planning and programming. It is believed that any state that does not have such a system in the years to come will be as out of date as a new automobile without an automatic transmission. To those states not yet using a rating method, it is highly recommended that they adopt one and give it a trial.

General Comments on Sufficiency-Rating Procedures

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IN DISCUSSING this topic, remarks will be directed toward giving a general summary of the principal characteristics of the procedures in use in various states. Areas of similarity and areas of difference will be noted together with comments on features of particular interest adopted by certain states.

The "Review and Digest of Sufficiency Rating Formula Procedures" published by the Highway Research Board last June makes certain significant comparisons between the various formulas in use. As those comparisons were rather abstract, it was thought of interest to apply the formulas outlined to a few typical road sections. The road sections were rated by all formulas, except those for Kentucky, Nebraska, and Virginia, for which the descriptive data were incomplete in one or more respects. The uniform sufficiency rating plan of the Bureau of Public Roads, currently being applied nation-wide to federal-aid primary, interstate, and forest highway systems, in connection with the regular maintenance inspections, is likewise not included in the following analysis.

Following is a brief description of the four road sections selected, all of which are in Minnesota:

Section A is located on the interstate system on TH152 extending southeasterly from the north Hennepin County line. It is 12.67 mi. in length and was a county road prior to its addition to the state highway system in 1934. The roadway width is 30 ft. with a bituminous surface course 2 in. in depth and 24 ft. in width placed on an unstable subgrade. The sight distance is restricted to less than 1,500 ft. on 76 percent of its length. There are four substandard curves on the section. The 1950 annual average daily traffic was 947, with a very substantial increase expected when the route and its extensions are improved to adequate standards.

Section B is a federal-aid primary route located on US 12 extending westerly from Long Lake in Hennepin County for 8.79 mi. It was graded in 1928 and a 20-ft. portland-cement concrete pavement with 8-ft. shoulders was placed in 1930. The sight distance is restricted to less than 1,500 ft. on 55 percent of its length. There is one substandard curve. The average traffic volume is 3,426 vehicles daily, with normal increases expected.

Section C is an interstate route located on US 65 south of the Minnesota River in Dakota County and is 7.36 mi. in length. It was graded in 1921 and a 6-in. portland cement concrete base and a 2-in. asphalt surface, both 18 ft. in width, were placed in 1922. The current effective shoulder width is about 3 1/2 ft. The sight distance is restricted to less than 1,500 ft. on 59 percent of its length. There are no substandard curves. The average traffic volume is 3,105 vehicles daily, with a greater than normal increase expected when this section is reconstructed.

Section D is a federal-aid primary route extending south-westerly from Stillwater in Washington County for 11.17 mi. It was graded in 1924 and an 18-ft. portland cement concrete surface was placed in the same year. The shoulder width is 7 ft., 2 1/2 ft. of which is bituminous surfaced. The sight distance is restricted to less than 1,500 ft. on 60 percent of its length. There are seven substandard curves. The average traffic volume is 2,575 vehicles daily, with normal increases expected.

Each of these sections was rated by the

formulas used by 16 states[1]. The rating formulas used by the various states generally fall in one of two broad classifications - sufficiency or deficiency. A sufficiency rating formula is one which compares the section being rated with a given standard, usually in terms of percentages expressed as whole numbers.

The deficiency-rating formula sums the deficiencies of the section being rated and may or may not express the total deficiency rating as 100 minus the sufficiency rating. If the deficiency rating does not represent 100 minus the sufficiency rating, it would represent the sum of a number of heterogeneous items, such as the number of substandard curves, substandard gradients, on the section. Eleven of the states studied use the sufficiency-rating formula providing elemental ratings for condition or structural adequacy, safety, and service. The formulas for three of the states, namely Colorado, Idaho, and Louisiana, are substantially the same. The formula used by the Bureau of Public Roads employs almost identically the same formula as part of its maintenance inspection procedure. Connecticut's formula is very similar to the sufficiency-rating formula, save that it does not include a condition element. The formulas for Georgia, Mississippi, and Montana rate deficiencies. Minnesota's formula considers three factors: relative traffic capacity, load-carrying capacity, and relative maintenance costs.

The 11 sufficiency-rating formulas were studied and analyzed as a group to determine the degree to which they would give the same composite ratings for each road section. It was found that there was considerable variation in the composite ratings. The average rating for Section A was 59.1 with a standard deviation of 9.5[2] and a relative dispersion of 16.1 percent[3]. Section B rated 83.5, with a standard deviation of 4.1 and a relative dispersion of 4.9 percent; Section C, 53.5 with a standard deviation of 8.3 and a relative dispersion of 15.5 percent, and Section D, 67.3 with a standard deviation of 4.6 and a relative dispersion of 6.8 percent.

The lower the rating the greater were the standard deviation and the relative dispersion. In other words, the results from all the formulas would be substantially the same on the better road sections but would show wider differences on the poorer sections.

As such wide variations from the average should not normally be expected, each of the three elements was expanded to a par value of 100, so comparisons could be made to discover the cause of the variations in ratings.

Average Ratings, Standard Deviations and Coefficients of Variation
Elemental and Composite Ratings on Four Road Sections

	Road Section											
	A			B			C			D		
	Avg. Rtg.	α	V %	Avg. Rtg.	α	V %	Avg. Rtg.	α	V %	Avg. Rtg.	α	V %
Condition or structural adequacy	48.4	20.8	43.0	83.6	7.7	9.2	49.6	23.9	48.2	74.8	18.3	24.5
Safety	61.3	6.7	10.9	83.3	2.6	3.1	50.0	4.8	9.6	59.5	4.2	7.1
Service	69.5	12.4	17.8	82.8	4.9	5.9	60.3	8.2	13.6	65.5	7.3	11.1
Composite	59.1	9.5	16.1	83.5	4.1	4.9	53.5	8.3	15.5	67.3	4.6	6.8

α Standard deviation
V Coefficient of variation

The greatest standard deviations from a par value of 100 were found for the condition elements which showed deviations of 20.8, 7.7, 23.9, and 18.3 for Sections A, B, C, and D, respectively.

[1] Arizona, Colorado, Connecticut, Delaware, Georgia, Idaho, Illinois, Louisiana, Minnesota, Mississippi, Missouri, Montana, New Hampshire, New York, Oregon, and Washington.

[2] Standard deviation is a measure of the degree of scatter or divergence of a set of variates from their arithmetical mean.

[3] Relative dispersion or coefficient of variation is the ratio of the standard deviation of a set of variates to their arithmetical mean.

The Colorado, Idaho, and Louisiana condition ratings were found to be with the highest. The reason for this condition is that their ratings are intended to reflect the structural condition which exists with respect to the standard to which the road surface was originally designed and subsequently improved. The rating is based on the amount or percent of deterioration beyond the scope of maintenance, if any, since construction. Rating on this basis does not give a true warrant of the need for reconstruction of the surface to meet current needs.

The Arizona, Delaware, and Illinois formulas generally gave the lowest ratings for condition or structural adequacy. These states place substantial stress on the remaining life factor on the basis of survivor curves. As most of the road surfaces studied were quite old, the condition rating was materially reduced thereby. If this factor is to be used in the formula, it is believed that it should be estimated in the field as is done by Missouri, rather than on the basis of survivor curves. Functional obsolescence is an important consideration in road life and is recognized by most of the factors considered under the safety and service elements.

The Arizona, Delaware, Illinois, and Missouri formulas gave the four lowest condition ratings on Section C, due not only to the road life factor but also to the maintenance economy factor. Maintenance economy is a factor that can quite easily be overlooked in rating a section. Because of its importance, its incorporation in the formula appears to be desirable.

The condition as determined by the New Hampshire formula falls in the median position on all four sections. The factors rated by New Hampshire are foundation, pavement, and shoulders.

There was no particularly great variation in the safety element, using the various formulas. The standard deviation ranged from 2.6 on Section B to 6.7 on Section A. The Illinois and New York formulas have a tendency to rate somewhat higher than the others. The Illinois safety rating was higher because it placed greater emphasis on surface width and less on stopping sight distances than did the other states. Of the formulas studied, New York's was the only one which did not consider surface and roadway widths under the safety element. In lieu thereof, surface and right-of-way conditions affecting safety are rated, which accounted for the higher rating for the safety element. It should be noted, however, that New York supplements the sufficiency rating in evaluating highway needs with accident rate data and the road's deficiency in capacity. Surface and shoulder width are considered in that latter item.

The variations in the service ratings were somewhat greater than on the safety element. The standard deviation ranged from 4.9 on Section B to 12.4 on Section A. The New York, New Hampshire, and Arizona formulas tended toward low ratings. All three formulas place greater emphasis on the riding qualities than do the other states. In addition, the New York formula does not consider surface width.

Missouri's formula tends to rate the service element higher, as it does not impose as severe a penalty for deficient alinement and surface width.

The sufficiency-rating formulas show such variation by states at the present time that on the basis of this particular study they cannot be used to draw comparisons between states.

Connecticut's formula differs from the usual sufficiency-rating formulas in that it does not consider the condition element. That state has a peculiar condition in that they have very few roads which are structurally inadequate. Weak spots which might develop are corrected under maintenance, and it is felt that this factor is adequately recognized in the item of this formula which considers maintenance costs. Connecticut's formula places great emphasis on the accident rate by assigning 30 out of a possible 100 points to that item. Passing sight distance, alinement and surface widths with par values of 20, 13, and 25, respectively, also are contributing factors to the accident rate.

The Mississippi, Montana, and Georgia deficiency rating formulas are difficult of comparison with the sufficiency-rating formulas. The ratings as computed from these formulas do not place the road section on the same relative order of adequacy, except that all three rate Section C as the poorest section.

The Mississippi formula sums various types of deficiencies, but has no theoretical maximum deficiency ratings.

The maximum deficiency from the Montana formula would be 100 percent, with a total of 60 percent allotted to surface and base deficiencies. This formula provides a more severe method of evaluating those two items than do the other formulas. As a result, these ratings are generally much lower than the others.

The Georgia formula showed the poorest relationship with the other formulas of all the formulas considered. This was due to the fact that it considers only surface-width and sight-distance deficiencies.

Composite Ratings on Test Sections by Use of All Formulas Studied

Formula	Rating				
	Par Value	Sec. A	Sec. B	Sec. C	Sec. D
Sufficiency Base					
11-State average	100	59.1	83.5	53.5	67.3
Connecticut	100	68	76	49	68
Deficiency Base					
Mississippi	None	43	45	63	55
Montana	Maximum deficiency = 100	70.7	38.9	71.9	43.5
Georgia	None	6.08	28.36	29.95	21.89
Other					
Minnesota					
Ratio: 30th peak hour to practical hourly capacity	Over 1.0 intolerable	0.9	1.4	4.4	1.9
Axle loading	9 tons	4	9	9	9
Maintenance cost per mile	None	1090	812	2335	870

The deficiency-rating formulas show far less agreement as a group than do the sufficiency rating formulas.

Minnesota's formula considers three elements: (1) the relationship of the thirtieth-highest annual hourly volume to the practical hourly capacity, (2) the load-carrying capacity, and (3) the relative maintenance cost. Its formula cannot be compared with the others, but does indicate that warrants for construction or improvement exist on all four sections. It is to be noted that Minnesota's formula indicates that Section B is in the need of improvement, which fact is not apparent from the sufficiency-rating formulas.

Having found that the various formulas showed considerable variation in the total rating for the same road section, the sufficiency-rating formulas were studied to determine the degree to which they agreed as to relative ratings between the four road sections.

The total ratings for Sections A, C, and D were compared with the rating for Section B. Section B was selected as the base for the comparisons as it had the highest rating, making it convenient to express the relative sufficiency of Sections A, C, and D in terms of Section B. If those percentage relationships for each formula were the same, the formula would rate the sections in the same relative order. It was found that Section A's average rating was 70.7 percent of Section B, but the standard deviation therefrom was 11.4. Section C's rating averaged 64.1 of Section B with a deviation of 9.9. Section D's rating averaged 80.6 of Section B with a standard deviation of 3.6.

The Connecticut formula indicated that the sufficiency of Section A, C, and D were 90 percent, 64 percent, and 90 percent, respectively, of Section B.

Relationship of Sufficiency Ratings on Sections A, C, & D to those on Section B

	Condition			Safety			Service			Total Rating		
	Avg.	σ	V %	Avg.	σ	V %	Avg.	σ	V %	Avg.	σ	V %
A	57.3	22.7	40	73.9	9.1	12.3	84.1	14.1	16.8	70.7	11.4	16
C	58.6	26.8	46	60.1	5.9	9.8	72.9	9.0	12.3	64.1	9.9	15
D	89.0	7.7	9	70.6	3.2	4.5	79.4	8.5	10.7	80.6	3.6	4

Converting the Montana deficiency rating to a sufficiency rating showed that Section A, C, and D were 48 percent, 46 percent, and 93 percent of Section B, respectively.

The indications are that when a large number of road sections are considered, the various formulas, with possibly one or two exceptions, will not rate the road sections in the same relative order.

Each of the formulas studied was tailored to fit the conditions existing in a particular state. As such it is not surprising that the formulas do not give the same composite ratings or rate sections in the same relative order where applied to conditions in any one state. In addition, the application of the various formulas to but four test sections certainly does not clearly establish the validity of any of the formulas. However, certain tenative conclusions are indicated: (1) there is a significant difference in the ratings derived by the use of the different formulas which make state comparisons of ratings of doubtful validity, (2) the major difference between the formulas is in the method of computing the condition of structural adequacy rating, (3) the formulas do not place the road sections rated in the same relative position with respect to sufficiency, and (4) there is closer agreement between the sufficiency ratings than there is between the deficiency ratings.

Possible Areas of Improvement in Rating Procedures

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THE RATING of highway sections with respect to their sufficiency is not new or unique. For many years states have developed their construction programs on the basis of the personal knowledge of their administrative staff of the need for improvement on the various portions of their state highway system. Such a method of program development, while unscientific, informal, and surely not free from personal bias, has been founded on an appraisal of the relative sufficiency of the many routes that comprise the system. Thus it must be realized that highway sections can and have been rated in the past for sufficiency whether formally or informally, casually or periodically.

Sufficiency-rating formulas have been devised and procedures developed, however, to provide a method whereby the rating of highway sections could be as unprejudiced, objective, and uniform as possible. To obtain this end, it is essential that no factor or element be used which cannot be precisely defined and adequately measured.

From one point of view, the act of rating is one of comparing individual highway sections, with respect to certain elements which have been selected as significant, with a hypothetical highway section. This hypothetical section meets certain geometric standards previously selected and established. These standards are essential, and they should be as objective and consistent as possible. Where they are not, the ratings obtained will be of low reliability, since the personal bias of the individuals rating the elements may produce considerable variation in the final rating values.

It is admittedly difficult, for example, to establish objective standards for the element "consistency"; consequently it becomes necessary to rate this element on the basis of a subjective evaluation. The personal judgment required to do this reduces the reliability of the rating. This may likewise be true of standards for such other elements as "sway in cross section," "roughness," or "surface driving condition." It is noted that some states do not use these elements, and it is suggested that the procedure might have greater acceptability if these elements, for which objective standards are not obtainable, be eliminated.

The standards used for the condition or structural adequacy rating appear to vary considerably as to objectivity. Here is a factor that purports to measure the structural adequacy of a roadway and yet in many instances the standard used is the one to which the roadway was originally designed and constructed. Standards for structural adequacy can best be established