sincere appreciation is given.

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Abridgment

Systematic Procedure for the Development of Maintenance Levels of Service

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One of the basic requirements for the proper management of highway maintenance activities is the establishment of maintenance levels of service. A systematic methodology was developed for determining the maintenance levels of service that would maximize the user benefits subject to the constraints on available resources. A demonstration of this methodology for two maintenance problems is described. The necessary inputs for the methodology were obtained from the data base of information currently available to the Louisiana Department of Transportation and Development. The data base included information available in the literature, studies conducted within the department, information available from maintenance management systems, and experience and judgment of knowledgeable individuals within the department. Results of the analysis produced levels of service that were intuitively satisfactory. Sensitivity analyses were conducted to determine the impact of conditions such as budget cuts and changes in the relative weights of different considerations on the determination of optimum levels of service.

Maintenance levels of service are defined as threshold conditions at which maintenance is considered to be needed. At the present time, there is no systematic, structured procedure for establishing maintenance levels of service or for adjusting such levels when resources are constrained or increased. Woodward-Clyde Consultants has completed a study for the National Cooperative Highway Research Program (NCHRP) to develop a methodology for establishing levels of service based on well-documented principles of decision analysis.

The purpose of this report is to describe the methodology by means of a demonstration of the procedures for two maintenance problems in the state of Louisiana.

APPROACH

The methodology to select maintenance levels of service involves the following steps:

1. Structuring the problem,
2. Estimation of the effects of alternative maintenance levels of service on various considerations,
3. Evaluation of the effects of alternative maintenance levels of service,
4. Determination of the optimum combination of maintenance levels of service,
5. Making a sensitivity analysis, and
6. Formulation of recommendations.

Structuring the Problem

The following tasks are involved in structuring the problem:

1. Select maintenance elements (e.g., shoulders, pavement),
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,
4. Select considerations (e.g., safety) for each maintenance element (e.g., shoulders),
5. Select attributes (e.g., percentage of drivers who cannot recover control) for various considerations (e.g., safety), and
6. Identify the maintenance conditions (e.g., edge of traveled-way drop-off) that affect each attribute (e.g., percentage of drivers who cannot recover control).

For the demonstration example in Louisiana, two maintenance elements--shoulders and roadside vegetation--were analyzed. Edge of traveled-way drop-off and undesirable vegetation growth on the roadside were selected as the maintenance conditions of concern. Alternative levels of service that included the current level of service, as well as those better and worse than the current level of service, were included. The attributes considered for the example were percentage of drivers who cannot recover control of car after driving over the edge of the traveled way, percentage of change in pavement rehabilitation cost because of edge of traveled-way drop-off, index of pleasing appearance of roadside vegetation, and index of environmental pollution caused by herbicide spraying used in controlling growth of vegetation.

Estimation of Effects of Alternatives

The effect of alternative maintenance levels of service on a given consideration (e.g., safety) is estimated in terms of the attribute of the consideration (e.g., percentage of drivers who cannot recover control of the car). The effects were estimated in Louisiana by interviewing the department specialists for given attributes. To assist the specialists in the estimation, pertinent information and data available in the literature were reviewed with the specialists.

Because of limitations of applicability associated with information in the literature, it was concluded that this source could not be used directly to establish the effects or impact of levels of service on pertinent considerations.

Therefore, the specialists were asked to extrapolate the available information to the real-world situation, based on their experience and judgment.

Evaluation of the Effects of Alternatives

The objective of this step is to establish a preference (value) structure for evaluating the effects of alternative levels of service on various considerations, such as safety and aesthetics. The effects on the considerations are measured in terms of the selected attributes. For example, in considering an edge of traveled-way drop-off, the effect of level of service on safety is measured in terms of the percentage of drivers who cannot recover control of the car. The assessment of preferences involves two steps:

1. Assessing individual value functions of different attributes: The objective of this step is to determine how much better (or worse) one level of an attribute (e.g., percentage of drivers who cannot recover control of the car) is relative to another (e.g., level 5 versus level 10). This assessment is best done by those individuals in a state agency who are most knowledgeable about a given attribute.
2. Assessing value trade-offs between different attributes: If a decision problem involves multiple attributes and limited resources, it may not be possible to achieve the best levels of all the attributes. The decision maker, therefore, is required to think about how much he or she may be willing to sacrifice on one attribute (e.g., aesthetics) in order to improve another (e.g., change in rehabilitation cost). These value trade-offs determine the relative weights of the attributes. The assessment of value trade-offs should involve individuals who are responsible for setting and implementing maintenance levels of service.

The first step was completed in Louisiana during meetings with department specialists about edge of traveled-way drop-off and roadside vegetation control. The second step was completed during a group session that involved maintenance engineers both from headquarters and from the district offices. A Delphi procedure was used to obtain group consensus regarding value trade-offs between different attributes.

Determination of the Optimum Combination

The objective of this step is to determine the optimum combination of maintenance levels of service for all of the maintenance conditions included 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.). The user benefits are specified in terms of the effects of levels of service on various considerations, such as safety, aesthetics, and protection of investment. The effects on these considerations are measured by the appropriate attributes, such as percentage of drivers who cannot recover car control, index of pleasing appearance, and percentage of change in pavement rehabilitation cost.

The resources required to maintain the current levels of service for edge of traveled-way drop-off and roadside vegetation growth were assumed for the base-case analysis. The optimum levels of service are

1. For the edge of the traveled-way drop-off, to repair when the drop-off is 1 in and
2. For vegetation growth, to mow 300 000 acres and spray 120 000 acres; this vegetation-control program would allow mowing grass full width before it reaches 8 in in urban areas and mowing grass 30 ft from the edge of the traveled surface after it exceeds 12 in in rural areas.

The costs of the selected policy are as follows:

Item	Available	Used
Material ($ 000s)	5130	5130
Labor (h 000s)	644	644
Equipment ($ 000s)	3380	3377

The attributes are evaluated as follows:

Attribute	Individual Value	Weighted Value
Safety (percentage of drivers who cannot recover car control)	1.000	0.438
Percentage of change in rehabilitation costs	1.000	0.321
Pleasing appearance	0.962	0.173
Environmental pollution	0.500	0.031

The value of this policy is 0.96.

The optimum levels of service provide the highest user benefits possible for the two maintenance conditions. No improvement in these levels of service would be possible even if higher amounts of resources were available. An examination of the contributions of the four attributes to the overall value reveals that the two attributes related to edge of traveled-way drop-off (percentage of drivers who cannot recover car control and percentage of change in rehabilitation cost) contribute 76 percent of the total value, and the roadside-vegetation attributes contribute the remaining 24 percent of the total.

Sensitivity Analysis

The objective of this step is to assess the influence of changes in some of the major inputs and assumptions on the selection of the optimum combination of levels of service. The output of this analysis would identify the parameters to which the selection of optimum levels of service is very sensitive. The assessment of such parameters would obviously warrant more careful consideration.

Formulation of Recommendations

Recommendations are formulated after an evaluation of the results of the base case and the sensitivity analyses. The recommendations should include (a) the optimum level of service for each maintenance condition in the system, (b) resources that would be used in implementing the optimum levels of service, and (c) situations (e.g., budget cuts) that would require significant changes in the optimum levels of service.

CONCLUSIONS

The effort in Louisiana shows that it is feasible to use the methodology developed in this project to select levels of service for highway maintenance that would maximize user benefits subject to the constraints of available resources. The types of inputs required for the analysis can be obtained from the data base of information currently available to a state transportation department. The data base includes information available in the literature, studies conducted within the department, information available from maintenance management systems, and experience and judgment of knowledgeable individuals within the department.

The methodology requires the assessment of value judgments regarding trade-offs between such considerations as safety, protection of investment, aesthetics, and environmental pollution. A Delphi procedure was used in Louisiana to obtain group consensus regarding trade-offs from a number of individuals who are responsible for selecting levels of service both in the field and at headquarters. Certain improvements in the implementation of the Delphi procedure would seem desirable based on the experience in Louisiana. However, the types of assessment questions that need to be asked in the Delphi procedure are certainly practical and relevant to individuals involved in highway maintenance.

It would be desirable to provide certain types of objective data to the participants in the Delphi exercise in order to obtain more consistent and reliable value judgments. Examples of such data include statistics on accidents resulting from driving over the edge of the traveled way at various depths of drop-off and surveys of user opinions regarding aesthetics of roadside vegetation under varying levels of service. These kinds of data are currently not available. The initial implementation of the methodology will identify the critical parameters on which objective data would be most useful. Limited studies to collect these data can be undertaken. The reliability of the results of the methodology would be expected to increase with the availability of additional data.

The computer program prepared for the use of the methodology facilitates the analysis significantly. The program is designed so that the assessed data can be directly input, and all parameters (such as value coefficients, relative weights, and regression coefficients) are computed internally in the program. This relieves the user of the burden of making external calculations, which would require some theoretical background in decision analysis techniques.

The demonstration example in Louisiana involved only 2 maintenance conditions--edge of traveled-way drop-off and roadside vegetation growth. However, a complete system of highway maintenance could involve 20 to 25 maintenance conditions of practical significance.

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Abridgment

Location of District Maintenance Centers by Least Transport Cost

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The largest and most difficult cost to determine in the economic life of a U.S. Forest Service ranger district maintenance center is usually the transportation cost of personnel to the work sites. Decreasing this cost through optimum location of centers presents one of the best opportunities for energy conservation and increased efficiency. The method described here permits the determination of the total transport cost to each work site so that costs can then be contoured; the least-cost contour delimits an area that may be analyzed for site location. Location analyses of five districts estimated savings from relocation in three districts that ranged from $12 700 to $32 000 over the life of the facility.

Government regulations have mandated that investments in government facilities must be cost effective and must conserve energy. The Energy Policy and Conservation Act of 1975 requires a 20 percent reduction in all federal agencies' energy consumption by 1985, during a time of increasing demands on public resources. The U.S. Department of Agriculture Forest Service, the agency primarily responsible for managing federal timber lands, consumes a great deal of its energy allotment in the construction, operation, and maintenance of support facilities for land management.

The smallest administrative unit in national forests, the ranger district, is responsible for maintenance of roads on the forest road system and of recreation areas, trails, timber stands, and fire-prevention facilities. Ranger district maintenance operates out of a work center that may or may not be in close proximity to the ranger's office. Location of the ranger's office must take account of administrative and public access considerations, but the location of the maintenance center must be influenced by the spatial distribution of the work sites. In most cases the largest and most difficult cost to determine in the economic life of a ranger district maintenance center is the transport cost of personnel to the work sites. Decreasing this cost through optimally locating maintenance centers presents one of the best opportunities for energy conservation and increased efficiency.

Studies of the location of industries and public service facilities abound in the literature, and the concepts involved may be applied to the location of maintenance centers (1,2). If there were only one work site in a ranger district, location of the maintenance center to minimize transport cost would