Programing Highway Accident Reduction

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•THE HIGHWAY accident analyses reported in this paper were undertaken to determine the degree to which the incidence of accidents is influenced by the level of adequacy of highways. It was accomplished in connection with the highway needs and planning studies in the States of Kansas, South Dakota and Kentucky. Answers were sought to such questions as whether a modern highway is safer than one that has deficiencies in its geometric and structural features, and if it is, how much safer.

In evaluating highway needs, and in recommending improvement programs, providing safety for the highway users assumes paramount importance. The studies in Kansas, South Dakota, and Kentucky had as a basic objective the creation of a continuing long-range plan for raising the service adequacy of the roads and streets to a level that provides efficiency and safety. There are guidelines available through established and widely accepted geometric and structural standards. And, the long-range plans are developed to meet these standards. There are, however, no definitive measures of what application of these standards will produce in the way of added safety, except for freeways—controlled-access highways.

(In addition to the value of having a broad appraisal of safety associated with highway improvements, there also is a potential in this kind of research to provide basic data for more effective analysis of accident hazards at spot locations. Rudy (1) pointed out limitations of previous spot location studies due to the difficulty of differentiating between accidents caused by chance and those caused by highway hazards. This has caused a situation in which most actual investigation of hazardous locations results from requests of the public or outside agencies instead of from analysis of accident records. This, he said, is somewhat of an indictment. The paper contains a technique for using statistical probability analysis to determine accidents caused by chance. It appears to be a workable technique and one which can be further enhanced by the type of research performed in Kansas, South Dakota, and Kentucky through development of average or mean occurrences in situations controlled by such things as roadway geometrics or structural conditions.)

Because the safety record in freeways has been so striking in contrast with conventional highways, and because accident records have been analyzed to provide direct comparisons, the safety associated with programs for freeways is well-established and represents an important reason for the support of highway modernization involving such highways. Rapid development of the Interstate System is justified to a great degree by the accidents it will eliminate and the lives it will save.

Figure 1 shows the potential for accident reduction on the Interstate System in Kansas. The accident rate on conventional highways serving the same traffic before Interstate construction is compared with the rate on the Interstate. Here then, clear evidence is provided of the safety of modern highways when these highways are freeways—controlled-access facilities.

It was recognized that freeways represent a special case and that the great mileages of other types of highway would not be at all comparable to freeways, in the contrast between existing low-standard facilities and new construction. In fact, up to this time, limited observations and the judgments of some highway engineers have left a question as to whether modernization was not increasing rather than decreasing the incidence of accidents.

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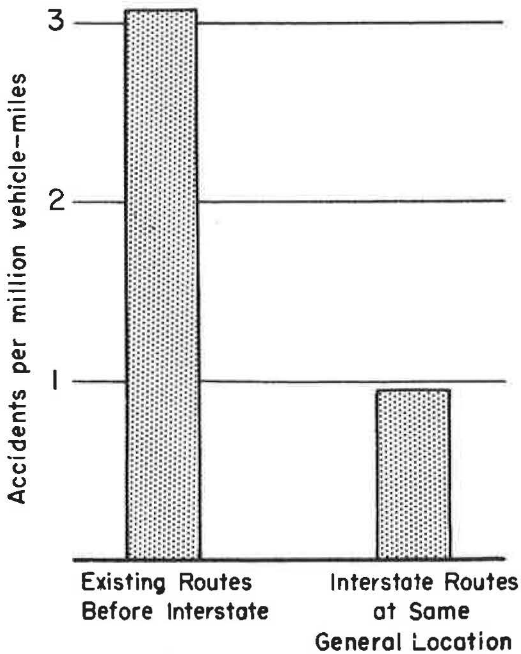

Figure 1. Accident rate comparison before and after Interstate construction, Kansas.

In undertaking this study, it was recognized that it would probably be necessary to accumulate large quantities of accident data and to group road sections of comparable service adequacy level in order to obtain a correlation between accidents and the level of improvement. The recorded accident data and the sufficiency ratings in the three States appeared well adapted to this kind of analysis.

In all three States, accidents on State highways are spotted on county maps by calendar year and can be summarized for specific road sections. Also, in these States sufficiency ratings have been made on rural State highways. These ratings reflect the geometric and structural adequacy of road sections against a rating scale of 100. Therefore, accidents occurring on road sections in a particular year can be counted, and the sufficiency rating for the same section reflects its adequacy—the degree to which the section meets fully adequate improvement standards.

In setting up the analysis in each State it was necessary to limit the number of years covered up to those in which both accidents and ratings for the year were available.

In the Kansas analysis, it was possible to use data for accidents occurring during the years 1956, 1958, 1959, 1960, and 1961. In total, over these years, there were 32,436 accidents included in the analysis. These accidents occurred on approximately 8,900 miles of rural State highways. There were 1,069 fatal accidents causing 1,381 deaths. Accidents causing personal injuries numbered 10,621, and the injuries were sustained by 19,413 persons. There were 20,746 accidents causing property damage only.

In South Dakota, accident data for rural State highways were used for two years—1960 and 1961. There were 4,126 accidents included in the analysis—207 of them fatal and 1,540 causing personal injuries. There were 261 persons killed and 3,034 persons injured. Summaries of the basic data analyzed in Kansas and South Dakota, broken down by years, are given in Tables 1 and 2.

The Kentucky data are not used in this report except for one illustration. Though generally indicating the same results as Kansas and South Dakota data, the correlations in Kentucky suffered from a shorter experience period (one year) and from limitations in associated data. Because departures from the Kansas and South Dakota results were found to be inconsistent in themselves when subjected to different analyses and breakdowns of data, illustrative material from Kentucky neither adds to nor detracts from consistent findings in the other two States. It is anticipated, however, that Kentucky will continue its analysis and make a worthwhile contribution to research in this area as time goes on and more data are obtained.

A tabulating punch card was prepared for each road section for each year included in the analysis. The cards contained summaries of accidents and information on road section identification, length, sufficiency rating, traffic volume group, and vehicle-miles for the year of record. No cards were made up for years when construction was under way, or other occurrences distorted the traffic picture or the physical make-up of the road section.

These tabulating punch cards were processed in several ways. The simplest correlation developed was the incidence of accidents on highways in different sufficiency

TABLE 1

SUMMARY OF DATA ANALYZED
KANSAS

Year	Miles of Highway	Veh-Mi/Day (× 1,000)	Accidents		Fatalities	
			Total	Per Million Veh-Mi	Total	Per 100 Million Veh-Mi
1956	9,170	11,723	7,909	1.85	399	9.35
1958	9,173	11,146	7,460	1.83	251	6.17
1959	8,828	9,942	6,417	1.77	251	6.92
1960	8,657	9,501	5,810	1.68	247	7.12
1961	8,798	9,731	4,840	1.36	233	6.56
Avg.	8,925	10,409	6,485	1.71	276	7.27

TABLE 2

SUMMARY OF DATA ANALYZED
SOUTH DAKOTA

Year	Miles of Highway	Veh-Mi/Day (× 1,000)	Accidents		Fatalities	
			Total	Per Million Veh-Mi	Total	Per 100 Million Veh-Mi
1960	6,849	5,293	2,042	1.06	145	7.51
1961	6,906	5,350	2,084	1.07	116	5.93
Avg.	6,878	5,321	2,063	1.06	131	6.72

rating groups. The results obtained in Kansas and South Dakota are shown in Figures 2 and 3. In the calculations for these charts, accidents and vehicle-miles were added for each rating group without regard to character of accident or volume of traffic in order to establish the incidence for the group. The grand totals of accidents and vehicle-miles for all rating groups provide an overall average for comparison purposes. Accident rates are expressed as the number of accidents occurring per million vehicle-miles of travel.

There is apparent from the charts a marked reduction in the accident rate from the poorest highways (rating less than 50) to the best highway rating 80 and over.

The marked difference between the average accident rates in Kansas (1.71) and South Dakota (1.06) may be, in part, a reflection of broader report coverage in Kansas. Although both States have the same legal requirements for reporting, Tables 1 and 2 show that the ratio of fatal accidents to total reported accidents is 1 to 30 in Kansas and 1 to 20 in South Dakota.

Although similar results were obtained in Kentucky, the trend in accident reduction for increases in sufficiency rating was not, by any means, smooth. One factor appearing to have considerable effect in this State was the short length of many sufficiency rating sections. Indications were that a disproportionate number of accidents occurred on short sections of highway (less than five miles in length) having a relatively high standard of adequacy. At any rate, eliminating these sections in the 80 to 100 sufficiency rating group and comparing the accident rate on the remaining longer stretches of highway (over five miles in length) with the average rate for all State highways produced the results shown in Figure 4. (Another problem affecting the Kentucky results, which also may have had considerable significance in the foregoing, was the difficulty of accurately spotting accidents on the proper highway sections due to differences between reports for the same accident.)

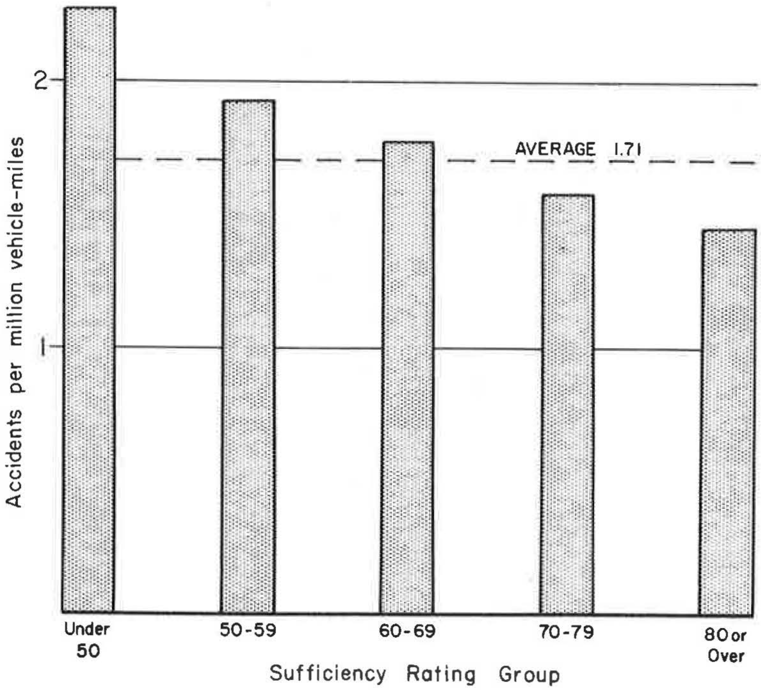

Figure 2. Accident rates, rural State highways, Kansas.

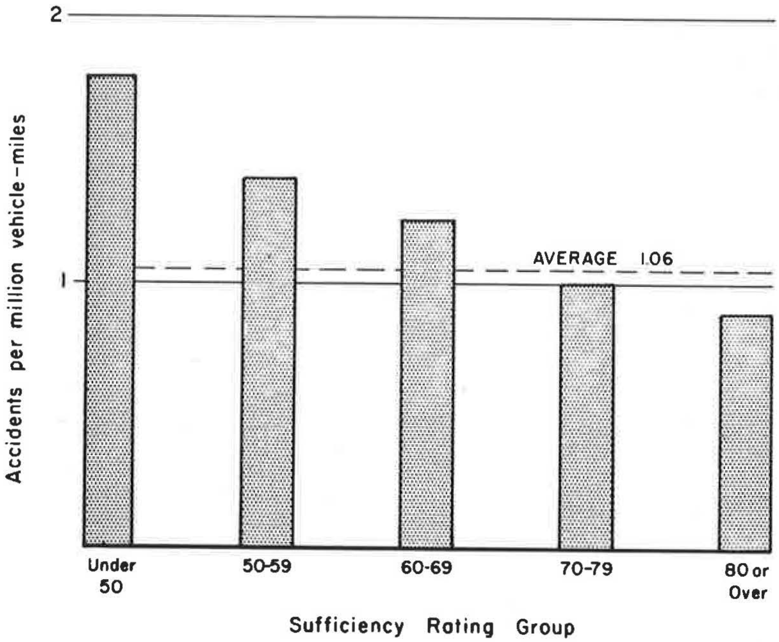

Figure 3. Accident rates, rural State trunk highways, South Dakota.

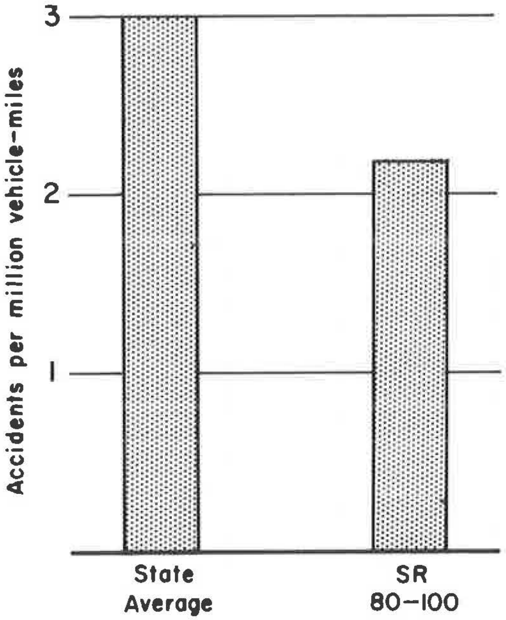

Figure 4. Accident rate comparison between State average and improved highways, Kentucky.

With the recognition that relative traffic volumes in themselves probably are a major factor in the incidence of accidents, correlations were made in all three States of accident rates by sufficiency rating within each traffic volume group. Once more, the Kentucky results showed the expected trends but were inconclusive. However, the Kansas and South Dakota results (Figs. 5 and 6) produced sufficiently clear patterns in both cases to support the following conclusions:

1. Accidents are reduced in all traffic volume groups by improving highways to more adequate standards.
2. Accident rates increase as traffic volume increases in most sufficiency rating groups.

With respect to the latter conclusion, an apparent conflict is in the results obtained in the two States on highways developed to, or close to, fully modern standards for the traffic they carry (sufficiency ratings 80 to 100). The South Dakota analysis indicates that accident rates on these highways are not greatly influenced by the volume of traffic. On the other hand, the Kansas analysis generally indicates that larger volumes of traffic bring increases in

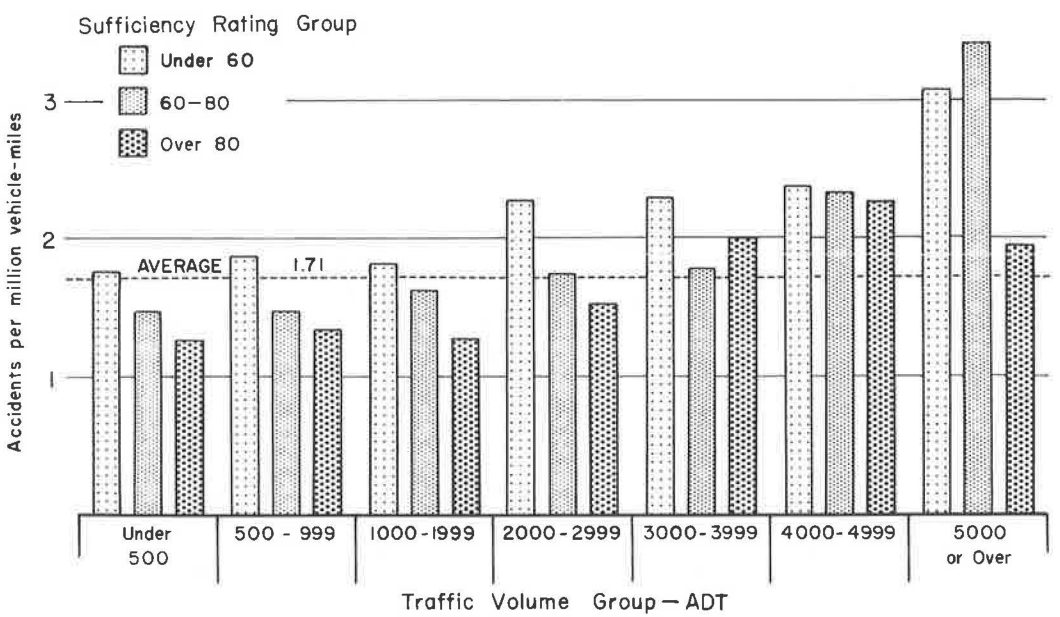

Figure 5. Accident rates by sufficiency rating and traffic volume groups, rural State highways, Kansas.

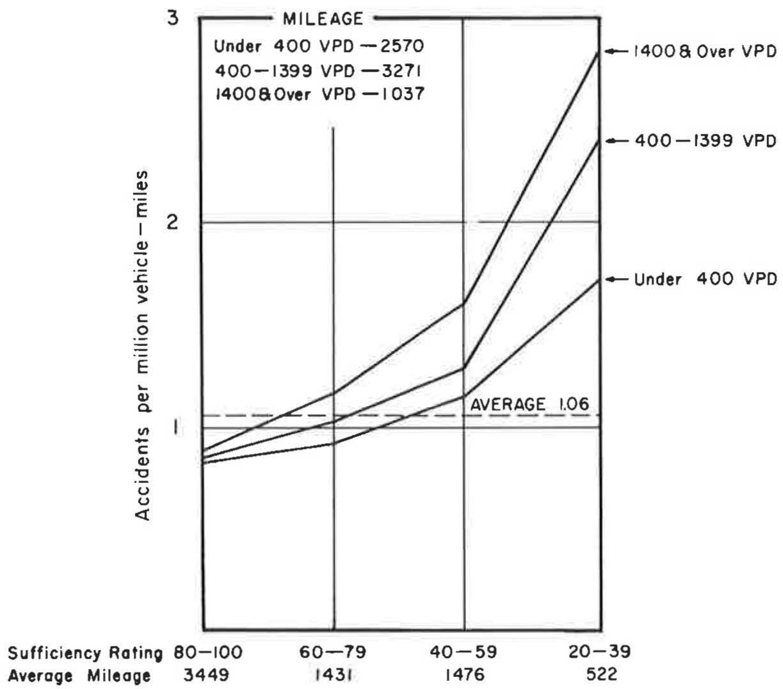

Figure 6. Accident rates by sufficiency rating and traffic volume groups, rural State trunk highways, South Dakota.

accidents regardless of whether highways in Kansas are operating nearer capacity than those in South Dakota.

Thorough evaluation of factors like this was not within the scope of the limited studies performed in connection with the highway needs determinations, nor were there any attempts mathematically to determine regressions and correlations. There also were limitations in currently available data in all cases. Some of the following undoubtedly account for discrepancies in trends and patterns:

1. Relatively small road mileages and/or total vehicle-miles of travel as represented in some sufficiency rating and traffic volume groups did not provide a basis for statistically sound comparisons.
2. Historical sufficiency ratings used to indicate basic road characteristics did not include evaluations of some significant road elements. For example, none of the sufficiency rating methods took capacity into account; only one took both gradients and curvature into consideration.

Most of these problems should be eliminated with more accident history, better reporting procedures, and amended sufficiency rating methods; the last can be made rather easily to reflect all important roadway characteristics.

In regard to the strong indication (Figs. 5 and 6) that accident rates are affected significantly by volumes of traffic alone (the commonly-accepted concept that an exposure factor should be applied in analyses of this type), correlations were made between accidents and traffic volumes without relation to sufficiency ratings. Results for Kansas are shown in Figure 7.

In South Dakota, data also were processed to show the relationship between accidents and surface widths, as shown in Figure 8.

Relationships between types of accidents and road adequacy were studied, with results as shown in Figures 9 and 10. Although the South Dakota data, assembled for two years only, do not represent a sufficient number of fatal accidents for conclusive

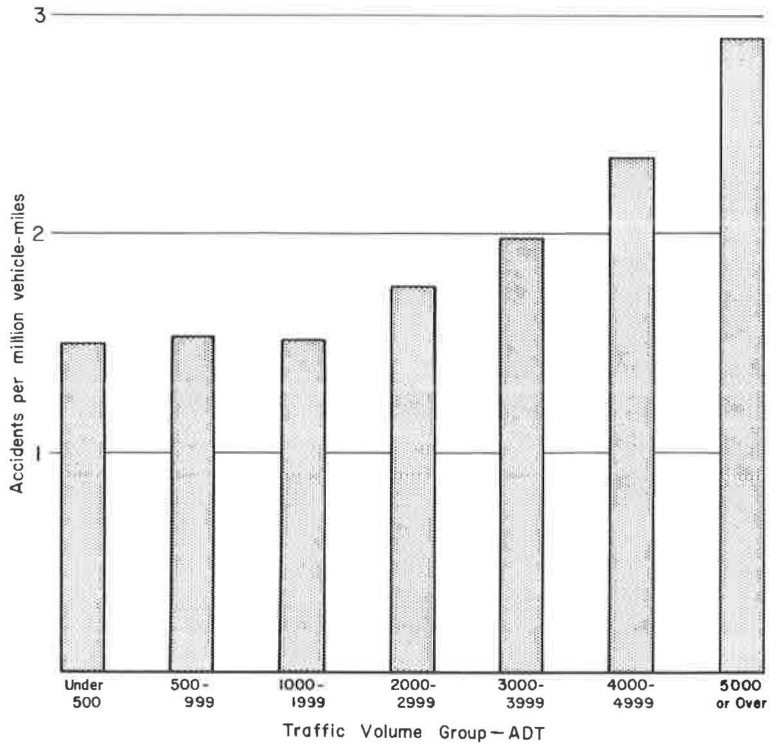

Figure 7. Accident rates by traffic volume groups, Kansas.

findings, there is considerable similarity in the pattern of fatal accident incidence for the two States. The most significant conclusion that can be drawn from this part of the analyses is that the severity of accidents is greater on higher standard roads because, even though there is a lower incidence rate for accidents, the fatality rate does not show a parallel reduction.

In Kansas, a further correlation was made between accidents occurring in different sections of the State as represented by the highway divisions and the weighted average sufficiency ratings of highways in these divisions. The results (Fig. 11) once more show the very marked influence of road adequacy on accident rates.

As a kind of bridge between the studies of the significance of road adequacy and traffic volumes in influencing accident rates and an economic evaluation of the results, the question was raised of how many accidents could be prevented by improving all roads to different minimum sufficiency ratings. This was answered by determining the average accident rate

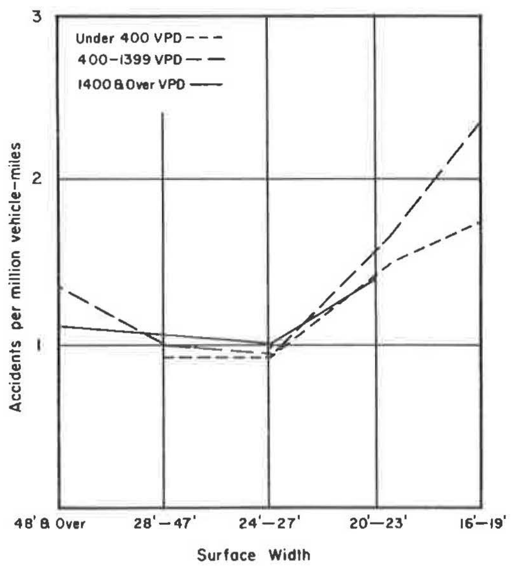

Figure 8. Comparison of accident rates and surface widths, South Dakota.

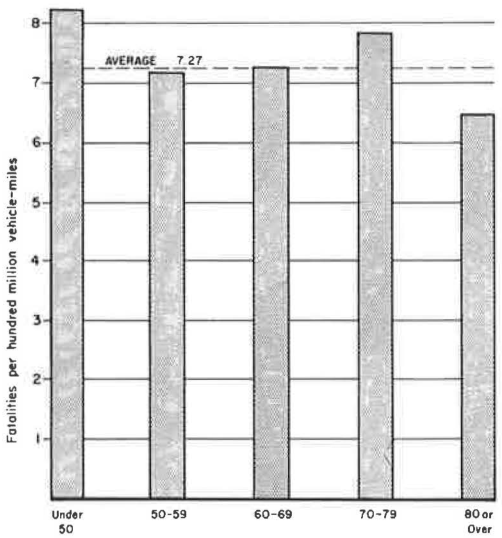

Figure 9. Fatality rates, rural State highways, Kansas.

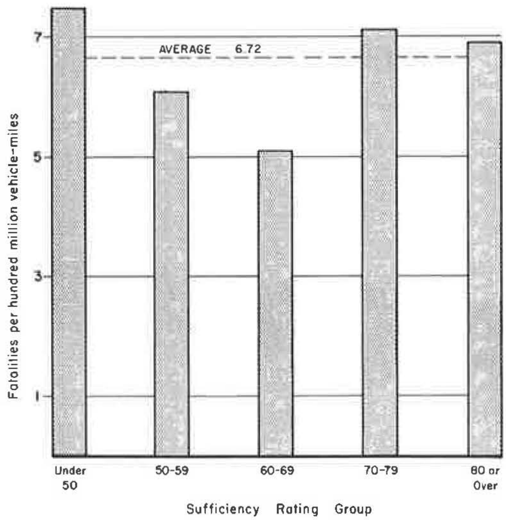

Figure 10. Fatality rates, rural State trunk highways, South Dakota.

over various sufficiency rating cutoff values—assuming present distributions of traffic—and by applying this rate, in each case, to all of the vehicle-miles traveled on the highway system. The details of this determination for Kansas are given in Table 3 and Figure 12.

A similar analysis was made in South Dakota on a slightly different basis, and economic loss values of accidents were applied as determined from the National Safety

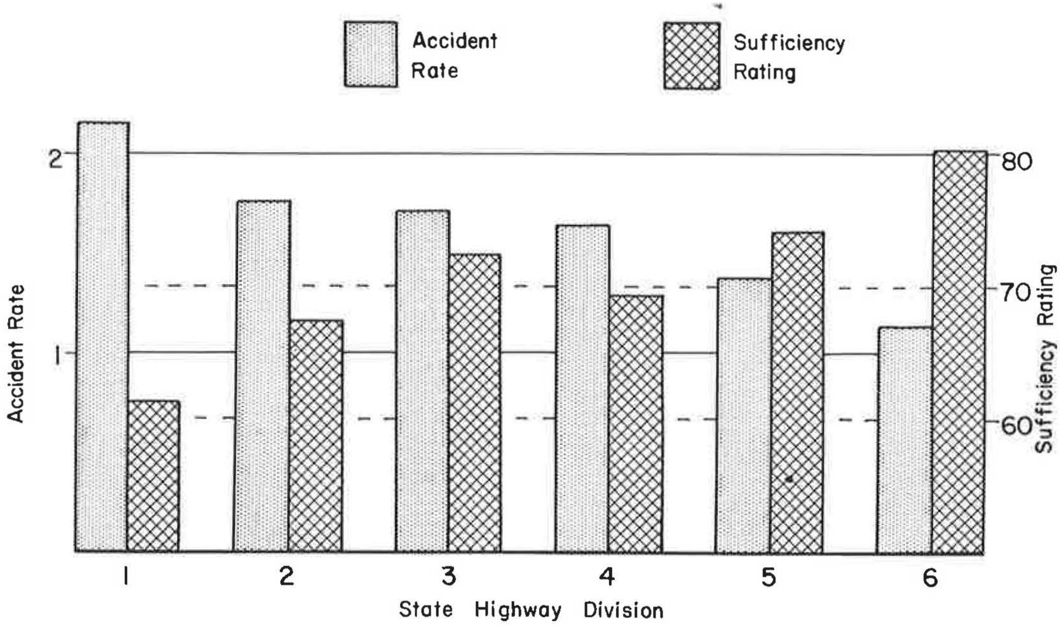

Figure 11. Comparison of accident rates and sufficiency ratings, Kansas.

TABLE 3

POTENTIAL ACCIDENT REDUCTION FROM HIGHWAY IMPROVEMENTS[1]
KANSAS

Sufficiency Rating Group	1956-61 Veh-mi per day (× 1,000)	1956-61 Accidents	Avg. Rate	Avg. Rate × 1961 Traffic[2]	Reduction
All	52,043	32,436	1.71	8,040	-
50 - 100	46,406	27,747	1.64	7,711	329
60 - 100	38,493	22,185	1.58	7,429	611
70 - 100	28,607	15,773	1.51	7,100	940
80 - 100	17,745	9,475	1.46	6,865	1,175

[1] 1956-61 average rates applied to 1961 traffic.
[2] Based on 4,702 million vehicle-miles on rural State highways in 1961. Represents number of accidents obtained by multiplying 4,702 by accident rate appropriate to SR group. Potential accident reduction obtained by subtracting result from 8,040.

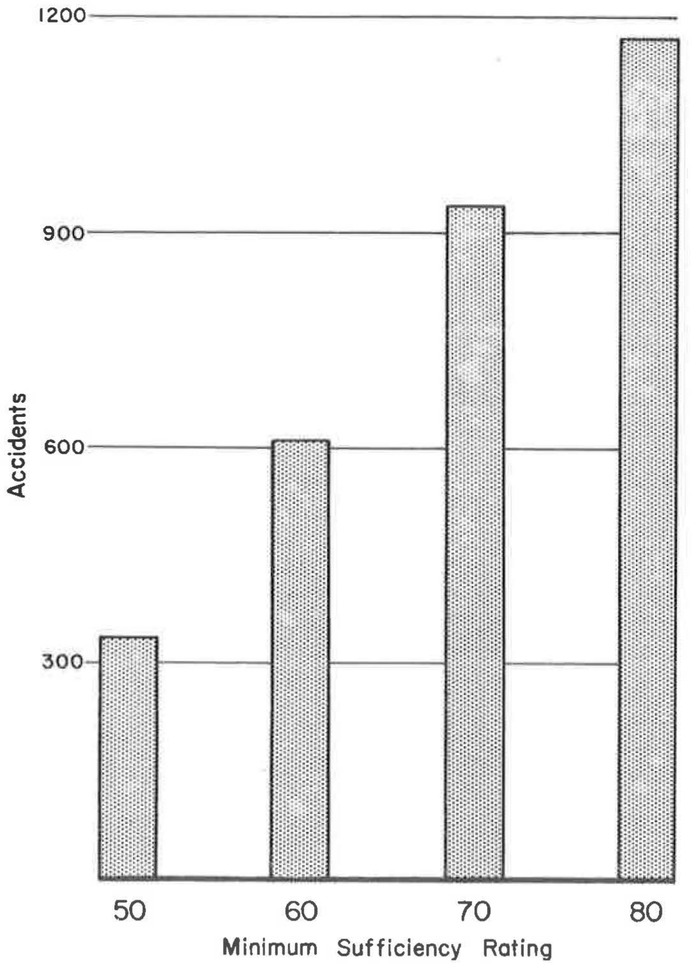

Figure 12. Potential annual accident reduction, rural State highways, Kansas.

TABLE 4

POTENTIAL ECONOMIC SAVINGS FROM HIGHWAY IMPROVEMENTS THROUGH REDUCTION IN ACCIDENTS
SOUTH DAKOTA[a]
FIRST METHOD

Sufficiency Rating Group	Miles of Highway	Avg. Annual Total Loss (x $100)	Avg. Annual VM Travel (x 100)	Avg. Annual Econ. Loss per Veh-Mi	Avg. Annual Veh-Mi of Highway	Avg. Annual Loss/Mi of Highway ($)	Avg. Annual Loss/Mi After Improvement ($)	Avg. Annual Savings[b] Mi of Improved Highway ($)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Under 60	1,998.3[1]	18,366	3,544,548	0.0052	177,379	922	727	195[1]
60 - 69	559.4[2]	8,406	1,836,339	0.0046	328,298	1,510	1,346	164[2]
70 - 79	871.4	15,540	3,554,757	0.0044	407,926	1,795	1,673	122
80 - 100	3,449.2	42,778	10,487,757	0.0041	304,060	1,247	1,247	-
Method		From data sheets (avg. of 1960, 1961 records)		Col. 3 / Col. 4	Col. 4 / Col. 2	Col. 5 × Col. 6	0.0041 × Col. 6	Col. 7 - Col. 8

[a] Based on 1960-61 data.

[b] Computation of annual savings by improving miles below SR 70:

[1] 1,998 miles at $195 = $389,610
[2] 559 miles at $164 = $ 91,676
Total annual savings = $481,286

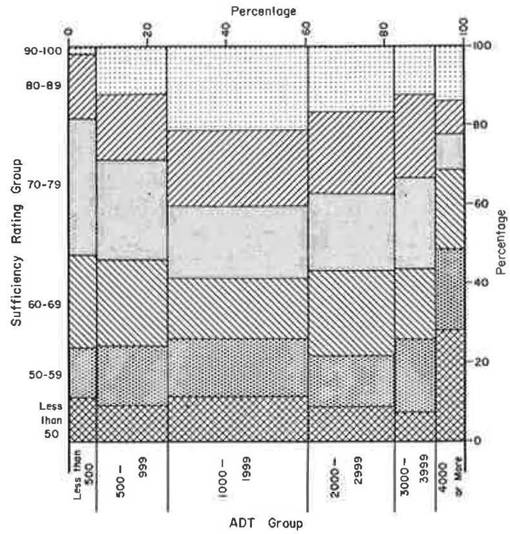

Figure 13. Distribution of vehicle-miles, rural State highways, Kansas.

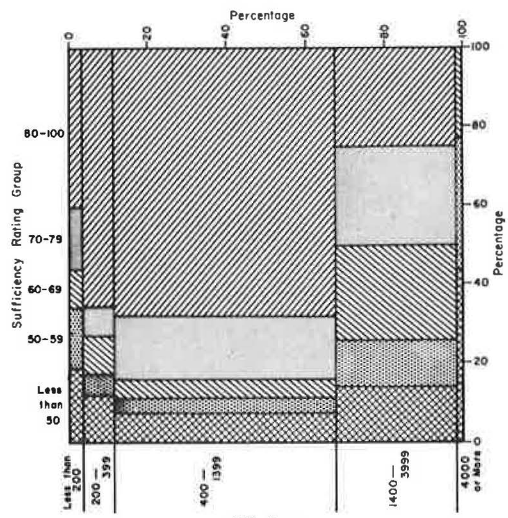

Figure 14. Distribution of vehicle-miles, rural State trunk highways, South Dakota.

Council's 1961 estimate rates. The details of this application are given in Table 4.

In this case, the assumption was made that all mileage under sufficiency rating 70 would be improved through construction to the 80 to 100 sufficiency rating category. The average annual economic loss per ve-

hicle-mile for this category ($0.0041) was applied to the vehicle-miles presently under 70, and a comparison was made with the economic loss on the unimproved mileage ($0.0052 and $0.0046, as given in the table). The results were related to the miles of highway assumed to be improved, and annual savings were calculated.

This simple application of average economic losses (derived by totaling types of accidents in the sufficiency rating groups, applying estimated costs for the respective types, and dividing the total resulting cost by vehicle-miles) neglects the possible effect of relatively different traffic volumes within the sufficiency rating groups, as sum-

TABLE 5

DISTRIBUTION OF VEHICLE-MILES
KANSAS

Sufficiency Rating Group	Vehicle-Mile Distribution per Day						
	Less than 500,000 Veh-Mi	500,000-999,000 Veh-Mi	1,000,000-1,999,000 Veh-Mi	2,000,000-2,999,000 Veh-Mi	3,000,000-3,999,000 Veh-Mi	4,000,000-or More Veh-Mi	Total All ADT Groups
90 - 100	16	229	797	384	132	108	1,666
80 - 89	122	311	690	464	230	65	1,882
70 - 79	264	467	686	444	246	65	2,172
60 - 69	179	407	547	488	196	161	1,978
50 - 59	94	284	549	301	200	156	1,584
Less than 50	84	163	400	188	76	216	1,127
Total	759	1,861	3,669	2,269	1,080	779	10,409

TABLE 6

DISTRIBUTION OF VEHICLE-MILES
SOUTH DAKOTA

Sufficiency Rating Group	Vehicle-Mile Distribution per Day					
	Less than 200,000 Veh-Mi	200,000-399,000 Veh-Mi	400,000-1,399,000 Veh-Mi	1,400,000-3,999,000 Veh-Mi	4,000,000 or More Veh-Mi	Total All ADT Groups
80 - 100	70	279	2,027	426	21	2,823
70 - 79	29	32	480	412	-	953
60 - 69	16	39	150	406	-	611
50 - 59	27	24	115	212	30	408
Less than 50	31	47	198	212	38	526
Total	173	421	2,970	1,668	89	5,321

TABLE 7

POTENTIAL ECONOMIC SAVINGS FROM HIGHWAY IMPROVEMENTS THROUGH REDUCTION IN ACCIDENTS
SOUTH DAKOTA[1]
SECOND METHOD

ADT	SR Group	Economic Loss per 1,000 Veh-Mi ($)	Annual Vehicle Miles under 70 (x 1,000)	Annual Total Accident Cost ($)	Savings[2] ($)
Under 400	Under 70	4.13	92,818	383,338.34	-9,281.80
	80 - 100	4.23	92,818	392,620.14	
400 - 1,400	Under 70	4.76	212,136	1,009,767.36	212,136.00
	80 - 100	3.76	212,136	797,631.36	
Over 1,400	Under 70	5.52	233,124	1,286,844.48	160,855.56
	80 - 100	4.83	233,124	1,125,988.92	
Total					363,709.76

[1]Based on 1960-61 data. [2]Difference between first (under 70) SR group and second (80 - 100).

TABLE 8

ACCIDENT COST REDUCTION, KANSAS, 1961

Accident Category	Number per Accident	Annual Reduction	Annual Savings per Accident ($)	Total Annual Savings ($)
Fatalities	0.0426	40	31,500	1,260,000
Injuries	0.5990	563	1,750	1,050,000
Property damage	-	940	300	282,000
Total				2,592,000

marized in Tables 5 and 6 and shown in Figures 13 and 14. As already indicated, volumes of traffic in themselves influence the accident rates.

For this reason, further analyses were made by individual traffic volume groups to verify the potential savings through accident reduction by improving all highways below a given adequacy or sufficiency rating level. The methodology and results are given in Table 7 for basically the same data used in Table 4. (In line with the basic assumption that only the mileage below 70 would be improved, the economic losses in the 70 to 79 group did not affect the calculations in either Table 4 or Table 7 analysis, although these losses are shown in the former table.)

In Kansas, the approximate annual reduction in accident cost that could be effected by raising all highways to sufficiency rating 70 was determined simply by calculating the average number of fatalities and personal injuries per accident, and the average amount of property damage per accident, from the 1956-1961 data, and by applying these incidences to the number of accident reductions from Table 3 (940). The results, as calculated for 1961, are given in Table 8.

Proceeding from these determinations, it is possible by projecting traffic to calculate the potential savings through construction performed over any future program period, if the objective of the program is to raise all highways to a minimum level of adequacy.

In reviewing what has been done in the analyses here reported, the following are apparent:

1. Positive safety values of considerable magnitude associated with raising the adequacy level of rural State highways.
2. Potentiality for further research exploitation of the massive amount of data on accidents which can be tied to road adequacy rating data and specific highway elements.
3. An opportunity ultimately to reflect the value of highway modernization in specific and authoritative terms showing savings in lives, injuries, and property damage.

ACKNOWLEDGMENTS

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REFERENCE

1. Rudy, B.M., "Operational Route Analysis." HRB Bull. 341, 1-17 (1962).