Sufficiency Ratings for Secondary Roads: An Aid for Allocation of Funds?

CLETUS R. MERCIER AND JAMES W. STONER

A new model that can be used to make sufficiency ratings of secondary roads is described briefly. The calibration and scales used with the rating criteria are described in some detail, with particular emphasis on both the linear and the nonlinear features of the scales. The flexibility of the model, particularly with the use of variable standards, is noted. This feature makes it possible to prepare new priority rankings based on revised functional classification or design standards, or both, for local use. It is also suggested that the model could be used as an aid in developing new road use tax allocation formulas. It is concluded that, though many other factors need to be considered, use of the same model across jurisdictions would provide realistic statewide needs assessments.

State highway organizations commonly use a numerical evaluation system for priority planning of roadway improvements. Most evaluation systems in use are patterned after a numerical rating scheme, first developed by the Arizona Highway Department in 1946 (*1–3*), that describes a highway's "sufficiency." The sufficiency rating method assigns a point score to each section of road on the basis of its actual condition and its ability (or inability) to carry its traffic load in a safe and efficient manner. There have been attempts to develop a successor to sufficiency rating, designed to take advantage of the computer's speed and flexibility by including additional factors and a sophisticated calibration procedure. However, most of the successors have failed to gain wide acceptance, although a formalized pavement management system (PMS) is gaining prominence (*4*).

The sufficiency rating for a given segment of road is a composite score; it represents the sum of evaluation scores of a number of highway and traffic elements. Much commonality exists among the lists of rating elements or criteria used by the various states, but there are also differences.

The differences are of two kinds. There are differences in choice of criteria used to evaluate a given road segment. There is a list of commonly used criteria, but some divergence in the choice of those actually used. There are also differences in how the criteria are actually weighted. Both produce some variations in rating formulas.

These differences can be explained in two ways. First, there are differences in conditions among the states. Second, there are valid differences in opinion, especially in the perception of relative importance (*5*). Sufficiency rating is often described as empirical, or based on practical experience (*1*).

C. R. Mercier, College of Engineering, Iowa State University, Ames, Iowa 50010. J. W. Stoner, College of Engineering, The University of Iowa, Iowa City, Iowa 52240.

Although most state highway organizations use sufficiency rating systems for priority planning, the practice is not prevalent among county highway organizations. There have been sufficiency rating systems developed and used by some county highway organizations; however, none appears to have survived the tenure of the administrator who put it in place or to have been used in other jurisdictions.

State and county highway officials face a similar problem in decision making: how should available funds be allocated? For state officials, an evaluation system that makes it possible to measure a given road segment's sufficiency relative to road segments in other parts of the state is important. A system that makes rational comparisons of needs greatly simplifies problems in priority programming. Used efficiently, it leads logically to allocation of available funds within a jurisdiction.

Another important consideration is the wide variation in average daily traffic (ADT) over the various primary roads. Without some "leveler" it would be nearly impossible to choose between taking care of the needs of a limited-access, four-lane highway with large ADT and those of a two-lane state highway carrying considerably less traffic. Therefore both functional classification and applicable design standards play key roles in priority programming. In addition, priority decisions can be more easily defended when an evaluation system is used, but the large size of a state road network would make specific challenges less likely.

In contrast, officials responsible for priority programming for secondary roads (particularly at the county level) are commonly quite familiar with all segments of the road network, and priority decisions often are made informally. Also, there are fewer variations in the road characteristics, as defined either by functional classification or by differences in design standards. As an example, area service roads make up about two-thirds of the secondary road network in Iowa, and most have a gravel surface, but it would be hard to find any significant difference in the design characteristics of most of these roads, no matter what the traffic volume. Therefore it is difficult to differentiate between two roads carrying different traffic loads in preparing priority lists. County officials also find it more difficult to defend their programming decisions because of the informal nature of the decision-making process. Therefore there is some interest in a sufficiency rating system for secondary roads.

In 1985 a research project, sponsored by the Iowa Department of Transportation (Iowa DOT), was completed that resulted in a model that could be used as a sufficiency rating system for secondary roads. The model is also empirically based—on the Arizona format and the experience of local engineering practitioners (6).

The resulting system has 14 rating elements that represent the expressed preferences of local practitioners. The preferences were expressed through a survey of county engineers in Iowa. Relative weights were also assigned on the basis of the opinions divulged in the same survey. The development of the scales for these rating elements and how they can affect the allocation of highway funds are described in this paper.

MODEL

Fourteen rating elements were selected for use with the proposed sufficiency rating system. They have been organized into three categories, similar to the Arizona format, and assigned relative weights. Table 1 gives the proposed list of rating elements and their suggested weights.

Form of Model

The basic model for the sufficiency rating system is a simple linear additive model. The maximum possible scores for the selected rating elements were determined from analysis of the data received. What remained was to solve the problem of how to assign scores when the rated road segment fails to meet the expected standard for a given rating element. To do this requires answers to two questions:

1. What is a defensible set of standards that could be applied to the rating elements selected?
2. Is there a scaling calibration that can be used with each rating element and that would yield meaningful scores when the rated road segment failed to meet the desired standard?

The answers to these two questions are critical to the problem of the assignment of scores. In the next two subsections the issues raised by these questions will be addressed and appropriate answers will be suggested.

Standards for Rating Elements

The determination of appropriate standards to apply to the rating elements is intermixed with economic and social issues: what level of financial commitment is the public willing to make to build and maintain the transportation infrastructure, and what is the dollar value of personal comfort, pain and suffering (due to traffic injury), and human life (when a person is killed in a traffic accident)?

Though these issues will probably never be settled, engineering practitioners have adopted standards that are reasonably consistent with prevailing public opinion. Evidence of public opinion is provided by the level of funding legislative bodies have allocated and by the force of individual and group pressures.

The resulting design standards are adopted by highway agencies for use on all of the different classes of roads throughout their jurisdictions. Comparable sets of design standards have been adopted by many state highway organizations. These standards are similar in many respects, but they also reflect local conditions. Design standards represent prevailing professional opinion on appropriate standards or norms for building a given road to serve expected traffic needs.

Iowa has developed design guides that call for higher standards of construction for roads carrying heavier volumes of traffic (and costing more) and concomitant lower standards for roads carrying less traffic. These design guides were developed by Iowa DOT staff for the 1982–2001 Quadrennial Needs Study (7) in consultation with the State Functional Classification Review Board (as specified by law), members of the County Engineers Association, and the League of Iowa Municipalities.

Because the design guides are prepared in consultation with so many interested parties (there are several nonengineers on the Review Board), there is an inference that the lowered standards are acceptable to the public. Further, it would appear logical that there is little reason to exceed the lowered standards for the lightly traveled roads, except when it can be done at little extra cost. Similarly, a rational approach to evaluation of sufficiency—a comparison with established ideals—should be based on current design standards for that road classification.

Therefore the sufficiency rating model developed for secondary roads incorporates applicable design standards from the

TABLE 1 FINAL PROPOSED SUFFICIENCY RATING SYSTEM MODEL

Rating Category	Item Rated	Maximum Points
Condition and maintenance experience (35 points)	Foundation	9
	Wearing surface	9
	Drainage	8
	Maintenance economy	9
Safety (40 points)	Accident rate	6
	Hazards	9
	Stopping sight distance	8
	Passing sight distance	5
	Traffic control	6
	Horizontal alignment	6
Service (25 points)	Pavement (roadbed) width	9
	Ride quality	5
	Snow problems	6
	Surface type (unpaved)	5
	Shoulder width (paved)	(5)

alternate design guide developed by Iowa DOT staff for the Needs Study. This guide was chosen for the model even though many counties use the Farm to Market Design Guides. It was chosen because of its breakdown of area service roads into three categories based on ADT. This provides for lower standards for lightly traveled area service roads. It also represents what are expected to be the design standards of the future.

Failure of a rated road segment to meet the applicable standard would cause a lowered score for that rating element. Established ideals for rating elements not covered by a design standard are based on current practices as evidenced by a combination of standards used in other sufficiency rating systems and on local practices.

Scaling Factors

An assessment of the maximum point value for a given rating element is made when the road segment meets or exceeds the current standard. However, a given rated road segment will sometimes fail to meet the current standard for each of the rating elements, making it necessary to develop some sort of scale to describe how close it comes to meeting that standard. Maximum point values for each of the rating elements are given in Table 1, so what is needed is a set of graduated scales for each.

Existing systems use, for the most part, a sequence of point values that is approximately linear in character. In most instances there is a score (often at about the middle of the scale) that represents an average value, below which a road segment is considered intolerable. The concept of tolerability is based on the supposition that, for each rating element, there is a tolerable standard that is less desirable than the ideal but that is still considered safe, or at least provides good service. The tolerable point is the lowest point on the scale permissible under current highway transportation requirements. Below that level, the rated road segment is considered intolerable in terms of that rating element.

The Iowa DOT uses a sufficiency rating system to evaluate Iowa's primary roads. The calibration system used establishes tolerable levels for each rating element of the system. (In this context, the term "scale" is used to describe the graduations along an axis, and calibration is the numerical values assigned to the graduations.) In each instance, the tolerable point is half of the maximum point value, rounded down to the next digit when the maximum point value is not an even number.

This general calibration method is used for the secondary road model (with slight variations), graduated linearly with decreasing values below the maximum score. Accompanying statements have used descriptors of "excellent," "good," "fair" (at tolerable scales), and "poor," together with status descriptions for each score. A summary of the model's scoring method is given in the next section.

However, there are some rating elements in the model that do not lend themselves well to the linear scale concept. They include elements grouped under the category of Safety. The score represents an accumulation of potential safety risks or hazards occurring along the rated road segment. Their existence represents a possible safety hazard, or deficiency, and they tend to be site specific instead of occurring regularly along the road. The rating elements are the type that can be counted (two narrow bridges are more hazardous than one). Some are based on design standards for secondary roads. An example is "narrow structures"—structures narrower than 20 ft (6 m). Any structure less than 20 ft wide is assumed to represent a safety hazard.

This suggests that part of the score for a rated road segment under the category of Safety could be based on the results of an evaluation of its relative safety. Deductions from a maximum value would be made for "conditions that exist on the road segment that constitute a possible threat to safe operation of the motor vehicle on that road."

Under this system, deficiency points would be assessed for the existence of a list of "threats to safe driving," using a predetermined point deduction for each deficiency. Road segments of varying length would be made comparable by adjusting for length. There would be no negative scores for safety, but a given road segment could receive a zero score.

The scaling system developed for use with the model is briefly described in the next section. The set of scales is described completely in Volume 2 of the project report (*8*).

Rating Scale Calibration

The rating scale system was designed to provide relative scores for the sufficiency ratings for each road in order to place road improvement projects in some priority order. In theory there is no score that "fails," but the rating system allows for comparison of scores for roads that carry different amounts of traffic. The system is neutral when comparing roads in different parts of the county highway department's jurisdiction, and it recognizes the differences in needs of the more heavily used arterial roads and the area service roads that carry substantially less traffic. This means that should two roads have scores of 70 and 65, the one with the lower score should have a higher priority for improvement, even if the road with the lower score carries substantially less traffic.

The validity of comparison of the scores of roads of different classifications is assured by including the variations in design standards for each road classification. This affected rating standards for several criteria under the categories of Safety and Service.

The scale calibration described next represents a sampling of the scales provided for each criterion used in the model and included in the project report.

Linear Scales

The format used in describing the calibration for the criteria in the category of Condition and Maintenance Experience is rather consistent. It provides a brief description of each criterion followed by the range of possible scores and descriptors designed to aid the evaluator in determining an appropriate score. An example is the calibration for Road Foundation, taken from the project report:

- Foundation—evaluated by considering adequacy of drainage ditches, breakup of surface, nonuniform settlement and lateral support, and condition of foreslopes. Maximum score = 9.
- Excellent, 8–9. No evidence of base failure. Foreslopes in excellent condition.

- Good, 6–7. Occasional evidence of minor base failure, fully correctable by spot repairs. No need for extensive reworking.
- Fair, 5. Frequent base failure requiring heavy maintenance. Causes reduction in traffic speeds below design speed. Should be considered for reconstruction. "Tolerable."
- Poor, 1–4. Severe base failure throughout rated section, extreme "washboard" condition. Traffic speeds substantially reduced. Reconstruction necessary.

Nonlinear Scales

Scores for some of the rating elements under the category of Safety are derived somewhat differently. As noted earlier, there are some rating elements that do not lend themselves to the linear scale used for the category of Condition and Maintenance Experience. Instead, deficiency points are assessed for the existence of "threats to safe driving." A predetermined point deduction is charged for each deficiency.

Two brief examples, using the rating criteria of Accident Rate and of Hazards, will help explain the concept. Each formula provides for comparison of road segments of varying lengths by use of the factor L, length of rated segment in miles.

- Accident Rate: Deficiency points are assessed for each accident occurring on that road segment over the past 5 years. Relative weights of each accident vary according to severity of the accident. Property damage accidents result in one deficiency point, while personal injury accidents are four and a fatal accident would be twelve deficiency points. The score for a given road segment uses the formula

$$\text{Rating} = 6 - (N/L)$$

where N is the sum of all deficiency points and L is the length of the rated road segment in miles. The maximum score is 6, but the minimum score would be 0.

- Hazards: Deficiency points are assessed for each hazard not included in any other rating element. These hazards include

1. Narrow structures (less than 20 ft),
2. Structure with poor approach alignment,
3. Railroad crossing at grade without automatic signals,
4. Abrupt or severe grade changes, and
5. Other fixed structures extending into the traveled way.

Rating scores are based on the average number of hazards per mile of roadway using the formula

$$\text{Rating} = 9 - 2(N/L)$$

where N is the number of hazards encountered and L is the length of the rated road segment in miles. The number 2 represents the perceived weighted severity index of the effect of the hazards on driving safety. The maximum score is 9 and the minimum is 0.

The effect of these factors (Accidents and Hazards) on the overall score for a road segment can be varied according to the perceived importance of the factors to driving safety. The weight of the type of accident can vary as well as the weighted severity index for hazards. Indeed, the index can vary according to the type of hazard encountered. Engineering practitioners can vary these weights—using the same rationale that was used to promulgate design standards. The basis for choice of relative weights could be "prevailing professional opinion" arising from the force of public opinion.

A third general type of scale, also nonlinear, is represented by some of the rating criteria under the category of Service as well as under Safety. This type of scale uses the applicable design standard for the rated road segment according to the adopted Design Guide. An example is the criterion of Pavement (roadbed) Width referring to traveled way for an unpaved road. (Shoulder width for paved roads is covered under a separate criterion.) The calibrations, taken from the project report, are

- Pavement (roadbed) Width—used to reflect inadequate traveled way widths as determined by a comparison with the appropriate design standard. Maximum score = 9.
- Excellent, 8–9. Width of pavement or traveled way meets or exceeds the width specified in the appropriate design standard.
- Good, 6–7. Width of pavement or traveled way is not more than 2 ft (0.6 m) less than the design standard.
- Fair, 5. A tolerable width. Width of pavement or traveled way is 2 ft (0.6 m) to 4 ft (1.2 m) less than the design standard.
- Poor, 1–4. Not tolerable. Needs to be wider. Width falls short of the design standard by at least 4 ft (1.2 m).

INCENTIVES FOR CHANGE

The exercise just described is potentially useful as an internal guide in programming for secondary road improvements, particularly if the variable design standards are used. An individual county can use it to provide the basis for allocation of funds for secondary road needs.

Properly used, the rating system provides a ranking for developing annual programs, and it can also be used to assist in maximizing stated objectives. However, it has the potential for use on a larger scale in the allocation of road use tax funds on the statewide level for highway construction, rehabilitation, and maintenance. State road use tax funds are commonly split among several jurisdictions, and there is never enough to go around. Currently, the combination of a deteriorating physical plant for primary highways with heavier traffic loads and heavier axle loads for trucks has caused the initiation of new discussions on the allocation of highway funds to the various political jurisdictions.

In rural states, rural-dominated legislatures have generally been able to retain a significant proportion of the road use tax funds for secondary roads, and will probably be able to do so for some time. However, the recent problems plaguing the farm economy have accelerated the displacement of farmers from rural to urban areas, further reducing an ever-shrinking farm population. Future reapportionment of state legislatures is likely to produce a more urban-oriented body of lawmakers, one less favorable to rural issues.

A problem that will face legislatures in the future, whatever their makeup, will be how to significantly increase the total highway funds available to a given political jurisdiction.

Though the dollar amount of funds is not really a fixed amount, it should be realized that there have been several significant increases in the gasoline tax during the past few years by both the federal government and state governments. At the time of writing, gasoline taxes in Iowa total $0.25 (out of about $1.00 per gallon at the pump), $0.16 for the state and $0.09 for the federal government. This is up from $0.07 for the state in 1978 and $0.04 for the federal government as recently as 1983. Any effort to increase that amount in the near future is likely to meet some resistance, at least at the state level.

Therefore any significant increase in the highway funds any political jurisdiction receives from road use tax funds is not likely to be accomplished by additional taxes but by a change in the allocation of funds. And because allocation is based at least to some extent on the results of needs studies, much time is likely to be spent analyzing the results of needs assessment studies.

Secondary roads have traditionally fared well when needs have been considered, given past methods of determining needs. It is difficult to ignore the results of needs studies, but it is possible to redefine needs. One way to redefine needs is to reconsider some of the currently accepted standards. For example, should a bridge that is 16 to 18 ft wide be considered inadequate (intolerable) for a road carrying fewer than 50 vehicles per day, even if it is considered safe, can carry expected loads, and is properly signed?

Design and Classification Changes

What is needed is a close reexamination of the way secondary roads are used. Some do carry moderate to heavy traffic loads, but many serve only as an access to abutting property. As farms continue to increase in size [in Iowa, from 276 acres (108 ha) in 1976 to an estimated 303 acres (122 ha) in 1986] and fewer farmsteads are occupied, there will be an increasing number of roads that merely serve as access to farmland.

Attempts have been made in the past to abandon some of these roads with title reverting back to the owners of adjoining property. However, many of these actions have encountered considerable resistance, making the total miles of secondary roads abandoned in most jurisdictions fairly insignificant. A recent study by Baumel et al. (*9*) generally supports these property owners. The study indicates that some of the roads normally considered candidates for abandonment should be retained in the road network because the benefits to the public of keeping the roads open equal or exceed the costs of closing the roads. A major factor in the analysis was the higher travel cost of farm equipment such as tractors, wagons, and combines.

The significance of farm equipment travel costs in the study suggests that the very-low-volume roads kept open need not meet the same standards as collector roads. This is because of the low speed at which much of this equipment moves. The Baumel report did suggest that some groups of low-volume roads could be converted to private roads, with the landowners assuming the maintenance costs. If the local owners perform the maintenance, these are likely to become "minimum maintenance" roads. Likewise, little reconstruction is likely to be done.

Changes in the characteristics of the use of these very-low-volume roads have been recognized by county officials in Iowa, as well as several other states, by their designation of some public roads as minimum maintenance roads. This represents the creation of a new functional classification carved out of the area service functional class. To date Iowa's experience with this concept has been good, and, by mid-1986, 45 percent of the counties had voluntarily adopted the classification and had designated about 10 percent of their secondary road mileage as minimum service (Service B classification) (*10*). By mid-1987, this was up to about 80 percent. Indications are also that this percentage will increase slightly over time. (Though Baumel et al. did refer to this possible approach, it was not examined in the report analysis.)

Iowa has also taken steps to provide design guides that provide for a wider range of design speeds, from 30 to 55 mph. The 1985 guidelines are given in Table 2. (Road surfacing is not covered by the design guide because that issue is addressed by a separate policy.) The Guide meets the design criteria set out in the current edition of the AASHTO *A Policy on Geometric Design of Highways and Streets*, Chapter V, and meets the expectations of courts of law with regard to tort liability (*11*). The new design standards also should manage to achieve cost savings through use of the varying design speeds.

It would appear appropriate, therefore, to take a closer look at the way secondary roads are used and to consider changes in design standards and possibly even functional classification. This needs to be done on a national basis because designation of functional classification is so closely tied to the disbursement of Federal-Aid Secondary funds. Without this, some of the needed reclassification would not occur. After all, who would expect county officials to downgrade a road's functional classification if it meant the loss of revenue, even if the lower classification were clearly warranted?

New Needs Assessment

Adoption of significant changes in design standards or functional class, or both, would require a new needs assessment for each jurisdiction because many existing roads would change. Should this be done, a reasonably uniformly applied sufficiency rating system could yield results that would better define secondary road needs statewide. If all jurisdictions used the same bases for needs assessment, a summation of the needs, both short and long range, could be used to aid in the determination of an allocation formula.

It should be noted here that a new needs assessment is not likely to be the only concern in determining a new allocation formula, though it would probably be an important factor. County governments in Iowa already are facing significant losses in revenue for use on secondary roads from two current sources. One is property tax revenue that is decreasing because of the lower land values throughout the state, and the other is loss of federal funds—revenue sharing and other federal sources. (Counties have consistently used a portion of their revenue sharing funds for secondary roads.)

TABLE 2 DESIGN (AASHTO) GUIDELINES FOR RURAL COLLECTORS, 1985

DESIGN ELEMENTS		ALL ROADWAYS														
(1) ADT--DHV --Design Year (in 20 yrs.) --Current Year		0-600 0-400			600-750 Over 400			100-200 750-1500 500-1000			200-400 1500-3000 1000-2000			Over 400 Over 3000 Over 2000		
TERRAIN		Flat	Rolling	Mount	Flat	Rolling	Mount	Flat	Rolling	Mount	Flat	Rolling	Mount	Flat	Rolling	Mount
DESIGN SPEED	mph	40	30	20	50	40	30	50	40	30	60	50	40	60	50	40
STOPPING SIGHT DISTANCE	ft	275-325	200	125	400-475	275-325	200	400-475	275-325	200	525-650	400-475	275-325	525-650	400-475	275-325
MAXIMUM CURVATURE	degrees	12.25	22.75	53.5	7.5	12.25	22.75	7.5	12.25	22.75	4.75	7.5	12.25	4.75	7.5	12.25
(2) MAXIMUM GRADIENT	%	7	9	12	6	8	10	6	8	10	5	7	10	5	7	10
PAVEMENT/SURFACING WIDTH	ft	20	20	20	22	22	20	22	22	20	24	24	22	24	24	24
SHOULDER WIDTH	ft	2	2	2	4	4	4	6	6	6	8	8	8	8	8	8
ROADWAY TOP WIDTH	ft	24	24	24	30	30	28	34	34	34	40	40	38	40	40	40
(3) BRIDGE WIDTH--NEW	ft	24	24	24	28	28	26	28	28	26	32	32	30	40	40	40
(4) BRIDGE WIDTH--EXISTING	ft	22	22	22	22	22	22	22	22	22	24	24	24	28	28	28
FORESLOPE		3:1	3:1	3:1	3:1	3:1	3:1	3:1	3:1	3:1	3:1	3:1	3:1	3:1	3:1	3:1
(5) CLEAR ZONE		10	10	10	BG	10	10	BG	10	10	BG	BG	10	BG	BG	10

NOTES:

(1) DHV governs
(2) Maximum Gradient may be steepened by one percent (1%) for short distance--(less than 500')
(3) a. Bridges over 100 feet long and DHV over 200, width may be traveled way plus three feet (3') each side
b. Design Loading should be HS-20
(4) a. For bridges less than 100 feet in length, over 100 feet analyze individually
b. Design Loading should be HW-15
c. Existing bridge width is considered to be at least pavement width
(5) CLEAR ZONE = 10' for 40 mph and below and according to Barrier Guide (BG) for 50 mph and above (Clear Zone Table in I.M. 3.215)

SUMMARY AND CONCLUSIONS

The objective of this study was to produce a sufficiency rating system that could be used to evaluate the adequacy of secondary roads in Iowa. The system developed should be reasonably easy to use yet yield results that are compatible with processes currently used in priority planning.

The final sufficiency rating formulation appears to do this, plus it provides a possible bonus. It could also be used as a basis for statewide allocation of funds, particularly if a more variable set of standards were used. The suggested lower standards for the very-low-volume roads can be factored into the model by using the different design guides and the calibrations employed with the rating criteria. Though a more variable set of standards would make the evaluation process slightly more complicated, it would provide more realistic rating scores that would more accurately reflect the nature of traffic on and the frequency of use of a given road.

In addition, use of the same set of scales across jurisdictions would make it possible for lawmakers to make more realistic needs assessments. More uniform guidelines can be used for needs assessment in the jurisdictions responsible for secondary roads. Then, comparison can be made between those needs and those of primary roads or urban streets, or both, using similar methods of needs assessment. Like jurisdictions can then be treated more equally in the allocation process.

The allocation process is still, of course, political, but lawmakers are provided with better information about needs. Many states already use either a sufficiency rating system or a similar numerical evaluation process to determine primary road needs more objectively. The same can be done with secondary roads to provide lawmakers with better data for use in determining allocation formulas for road use tax funds.

REFERENCES

1. K. Moscowitz. Numerical Ratings for Highway Sections as a Basis for Construction Programs. *Bulletin 17*, HRB, National Research Council, Washington, D.C., 1948, pp. 28–39.
2. W. E. Willey. Arizona's Experience with Sufficiency Ratings. *Bulletin 53*, HRB, National Research Council, Washington, D.C., 1952, pp. 3–7.
3. C. V. Zegeer and R. L. Rizenbergs. Priority Programming for Highway Reconstruction. In *Transportation Research Record 698*, TRB, National Research Council, Washington, D.C., 1979, pp. 15–23.
4. T. F. Humphrey. *NCHRP Synthesis of Highway Practice 84: Evaluation Criteria and Priority Setting for State Highway Programs*. TRB, National Research Council, Washington, D.C., Nov. 1981, 32 pp.
5. J. A. Swanson. General Comments on Sufficiency Rating Procedures. *Bulletin 53*, HRB, National Research Council, Washington, D.C., 1952, pp. 7–11.
6. C. R. Mercier. Sufficiency Rating for Secondary Roads: Model Development. In *Transportation Research Record 1076*, TRB, National Research Council, Washington, D.C., 1986, pp. 7–13.
7. R. L. Carstens. *Quadrennial Needs Study, 1982–2001*. Iowa Department of Transportation, Ames, 1982.
8. C. R. Mercier. *A Sufficiency Rating for Secondary Roads in Iowa.* Project Report HR-264. Iowa Department of Transportation, Ames, 1985.
9. C. P. Baumel, C. A. Hamlett, and G. R. Pautsch. *The Economics of Reducing the County Road Systems: Three Case Studies in Iowa*. Project Report HR-242. Iowa Department of Transportation, Ames, 1987.
10. C. R. Mercier and L. E. Richardson. Area Service B Classification: A Legal Approach to Setting Road Maintenance Levels for Little Used Low-Volume Roads. In *Transportation Research Record 1106*, TRB, National Research Council, Washington, D.C., 1987, Vol. 1, pp. 34–38.
11. R. L. Carstens. Highway-Related Tort Claims to Iowa Counties. In *Transportation Research Record 833*, TRB, National Research Council, Washington, D.C., 1981, pp. 18–24.

Publication of this paper sponsored by Committee on Transportation Programming, Planning and Systems Evaluation.