyn. 1978. Roadside Management for Pheasants in Illinois: Acceptance by Farm Cooperators. The Wildlife Society Bull., 6(3):128-134. Fall.

Way, J.M. 1969. Management of Roadsides for the Conservation of Wildlife in Britain. 28th Ohio State University Short Course on Roadside Development. pp. 69-76.

White, D.B., and M.H. Smithberg. 1971. Methods and Materials for the Maintenance of Turf on Highway Rights-of-Way - An Annotated Bibliography. Department of Horticultural Science, University of Minnesota. Investigation Number 619. June, 102 pp.


Herbicides. Although considerable literature exists on the use and effects of herbicides for roadside vegetation management, much of this literature is now obsolete. Herbicide development and technology has dramatically changed in response to the expansion of government regulations. Usage is now limited to those substances that are proven to be environmentally safe. Scores of chemicals developed in the early 1900s which have proven deleterious to various ecosystems are now illegal.

Some of the most frequently recommended herbicides for roadside vegetation maintenance have recently been the focus of concern because of the toxicity which they exhibit in the environment. The EPA recently suspended the use of 2,4,5-T and Silvex in all areas except rice fields and rangelands. Both these herbicides contain the toxic substance TCDD (dioxin). The herbicide 2,4-D is under special review and a Pre-RPAR (Rebuttable Presumption Against Registration) review has been issued for Paraquat. Table F-5 lists some of these herbicides and possible areas of concern for them (EPA 1979).

An article by Pimentel and Pimentel (1979) also points out some problems with 2,4-D use.

> "A few corn herbicides, 2,4-D in particular, render corn more susceptible to pathogens and insects such as the corn leaf aphid. In fields treated with usual dosages of 2,4-D, corn leaf aphid populations have numbered more than three times those on untreated corn. Corn exposed to 2,4-D also suffer one-third more attacks from European corn borer, another pest. Laboratory studies have shown that corn borer pupae growing on plants exposed to 2,4-D were about one-quarter larger than those on untreated corn plants, and moths from these larger pupae produced one-third more eggs. Corn exposed to 2,4-D was not only more susceptible to aphids and borers, it also had more southern corn leaf blight infections and larger corn smut galls than did





Table F-5. POSSIBLE TOXIC EFFECTS FOR SOME HERBICIDES[1]

| Chemicals (Class of Chemicals) | 40 CFR 162.11 Criteria Possibly Met or Exceeded |
|---|---|
| 2,4,5-T<br>2,4,5-tri-chlorophenoxy acetic acid | Oncogenicity[2], teratogenicity[3] and fetotoxicity[4] |
| Paraquat | Acute inhalation, teratogenicity, emergency treatment, chronic effects, reduced fertility, environmental effects, and data gaps (oncogenicity and mutagenicity[5]) |
| Silvex<br>2-(2,4,5-tri-chlorophenoxy) propionic acid (related to 2,4,5-T) | Oncogenicity, teratogenic, and fetotoxic effects |

1 This information was excerpted from the Special Pesticide Review Division Status Report for Issued RPAR's (Rebuttable Presumption Against Registration) (EPA 1979).
2 The capacity to induce or form tumors.
3 The tendency to cause developmental malformations and monstrosities.
4 The capacity to be toxic to a fetus.
5 The capacity to induce mutations.

untreated corn. Evidently, some herbicide treatment of corn and other crops may increase risks of disease and insect attack."

Bibliography. The following publications may provide useful information on the use of herbicides for roadside vegetation maintenance. Although some of the documents may refer to chemicals already banned, they are included here because they may contain information pertinent to herbicides in a generic sense.


Allen, T.J., and W.G. McCully. 1976. Establishment and Management of Roadside Vegetation. Texas Transportation Institute, Texas A & M and Texas State Department of Highways and Public Transportation. December, 137 pp.

Anonymous. 1974. Vegetation Management for Safe and Sightly Roadsides. Public Works. 105(4):86-87, April.

Anonymous. 1979. EPA Suspends Use of 2,4,5-T. Conservation News. April, p 6.

Anonymous. 1979. Chemical Programs. Public Works Manual. May, Section B-8.2, pp. B-65 - B-66.

Borup, B. 1978. 'Bugs', Mowers and Sprays - Part 2, Roadside Maintenance. Rural and Urban Roads. February.

Creech, M.F. 1977. Deferred Maintenance: Roadside Vegetation and Drainage Facilities. Byrd, Tollamy, Macdonald and Lewis, A Division of Wilbur Smith and Associates. Prepared for Federal Highway Administration. Report Number FHWA-RD-77-502. August, 114 pp.

Dailey, N.S. 1978. Environmental Aspects of Transmission Lines - A Selected, Annotated Bibliography. Oak Ridge National Laboratory. Oak Ridge, Tennessee. January. 190 pp.

Environmental Protection Agency. 1979. Special Pesticide Review Division Status Report for Issued RPAR's (Rebuttable Presumption Against Registration). March 9.

Environmental Protection Agency. 1978. Suspended and Cancelled Pesticides and Toxic Substances Enforcement Division, Scientific Support Branch. May, 17 pp.





Fedderson, R.L. 1970. Herbicide Drift Damage and Its Control. 29th Short Course on Roadside Development. Ohio Dept. Highways and Ohio State Univ. Dept. Landscape Arch. pp. 98-101.

Hay, J. 1978. Oregon's Approach to Roadside Vegetation Control. Public Works. 109(12):36-37. December.

L.R.E. 1979. EPA Suspends the Major Uses of Two Herbicides. Environmental Science and Technology. 13(6): 640-641, June.

Miller, A.S. 1979. 2,4,5-T: Chemical Time Bomb. Environment. 21(5): 2-4, June.

Moore, D.J. 1976. Chemical Control of Brush and Environmental Safety of Roadside Vegetation Management Chemicals. Purdue University and the Indiana State Highway Commission. Joint Highway Research Project, JHRP-76-32.

Moore, D.J., and D.A. Werderitsch. 1972. Chemical Weed Control. Purdue University and Indiana State Highway Commission. Joint Highway Research Project No. 24. 102 pp.

Pimental, D. and M. Pimentel. 1979. The Risks of Pesticides. Natural History. 88(3): 24, 28, 30-31.

Pouciau, O.M., Jr. 1976. The Benefits and Savings of Roadside Spraying Programs. Rural and Urban Roads. February, pp 56, 59.

University of Washington. 1970. A Preliminary Bibliography on Rights-of-Way Management. College of Forest Resources. Seattle, Washington. January.

U.S. Forest Service. 1973. Vegetation Management with Herbicides Program on the Umatilla, Malheur, and Wallova-Whitman National Forests, Oregon. Final Environmental Impact Statement. USFS, Pacific Northwest Region. Portland, Oregon. EIS-OR-73-0931-F. May, 410 pp.

White, D.B., and M.H. Smithberg. 1971. Methods and Materials for the Maintenance of Turf on Highway Rights-of-Way - An Annotated Bibliography. Department of Horticultural Science, University of Minnesota. Investigation Number 619. June, 102 pp.

White, D.B., and T.B. Bailey. 1969. Vegetation Maintenance Practices, Programs, and Equipment on Minnesota Highways. Department of Horticultural Science, University of Minnesota. Investigation Number 619. February, 69 pp.

Whittington, E.L. 1977. Improving Grassing Construction and Maintenance. Georgia Department of Transportation. Departmental Research Special Report. Atlanta, Georgia. January, 72 pp.

Zak, J.M, J. Troll, J.R. Havis, R.N. Carrow and S.H. Mosler. 1976. Roadside Vegetation Cover for Critical and Eroded Areas. Massachusetts University, Department of Plant and Soil Sciences. Amherst, Massachusetts. Massachusetts Department of Public Works. Wellesley Hills. Federal Highway Administration, Research and Materials Division. Washington, D.C. October, 137 pp.

Zak, J.M., J. Troll, S.H. Mosler, and R.S. Zak. 1977. Massachusetts Roadside Development Research - 1977. Massachusetts University, Department of Plant and Soil Sciences. Amherst, Massachusetts. December, 49 pp.

Zak, J.M, J. Troll, J.R. Havis, H.M. Yegian, P.A. Kaskeski, W.W. Hamilton, and L.C. Hyde. 1972. The Use of Adaptable Plant Species for Roadside Cover in Massachusetts. University of Massachusetts, Department of Plant and Soil Sciences. February, 160 pp.

Growth Inhibitors/Suppressants. A summary of the use and effectiveness of growth inhibitors is presented in "Turf Methods and Materials for Minnesota Highways" (White and Smithberg 1972). In general, these substances are used in areas of difficult access (e.g., around guardrails or on slopes) or when application presents safety problems (e.g., in meridians).

The report cites a number of drawbacks using growth retardants, including:

- the necessity for precise timing of application must correspond to plant growth stages for effectiveness
- application loss when closely followed by precipitation
- the necessity of mowing before application (in some cases).





Zak, et al. (1976) found that growth inhibitors could potentially reduce maintenance costs and time and also equipment wear on turf sites that are periodically mowed. Some of the drawbacks encountered with inhibitors included:

- turf discoloration
- thinning
- variability in suppression
- lack of persistence
- treatment timing.

At least one state DOT contacted noted that applying growth retardants costs as much as mowing (and they preferred to mow).

Bibliography. The following documents may provide information pertinent to the use of inhibitors and roadside vegetation maintenance.

Anonymous. 1978. Plant Growth Regulator Reduces Mowing Need. Public Works. December pp. 40-41.

Anonymous. 1970. Herbicide Controls Roadside Vegetation in California. Better Roads. 40(2):24-26.

White, D.B., and M.H. Smithberg. 1972. Turf Methods and Materials for Minnesota Highways. Final Report. Department of Horticultural Science, University of Minnesota. Investigation Number 619. November, 145 pp.

White, D.B. and M.H. Smithberg. 1971. Methods and Materials for the Maintenance of Turf on Highway Rights-of-Way - An Annotated Bibliography. University of Minnesota, Department of Horticultural Science. Investigation Number 619. June, 102 pp.

Zak, J.M, J. Troll, J.R. Havis, R.N. Carrow and S.H. Mosler. 1976. Roadside Vegetation Cover for Critical and Eroded Areas. Massachusetts University, Department of Plant and Soil Sciences. Amherst,

Massachusetts. Massachusetts Department of Public Works. Wellesley Hills. Federal Highway Administration, Research and Materials Division. Washington, D.C. October, 137 pp.

Zak, J.M., and E.J. Bredakis. 1967. Establishment and Management of Roadside Vegetative Cover in Massachusetts. University of Massachusetts, Agricultural Experiment Station. Amherst, Massachusetts. Bulletin Number 562. January.

Zak, J.M., J. Troll, S.H. Mosler, and R.S. Zak. 1977. Massachusetts Roadside Development Research - 1977. Massachusetts University, Department of Plant and Soil Sciences. Amherst, Massachusetts. December, 49 pp.

Zak, J.M, J. Troll, J.R. Havis, H.M. Yegian, P.A. Kaskeski, W.W. Hamilton, and L.C. Hyde. 1972. The Use of Adaptable Plant Species for Roadside Cover in Massachusetts. University of Massachusetts, Department of Plant and Soil Sciences. February, 160 pp.

## Additional References

A number of citations were found that suggested additional information on roadside vegetation management in general. They are listed below.

## Bibliography

Alban, E.K., and K.W. Reisch. 1973. A Study of Roadside Maintenance and Landscape Plant Development. Ohio State University, Department of Horticulture. Research Project 285. Ohio-DOT-13-173. June, 65 pp.

Anonymous. 1976. Vegetation Control on California Highways. Agrichemical West. December.

Andresen, J.W., and Lewis-Watts, P. 1977. Roadside Vegetation Management in Ontario. Ontario Ministry of Transportation and Communications. Ontario, Canada. August, 41 pp.

Beard, J.B., J.A. Fischer, J.E. Kaufmann, and D.P. Martin. 1971. Improved Establishment and Maintenance of Roadside Vegetation in Michigan. Michigan State University. 66 pp.



Blaser, R.E., G.W. Thomas, C.R. Brooks, G.J. Shoop, and J.B. Martin, Jr. 1961. Turf Establishment and Maintenance Along Highway Cuts. Roadside Development. Highway Research Board; Washington, D.C. 928:5-19.

Fletchall, O.H. 1974. Vegetation Control on Roadsides and Similiar Areas. University of Missouri, School of Agriculture, Agronomy. Columbia, Missouri.

Hoogerkamp, M. 1973. De Aanleg En Het Onderhoud Van Kortblijvende Wegbermvegetaties (Planting and Maintenance of Low Roadside Vegetation). Landbouwkundig Tijoschr 85(2):53-56. February. English Summary.

McCully, W.G., and J.L. Stubbendieck. 1972. Establishment and Management of Roadside Vegetation, 1971. Texas Highway Department in cooperation with the U.S. Department of Transportation, Federal Highway Administration, Texas Transportation Institute, and Texas A&M Unversity. Research Report 142-3. Research Study 2-18-69-142. 12 pp.

McCully, W.G., W.J. Bowmer, and J.L. Stubbendieck. 1970. Problems in Establishing or Maintaining Vegetation on Roadsides. Texas Highway Department in cooperation with the U.S. Department of Transportation, Federal Highway Administration. Research Report 142-1. Research Project 2-18-69-142. 18 pp.

McKee, W.H., R.E. Blaser, A.J. Powell, R.B. Cooper, U. Yader, and P. Bosshart. 1965. The Establishing and Maintenance of Vegetation on Various Environments Along Interstate Highways. Virginia Agricultural Experiment Station in cooperation with the Virginia Council of Highway Investigation and Research and U.S. Bureau of Public Roads. Annual Report. 60 pp.

## INFORMATION REGARDING ACCEPTABLE TRADEOFFS BETWEEN CONFLICTING CONSIDERATIONS

Little information was found on user opinion of roadside vegetation maintenance or the willingness to make tradeoffs between various maintenance considerations. The information that was found is discussed below.

A study was conducted in North Dakota (1968 to 1969) to determine the effects of interstate rights-of-way mowing on duck nesting. Portions

of the rights-of-way and half the interchange triangles in the study area were left unmowed for up to 1 year. The study found that "the majority of 182 motorists interviewed had not noticed the mowed/unmowed conditions of the rights-of-way, but most preferred the mowed condition when faced with the treatments" (Oetting and Cassel 1970).

Most of the DOTs contacted reported that they receive occasional complaints (especially when sight distances are reduced by tall grasses) and very few positive comments on roadside vegetation management programs. Some feel that public education (such as signing of native vegetation restoration or wildlife habitat improvement projects along roadsides) will help to eliminate adverse opinions about unmowed areas under these types of programs.





REFERENCES

Anonymous. 1979. Chemical Programs. Public Works Manual. May, Section B-8.2, pp. B-65 - B-66.

Anonymous. 1979. EPA Suspends Use of 2, 4, 5-T. Conservation News. April 1, p 6.

Anonymous. 1979. Turf and Roadside Maintenance. Public Works Manual. May, Section B-8, pp. B-62 - B-66.

Anonymous. 1978. Cloverleaf - More Than a Roadway Design. Public Works. December, p. 49

Creech, M.F. 1977. Deferred Maintenance: Roadside Vegetation and Drainage Facilities. Byrd, Tollamy, MacDonald and Lewis, A Division of Wilbur Smith and Associates. Prepared for Federal Highway Administration. Report Number FHWA-RD-77-502. August, 114 pp.

Dailey, N.S. 1978. Environmental Aspects of Transmission Lines - A Selected, Annotated Bibliography. Oak Ridge National Laboratory. Oak Ridge, Tennessee. January, 190 pp.

David, L.M., and R.E. Warner. 1978. Update: Roadsides for Wildlife. Illinois Department of Conservation. Outdoor Highlights. May 8, 4 pp.

Duell, R.W., and R.M. Schmit. 1975. Better Grasses for Roadsides. Rutgers University. Final Report HPR-7726. 66 pp.

Duell, R.W. 1969. Highway Vegetation: For Utility, Safety, Economy and Beauty. Rutgers University Agriculture Experiment Station. Bulletin No. 822. 30 pp.

Environmental Protection Agency. 1979. Special Pesticide Review Division Status Report for Issued RPAR's (Rebuttable Presumption Against Registration). March 9.

Environmental Protection Agency. 1978. Suspended and Cancelled Pesticides. Pesticides and Toxic Substances Enforcement Division, Scientific Support Branch. May, 17 pp.

Hesse, J.F., and S.S. Salac. 1973. Effects of Mowing on the Vegetative and Reproductive Development of Species of Wild Flowers. Department of Horticulture and Forestry, University of Nebraska. Lincoln, Nebraska. June, 38 pp.

Illinois Department of Transportation. 1978. Effects of Roadside Vegetation on Drifting Snow. Bureau of Maintenance. September, 14 pp.

Illinois Division of Highways. 1979. Communication to Woodward-Clyde Consultants. Bureau of Design. February 13.

L.R.E. 1979. EPA Suspends the Major Uses of Two Herbicides. Environmental Science and Technology. 13(6): 640-641, June.

Miller, A.S. 1979. 2,4,5-T: Chemical Time Bomb. Environment. 21(5): 204, June.

Moore, D.J. 1977. A Low-Cost Maintenance Program for Indiana Roadsides. Purdue University and Indiana State Highway Commission. Joint Highway Research Project, JHRP-77-13. July, 101 pp.

Natural Resources Committee of State Agencies. 1967. Selective Brush Management Program for Wisconsin Roadsides. Madison, WI. July, 16 pp.

North Carolina Department of Transportation. 1979. Communication to Woodward-Clyde Consultants. Division of Highway Maintenance. February 13.

Oetting, R.D., and J.F. Cassel. 1970. Effects of Interstate Right-of-Way Mowing on Wildlife, Snow Buildup, and Motorists Opinions in North Dakota. A Preliminary Report. Highway Res. Abstracts 39(12):74.

Pennsylvania Department of Transportation. 1979. Communication to Woodward-Clyde Consultants. February 13.

Pennsylvania Department of Transportation, District 6. 1979. Communication to Woodward-Clyde Consultants. February 13.

Pimentel, D., and M. Pimentel. 1979. The Risks of Pesticides. Natural History. 88(3):24,28,30-31.

Vredenbregt, P. 1978. Colors Easy on the "I." Wisconsin Natural Resources.[17] 2(4):28-29, July-August.

Warner, R.E., and G.B. Joselyn. 1978 Roadside Management for Pheasants in Illinois: Acceptance by Farm Cooperators. The Wildlife Society Bull., 6(3):128-134. Fall.

Way, J.M. 1969. Management of Roadsides for the Conservation of Wildlife in Britain. 28th Ohio State University Short Course on Roadside Development. pp. 69-76.



White, D.B., and M.H. Smithberg. 1972. Turf Methods and Materials for Minnesota Hghways. Final Report. Department of Horticultural Science, University of Minnesota. Investigation Number 619. November, 145 pp.

White, D.B. and M.H. Smithberg. 1971. Methods and Materials for the Maintenance of Turf on Highway Rights-of-Way - An Annotated Bibliography. University of Minnesota, Department of Horticultural Science. Investigation Number 619. June, 102 pp.

Wisconsin Department of Transportation. 1979. Communication to Woodward-Clyde Consultants. Wayside and Landscape Division. February 27.

Wisconsin Natural Resources Council of State Agencies, and Southeastern Wisconsin Regional Planning Commission. 1972. A Roadside Conservation and Beautification Program for Southeastern Wisconsin Watersheds. 26 pp.

Zak, J.M., J. Troll, S.H. Mosler, and R.S. Zak. 1977. Massachusetts Roadside Development Research - 1977. Massachusetts University, Department of Plant and Soil Sciences. Amherst, Massachusetts. December, 49 pp.

Zak, J.M, J. Troll, J.R. Havis, R.N. Carrow and S.H. Mosler. 1976. Roadside Vegetation Cover for Critical and Eroded Areas. Massachusetts University, Department of Plant and Soil Sciences. Amherst, Massachusetts. Massachusetts Department of Public Works. Wellesley Hills. Federal Highway Administration, Research and Materials Division. Washington, D.C. October, 137 pp.

Zak, J.M, J. Troll, J.R. Havis, H.M. Yegian, P.A. Kaskeski, W.W. Hamilton, and L.C. Hyde. 1972. The Use of Adaptable Plant Species for Roadside Cover in Massachusetts. University of Massachusetts, Department of Plant and Soil Sciences. February, 160 pp.

# APPENDIX G

## GUIDELINES FOR CITIZEN PARTICIPATION IN ESTABLISHING MAINTENANCE LEVELS OF SERVICE

### INTRODUCTION

It is often argued that the users of transportation systems (the general public) should be given a larger role in the transportation planning and decision making process. Most highway departments and planning agencies across the country have tried to incorporate citizen participation in transportation planning. This appendix is a general discussion of some of the issues involved with citizen participation, the pitfalls that are often overlooked, and includes some practical ideas about applying the participation process in establishing maintenance levels-of-service.

### WHAT IS CITIZEN PARTICIPATION

Citizen participation refers to the process of motivating people to become directly involved with the planning and/or decision making process so that they are provided with better services that are more responsive to their needs. This process is based on the principles of democracy and the responsibility of elected officials to respond to the citizens they serve.

The benefits of citizen participation are numerous. Vastly improved decision making occurs when citizens are involved throughout the planning and policymaking process. In contrast, when citizens are excluded from this process, controversy, hostile feelings, wasted effort and unacceptable plans often result. Hence, the pragmatic rationale for active citizen participation, aside from the democratic principle,



is that by effectively using the process, timely and less costly decisions can be reached and better services can be provided to the citizens for whom policy decisions are made.

Despite the benefits of citizen participation, many questions, obstacles, and pitfalls are involved in the design and implementation of successful participation programs. The most important questions to be considered are the following:

- Who should participate
- How can people be motivated to participate
- How should the diverse opinions of the populace be sought
- How can one ensure that the views expressed are a representative sample
- How can citizen participation be effectively utilized
- How can diverse and often contradictory opinions be integrated into acceptable plans and policies
- How should a citizen participation program be developed and implemented.

The answer to these questions varies depending on the particular application under consideration, the amount of time and other resources available, and the quantity and quality of responses.

In the following pages, we will briefly discuss some of the issues involved and suggest practical ways to accomplish an effective citizen participation program in the context of establishing maintenance levels-of-service for highway planning. The reader is referred to Stein Hudson and Lindon's work (4) for a detailed discussion of some of these topics.

## WHO SHOULD PARTICIPATE IN CITIZEN PARTICIPATION

Every person affected by planning and policy decisions should be involved in citizen participation programs. On a state-wide or regional scale, such citizen participation may be difficult. A more practical and reasonable goal would be to obtain a representative cross-section of the populace involved. The problem is how to find such a "representative" group and how to motivate them.

The selection of a "representative" group that reflects the views of the general public is somewhat similar to a jury selection process. In both cases the group must be carefully selected so that preconceived biases are avoided and that members of all ages, incomes, occupations, and minority groups are included. Finding such an ideal sample is not an easy task: people most willing to participate in these programs may not represent such a group and a group that is selected based on a list of criteria may not be willing to participate.

In addition, limitations on the planning agency's resources (e.g., time and money) will usually eliminate many potentially promising



options. Hence, it is necessary to analyze the particular situation under consideration to identify how citizen participation can best be accommodated and implemented. For instance, suppose one is interested in finding out what highway elements (e.g., smooth ride, wide shoulders, pleasing roadside views) are considered to be most important by highway users and to solicit their views and suggestions. If one were to, for example, install suggestion boxes in all rest areas along the highways, he would most likely find an unproportionate number of out-of-state and long-distance travelers (groups most likely to use such rest areas) with negative comments. Similarly, truck drivers whose livelihood depends on the existence and maintenance of good highways are likely to be overly represented in such a survey. Random telephone surveys and written questionnaires will most likely have problems of their own. Even if the initial list of names is "random" and "representative," the responses received (i.e., those who bother to fill and return the questionnaire) may not.

Certainly, a great deal of planning must precede the implementation of citizen participation programs. Furthermore, a given group and method most appropriate for a particular application may be inappropriate in a different context and situation. For example, a successful program to establish optimal maintenance levels-of-service on interstate highways will not be appropriate for urban thoroughfares or rural roads, mostly because different groups of citizens use different kinds of highways.

## HOW CAN PEOPLE BE MOTIVATED TO PARTICIPATE

It is often said that citizen participation is most productive if people can be involved in the early stages of planning when plans are flexible and changes can easily be accommodated. It is also usually true that it is difficult to motivate citizens to become involved at such early stages and expect them to participate throughout the long and tedious planning process. In contrast, if a particular issue directly affects a given community or group, then one is likely to see an overhwhelming interest on the part of affected citizens to participate. This is especially true when a negative impact is perceived by the affected group. In such instances, a small group can be expected to strongly object to the proposed policy despite the policy's overall net benefits.

To motivate citizens the public must be assured that their input

- is earnestly solicited and welcomed
- will be acknowledged and considered
- will have a positive impact on them and their community
- will lead to a better understanding between them and highway policymakers
- will be a valuable and worthwhile educational experience which will increase their understanding of the decision-making process.



Successful citizen participation cannot be expected if one or more of the above elements are not met. Hence, an atmosphere of positive cooperation must be developed between the agency and the citizens whose input is required before citizen participation can occur.

Mere initiation of a citizen participation process, however, may not lead to a successful citizen participation program. Particpiants must be kept assured that their views are valuable, are integrated in the policymaking process, and will improve the nature of decisions.

## HOW CAN CITIZEN PARTICIPATION BE USED EFFECTIVELY

To effectively use citizen participation it is necessary to familiarize the participants with the intricacies of the planning process so that they can participate productively. The lack of understanding about the limitations and interdependencies of planning can lead to the failure of an otherwise successful citizen participation program. A major problem is the lack of communication between the two parties. The participants often find it difficult to understand the technical language of the planners and decision makers while the planners and policy makers fail to appreciate the concerns and comments of the citizens who use nontechnical language to express their opinions.

In addition, the citizens often focus their attention on relatively small issues without understanding the interdependencies of small problems in the context of the aggregate planning process. To overcome this

problem it is necessary to educate the participants about such inter-dependencies and the hazards of piece-meal planning.

This problem is essentially a communication problem between the "experts" and people not trained in matters like planning, economics, and management whose assent and coooperation are sought. The solution to the problem is the establishment of effective information feedback between the "experts" and "non-experts" about planning alternatives, consequences and preferences. Needless to say, as long as the people affected by policy decisions cannot envision the implications of given alternatives they cannot be expected to have informed opinions about the issues and express their attitudes and opinions in a productive manner.*

*In an interesting paper, Bauer and Wegener (1) discuss a particular urban simulation and information feedback system where the non-expert participants can "visually" see the consequences of certain planning policies and learn to improve their decisions in response to the predictions of an urban simulation model. Such elaborate discussions, however, go beyond the limited scope of this appendix.



RESOLVING CONFLICTING VIEWS

Citizen participation will inevitably lead to two kinds of conflicts: (1) intra-personal conflicts,* and (2) inter-personal conflicts. The first kind of conflict arises because, whether people are aware of it, most people have conflicting objectives in their preferences. The second type arises because different individuals or groups of individuals have conflicting opinions about the importance of given issues and on methods to achieve desired results. An example of intra-personal conflict is an individual who is opposed to construction of new highways for environmental reasons but who would like to see his commuting time reduced. An example of inter-personal conflicts is the disagreement between a group which favors more expenditure on the roads versus another group which favors more expenditure on the roadside improvements.

The first kind of conflict can be handled through multiattribute utility theory (MAUT)** whereas no formal procedure is universally acceptable to resolve the second kind of conflict. Mack and Snyder (3) postulate that inter-personal conflicts between two groups arise because of one or more of the following reasons:

- satisfying the interests of both groups is not simultaneously possible and the "winning" of one group implies the "loss" of the other

*Two goals are said to be in conflict if achievement of one reduces the probability of achieving the other.

**For an extensive treatment of the subject matter see (2).

- one group is more influential than the other and would like to preserve its power

- both groups are aware of the difference between their interests and of the inequalities in their influence.

The first measure of conflict, namely a divergence of preferences, can be handled using different weights and utility functions.* Three types of conflict measures should be considered in such cases:

1. Correlation between the weights assigned to the goals or objectives by each group. This can be taken as a measure of agreement on priorities.

2. Correlation between the utility values calculated for each plan using the utility functions of each group. This can be taken as an indicator of agreement on satisfaction (or attainment) levels.

*There are many ways of measuring differences between weights and utility functions of two individuals or groups of individuals. The simplest way is to use linear correlation. More sophisticated methods, such as product-moment correlation coefficient (also known as Bravais Pearson product-moment correlation coefficient) which is considered to be a good measure of similarity of judgment (a coefficient of +1 indicating complete agreement and a coefficient of -1 indicating complete antagonism between two preferences) can also be used.





3. Correlation between the weighted utilities of each plan for each group. This can be interpreted as a measure of agreement on achieved satisfaction.

The other two kinds of conflict are more difficult to address because they require that the distribution of power between the groups and/or their perception of their influence be available, neither of which is easy to measure or document.

INTEGRATION OF CITIZEN'S VIEWS INTO POLICY

The crucial step in a citizen participation program is integration of expressed views into unified and objective policies or plans that can be adopted and implemented. Citizen participation will not be successful unless this vital link occurs.

The problem of developing a coherent and objective policy that on the one hand meets the constraints of the planning agency or on the other is acceptable to the majority of the citizens (particularly those whose views were solicited and obtained) can best be expressed using an interactive model such as the one schematically shown in Figure G-1.

For purposes of illustration the contributors in a planning or policy making process can be identified as:

1. The citizens whose lives are affected in one way or another and whose views should be solicited and approval sought prior to policy implementation.

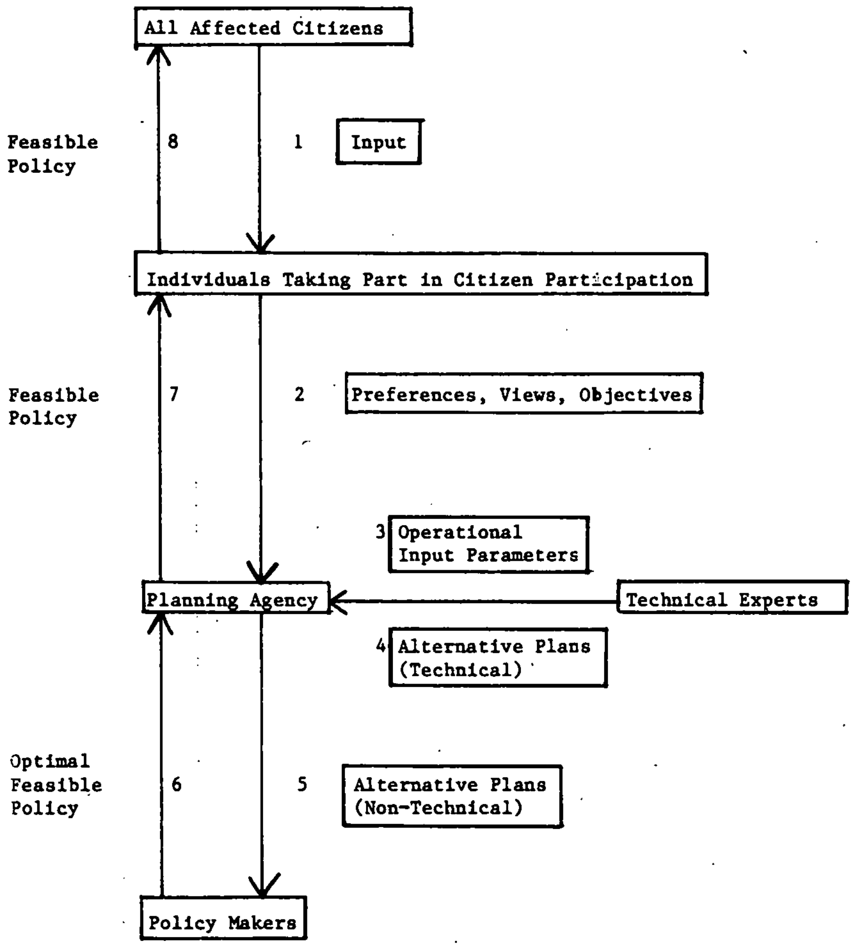



Figure G-1. INTERACTIVE MODEL OF CITIZEN PARTICIPATION WITH FEEDBACK



2. The technical experts (planners, engineers, data collectors, demographers, economists, etc.) whose task is to develop policies and plans which satisfy the objectives of the populace.

3. The policy-makers whose approval is required if a given policy is to be implemented and who will bear ultimate responsibility for the success or failure of the policy.

Needless to say, these three groups of contributors have very little in common and will most likely have difficulty communicating with one another. Hence, the need arises for a go-between: an organization or agency which links these diverse groups and produces the communication network necessary to carry out the collection of ideas, to develop these ideas into coherent plans, and to adopt policies that implement these plans. For lack of a better term, we will name this go-between the "planning agency." The various steps involved in this interactive model of citizen participation with feedback can be described as follows:

1. The views of all citizens are assumed to be reflected in those who take part in citizen participation. This is why the representativeness of this group is considered important.

2. The planning agency or the organization sponsoring citizen participation will solicit and hopefully obtain the true preferences, views, and objectives of the community through the participating group.

3. The views obtained are not, however, operational in their original form. One of the important functions of the planning agency is to translate and express these views into operational parameters. For example, the participants may indicate that a certain amount of riding discomfort may be tolerated before it would become annoying. Such a statement is a valuable piece of information, but it is not operational in its present form. The highway maintenance supervisors would like to know exactly what the average driver's "threshold of annoyance" is.

4. Technical design and planning, however, is indicated as a separate activity that is undertaken by technical experts (say, engineers, planners, etc.). The output of their analysis is fed back to the planning agency in the form of alternative plans or options that are consistent with the input of the operational parameters.

5. The planning agency has to digest these alternative technical plans and turn them into alternative policies, only one (or a combination) of which can be adopted as the preferred policy.

6. Such policy decisions are usually made by a combination of politicians and management level decision-makers who have to incorporate the relative costs and benefits of each policy option in view of major legal, economic, political and other constraints. Hence, it is not unusual to find that the policy which is





"technically" optimal is not adopted while an alternative (technically sub-optimal) policy is considered preferable because of cost considerations or other constraints. The chosen policy is referred to as the (first-iteration) optimal feasible policy.

7. The planning agency analyzes the (first-iteration) optimal feasible policy and relays its ramifications to the citizen participation group. Once again, the importance of the role of the planning agency cannot be overstated because the adopted policy may be too complex and involved for the average participant and its long-run consequences difficult to comprehend. The planning agency's role would be to review the policy and explain its implications in simple terms (say, how it would improve the level of service, how much would it cost in extra taxes, etc.) to the participants.

8. The final step (in the first iteration) is a complex re-evaluation process during which the participants (or the citizens as a group) ask themselves if they will be satisfied with the proposed policy if it were adopted and implemented. Would it accomplish what they had expected? Would it be worth the extra cost (if applicable) and so on? It may, for example, turn out that citizens realize that certain objectives are simply to costly to implement and that they are better off without such improvements or that the immediate positive net gain in a given policy may be more than offset in negative consequences at some point

in the future. Bauer and Wegener's paper (1) particularly illustrates this point by emphasizing information feedback between the planning "experts" and the non-expert citizens. They argue that the non-experts can make better decisions and become more productive participants once the consequences of given alternatives or plans are vividly explained to them.

These eight steps complete the first iteration of the interactive model. The process can be repeated until an equilibrium policy is reached. One important point is the fact that the planning agency acts as a catalyst in the sense that it does not introduce its own opinions and views in the process but merely acts as a communication network between the other groups. A second important point is that by going through these cycles the interest groups can see the effects of given objectives, preferences, and views on the feasible policies. Hence, it can be argued that different interest groups may find it easier to overcome their disagreements on given options. Similarly, intra-personal conflicts of interest can be better understood and resolved.

HOW SHOULD A CITIZEN PARTICIPATION PROGRAM BE DEVELOPED AND IMPLEMENTED

While there are no set rules as to what makes a citizen participation program successful, certain general remarks are in order:

- The decision to use a citizen participation program should not be enforced in all planning and decision-making processes.



There may be instances where citizen participation is not necessary or productive.

- If, based on some preliminary analysis, it is determined that a citizen participation program is desirable, then it must be decided what kind of program would produce the best results within the resources of the sponsoring agency.

- Citizen participation requires careful planning and organization. Among the important parameters to be considered is the problem of coming up with a well-balanced and representative group of participants whose views could be taken to reflect the interests and aspirations of the affected community at large.

- Citizen participation requires the long-term commitment of a variety of resources, including the training of personnel who can carry out the duties of the "planning agency" as depicted in Figure G-1.

- Citizen participation should be flexible to accommodate new developments as they arise throughout the program.

- Contributors (see Figure G-1) should be made aware of their interdependence and be encouraged to accommodate others desires and limitations.



- The whole process should proceed in a positive climate of cooperation, mutual understanding, and should have the support of all involved if it is to succeed.

# REFERENCES


## REFERENCES CITED

1. Bauer, V. and M Wegener, "A Community Information Feedback System with Multiattribute Utilities", paper presented in International Institute for Applied System Analysis (IIASA) Workshop on Decision Making with Multiple Conflicting Objectives", Laxenburg, Austria, October 20-24, 1975.

2. Keeney, R and H. Raiffa, Decisions With Multiple Objectives, New York: Wiley, 1976.

3. Mack, R.W. and R.C. Snyder, "The Analysis of Social Conflict: Toward an Overview and Synthesis", Journal of Conflict Resolution, Vol II., No. 2, 1975.

4. Stein Hudson, K.E. and T.J. Lindon, "Guidelines on Citizen Participation in Transportation Planning", Prepared for NCHRP, Transportation Research Board, National Research Council, October 1977.

## ADDITIONAL REFERENCES NOT CITED IN TEXT

1. Citizen Participation Technology, Council of Planning Librarians (CPL) Exchange Bibliography #1329, August 1977

2. Citizen Participation in Urgan and Regional Planning: A Comprehensive Bibliography, CPL Exchange Bibliography #1297, June 1977.

3. Federal Highway administration, Socio-Economic Studies Division, Effective Citizen Participation in Transportation Planning, Volumes I and II, U.S. Department of Transportation, Washington, D.C., 1976.

4. Federal Highway Administration, Office of Environmental Policy, An Introduction to Community Involvement in the Transportation Planning Process, U.S. Department of Transportation, Washington, D.C., March 1976.





5. Federal Highway Administration, Office of Environmental Policy, Community Involvement in Highway Planning and Design: A Manual of Techniques, U.S. Department of Transportation, Washington, D.C., January 1977.

6. Ragan, James F., Jr., Guide 1: Effective Public Meetings, Environmental Protection Agency (EPA), Washington, D.C., May 1977.

**THE TRANSPORTATION RESEARCH BOARD** is an agency of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 150 committees and task forces composed of more than 1,800 administrators, engineers, social scientists, and educators who serve without compensation. The program is supported by state transportation and highway departments, the U.S. Department of Transportation, and other organizations interested in the development of transportation.

The Transportation Research Board operates within the Commission on Sociotechnical Systems of the National Research Council. The Council was organized in 1916 at the request of President Woodrow Wilson as an agency of the National Academy of Sciences to enable the broad community of scientists and engineers to associate their efforts with those of the Academy membership. Members of the Council are appointed by the president of the Academy and are drawn from academic, industrial, and governmental organizations throughout the United States.

The National Academy of Sciences was established by a congressional act of incorporation signed by President Abraham Lincoln on March 3, 1863, to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance. It is a private, honorary organization of more than 1,000 scientists elected on the basis of outstanding contributions to knowledge and is supported by private and public funds. Under the terms of its congressional charter, the Academy is called upon to act as an official—yet independent—advisor to the federal government in any matter of science and technology, although it is not a government agency and its activities are not limited to those on behalf of the government.

To share in the tasks of furthering science and engineering and of advising the federal government, the National Academy of Engineering was established on December 5, 1964, under the authority of the act of incorporation of the National Academy of Sciences. Its advisory activities are closely coordinated with those of the National Academy of Sciences, but it is independent and autonomous in its organization and election of members.

**TRANSPORTATION RESEARCH BOARD**
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

ADDRESS CORRECTION REQUESTED

NON-PROFIT ORG.
U.S. POSTAGE
PAID
WASHINGTON, D.C.
PERMIT NO. 42970

000015M003
MATERIALS ENGR
IDAHO TRANS DEPT DIV OF HWYS