Appendix on Procedures

SUFFICIENCY-RATING FORMULAS

DURING THE EARLY years of highway construction, one of the first objectives of highway officials was the development of a highway network which would provide year-round travel. In accomplishment of this objective, there was little disposition on the part of the general public or legislative bodies to differ as to which routes were to be constructed or improved. The need was so self-evident that there was virtually unanimous support, financial and otherwise.

As integrated systems of highways began to emerge with an ever-increasing ownership of motor vehicles, the operating characteristics and use of which were constantly being improved and expanded, highway officials soon became cognizant of the demands for improved highway facilities. It became increasingly impossible to satisfy all of those demands to standards acceptable to all concerned, so in effect the programming of construction projects, even though done with the best of engineering judgment, did not reflect defensible priority for improvement because of the many intangible factors involved. With the mounting of pressure for highway improvements to higher standards and in many instances with no increased financing, the need for a satisfactory, realistic, and factual means of evaluating highway needs became apparent to highway administrators.

Regardless of the type of rating formula used, the purposes for which they have been thus far developed are substantially the same and may be summarized as follows: (1) To aid in the assignment of priorities for reconstruction by evaluating the relative adequacy of each highway section according to certain prescribed standards; (2) to minimize or eliminate the element of personal judgment in the assignment of ratings; (3) to evaluate the road section's ability to carry traffic safely, rapidly and economically; (4) to hold to a minimum political and community pressure in highway planning and construction; (5) to keep legislative officials advised as to the current status of the highway plant and the funds that will be required to achieve a given standard of improvement on a statewide basis. The accomplishment of this objective would counteract legislative allocation based on political expediency; (6) to measure at annual intervals the average rating of the highway system so the rate of progress of the highway program can be determined (the rate of progress, whether plus or minus, provides a means of measuring the adequacy of highway revenues); and (7) to budget funds for highway improvements in the relative order of need, thus protecting the public's investment in highways.

STRONG POINTS

The task of selecting highway projects for construction or improvements is fraught with the consideration of many factors in addition to those which can be reduced to a formula. At best, a rating formula should be used as a guide in formulating improvement programs. The use of a formula does result in many definite advantages, chief of which are: (1) Ratings are accepted by the public as a practical method of determining construction priorities. (2) Ratings when plotted on a map are easily understood and permit a graphical review of the status of the highway system. This type of presentation is very helpful before legislative bodies and civic groups interested in highways. (3) The highway sections and elements thereof are compared with a standard rather than with one another. (4) Special lists may be prepared which will bring critical sections to the attention of programming officials. (5) Special maps and lists likewise can be prepared which will call attention to those sections which have certain elements, such as the surface item, in critical status even though the average rating for the section may not be critical. (6) The ratings are relative and supposedly in order of need based on the elements considered therein.

WEAK POINTS

Any attempt to rate a road section by an empirical formula is subject to argument. The fact remains, however, that the States which have used formulas of this type have found them satisfactory. It is noted that the formulas in use show considerable variation in elements evaluated and the weights given to them. A tentative conclusion may be drawn to the effect that no one formula has been developed which has been found satisfactory to all states.

The formulas in use, regardless of the elements considered or their par values share a number of weaknesses which may be summarized as follows: (1) It is practically impossible to subdivide the roads into units which are homogeneous in all respects. (2) Unless small sections are rated individually, the seriousness of a particular deficiency may not be apparent. (3) The average weighting given to a rating element may not indicate the seriousness of the components of the average. (4) Average daily rather than design-hour traffic volumes have been used in setting up the basic standards. (5) Except as to variation in standards, the cost of the improvement is ignored. This is an important consideration where the cost is disproportionately effected by an expensive bridge, costly right of way acquisition, or the surmounting of some physical barrier. (6) It is virtually impossible to obtain accurate maintenance costs on short sections. (7) Short though critical deficiencies such as narrow or structurally weak bridges are not rated. (8) It is difficult to rate conditions at locations involving intersections, interchanges, urban boundaries, etc. (9) The need for new routes is not considered. (10) Reasonably reliable accident data are not ordinarily available and, when used, certain precautions must be exercised. Some sections with a very good safety rating have a high accident frequency, possible because factors such as access points, land use and the like are not considered in the formula. (11) Unless a separate adjustment is made traffic sections with extremely low traffic volumes will appear near the top of the list even though they have low basic sufficiency ratings. This would indicate that either the elements are weighted in favor of the high traffic volume roads or that the basic standards are not in correct relationship by traffic volume groups.

SUCCESSFUL USE

The Arizona Highway Department developed and has used the sufficiency rating system since 1946. With necessary modifications it has been applied to both rural and urban roads and to the state primary system (F.A.), state secondary system (F.A.S.), and county primary system (F.A.S.). The use of the sufficiency rating system has been widely accepted by the public as an impartial, unbiased method of allocating funds against the most urgent road construction needs. During the years it has been employed, more than 80 percent of the items appearing in the construction budget were included in the critical rating list. The political aspect of the annual public budget hearings with pressure groups vying for special consideration has disappeared. These hearings are now very orderly and brief with only a few people in attendance which attests to the public acceptance of the system.

Nationwide and even international attention has been received by Arizona and its rating system. At least nine states have used this rating method, modified to suit their particular conditions. Some have applied it on an experimental basis to all or part of their primary systems. In some cases this experimentation has led to modifications and changes that depart quite radically from the original procedure.

A few states have adopted a rating method and are using it for the second or third year on both their primary and secondary systems. Statistical tables of components of ratings such as Arizona publishes annually have been published by Connecticut, Washington, Louisiana, Colorado, and Oregon.

Connecticut has used its sufficiency rating system to substantiate the long range construction needs program which had been previously chosen on the basis of engineering judgment and miscellaneous facts. Their district engineers have been supplied with priority lists of ratings of various components and maintenance programs and requests for work authorizations are checked against these ratings. State police officials have also been supplied priority lists for the safety compon-

ent of the rating as a guide to the assignment of patrol effort.

Several states by a comparison of final factors of each year, have been able to indicate the gain or loss in providing adequate highways for the traveling public.

USE OF VARIOUS ROAD SYSTEMS

Only a few states have used the sufficiency rating procedure on any roads other than their state primary system. In the limited number of states where it has been used on the secondary system, no modification of the formula has been deemed necessary. It is felt that the type of terrain and the traffic volume are the controlling elements and, therefore, rating standards should be established on the basis of these two factors. In some cases, separate rating standards have been set up for each system such as the interstate, primary, and secondary and with the standards further classified by traffic volume and terrain type. It should be emphasized, however, that no change was made in such cases in the rating formula or its application.

One state suggests that if the interstate or primary system warrants priority for military or other strategic purposes, this can be considered separately or an adjustment to the rating may be made. It warns that systems and adjustments so made should be thoroughly explained so they don't fly under false colors and will not be given preferential treatment without full knowledge of the reason.

Arizona uses the same sufficiency rating formula for urban areas as it does for rural areas. The terms marginal friction, medial friction, intersectional friction, and safe speed have been substituted for roadway and surface width, stopping sight distance, and alignment, although point values for these characteristics remain the same.

Connecticut recognizes that certain elements rated for a rural system are inapplicable in an urban area. Such an element would be sight distance available for passing. Lower speeds and higher practical capacities in urban areas provide for less freedom of flow than do rural standards.

In villages, New Hampshire substitutes the number of street intersections, service stations, and other types of driveways for the number of stopping sight distance restrictions used in rural areas.

It is quite apparent that the field is wide open for further development of sufficiency rating procedures to be used in urban areas. The thoroughfare and intersectional congestion so prevalent in such areas would seem to place great importance on the sufficiency of the practical capacity based on a desirable average operating speed. Structural adequacy or condition and traffic capacity that provides a desirable freedom of flow with reasonable safety are undoubtedly the two most important factors to be considered in determining the sufficiency of urban routes.

BPR MAINTENANCE INSPECTION RATINGS

It is a function of the Maintenance Branch of the Bureau of Public Roads to administer that part of the Federal Aid Highway Act which requires the states to perform the maintenance on roads following construction under the provisions of the act. In carrying out this responsibility on the extensive mileage of the federal-aid systems, the need for a uniform and practical method of making maintenance inspection reports is paramount.

Maintenance reports since 1933 have described condition, safety, and service factors on federal-aid projects in various stages of deterioration and obsolescence to the extent where they have become a burden on maintenance forces and require reconstruction. In recent years the Maintenance Branch conducted a study in 16 states of the advantages to be gained through adoption of the sufficiency rating plan whereby numerical ratings are assigned to various items comprising the elements of condition, safety, and service, and weighting these factors to obtain a composite rating.

It was concluded from this study that the sufficiency rating plan had many advantages including greater uniformity of procedure and precision of reporting. The ratings of projects consolidated into route sections furnish a means of ranking the sufficiency of each segment of the highway and gives those responsible for maintenance an opportunity to be heard at the program stage regarding projects requiring excessive maintenance. It also fur-

nishes a basis for the preparation of more scientific maintenance budgets and a record for future years of the loss or gain in highway plant rehabilitation. Accordingly, this plan was extended to all states in 1951 and is now incorporated as part of the maintenance inspection procedure of the Bureau of Public Roads.

During the course of the study mentioned above, the Bureau of Public Roads Division Office at Portland, Oregon, prepared a manual covering the maintenance inspection procedure to be followed in the states in Division 8, namely Idaho, Montana, Oregon, and Washington. This manual is now the accepted guide within the Bureau of Public Roads for making maintenance inspections of federal-aid and forest-highway mileage. The State Highway Department of Idaho has adopted and now employs almost identically the same procedure. Thus, reference may be made to the material concerning the Idaho procedure contained elsewhere in this report for a summary of the rating plan currently being employed within the Bureau of Public Roads.

SUMMARY OF SUFFICIENCY RATING PROCEDURES

RATING ELEMENTS	REFERENCE LETTER	ARIZONA	COLORADO	CONNECTICUT	DELAWARE	IDAHO	ILLINOIS	KENTUCKY	LOUISIANA	MISSOURI	NEBRASKA	NEW HAMPSHIRE	OREGON	WASHINGTON
CONDITION OR STRUCTURAL ADEQUACY		(35)	(40)	Not Used	(40)	(40)	(350)	Not Used	(40)	(35)		(40)	(40)	(40)
Structural Adequacy	a	17			22									
Observed Condition	b						100			15	20			
Remaining Life	c	13			12		100			10	20			
Maintenance Economy	d	5	1/		6	1/			1/	10	20		1/	1/
Maintenance Cost	e						150							
Foundation	f											20		
Pavement	g											14		
Shoulders	h											6		
SAFETY		(30)	(30)	(50)	(30)	(30)	(350)		(30)	(30)		(30)	(30)	(30)
Roadway Width	k	8	8				70					8		
Surface Width	m	7	7		8	7	150	26	7	7	16	7	7	7
Shoulder Width	n				7	8		17	8	8			8	8
Sight Distance	o	10		20							10			
Stopping Sight Dist.	p		10		10	10	60		10	10		10	10	10
Consistency	q	5	5		5	5	50		5	5		5	5	5
Accident Rate	r			30			20							
SERVICE		(35)	(30)	(50)	(30)	(30)	(300)		(30)	(35)		(30)	(30)	(30)
Alignment	s	12	12	13	12	12	120	23	12	12	7	10	12	12
Passing Opportunity	t	8	8		8	8	80	34	8	8	7	7	8	8
Surface Width	u	5	5	25	5	5			5	6		5	5	5
Sway in Cross Section	v	5										4		
Roughness	w	5										4		
Surface Driving Cond.	x		5		5	5	100		5	9			5	5
Maintenance Rating	y			12										
BASIC RATING		(100)	(100)	(100)	(100)	(100)	(1000)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
Adjustments	z	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

NOTES TO TABULAR SUMMARY OF SUFFICIENCY RATING PROCEDURES

Arizona

Ratings determined by field inspection by comparing each road section with present day standards for that section. These standards vary according to traffic volume and topography.

Bridges are rated separately and a priority list established which includes only

bridges whose overall rating was lower than the adjacent sections of road. This is based on the theory that a low rating bridge will be included in any program to raise the standards of low rating approaches or adjacent sections of low rating roadways.

(a) Ratings: Excellent = 16-17, Good = 12-15, Fair = 8-11, Poor = 0-7.

(c) One point for each year of expected remaining life, up to 13 points. Actual present age is the determining factor with remaining life based on experience tables of similar road types.

(d) Rated from 0 to 5 points depending upon evidence of expenditures greater or less than average.

(k) Rating = 8 - $\frac{(\text{Standard width - Actual width})}{2}$

(m) Two lane roadway: Rating = 7 - (Standard width - Actual width)

Four lane highway: Rating = 7 - $\frac{(\text{Standard width - Actual width})}{2}$

(o) In cities this is termed "intersectional friction" and the rating is based on the frequency of intersections and access points.

(q) Consistency is defined as the absence of abrupt surprises such as narrow bridge structures or so called death curves.

(s) Rating based on desirable design speed which is determined by topography and traffic volume.

(t) Rating is a function of roadway congestion or of the number of times that a driver is unable, for any reason, to pass the car just ahead.

(u) Same as (m) using par value of 5 points.

(v) Rating based on occurrence of roadway features making driving difficult such as settlements, heaves, or irregularities in cross section or super-elevation etc.

(w) Roughness of texture takes into consideration rocky surface, multiple corrugations, irregular bridge decks, etc.

(z) Basic rating is adjusted by applying a correction which gives a lower sufficiency rating to exceptionally heavy traveled roads and a higher sufficiency rating to roads carrying a low volume of traffic. The resultant rating is called the "adjusted sufficiency rating." The adjustment is made in proportion to the amount of deviation from the average traffic volume on the system under consideration by the following formula:

$$R = B + \frac{B^2 - 100\,B}{50 \text{ Log } T_s} (\text{Log } T - \text{Log } T_s)$$

Where T_s = 300 = 1949 Average daily traffic on State FAS system or T_s = 1400 = 1949 Average daily traffic on State primary (FA) system

R = Adjusted sufficiency, B = Basic sufficiency

T = Traffic volume on section

Colorado

Ratings are made according to an approved set of geometric standards which takes into consideration the traffic volume groups and types of terrain within the state. Each system is studied and rated separately by means of a field survey procedure.

1/ Structural-adequacy rating computed by the use of the following formula:

Structural adequacy = 40 - (percent permanent deterioration)

or

Structural adequacy = 40 - (maintenance rating - surface rating)

(k) This element is considered on the basis of the required shoulder width as shown in the table at the top of page 46.

(m) Rating = 7 - (Standard width - actual width) When traffic justifies 4 lanes, a two or three-lane surface is rated zero.

(p) Based on the number of substandard features per mile as follows:

Rare substandard (1 per mi.) = 8 to 9

Occasional substandard (2-3 per mi.) = 6 to 7

Substantial substandard (4-5 per mi.) = 3 to 5

Continuous substandard (6 or more) = 0 to 2

(q) Rating involves the consistency of alignment, gradient, horizontal, and vertical curves and the hazard resulting from their incidence. Consistently good = 5, Consistently poor = 4, Occasional surprises = 1 to 3, Death curves, etc. = 0

Shoulder Width		
Standard	Actual	Value
10	10	8
10	8	7
10	7	6
10	6	5
10	5	3
10	4	1
10	1 to 3	0
8	8	8
8	7	7
8	6	6
8	5	4
8	4	2
8	1 to 3	0

Shoulder Width		
Standard	Actual	Value
4	4	8
4	3	6
4	2	3
4	1	0
3	3	8
3	2	5
3	1	2
3	0	0
2	2	8
2	1	4
2	0	0
1	1	8
1	0	0

(s) Rated according to the number of substandard horizontal curves in relation to the safe speed as compared to the design speed for the highway section.

Rare substandard (1 in 3 mi.) = 10 to 11
Occasional substandard (1 or 2 per mi.) = 8 to 9
Substantial substandard (3 or 4 per mi.) = 4 to 7
Continuous or hazardous (5 or more per mi.) = 0 to 3

(t) Based on number of restrictions per mile by using the following formula:

$$\text{Rating} = \frac{\text{Total length} - \text{Total length substandard}}{\text{Total length}} \times 8$$

or

Rare substandard (1 restriction in 3 miles) = 7
Occasional substandard (1 or 2 restrictions per mile) = 5 to 6
Substantial substandard (3 or 4 restrictions per mile) = 2 to 4
Completely substandard (5 or more restrictions per mile) = 0 to 1

(u) Same as (m) using par value of 5 points.

(x) Ridability Ratings: Excellent = 5, Good = 3 to 4, Fair = 1 to 2, Poor = 0

(z) Basic rating is adjusted for lack of adequate surface or for lack of dustless surface. This is done by subtracting values ranging from 0 for a road carrying 2000 vehicles per day to 10 points for 5000 vehicles per day for lack of adequate surface. For lack of dustless surface, values to be deducted range from 0 for roads carrying 100 vehicles per day to 20 points for 600 vehicles per day. The corrections are obtained from two curves, one plotted for each condition.

Rating is adjusted for the traffic actually using the highway section by the use of a group of curves plotted from the following formula:

$$Y = X + \frac{X^2 - 100X}{50 \text{ Log } T_S} (\text{Log } T - \text{Log } T_S)$$

Where Y = Adjusted sufficiency
X = Basic sufficiency
T_S = Assumed as 500 vehicles per day

Connecticut

Sections of road to be rated are control sections set up in the 1949 Highway Log from which are determined the length of each section, the type of pavement, actual surface width, and the average daily traffic volumes. The actual shoulder width, curvature, accident data, maintenance costs, and sight distance data are all taken from available records, plans, road inventory notes, and sight distance profiles.

The design classification is determined according to the average daily traffic volume and rural or urban designation. The standards for the applicable design classification are then used.

(o) Rating is based on percent of section on which there is safe passing sight

distance for the design speed involved. Safe passing sight distance on 60 percent or more of the section gives the full credit of 20 points, and on 0 percent no credit. The rating is assigned from a table and increases faster in the lower percentages than in the higher. Divided highways automatically get a perfect rating.

(r) Based on the assumption that an accident rate of 1000 per 100 million vehicle miles is inadequate and should rate zero.

$$\text{Rating} = 30 - \frac{A}{33}$$

Where A is the accidents per 100 million vehicle miles

$$\text{(s) Rating} = R = 13 \left[1 - 3 \frac{(N - r_c)}{(LD_s)} \right]$$

Where L = Length of section in miles
D_s = Standard maximum degree
D_a = Actual degree of curvature for each substandard curve
N = Number of substandard curves

$r_c = \sqrt{\frac{D_s}{D_a}}$ proportion of standard (intensity) for each curve

(u) Where contrasting surface and shoulder materials occur, the 25 points are divided as follows:

(1) Surface width 15 points based on the formula

$$R = 15 - 2 (W_{ss} - W_{as})$$

Where W_{ss} is standard surface width
W_{as} is actual surface width

(2) Shoulder width 10 points
For black top shoulders $R = 10 \times \frac{S_{aw}}{S_{sw}}$

Where S_{sw} is standard shoulder width
S_{aw} is actual shoulder width

For grass shoulders (when standards call for paved shoulders)

$$R = 7 \times \frac{S_{aw}}{S_{sw}}$$

Where S_{aw} and S_{sw} are as stated above

Where blending surface and shoulder materials occur, a rating value of 25 points is assigned to roadbed width (shoulder to shoulder):

$$R = 25 - 1\ 1/2 (W_{ss} + 2 S_{sw} - W_{ar})$$

Where W_{ss} is the standard surface width
S_{sw} is the standard shoulder width
W_{ar} is the actual roadbed width

Surface width rating adjustment

Rural For all sections of two-lane roads reduce surface width rating 1 point for each 100 vehicles in excess of 5,000 average daily vehicles.

Urban For all sections of two-lane roads reduce surface width rating 1 point for each 100 vehicles in excess of 7,500 average daily vehicles.

(y) Based on a minimum maintenance cost of $200 per mi. for full rating of 12 points and $1,400 per mi. for zero rating.

$$\text{Rating} = R = 12 - \left(\frac{M}{100} - 2\right)$$

Where M is maintenance cost per mile

Delaware

This method of sufficiency rating has been applied only to the federal-aid primary system.

Standards with respect to surface width and surface type were established by traffic volume groups. Evaluation of road sections against these standards is done by means of a field survey making use of available road inventory records. The field party also makes estimates of the amount of work which will be needed to bring a deficiency up to standard.

(a) Elements and point values are as follows:

Surface Type: 2, 1, or 0 Points for High, Intermediate, or Low types
Shoulder Type: 2, 1, or 0 Points for Good, Fair, or Poor Condition
Surface Thickness: 4 Minus deficiency in inches
Surface Condition: 6, 3-5, 1-2, or 0 Points for Excellent, Good, Fair, or Poor
Drainage: 8 Points as follows:
- Subgrade: 2, 1, or 0 Points for Good, Fair, or Poor Condition
- Cross Road: 2, 1, or 0 Points for Good, Fair, or Poor Condition
- Roadside (Lateral): 2, 1, or 0 Points for Good, Fair, or Poor Condition
- Lead Off: 2, 1, or 0 Points for Good, Fair, or Poor Condition

(c) Concrete: Years of life remaining = Value up to 12 (using average life of 20 years) ± 2 for field observation.

Bituminous Concrete: Same except

average life of 12

(d) Low = 6, Medium = 3-5, High = 0-2 from field observation

(m) 8 Minus deficiency in feet depending on standard. When number of lanes is substandard, rating = 0

(n) 8 ft. & over = 7, 7 ft. & over = 6, 6 ft. & over = 5, 5 ft. = 3, 4 ft. = 1, 3 ft. & under = 0 depending on standard. When number of lanes is substandard, rating = 0

(p) Same as Colorado

(q) Same as Colorado

(s) Horizontal curvature: No substandard curves = 12, 1 per mile = 10-11, 2-3 per mile = 8-9, 4-5 per mile = 4-7, hazards = 0-3

(t) No sight distance restrictions = 8, 1 per mile = 7, 2-3 per mile = 5-6, 4-5 per mile = 2-4, over 5 = 0-1

(u) 5 Minus deficiency in width depending on standard

(x) Ridability: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, Poor = 1, Very Poor = 0 depending on observation

(z) Same as Arizona

Idaho

The system of evaluation used to derive the sufficiency ratings was applied to the Primary System. Basic ratings were made by a field survey party based on control sections and sub-sections. Prior to covering a section, a determination as to what standards should be used for rating was decided upon. In most instances, the standard selected was on the conservative side.

1/ Condition Rating = 40 - (Surface maintenance rating - Surface condition rating)

(m) Same as Colorado

(n)

ACTUAL SHOULDER WIDTH ft.	POINT VALUES INTERSTATE SYSTEM: Other Than Mountain Roads	INTERSTATE SYSTEM: Mountain Roads	F. A. PRIMARY SYSTEM: Other Than Mountain Roads ADT 1000 or More	F. A. PRIMARY SYSTEM: Mountain Roads ADT Less Than 1000
10	8	-	-	-
8	7	-	8	-
7	6	-	7	-
6	5	-	6	-
5	3	-	4	-
4	1	8	2	8
3	0	6	0	6
2	0	3	0	3
1	0	0	0	0

(p) Same as Colorado

(q) Same as Colorado

(s) Same as Colorado

(t) Rare substandard (1 restriction in 3 miles) = 7

Occasional substandard (1 or 2 restrictions per mile) = 5 to 6

Substantial substandard (3 or 4 restrictions per mile) = 2 to 4

Completely substandard (5 or more restrictions per mile) = 0 to 1

(u) Same as Colorado

(x) Ridability same as Colorado

(z) Basic rating adjusted for traffic by the use of curves plotted from a formula in which an average traffic volume of 893 vehicles per day is used for the Federal Aid System.

Illinois

The sufficiency rating system used by Illinois is in a tentative or trial stage and may be subject to some revision based on knowledge gained in its application. It is designed for use on primary rural highways only. Ratings were made on control sections and in certain specific instances these were broken into smaller increments. The allotting of point values to each factor was made on the basis of design standards, standard costs or other average values as applicable.

(b) Based on field inspection by district engineers and their assistants, thus making use of their knowledge and experience concerning the behavior of the physical properties of the road. Rating is obtained from a graph based on the year of structural deficiency previously determined from a needs study.

(c) Life expectancy is determined from known age and type of pavement making use of survivor curves developed from the results of retirement studies in Illinois and in the entire nation. Point values are obtained from straight line graphs, one for each type of pavement.

(e) Based on comparison of average maintenance cost for the last 5 years for section under consideration with standard maintenance cost for a road of same width and surface type. Separate charts are used for rigid pavement and low type bituminous pavements. Costs do not include overhead and depreciation charges. Costs for multilane pavements must be converted to their 2-lane equivalents before they are rated.

(k) $\text{Rating} = \frac{1}{6}\left(700 \times \frac{\text{Actual width}}{\text{Design width}} - 280\right)$

(m) $\text{Rating} = \frac{1}{7}\left(1500 \times \frac{\text{Actual width}}{\text{Design width}} - 450\right)$

Surface width of less than 18 ft. is given a rating of zero.

(p)

Restricted Stopping Sight Distance Per Mile	Rating
0	60
1	45
2	35
3	26
4	17
5	8
6	0

(q) Absence of abrupt surprises in the physical features of the road itself such as narrow bridges, sharp curves, steep grades, and other features which surprise the driver and present traffic hazards. In the absence of an objective method of rating this element, the subjective judgment of the district engineer and his staff is employed.

The following rating schedule has been suggested for use:

Inconsistencies Per Mile	Rating
None	50
0.5	34
1.0	28
1.5	23
2.0	18
2.5	15
3.0	11
4.0	5
5.0	0

(r) Rating = 24 - 4 (Accidents per million vehicle miles per year)

(s)

Deficient Curves per Mile	Rating
10	0
9	6
8	11
7	17
6	24
5	31
4	39
3	49
2	60
1	77
0	120

(t) Scored on the basis of the total number of crest vertical curves and horizontal curves which have deficient sight distances regardless of the fact that sight restrictions may frequently overlap each other.

Restricted Sight Distances Per Mile	Rating
10	0
9	5
8	10
7	16
6	21
5	27
4	33
3	40
2	48
1	59
0	80

(x) Determined by actual field inspection. Unsatisfactory = 0 to 30, Poor = 30 to 55, Fair = 55 to 75, Good = 75 to 90, Excellent = 90 to 100

(z) $R = B + \frac{B^2 - 1000\,B}{500 \text{ Log } T_S}(\text{Log } T - \text{Log } T_S)$

Where R = Adjusted rating
B = Basic rating
T = Average daily traffic on the section
T_S = Average daily traffic for the entire State

Kentucky

This sufficiency rating procedure was applied to 2,512 mi. or approximately 66 percent of the primary system late in 1949 for the purpose of planning a five year construction program. Information needed for evaluation was obtained from the interstate system report to the BPR and from plans. Information on sight distances and grades was secured by the use of field

parties. The assembled data were plotted on graph sheets by control sections and evaluation of these sections made.

Kentucky's state highway standards were used except on interstate highways where widths under 24 ft. were shown as deficient. Deficiencies were marked for a 30 percent increase in traffic although in all computations 1949 traffic was used.

Point values of 15 were initially used for accident rate and for maintenance costs but were later dropped and a factor of 1.42 applied to the remaining values to bring the total rating from 70 up to 100.

(m) Original Rating = 18 points; Revised Rating = 18 x 1.42 = 26 points

$$\text{Rating} = 100 - \left[\left(\frac{W_{ss} - W_{as}}{C}\right)^2 \times 100\right]$$

Where $W_{ss} - W_{as}$ = Standard surface width - Actual surface width

C = Standard surface width - 14

(n) Original Rating = 12 points; Revised Rating = 12 x 1.42 = 17 points

$$\text{Rating} = \frac{S_{aw}}{S_{sw}} \times 12$$

Where S_{aw} = Actual shoulder width

S_{sw} = Standard shoulder width

(s) Original Rating = 16 points; Revised Rating = 16 x 1.42 = 23 points

$$\text{Rating} = 16 \left[1 - 3 \left(\frac{N - \Sigma r_c}{LD_s}\right)\right]$$

Where L = Length of section in miles

D_s = Standard maximum degree of curvature

D_a = Actual degree of curvature for each substandard curve

N = Number of substandard curves

$r_c = \sqrt{\frac{D_s}{D_a}}$ (Proportion of Standard Intensity for each curve)

(t) Sight Distance: Original Rating = 24 points; Revised Rating = 24x 1.42 = 34 points

Rating is based on two sets of curves, one employing a minimum standard sight distance of 1,500 ft. for flat and rolling terrain and the other set employing a minimum standard sight distance of 1,100 ft. for mountainous terrain. The curves represent various ranges in traffic volumes for the thirtieth highest hour: 350 to 450, 450 to 550, etc. Each curve shows the percentage distribution of passing sight distance desirable ranging from 2600 ft. to 475 ft. in flat or rolling terrain and 2000 ft. to 400 ft. in mountainous terrain. For each percentage value corresponding rating point values are given which total 24 points.

(z) The Arizona formula was used for adjusting for traffic but this adjustment was found to be very slight.

Priority was established by dividing the ratings into the 30th highest hour traffic and the largest quotients thus obtained were placed at the head of the priority list.

Louisiana

This sufficiency rating procedure was used in 1950 on the primary state highway system totaling 2,302 mi. The rating was done by a field survey party consisting of two experienced engineers, one from the construction section and the other from the maintenance section. Ratings were made by control-units which were divided into subsections where necessary. Information already on hand such as traffic volume data, year built, section lengths and surface type, width and thickness was worked upon rating sheets which were taken into the field. AASHO design standards were used.

1/ Termed Structural Adequacy otherwise same as Idaho.

(m) Same as Colorado

(n) 2-LANE ROADWAYS:

INTERSTATE SYSTEM

Act. Shoulder Width	Rating
10 ft.	8
8	7
7	6
6	5
5	3
4	1
1 to 3	0

F. A. PRIMARY SYSTEM

Act. Shoulder Width	Rating
8 ft.	8
7	7
6	6
5	5
4	2
1 to 3	0

4-LANE ROADWAYS:

Median Width and Design	Rating
4 ft. raised median or higher type	8
4 ft. flush median	6
3 ft. flush median	4
2 ft. flush median	2
Less than 2 ft. median	0

Shoulder values for 4-lane highways are determined by average ratings for shoulder width and median type.

(p) Same as Colorado
(q) Same as Colorado
(s) Same as Colorado
(t) Same as Idaho
(u) Same as Colorado

(x) Ridability Ratings: Excellent = 5, Good+ = 4, Good- = 3, Fair+ = 2, Fair- = 1, Poor = 0

(z) The correction charts used for making the traffic volume adjustment consist of a family of curves for various traffic volumes plotted from results of the formula:

$$Y = X + \frac{\left[(X - 100)\ X\right]\ (\text{Log } T - \text{Log } T_S)}{100}$$

Where T = Traffic on road section being adjusted
T_S = State wide average for system
X = Basic rating

Adjustment is made in the above adjusted sufficiency rating for lack of paved surface where applicable. This is done by deducting points in accordance with the following:

Vehicles Per Day Annual Average	Deduct
100 or less	0
101 to 150	2
151 to 200	4
201 to 250	6
251 to 300	8
301 to 350	10
351 to 400	12
401 to 450	14
451 to 500	16
501 to 550	18
551 to 600	20
Over 600	20

Missouri

Approximately 5,300 mi. of the state primary system was rated in 1950 based on AASHO standards. Information available from office records and plans was utilized but field inspection work was required. This was performed by one man in order to minimize the personal equation.

(b) Determined by field inspection. Ratings: Excellent = 15, Good = 11-14, Fair = 6-10, Poor = 0-5

(c) In most cases this item was rated in the field. One point was allowed for each year of estimated remaining life up to a maximum of ten points. Road Life curves were used only where a section was considered typical. Maximum remaining life for various surface types are as follows:

1 1/2"	Bituminous on P.C.C.	4 years
2"	Bituminous on P.C.C.	5
3"	Bituminous on P.C.C.	7
4"	Bituminous on P.C.C.	10
Low type bituminous		3
Bituminous surface treatment		1
High type bituminous (asphaltic concrete, etc.)		5
P.C.C. and brick		10

(d) Determined by field inspection of surface. Shoulder maintenance is included where 18-ft. pavement carries heavy truck traffic. In such cases the ratings are reduced 1 or 2 additional points, dependent on the apparent damage being done. Ratings: Excellent = 10, Good = 7-9, Fair = 4-6, Poor = 0-3

(m) Rating = 7 minus deficiency in feet depending on standard.

$$\text{(n) Rating} = 8 \times \frac{\text{Actual roadway width} - \text{Standard roadway width}}{\text{Standard roadway width} - \text{pavement width}}$$

(p) Rated from tabulation of deficient sight distances taken from final plans using following formula:

$$\text{Rating} = 10 - \frac{25NS}{5280L}$$

Where N = Number of deficient sight distances
S = Standard stopping sight distance in feet
L = Length of section in miles

(q) Rated in the field and relates to blind

curves, reverse curves, sharp curves at ends of bridges or any other exceptionally hazardous condition due to alignment. Ratings: Good = 5, Fair = 3-4, Poor = 1-2, Blind and Reverse Curves = 0

(s) Alignment safe speed was rated from an office tabulation of substandard curves made from final plans. Ratings as follows:

None	12 points
1 in 3 miles	11
1 in 2 miles	10
1 or 2 per mile	8-9
3 or 4 per mile	4-7
5 or more per mile	0-3

On heavy traffic roads evaluation made by proportion of normal operating speed to design speed.

(t) Data from final plans. Rating as follows:

Unrestricted	8 points
1 opportunity in 1 mile	7
1 opportunity in 2 miles	5-6
1 opportunity in 3 miles	2-4
1 opportunity in 4 miles	0-1

(u) Rating = 6 minus deficiency in feet

(x) Ridability. Rated according to waviness and sidesway caused by any deformation of the grade or cross section which would cause driver fatigue. Rough surface texture or breaks in the pavement were not considered deficiencies. Ratings: Excellent = 9, Good = 7-8, Fair = 4-6, Poor = 0-3

(z) Adjustment for traffic the same as Arizona with T_S = 1750

Nebraska

This priority rating procedure was applied to a recommended list of needs for administrative purposes. Standards used were the same as those used to ascertain needs.

(b) Originally based on a report by the District Engineers on the physical condition of the paved highways. Suggest use of crack survey for concrete and similar survey for bituminous surfaces to be conducted by experts in each case.

(c) Based on theoretical life of road life experience for each type of surface.

(d) Based on several years' cost records of patrol sections.

(m) No method of point determination stated.

(o) Arizona type of sight distance rating adjusted for traffic volume.

(s) Because of the terrain, this was not a definitive item and would not be recommended for use in this State.

(t) Considers element of traffic volume and number of restricted sights.

New Hampshire

This rating procedure is in a preliminary stage and is subject to change before actual field ratings are made for the first time in 1951. Most elements will be inspected and rated in the field. Evidently it is planned to rate both the primary and secondary roads.

(f) Foundation:	
Drainage	5 points
Stability - Strength (degree of heaving, ability to support legal loads)	10
Relative grade	5
(g) Pavement:	
Out of shape	5 points
Broken or cracked in general or scaled	6
Broken edges	3
(h) Shoulders:	
Condition (soft, eroded, rough, too low)	3 points
Backslopes (steep, eroded, unstable)	2
Guard rail	1

$$\text{(k) Rating} = 8 \times \frac{\text{Actuated road width} - \text{Standard surface width}}{\text{Standard road width} - \text{Standard surface width}}$$

(m) Rating = 7 + Actual width - Standard width

(p) Same as Missouri. Rating may be obtained in field by noting the number of restricted places per mile and using the rating table. In villages: number of street intersections, service stations and other types of driveways.

Restrictions Per mi.	RATING 30 mph.	40 mph.	50 mph.	60 mph.	70 mph.
1	9	9	8	8	7
2	8	7	7	6	4
3	7	6	5	3	1
4	6	5	3	1	0
5	5	3	2	0	
6	4	2	0		
7	3	1			
8	2	0			
9	1				
10	0				

(q) Absence of abrupt surprises, narrow bridges, death curves. Subtract one point per mile for each surprise.

(s) Rated in accordance with the safe speed as follows:

mph.	POINTS
50	10
45	9
40	8
35	6
30	4
25	2
Under 25	0

(t) Based on percent of section on which the driver is unable to pass the vehicle just ahead.

(u) Rating = 5 + Actual width - Standard width. Standard widths as follows:

0-800 A.D.T. = 20 ft.
800-4000 A.D.T. = 24 ft.
Over 4000 A.D.T. = 48 ft.

In villages: Rating = 5 + Curb to curb width - Parking width - 24 feet

(v) Settlements, heaves, warped cross-section, poor superelevation; anything that makes driving difficult.

(w) Roughness of texture: Rocky surface, corrugations, irregular bridge decks; anything that makes car chatter.

(z) Traffic adjustment same as Arizona but modified for New Hampshire traffic. Two charts will be used, one for Primary Roads and another for Secondary Roads.

Oregon

A field study for the purpose of gathering data for computing sufficiency ratings on the primary system was conducted during the summer and fall of 1950. Ratings were based on A.A.S.H.O. standards as of July 1, 1950.

1/ Structural Adequacy = 40 - (Maintenance rating - Condition rating) Maintenance rating determined as a measure of the fulfillment of necessary maintenance with a par of 40 points.

Condition rating composed of the following elements:

Sub-grade	8 points
Drainage	7
Base and sub-base	15
Wearing surface	10
Total	40 points

(m) Same as Colorado. Requires 4-lanes if ADT exceeds 4000 and then two or three lane pavement rates zero

(n) Same as Idaho

(p) Rare substandard (1 per mile) 9 points
Rare substandard (1.5 per mile 8
Occasional substandard (2 per mile) 7
Occasional substandard (3 per mile) 6
Substandard (4 per mile) 5
Substandard (5 per mile) 4
Continuous substandard (6 or more per mile) 0-2

If stopping sight distance restrictions are more or less continuous, rate on a percentage basis.

(q) Good - Curves well distributed 5 points
Poor - Curves non-uniformly distributed 4
Occasional surprises 1-3
Death curves 0

(s) Based on the number of substandard curves.

Rare substandard (1 in 3 miles 11 points
Rare substandard (1 in 2 miles) 10

Occasional substandard (1 per mile)	9
Occasional substandard (2 per mile)	8
Substandard (3 per mile)	7
Substandard (4 per mile)	5
Continuous substandard (5 per mile)	3
Continuous substandard (More than 5 per mile)	0

(t) Rare substandard (1 in 3 miles) 7 points

Occasional substandard (1 per mile)	6
Occasional substandard (2 per mile)	5
Substandard (3 per mile)	4
Substandard (4 per mile)	3
Continuous substandard (5 per mile)	0

(u) Rating = 5 - (Standard width - Actual width) Requires 4-lanes if ADT exceeds 4000 and then two or three lane pavement rates zero.

(x) Ridability rating same as Louisiana.

(z) The basic sufficiency total obtained from condition, safety, and service ratings before final values are established, are subject to correction before being used by applying an average correction factor based on and determined by the ADT of the section in relation to the ADT of all primary highways in the State.

Washington

Sufficiency-rating procedure was applied to only the state primary highway system in 1949. In 1950 both the state primary and state secondary systems were rated by a field party on the basis of road life control sections. Where it was deemed necessary due to terrain, type of existing construction, or where a radical change in traffic volume occurred, control sections were further subdivided into sub-sections with individual ratings.

Prior to the field inspection all data concerning the construction history of each highway, such as surface type and width, year constructed, etc., were entered on the inspection forms. Ratings are based on state design standards which are divided into five classes according to 1970 Annual Average Daily Traffic. The standards for design speed, maximum curvature and gradient are further subdivided by type of terrain.

No rating is made for inadequate structures. Priority for improvement of all structures is determined by the department's bridge section, generally from a list of bridges now restricted to less than legal loads.

1/ Same as Oregon

(m) Same as Colorado

(n)

Class II & III (10 foot standard) Actual	Rating	Class IIIA & IV (8 foot standard) Actual	Rating
10	8	8	8
8	7	7	7
7	6	6	6
6	5	5	5
5	3	4	2
4	2	1-3	0
1-3	0		

Class V (3 foot standard)

Actual	Rating
3	8
2	5
1	2

(p) Restrictions per mile	Rating
0 to 0.5	10
0.6 to 1.1	9
1.2 to 1.7	8
1.8 to 2.4	7
2.5 to 3.1	6
3.2 to 3.8	5
3.9 to 4.5	4
4.6 to 5.1	3
5.0 to 5.5	2
5.6 to 6.0	1

(q) Same as Colorado. A road section with many substandard curves may be assigned a maximum rating for consistency if the curves are uniform and evenly spaced.

(s) Substandard Curves	Rating
1 in 4.0 miles	12
1 in 3.0 miles	11
1 in 2.0 miles	10
1 in 1.0 miles	9
1.1 to 1.5 per mile	8
1.6 to 2.0 per mile	7
2.1 to 2.5 per mile	6
2.6 to 3.0 per mile	5
3.1 to 3.5 per mile	4
3.6 to 4.0 per mile	3
4.1 to 4.5 per mile	2
4.6 to 5.0 per mile	1

(t) Rating = Percentage of section in which passing opportunity exists x 8

(u) Same as (m) using par value of 5 points.

(x) Same as Louisiana

(z) To attain a relative value for each road section on a system-wide basis, a correction is applied to the basic score which reflects the relation of a single road section in terms of traffic service, to the road system of which it is a part. This is done by the use of a traffic adjustment chart which reduced the basic ratings on high volume roads and increases the ratings on low volume roads to obtain comparable values which may then be listed in numerical order for the purpose of analysis. The correction chart consists of a family of curves for various traffic volumes, plotted from the results of the formula:

$$Y = X + \frac{(X^2 - 100X)}{120} (\text{Log } T - \text{Log } T_S)$$

Where Y = Adjusted rating
X = Basic rating
T = Average traffic for subsection
T_S = 800 for Secondary Highways
T_S = 1440 and denominator changes to 100 for Primary Highways

EVALUATION OF THE MAJOR FACTORS

The following discussion will indicate points of similarity and difference among the several States in the detailed methods of evaluating the three major factors: Condition or Structural Adequacy, Safety, and Service.

Condition or Structural Adequacy

Three general procedures are noted among the thirteen states listed in the tabular summary. Arizona, Delaware, Illinois, Missouri, and Nebraska all use the elements of observed condition (structural adequacy), remaining life and maintenance economy (maintenance cost). Observed condition is rated by field inspection of the physical condition of the surface, with consideration of roughness, cracking, pumping, patching, etc. Knowledge of behavior of surface and subgrade is of equal importance. Remaining life is rated from the actual percentage and the use of experience tables or graphs for similar road types. Maintenance economy is rated by evidence of expenditures greater or less than average for similar surface types. Actual cost data are used but variations in assignment of costs to sections require field knowledge of maintenance experience. Surface maintenance only is considered except as noted.

Colorado, Idaho, and Louisiana rate the Structural Adequacy of the surface only. The difference between surface maintenance rating and surface condition rating is intended to reflect the degree of permanent deterioration of the surface not correctably by normal maintenance. The surface maintenance rating is a measure of the quality of normal maintenance, based on observation, with a par value of 40 assigned for normal maintenance effort that is "everything that it should be" even though the resulting condition is less than perfect due to inadequate design or construction. Failure to repair holes or breaks, to keep joints and cracks properly filled, to correct sharp sags and heaves, to correct pumping slabs, etc., are items which reduce the surface maintenance rating in proportion to the severity of the faulty maintenance performance.

The surface condition rating is intended to reflect the structural condition which exists with respect to the standard to which the road surface was originally designed or subsequently improved. The actual rating, also having a par value of 40, is based on observation and judgment of the amount or percent of deterioration, if any, since construction. This includes both temporary deterioration correctable by normal maintenance and permanent deterioration correctable only by reconstruction or major repair.

Washington, Oregon, and New Hampshire each have variations from the two general procedures noted above. Washington and Oregon utilize the same basic concept expressed in the formula:

Structural Adequacy = 40 - (Maintenance rating - Condition rating)

Both States, however, make two important changes in defining the Condition Rating. First, it is based on present design standards for traffic, climatic and topographical conditions, rather than the stand-

ards of original construction or reconstruction. Second, the rating includes considerations in addition to the surface, such as drainage, base and subbase, and subgrade. These items are evaluated by reference to such design factors as height of grade line above water table, capacity of ditches and pipes, adequacy of subdrainage, soil stability and need for sand cushion, and thickness and width of base and subbase. Thickness and durability of surface, of course, are considered with reference to modern design standards.

In addition to the above, Oregon also uses the same method for determining structural adequacy as described for Colorado, Idaho, and Louisiana but records the results as "obligation ratings, surface" with maintenance and condition indicated separately. This apparently supplements the structural adequacy rating and is not used in determining the basic sufficiency rating.

New Hampshire's rating of condition includes more than the surface. It is based on a field inspection of the foundation, pavement, and shoulders with ratings given to the various elements of these factors as shown in the reference notes to the tabular summary.

It appears that condition ratings should be based on design requirements and include more elements than would be considered in connection with the surface alone. Many states already have special studies of road condition which can be used effectively as the basis for a condition rating.

The importance of a rating of maintenance economy indicates the desirability of long-time consistent maintenance cost data which are properly classified and identified with rating sections or subsections.

Safety

Ten of the 13 states listed in the tabular summary rate this factor in a similar manner using the same elements but with some variation in the point values assigned to each. The sufficiency of each element is rated in accordance with the deviation of actual conditions from present design standards for conditions of traffic, topography, etc. As in all other elements, should actual values exceed standard, none are rated higher than assigned par values, and none are rated below zero.

For rating roadway or shoulder width, Arizona, Missouri, and New Hampshire use a formula involving roadway width to account for the lack of physical distinction between the actual pavement and surfaced shoulders. Thus, in such cases, it is assumed that surface width is standard and the balance of the roadway, whether surfaced or not, is shoulder. Illinois also uses a formula for rating roadway width, but this formula is distinctively different from any other that is used. Colorado, Delaware, Idaho, Louisiana, Oregon, and Washington measure actual shoulder width and employ a table of point values based on the deviation from standard. A sliding scale gives greater proportional reduction in assigned points as the shoulder width narrows. Louisiana includes a table on median widths for four-lane highways and averages the point values for these with shoulder point values. Kentucky rates shoulder width by the ratio of actual shoulder width, as field measured, to standard shoulder width.

Surface width is rated by most of the states by deducting one point from the par value for each foot of surface width deficiency. Illinois and Kentucky each compute their ratings by the use of formulas which are dissimilar. Most States rate two or three lane pavements as zero when four lanes are needed for traffic. Arizona uses 1/2 point per ft. under standard on existing four-lane pavements.

Stopping sight distance is rated by most states in accordance with the number of substandard stopping sight distances per mile with some variation in point values among the states. Missouri and New Hampshire (and possibly Arizona) use a similar formula which reduces the rating on the basis of the number of substandard stopping sight distances, the standard stopping sight distance and the length of section. The data are secured from plans or by field measurement.

Consistency is pretty generally rated on the basis of a subjective evaluation of the alignment with point values assigned to four degrees of consistency. Colorado, Louisiana, Washington, and Missouri further indicate that road sections with many substandard curves may be assigned a maximum rating for consistency if the curves

are uniform and evenly spaced. Illinois assigns point values in accordance with the number of inconsistencies per mile. In so doing it joins Missouri, Arizona, and New Hampshire in considering both horizontal and vertical curvatures, grades, narrow bridges, or other sudden restrictions. New Hampshire deducts one point for each such "surprise."

Connecticut uses 20 points for sight distance with the rating value assigned on the basis of the percent of the length of highway which has safe passing sight distance. This determination is made from sight-distance profiles.

Both Connecticut and Illinois use accident rate with rating values of 30 and 20 points respectively in addition to the other elements included under safety. It is felt that accident data should be used by more States especially where such data are available and properly located. In any case the accident experience over a period of several years would seem most desirable.

It is noted that alignment and passing opportunity, now rated under service, also have an influence on safety and could be incorporated in both factors as is surface width.

Service

Nine of the 13 states listed in the tabular summary use the same four basic elements in rating this factor with some minor variations in point values.

Alignment, an element used by all thirteen states, is rated by comparing the design speed of horizontal curves on the existing road with the modern design speed curvature standards for the topography. Data are obtained either from plans or from field driving tests. Most states assign point values according to the number of substandard curves per mile. Arizona, Connecticut, and Kentucky compute the rating value by the use of the formula developed by Karl Moskowitz. New Hampshire specifies point values based on safe speed over the section. Arizona and Missouri note that on high volume roads, the relation is based on normal operating speed compared to the design speed.

Passing opportunity is rated by most of the states by means of a table of point values which vary with the number of passing sight restrictions per mile. Illinois counts each restriction regardless of overlap. Missouri uses a table based on the frequency with which a passing opportunity occurs. Colorado uses as an alternate method, the reduction of the par value in proportion to the ratio of total length standard to total length. Washington and New Hampshire establish the rating by multiplying the par value times the percentage of the section on which passing opportunity exists. Arizona indicates that the rating is "a function of the congestion on the roadway or of the number of times that a driver is unable, for any reason, to pass the car just ahead." Kentucky evaluates sight distance on the basis of the percentage distribution of desirable passing sight distance for various traffic volumes and types of terrain. Nebraska employs the Arizona type of sight distance rating adjusted for traffic volumes. Missouri specifies that data are secured from final plans, and the remaining States determine data mainly from field evaluation. In a case where the traffic volume justifies four lanes, the rating is reduced to zero for existing two lane roads.

Surface width is repeated as an element of service as well as safety, thus assigning a total of 12 to 15 percent of the total par rating to this element. Exceptions to this are Illinois, Kentucky, and Nebraska. Another exception is Connecticut which assigns 25 points to surface width and includes it only under the service factor. Provision is made for alternate methods of rating this element where contrasting surface and shoulder materials occur and where blending surface and shoulder materials occur. Connecticut also provides for a surface width rating adjustment based on the annual daily traffic when it exceeds a specified amount. Other states determine point values in the same manner as is done under safety, except that the par value is less under service.

Surface driving condition, termed ridability by seven states, is rated by field observation and judgment from "excellent" to "poor" and points assigned accordingly. In these states the term "ridability" is considered self-explanatory, but Missouri rates it according to "waviness and side sway caused by any deformation of grade or cross section

causing driver fatigue. Rough surface texture or pavement breaks were not considered deficiencies for this item." Arizona and New Hampshire subdivide the rating of this element into "sway in cross section" and "roughness of texture" with equal point values for each of these two supplements.

Connecticut includes the item "maintenance rating" under service with point values based on the average annual maintenance cost per mile for the road section under consideration. Point values vary from par for a specified minimum cost to zero for a specified maximum cost.

The method of rating the service factor has been adopted by the majority of the states with but little modification even with respect to the point values assigned to the various elements. Suggestions, however, with respect to one or two of the rating elements appear to be desirable. Passing opportunity is best rated on the basis of the percent of 1,500 ft. sight distance available in the length of the section under consideration. This usually requires a special log or sight distance graph such as is used by Connecticut. Ridability may be given too much weight in the total rating scheme when it is considered that the condition factor already includes elements that would contribute to poor ridability.

Adjustment for Inadequate Surface

Upon completion of the basic sufficiency rating, Colorado makes an adjustment for lack of adequate surface or for lack of dustless surface. This is done by subtracting values ranging from zero to 10 points from the basic rating for lack of adequate surface and up to 20 points for lack of dustless surface. Point values in each case vary with the annual daily traffic on the road section. Louisiana also adjusts for lack of paved surface, deducting zero to 20 points from the basic rating depending on the annual daily traffic.

Bridges

Illinois and Arizona rate bridges by separate criteria; Arizona establishes a priority list which includes only bridges whose overall rating is lower than the adjacent sections of road. New Hampshire indicates that they will be rated by "the same criteria but will be listed separately." Other than these, there is no indication in available data that bridges are given sufficiency ratings in the same sense that road sections are rated. Narrow bridges, bridges on poor alignment, or bridges with rough decks are given some weight in their respective items of road sufficiency rating in some of the states.

Special Comment

In commenting upon the major factors, Oregon observes that their procedure does not include any values for the costs of reconstruction or of maintenance. Oregon also suggests that traffic should be projected ahead for ten to fifteen years in order to place a reasonable value upon the benefits accruing to the road user by reason of the improvement and perhaps the solvency of the project or the annual road-user earnings in relation to the annual costs.

Field Methods

With respect to field survey methods some states have recommended that one engineering crew of a few men rate an entire road system, in the interest of uniformity. Others feel that the rating system may be applied by a number of different engineers who are more familiar with individual sections. Both methods have advantages and disadvantages. The former requires more time and does not fully utilize the intimate knowledge of local engineers. The latter method may result in more inaccuracies and a tendency to rate similar items differently among various districts. Perhaps a combination of both methods is best. Local engineers would accomplish the rating based upon the maximum use of firm data supplied by the central office and supplemented by formulas narrowing the limits of judgment wherever practicable. Their work could be supervised and checked by a special rating crew.

This combination plan is looked upon with favor by the Division 8 (Portland, Oregon) office of the Bureau of Public Roads, which considers that in each State a two-man field crew could cover each year the entire primary mileage, supple-

mented in the local construction and maintenance districts by men familiar with the past histories of the various sections of routes. It is pointed out that intensive work on preparatory data is essential before the crew takes to the field. They also observe that the value of the rating system lies in simplicity without sacrificing essentials by over simplification. The opinion is expressed that a complicated system will make no appreciable difference in the results obtained, will be more difficult to apply, will be more time consuming and costly, and will be less readily accepted.

Field data should be recorded in a log which shows limits of variations within the rating section. When this is done, it is then possible to restudy sections found to be in need of improvement and develop a separate sufficiency rating for all such sections (as distinguished from the control section which may extend over longer limits).

OTHER RATING PROCEDURES

In addition to the 13 states included in the tabular summary of sufficiency rating procedures, six states have developed other methods for evaluating construction needs and establishing priority ratings. These methods are treated separately since they are not adaptable to tabular summarization.

Georgia

In order to develop a means of evaluating the present highway facilities in relation to the traffic service required, a roadway deficiency formula was devised. Much preliminary development work was done with the formula during the early post war years employing prewar traffic volume data.

Using the perfected deficiency formula and 1949 traffic volumes, tabulations of the deficiency indices were produced for rural roads on the federal-aid primary system as of July, 1950. These tabulations were classified by county and by priority number of deficiency index. The priorities were then placed on a map of the system on which were also indicated by color, the traffic volume group into which each road section fell, by which it was possible to perceive any continuity by routes of deficient sections.

It was recognized that the deficiency index did not reflect the present condition of existing pavements and so each division engineer was requested to prepare lists of projects, within their respective areas, of needed improvements, based on present conditions and listed in order of importance, according to his opinion and describing the extent of deterioration defects and structural weaknesses.

There followed an exhaustive corelation study, by inspection of the present condition information and the geometric requirements as shown by the deficiency indices. From this study a pool of projects was created that included at least all road sections with deficiency indices of 40 or less and those projects listed by five division engineers. This pool of projects was listed in the numerical order of the indices beginning with the lowest index of 2 through the highest, 123. The estimated cost of construction for these projects totaled $77,896,000.

At this cost, the pool of projects was more than could be accomplished with the funds available so a further refinement was necessary. The pool was presented to the members of the state highway board, who indicated their final selection of projects to be considered for a two to four year program.

The above process gives consideration to deficiencies in geometrical design and weaknesses in structural strength, and yet tailors the needs to the amount of funds available. It is flexible enough to permit the administrative authorities to use their initiative and judgment for improvements not ordinarily studied in statistical forulas, such as access roads to newly developed industries, military installations and underdeveloped areas.

The formula devised for determining and rating roadway deficiencies relates the volume of traffic over the road to the surface width, miles of substandard sight distances and the type of topography traversed by the road. The index numbers, or indices obtained from this formula serve as a kind of "yardstick" for measuring and determining the degree of deviation from desirable standards recommended for rural hard surfaced roads. The formula is as follows:

$$DI = (W + S)\,TF$$

Where DI = Deficiency index for rural hard surface roads

W = Number of feet less than desired width of surface

S = Percent of total miles having substandard sight distance expressed as indicated by the following examples: 17% = 2; 43% = 4

T = Traffic volume expressed in thousandths (1137 = 1.14)

F = Topography factor =

flat	= 1.0
rolling	= 0.8
hilly	= 0.7
mountainous	= 0.5

The following tabulation shows the recommended surface widths as related to traffic groups.

24-Hr. Traffic Volume	Minimum Width of Road Surface
4000 and over	Divided lanes
2000-4000	24 ft.
1000-2000	22 ft.
500-1000	20 ft.
0-500	18 ft.

The topography factor was determined by relating the desired design speeds of roads classified as having a topography of rolling, hilly or mountainous to the recommended design speed for roads having topography classified as flat.

All the required information was obtained from general road inventory and critical feature punch cards which were matched with respect to county number, route number, and road section number. The desired information from both sets of cards was reproduced into road index cards which in turn were used for computing the deficiency indices.

Minnesota

Minnesota has no empirical formula for sufficiency, deficiency or priority indices. In connection with the development of a procedure by which a record of highway construction needs might be kept on a continuing and up to date basis, considerable study has been devoted to a suitable means of programming these needs. Consideration is being given to the adoption of three basic factors for evaluating the needs of various highway sections for reconstruction. It is not proposed that these factors be combined into a single numerical rating but that separate listings of road sections be made for each of the three factors, thus making possible the programming of projects which may be badly deficient with respect to only one of the factors.

The first factor has to do with the ability of a road to provide safe, rapid and economical transportation for the volume of traffic which desires to use it. The rural highway congestion index is the means by which may be measured the relative ability of the road section to carry traffic compared with the similar ability of all other road sections. This index is the ratio between the practical hourly capacity and the thirtieth peak traffic hour volume expressed as follows:

$$\text{Congestion Index} = \frac{\text{30th peak traffic hr. volume}}{\text{Practical hourly capacity}}$$

The thirtieth peak traffic hour volume is estimated from traffic survey data. The practical hourly capacity is computed from critical features and basic data in accordance with procedures outlined in the Highway Capacity Manual. Four of the factors commonly used in the safety element and three of the factors generally used in the service element of Sufficiency Rating Formulas are used in determining the practical capacity of a road section.

The load-carrying capacity or structural adequacy of a road is the second factor to be considered. With a road system that is subject to a loss of load carrying capacity each spring, it has been necessary to establish tolerable standards of load carrying capacity during this period for various portions of the Trunk Highway System. It is proposed that a determination based on bearing capacity tests be made which will indicate the extent of the improvement needed to bring any road section up to designated tolerable standard of load carrying ability.

Condition as reflected by the relative magnitude of the average annual maintenance costs is the third factor to be considered.

Mississippi

The following deficiency index rating

has been devised for rural roads on the primary system:

Deficiency Index = $F_1 + F_2 + F_3 + F_4 + F_5 + F_6 + F_7$

F_1 = Surface width and sight distance factor = $[(S-W) + 10L]$ T

Where S = Standard surface width
W = Actual surface width
L = Percent of section having restricted sight distance
T = Annual average daily traffic volume in thousands

F_2 = Shoulder width factor = S-W

Where S = Standard shoulder width
W = Actual shoulder width

F_3 = Maintenance cost factor = C - 2

Where C = Average cost per mile in hundreds

Maximum deficiency = 10 points

F_4 = Surface age = $\frac{10A}{L}$

Where A = Age of surface in years
L = Anticipated total service life in years

F_5 = Surface condition

Excellent = 0-2; Good = 3-4; Fair = 5-6; Poor = 7-10

F_6 = Surface type = 1 point for each type deficiency where design calls for a high type surface.

Dirt = 4; Gravel = 3; Surface treatment = 2; Intermediate = 1; High = 0

F_7 = Curvature = N

Where N = The number of curves over standard maximum for the section

The standards used are dependent upon the road category and traffic volume group.

Road sections thus rated are divided into five priority rating groups. Those sections with over 40 points are put in the first group and should be considered for immediate construction or reconstruction.

Group 2 = 35.01 to 40.00 points
Group 3 = 30.01 to 35.00 points
Group 4 = 20.01 to 30.00 points
Group 5 = 0.00 to 20.00 points

Groups 4 and 5 are usually adequate for present traffic and would be assigned to the long-range program.

Montana

In 1943 and the early part of 1944 Montana worked on the development of a formula which would show the deficiency of a highway in percent as well as the construction priority of any particular section. A formula was finally developed which approximately accomplishes these purposes. It has been given extensive study and has been used in practice for several years. Minor revisions and improvements have been made from time to time. The formula is used as an aid and a check in selecting projects for programming as in the final analysis dependence must be placed on field inspections and engineering judgment.

The following explanation covers the formula as now in use:

Priority rating = $(ADT)^{3/5} (A + B + C + 3D + 3E + F)^{1/10}$

Percent of deficiency = $(F_1 + F_2 + F_3 + 3F_4 + 3F_5 + F_6)^{1/10}$

Maximum percent of deficiency = 100%

All calculations are on a percentage basis showing percent of deficiency.

A = Percent grade deficiency

$$= 100 \times \frac{\text{Length of substandard grades}}{\text{Length of section}}$$

If no road exists, use 100%

B = Percent alignment deficiency

$$= 100 \times \frac{\text{Length of substandard curvature}}{\text{Length of section}}$$

If no road exists, use 100%

C = Percent sight distance deficiency (vertical and horizontal)

$$= 5 \times \frac{\text{Number of substandard vert. and horiz. sight distances}}{\text{Length of section in miles}}$$

Where 5% is allowed for each substandard sight distance per mile. If no road exists, use 100%

D = Percent surface deficiency (width and thickness)

$$= 100 \times \frac{(WT - W_1T_1)}{WT}$$

Where W = Required surface width
T = Required surface thickness
W_1 = Existing surface width
T_1 = Existing surface thickness

If no surface exists, or if no road exists, use 100%

E = Percent base deficiency (width and thickness)

$$= 100 \times \frac{(B - B_1)}{B}$$

Where B = Required base thickness
B_1 = Existing base thickness
If no base exists, or if no road exists, use 100%
F = Percent roadbed width deficiency

$$= 100 \times \frac{(R - R_1)}{R}$$

Where R = Required roadbed width
R_1 = Existing roadbed width
If no road exists, use 100%

The traffic factor (ADT) used is based upon 1947 traffic multiplied by 125 percent to represent estimated traffic for 1965 and the volume that should be used for design purposes.

Before any computations are made, each piece of road is rated "good", "fair", "poor", or "worn out", according to the present condition of the surfacing and base. This rating is based on the latest Public Roads' maintenance inspection. Where a road is classified as "good", full value is given to the present surfacing and base thickness. Where the road is classified as "fair", two thirds value is given and where classified as "poor", one third value is given. Roads classified as "worn out" receive no value for surfacing and base thickness.

The standards adopted for comparing each section of road were those approved by the American Association of State Highway Officials, or better. Only the 40 and 60 mph. design speeds as applied to mixed traffic were used. The sections employing 40 mph. design standards were all in the mountains where cost would be prohibitive to design for a 60-mph. speed.

New York

The necessity for some means of determining the actual needs of the highway system led to the development of the following method of measuring deficiencies and rating highway sections with respect to their relative deficiencies.

The data were gathered from existing records and plans supplemented by field observations by experienced engineers. Appraisal of each road section was made by use of a scoring system with ratings for structural adequacy, safety, and service which were based on the existing physical conditions.

Structural Adequacy = 35 points
- R.O.W. = 5 points
  - Ditches and Drainage = 2.5
  - Shoulders = 2.0
  - Backslopes = 0.5
- Subgrade = 10 points
  - Stability - Strength = 8.0
  - Relative Grade = 2.0
- Pavement = 10 points
  - Surface = 4.0
  - Heaved - Separated = 2.0
  - Broken - Cracked = 4.0
- Life as is = 10 points

Safety = 33 points
- Pavement = 10 points
  - Joints, Edges, Bumps, Warps = 6.0
  - Drainage To = 2.0
  - Texture = 2.0
- R.O.W. = 8 points
  - Shoulders = 4.0
  - Guide Rail = 1.6
  - Marginal Friction = 1.6
  - Hazard at Structure = 0.8
- Sight Distance = 15 points
  - Curve, Grade, Trees-Planting, Structures

Service = 32 points
- Alignment (Speed) = 12 points
  - Curves, Grades, Bottlenecks
- Passing Opportunity = 10 points
  - Curves, Grades, Marginal Friction
- Ridability = 10 points
  - Warped uneven surface = 7.0
  - Roughness - Surface = 3.0

Each sequence section was rated for traffic capacity using the factors of pavement width and weighted score for right of way conditions, sight distance and percentage of trucks in relation to the type of terrain traversed by the highway. The product of these three factors and the one way peak hour capacity for uninterrupted flow gave the adjusted or practical one-way peak-hour capacity. The difference between the average rated capacity and the average peak hour volume was used to determine the present deficiency or excess capacity. Anticipated deficiency was determined by using anticipated one-way peak-hour volumes for 1955, 1960, and 1965.

An accident index was computed for each capacity-rated section of road. The number of accidents of each type occurring in the section was multiplied by the appropriate frequency factor and the resulting numbers summed. The factors used were based on the frequency of occurrence

of property type, injury type, and fatal accidents and were 1,2, and 36 respectively. This weighted sum divided by the number of millions of vehicle miles of travel on the highway section annually gave the accident index for the section.

In order to select a tolerable accident rating, a 500 mile sample of random sections of the system was analyzed with respect to the accident index. This analysis revealed that 67 percent of the mileage was between 0 and 10 and that above 10 was widely distributed. It was, therefore, decided that an index above 10 should be considered excessive. This tolerable rating was tested against a tolerable rating of 60 established for safety, service, and structural rating. The results were considered to be reasonably consistent.

The priority listing of highway sequences was developed on the theory that the most important highway deficiencies are capacity and structural inadequacies. The deficiencies of service, safety, and accident experience were considered subordinate to structural and capacity deficiencies. The measures applied for the correction of structural and capacity deficiencies normally will correct those in other categories. The deficiency rating table was, therefore, developed on the following basis:

The highways urgently needing attention are those on which deficiencies occur in all five categories; the second grouping are those which have structural and capacity deficiencies plus deficiencies in two of the remaining three categories. In group three are highways which have structural and capacity deficiencies plus one deficiency in the remaining three categories. This line of reasoning was followed in the development of the deficiency rating table illustrated.

INDEX RATINGS OF DEFICIENCY GROUPS

A = Excessive Accident Index	(10+)
B = Deficiency Safety Score	(20-)
C = Deficiency Service Score	(19-)
D = Deficiency Structural Score	(21-)

E = Deficient Capacity / Volume Rating ($\frac{\text{Capacity}}{\text{Volume}}$ is less than one)

The index for each section of highway is determined by the combinations of deficiencies from the following index numbers and deficiency group combinations.

Index 1	Index 6	Index 10
A B C D E	A B - D -	A B - - -
	A - C D -	A - C - -
	- B C D -	- B C - -
Index 2	A B - - E	
A B - D E	A - C - E	Index 11
A - C D E	- B C - E	A - - - -
		- B - - -
	Index 7	- - C - -
Index 3	A - - D -	
A - - D E	- B - D -	
- B - D E	- - C D -	Index 12
- - C D E	A - - - E	No Current Deficiencies
	- B - - E	
	- - C - E	Index 13
		No Deficiencies Thru 1955
Index 4	Index 8	
- - - D E	- - - D -	Index 14
	- - - - E	No Deficiencies Thru 1960
Index 5		
A B C D -	Index 9	Index 15
A B C - E	A B C - -	No Deficiencies Thru 1965

Virginia

The Virginia sufficiency rating was developed as an integral part of the current study of Virginia's highway needs in connection with developing a program of minimum improvements to sustain transportation with reasonable safety and efficiency during the present emergency. Both primary rural roads and urban extensions are rated, but separate formulas are used for each. Predetermined design standards for varying conditions set the par values.

For primary rural roads, sufficiency ratings are compiled on a control section basis, and a separate rating is made for each 1-mi. section within the control section and an average rating for the control section then computed. Bridges are not given separate ratings, but are considered with the section of roadway in which they are located. Structural adequacy, service, and safety are the three principal rating elements considered, with weightings of 40, 30, and 30 percent, respectively.

Structural adequacy is based upon a field physical condition survey, with reductions being made for sections which have high maintenance costs, inadequate design strength or which contain structures of limited load carrying capacity.

The service factor is determined from the relative practical capacity of each section at standard operating speeds for 1950 traffic volumes. The maximum service rating is given where there is an excess of practical capacity; but where traffic is in excess of the practical capacity the maximum point value is multiplied by the ratio of the squares of the computed capacity to the 1950 ADT. The service rating is further reduced where existing curvature reduces operating speeds below standard and also where the section is subject to periodic flooding.

The safety rating is obtained by comparing existing lane width, shoulder width, stopping sight distance, and passing sight distance with design standards. Further deductions are made if the section has curves below standard, has obstructions too near the pavement edge, has below standard vertical clearances, has a high accident rate or, if four-lane, has no median strip. It will be noted that many of the elements used in determining the safety rating are identical to those upon which the computation of practical capacity must be based in determining the service rating.

For urban extensions of primary roads, sufficiency ratings are likewise compiled on a control section basis with each 1/2 mi. of urban roadway comprising a separate rating section. Structural sufficiency, 20 percent, and functional sufficiency, 80 percent, are combined to make the final rating. The structural rating is obtained in the same manner as for rural roads. Functional sufficiency is found by comparing the measured capacity, delay to movement, and the presence or absence of certain operational features (inadequate curb radii, lack of channelization where needed, excessive grades, and the like) with today's standards. Within the functional rating, the elements are subdivided into two groups: (a) service, consisting of capacity and delay items and (b) safety, consisting of operational features and accident frequency. These two groups are given weightings of three fourths and one fourth, respectively, in computing the functional rating.

PROCEDURES FOR INCLUDING THE TRAFFIC FACTOR

An examination of the several sufficiency-rating methods discloses a variety of ways of incorporating the traffic-volume factor. Some states incorporate this factor into the rating formula, some incorporate it indirectly as a basis for the design standards which form the criteria for rating, and some use it again as a supplemental adjusting factor after the basic sufficiency rating has been derived. None of the methods examined includes a traffic composition factor, or purpose classification factor.

The methods employed in using the traffic factor lend themselves to a classification into three broad categories, namely: the Arizona method, the Montana method, and the Minnesota method.

Arizona Method

Each state which has adopted the constituent parts of the Arizona Method has modified the parts to suit its own distinctive individuality. Procedures for including

the traffic factor in particular have been modified from the original. In some instances, there has been a marked departure from the original Arizona Method in procedural details, including the use of the traffic factor. Notable among these states are Kentucky and Connecticut.

Essentially, the Arizona method consists of an appraisal of a highway system to determine, section by section, the deviation from desirable criteria, which have been developed for its physical condition, safety, and service.

An investigation of the items rated discloses that those whose desirable standards derive from traffic characteristics comprise a possible 50 percent out of a total 100 percent rating. The items contributing to this 50 percent are composed of features depending upon geometrical design. Criteria for rating the other items (except for "Remaining Life") are not stated in terms related directly to traffic characteristics.

In the section by section rating accomplished, a comparison is made of the current sufficiency of each respective section with the present standard of sufficiency for that section. This is called in the original Arizona method the basic sufficiency. Quoting from the Arizona manual: "The basic sufficiency is simply a numerical expression of a comparison of each road section with standards for that section. Since these standards depend to a large extent upon the traffic volume, the basic sufficiency does recognize, to a degree, traffic on each section." It would appear that the basic sufficiency rating, showing each section's deviation from its standard, gives its relative sufficiency in terms of its own desirable current requirements based on its traffic characteristics and type of terrain, in other words, its priority as compared to other sections having identical standards of sufficiency.

The Connecticut method, upon arriving at this point, lists the ratings thus obtained in progressive order. This listing becomes their sufficiency-rating list. But this list of ratings is not directly translated into a list of priority ratings for the construction program in Connecticut.

Other states in adapting the Arizona method to their own purpose followed very closely the procedures of the original method for adjusting the basic sufficiency rating in order that the adjusted rating could be used as a "priority rating" showing the relative urgency for improving each section according to its system-wide importance.

In comparing the several basic sufficiencies, the Arizona manual notes that a 30 percent deficient section carrying 10,000 vehicles would rank no higher for construction priority than a 30 percent deficient section carrying 100 vehicles. It was also recognized that if the deficiency percentage were multiplied by the traffic volume for a volume-deficiency priority rating, the high-volume roads would secure such great advantage over the low-volume roads that the low-volume roads would never appear on the construction program.

An examination of the several sufficiency rating procedures does not indicate to what extent the economic aspects, such as costs, earnings and benefits, are considered in construction programming. Rather it appears that the basic sufficiency rating is converted by one step into a priority rating, this one step consisting of an adjustment related to the logarithm of the traffic volume.

Since neither the basic rating nor the adjustment is developed by a rational method, it is difficult to make a rational appraisal of the results obtained in either the basic or adjusted rating. Quoting again from the Arizona manual: "It is empiric in that it is better than arbitrary and less than mathematically rational." In empiric formulas the factors are adjusted to provide answers which "fit" or conform to results obtained by other means, for instance, experience and judgment. As noted in both the Connecticut and Arizona methods, the ratings obtained from surveys were tested for fit and proved to be satisfactory.

The Arizona method includes a rather ingenious device for traffic adjustment. It appeared that a 100 percent rating and a 0 percent rating required no adjustment. Between these limits a graduated scale of adjustment would be required in approaching from both directions the maximum adjustment for the 50 percent rating.

In making adjustments the annual average daily traffic system-wise was taken

for the point of par value, ratings on sections carrying higher volumes than the par value were scaled down by adjustment, and ratings on sections carrying lower volumes were scaled upward. The following table shows the T_S values for traffic on the various systems in several states together with the values for the constant C used in the formula:

$$R = B + \frac{B^2 - 100B}{C \text{ Log } T_S} (\text{Log } T - \text{Log } T_S)$$

State	Primary C	Primary T_s	Federal Aid C	Federal Aid T_s	Secondary or FAS C	Secondary or FAS T_s
Arizona	50	1400			50	300
Colorado			50	500		
Idaho			50	893		
Illinois			500	1800		
Louisiana	30	2340				
Missouri	50	1750				
Washington	31	1440			41	800

In the logarithmic scale of adjustment, the value assigned to C determines the spread of the family of curves, or the range of values from the rating of T_S (average traffic volume of the system) to the rating of the extreme low and high volumes. It is apparent that some states have used smaller values for C in order to obtain more spread between the curves for various traffic volumes, thus effecting a greater adjustment in the basic sufficiency rating. This may be especially desirable for a system having a high average traffic volume and a narrow range of traffic volumes.

The spacing within the spread of the curves, however, is determined by the assumption of the logarithmic scale of adjustment. This spacing between the curves, which shows the relative value or importance of the various traffic volumes, follows the regressive characteristics of the log function.

A further development over the Arizona method was made by Colorado in establishing a numerical "warrant" for construction. Through an investigation of the sufficiency ratings of tolerable standards, it was determined that the tolerable standard rated approximately 70 percent of the desirable standard, hence a rating less than 70 percent constitutes a warrant for construction. This is a prima facie warrant, so to speak, and does not necessarily exclude ratings over 70 percent from the construction program.

A unique modification of the Arizona method of adjustment for traffic volume has been developed in Kentucky indicating the empiricism of the method. It was discovered that the original adjustment, based upon the logarithmic function of the traffic volume of the section evaluated, did not give proper relative importance to the several projects. In order to get a better fit for Kentucky projects, the final rating was determined by dividing the adjusted rating into the thirtieth highest hour traffic volume for each project. This operation reverses the sequence so that the high ratings become the high priorities. This modification points up the trial-and-error method of the development of sufficiency ratings.

In discussing traffic adjustments the Arizona manual notes two possibilities: (1) dividing the basic rating by the traffic volume, or (2) subtracting the basic sufficiency rating from 100 to obtain the deficiency, and then multiplying by the traffic volume.

Comparing the Kentucky method with these two methods, we have:

1. Kentucky method = $\frac{T}{S}$
2. As noted above in (1) = $\frac{S}{T}$
3. As noted above in (2) = T (100 - S) = TD

Where T = Traffic volume
S = Sufficiency rating
D = (100 - S) = Deficiency rating

The formulas in 1 and 2 are reciprocal and by reversing the order of ratings in the final listing between 1 and 2, the priorities would follow in the same sequence.

The following examples illustrate the differences in rating values obtained from the three formulas:

Assume $T = 100$

$S_1 = 1$ $\quad D_1 = 99$
$S_2 = 50$ $\quad D_2 = 50$
$S_3 = 99$ $\quad D_3 = 1$

Formula 1	Formula 2	Formula 3
$\frac{T}{S_1} = 100$	$\frac{S_1}{T} = 0.01$	$TD_1 = 9900$
$\frac{T}{S_2} = 2$	$\frac{S_2}{T} = 0.02$	$TD_2 = 5000$

$\frac{T}{S_3} = 1.01$ $\frac{S_3}{T} = 0.99$ $TD_3 = 100$

Comparing Formulas 1 and 2, it will be seen that the greatest spread in adjusted values occurs in the lower ranges of sufficiency ratings in the first instance and in the higher ranges in the second.

In the case of Formula 3, the spread of adjusted values is very great, and the values vary uniformly, with the same traffic volume, from high deficiency ratings to the low ratings. Comparing Formulas 1 and 3, the adjusted values, for a given traffic volume, are in the ratio of 99 to 1 when the sufficiency rating is 1, 2500 to 1 when it is 50, and in the ratio of approximately 100 to 1 when the sufficiency rating is 99.

Montana Method

In the Montana "Deficiency and Construction Priority Formula", the traffic factor is included in the basic formula. Desirable standards based on traffic volumes are used for rating some six items for deficiency. After the deficiencies among these six items are added, the sum is multiplied by the traffic factor, "The traffic factor is based upon the 1947 AADT multiplied by 125 percent to represent estimated traffic for 1965 and the volume that should be used for design purposes." (From the 1948 Montana manual)

Upon adding the deficient percentages found in the six items rated and multiplying the sum of deficient percentage by this estimated 1965 AADT, it was discovered that there was too much spread in priority ratings between high volume roads with slight deficiencies and low volume roads with excessive deficiencies. In order to effect a better relative position, the 1965 AADT was raised to the 3/5 power before using it as a multiplier.

As a matter of corollary interest, it is noted that in some preliminary studies made in West Virginia in 1938 the square root of the traffic volume was toyed with as a possible factor for use in an allocation formula.

For purpose of comparison, the following tabulation is given:

Number	Diff.	Factor	$\sqrt{\text{Number}}$	Diff.	Factor	(Number)3/5	Diff.	Factor
10			3.16			4		
	90	10		6.84	3		12	4
100			10.00			16		
	900	10		21.62	3		47	4
1000			31.62			63		
	9000	10		68.38	3		198	4
10000			100.00			251		
5000			70.7			166		
	15000	4		70.7	2		214	2.3
20000			141.4			380		

It will be seen that the numbers in each of the above series here shown increase in geometrical order but at different rates.

The relationship of 5,000 to 20,000 shown above is pointed out particularly to show the factor value. It will be recalled that a traffic volume of 5,000 is about the maximum for two-lane roads and a volume of 20,000 is about the maximum for a four-lane highway. Since the geometric requirements for a four-lane highway are about twice those for a two-lane, it is of interest to note that the log function gives a factor of 1.2, the square root function a factor of 2.0, and the three-fifths power a factor of 2.3. Of course, other relationships are involved as well as two-lane and four-lane criteria in the determination of the proper relation between traffic volumes and geometric requirements.

An analysis of the effect of applying the various formulas for traffic adjustment would appear to be desirable.

It is self-evident that no adjustment is required when the rating is 100 percent. This rating denotes complete sufficiency, or in other words, a zero deficiency which cannot be changed from zero by a multiplying factor. But Arizona asserts that "no adjustment is necessary nor desirable

if the basic rating is either 0 or 100." This statement says in effect that the rating of a wholly deficient road needs no adjustment for traffic volume, that it is no more important to correct such a road for volume of 10,000 vehicles than it is to correct it for a volume of 1,000 vehicles, or a volume of 100 vehicles. The point in question becomes academic, however, when consideration is given to the probability of any road section being rated as wholly deficient, especially one that is required to carry a substantial volume of traffic. With the Arizona or Kentucky Methods, a traffic volume adjustment is not required to bring extremely deficient road sections to the top of a priority listing.

The traffic adjustment factor is a multiplier used to obtain an importance index varying in accordance with magnitude of traffic volume and magnitude of deficiency. The importance index will increase as traffic and deficiency increase. The rate of increase will depend upon the value assigned to traffic volume ratios, and whether arithmetic or geometric progression is used, together with the rate of progression used.

A comparison of the results obtained by four methods of rating (Arizona, Montana, Kentucky, and traffic times deficiency) is shown in the following tabulations:

Basic Rating			ADJUSTED RATINGS AND PRIORITIES							
		Traffic	Arizona T_s = 500		Montana D x T3/5		Kentucky T/S		Traffic x Def.	
S	D	Volume	Rating	Priority	Rating	Priority	Rating	Priority	Rating	Priority
99	1	50	99+	15	11	15	0.5	15	50	15
99	1	100	99+	14	16	14	1.0	12	100	14
99	1	1000	99-	13	63	13	10.1	7	1000	13
70	30	50	85	12	314	12	0.7	14	1500	12
70	30	100	81	11	474	11	1.4	11	3000	10
70	30	1000	65	9	1893	4	14.3	6	30000	4
50	50	50	68	10	524	10	1.0	13	2500	11
50	50	100	63	8	790	9	2.0	10	5000	7
50	50	1000	44	7	3155	3	20.0	5	50000	3
20	80	50	32	6	838	8	2.5	9	4000	9
20	80	100	28	5	1264	6	5.0	8	8000	6
20	80	1000	16	4	5048	2	50.0	4	80000	2
1	99	50	1+	3	1035	7	50.0	3	4950	8
1	99	100	1+	2	1564	5	100.0	2	9900	5
1	99	1000	1-	1	6247	1	1000.0	1	99000	1

This tabulation shows fifteen highway sections (of three traffic-volume groups and five basic sufficiency ratings) the priority for each of which is established by four methods of making the traffic adjustment to the basic rating. It will be noted that the priorities do not follow the same sequence by the several methods. For example, the section which rates seventh in order of priority by the modified Arizona method, rates third by the Montana method, fifth by the Kentucky method, and third by the traffic-volume - deficiency method.

The order of sequence and the degree of sufficiency are both of prime importance in any rating method. It is, therefore, extremely important that the analyst determine whether basic assumptions are correct and also what the formulas used do to the assumptions.

Minnesota Method

While this method is still in the development stage yet, there are some features of interest in the method as contemplated:

First, a consideration would be given to the weight characteristics of traffic in rating the structural adequacy of roads. Designated tolerable standards of load carrying capacity criteria would be set up for rating highway sections in three classifications of axle loads, (as applicable to the spring break-up period), namely: 5-ton, 7-ton, and 9-ton axle loads. This axle-load-rating method, or structural-capacity-rating method, is unique in sufficiency-rating

methods.

Second, the geometric sufficiency of the road is based on the actual volume of traffic served in terms of its practical capacity. Setting 45 mph. as the desirable minimum average speed, the cross-section of the roadway and the sight distance profile are translated into the practical operating capacity per hour for this speed. The thirtieth highest hour of traffic volume observed on the section is then determined and divided into the practical capacity figure. If the quotient is less than unity, of course, the average speed will not be reduced below 45 mph., if above unity the speed will be reduced. Quotients above unity, then, signal attention for geometric deficiency.

Thus, in the Minnesota method the traffic factors enters into two of the three elements rated as a fundamental part of the rating formula. The third element is that of maintenance costs. It is not clear whether these will be correlated to traffic volumes in the rating method.

Another unique feature of the Minnesota method is that a warrant for construction in each of the three major elements is contemplated. This is analogous to the plan for rating intersections for signal warrants, in which if any one of five conditions are met, a warrant is established. In Atlanta for example, the priority rating for signallization is based on "percentage of requirements" as related to the five warrants for signallization. A signal is justified if any of the five warrants is met. Following such a procedure for warrants for highway construction programming, each of the elements which would constitute a warrant could rate 100 percent, so that a possible total would be 300 percent. Then when a deficiency of some predetermined amount was discovered in any of the three indices, a warrant for construction would be obtained.

CONCLUSION

The above discussion has not attempted to present a critical review of the methods used, but rather to point out the use made of the traffic factor in the various rating methods.

Some comparisons are made which may be helpful to one trying to appraise the validity of various procedures, but as mentioned previously, since the developments so far have not been by rational synthesis, a rational analysis is impossible.

It is hoped that a rating of actual instantaneous operating performance on a speed-volume-accident basis will be developed for a check rating method, if not a substitute rating method, for determining sufficiency of geometrical design, regulation and control. It is believed that an evaluation of deficiencies might be made without trying to keep it scaled to a 100-point total in the adjusted rating. If it is desired, the adjusted ratings can be reduced to a 100-percent scale.