Interstate Highway-Accident Study

MORTON S. RAFF, Mathematician,
Highway Transport Research Branch, Bureau of Public Roads

THE purpose of this study was to find out how accident rates on main rural highways are affected by design features and use characteristics. Fifteen states provided information covering a year's accident experience on about 5,000 mi. of highway.

The basic technique involved dividing the study routes into a large number of short, homogeneous sections, which could then be combined so as to group the sections according to any factors whose effects were of interest. An accident rate, based on vehicle-miles or other suitable units, was computed for each group. The factors studied include number of lanes, average daily traffic volume, degree of curvature, pavement and shoulder widths, frequencies of curves and other sight-distance restrictions, percentage of intersection traffic on the minor road, and many others.

Traffic volume was found to have strong effect on accident rates. On most types of highway sections the accident rate becomes higher with increasing traffic volume (except at extremely high volumes, where there is a slight reversal due to congestion). However, two-lane curves and intersections show a different trend, with the accident rates declining as volumes increase.

Sharp curves have higher accident rates than flat curves for roads carrying the same amount of traffic. The volume effect described above is more pronounced on sharp curves than on flat ones.

Wide pavements and shoulders encourage safety on two-lane curves. On two-lane tangents they do not have any consistent effect.

At intersections, the percentage of the total traffic on the minor road is extremely important. It takes only about 15 percent cross traffic to make an intersection more than twice as hazardous as when the cross traffic is less than 10 percent. Another important intersection characteristic is the number of approaches, e.g., three-way intersections are considerably safer than four-way crossings.

At bridges and underpasses there was found to be great value in having the roadway on the structure several feet wider than the approach pavement.

A number of roadway features do not appear to have any consistent effect on accident rates. These include grade, frequency of curves, and the percentages of commercial and night traffic.

● A POPULAR view has it that every accident has some principal cause, like speeding or driving on the wrong side of the road. The way to prevent accidents, according to this view, is to stop drivers from doing the things that stand highest on the list of principal causes.

The problem is not so simple. Every accident has many causes, if we consider a cause to be any remediable condition whose correction would have prevented the accident. For example, suppose two cars driven at high speed have a head-on collision at night on a two-lane road. The speed of the vehicles is obviously one cause of the collision. Other causes may be the use of blinding headlights, the absence of lighting on the highway, inadequate pavement width, and the fact that the road carries two-way instead of one-way traffic. Any of these may have contributed equally with speed to the accident, but the chances are that speeding will get most of the blame.

It is desirable to examine all the causes of an accident instead of concentrating on a single cause, because a wide variety of corrective measures may be suggested by a broad approach. Classifying accidents according to all their circumstances, regardless of how unimportant any particular circumstance may seem at first, offers the hope of discovering significant relationships between accident frequencies and associated circumstances which might otherwise escape notice.

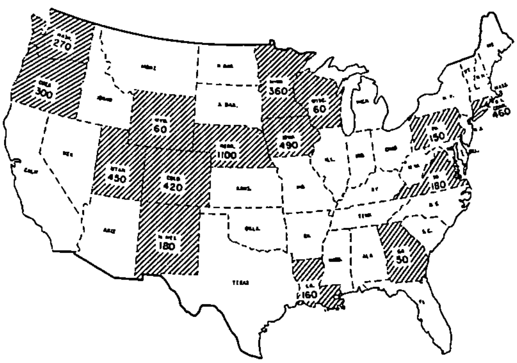


Figure 1. Mileage of study routes.

DESCRIPTION OF THE STUDY

The present study is an attempt to find out how rural traffic-accident rates are affected by various physical features of the highway and by certain use characteristics, such as average daily traffic and percentage of commercial vehicles. These are by no means the only causes of accidents. But if it should turn out, for instance, that roads with flat curves are appreciably safer than roads with sharp curves, then it would be possible to predict with some assurance the accident savings that would result from building flatter curves into the highways. Accidents have many causes, and an effective accident-reduction program ought to use the full range of remedies. This study is intended to throw light on those remedies which are in the domain of the highway designer.

Summary of the Findings

The most significant factors affecting accident rates are traffic volume, degree of curvature, pavement and shoulder width on curves, percentage of cross traffic at intersections, and the width of bridge roadways, both absolutely and in relation to their approach pavements. In most cases the effects are in the expected directions, but there are certain exceptions.

Volume of traffic has a strong effect on the accident rate on nearly all types of highway sections. In general, except for curves and intersections on two-lane roads, the accident rate becomes higher as the volume is increased. There is often a slight reversal of this trend at very high volumes, presumably because extreme congestion inhibits the drivers' ability to make passing maneuvers.

At curves and intersections on two-lane roads the trend goes the other way. Here the accident rates become lower with increased traffic volume. This effect has been well substantiated, but the reason for it remains a matter of speculation. A plausible theory is that the two-lane curves and intersections present conditions which most drivers recognize as hazardous, particularly when there is a considerable amount of traffic. Accordingly, the driver pays enough extra attention when these facilities are busy to more than compensate for the added potential danger.

Sharp curves have higher accident rates than flat curves. The volume effect described in the preceding paragraph is more pronounced on sharp curves than on flat ones.

Wide pavements and shoulders help to reduce the accident rates on two-lane curves. This is in contrast to the two-lane tangents, where no particular effect could be traced to the width of the pavement or the shoulders.

The percentage of cross traffic at an intersection has a tremendous effect on its accident rate. It takes only about 15 percent cross traffic to make an intersection more than twice as hazardous as

TABLE 1

LENGTH AND AMOUNT OF TRAVEL ON THE STUDY ROUTES

State	Year	Approximate length			Travel in study year		
		Tan.	Curves	Total	Tan	Curves	Total
			mi.		Million Veh	-mi.	
Colorado	1941	350	70	420	380 4	77.3	457 7
Connecticut	1941	300	150	450	639. 1	249 0	888. 1
Connecticut	1946	310	150	460	508. 6	200. 0	708 6
Georgia	1940	40	10	50	40 5	13 7	54 2
Iowa	1941	430	60	490	303. 2	41 9	345. 1
Louisiana	1941	130	30	160	175 0	30 9	205 9
Minnesota	1946	290	70	360	180 4	48 0	228. 4
Nebraska	1941	1,000	100	1,100	547 5	57 3	604. 8
New Mexico	1941	160	20	180	64 9	5 0	69 9
Oregon	1941	210	90	300	220 9	58 0	278. 9
Pennsylvania	1941	100	50	150	133 2	74 0	207 2
Utah	1941	370	80	450	238 9	46 0	284. 9
Virginia	1941	150	30	180	275 4	54 9	330 3
Washington	1941	200	70	270	469 1	135. 8	604. 9
Wisconsin	1941	50	10	60	70 3	11 0	81. 3
Wyoming	1941	50	10	60	22 4	4 4	26 8
Total		4,140	1,000	5,140	4,269.8	1,107.2	5,377.0

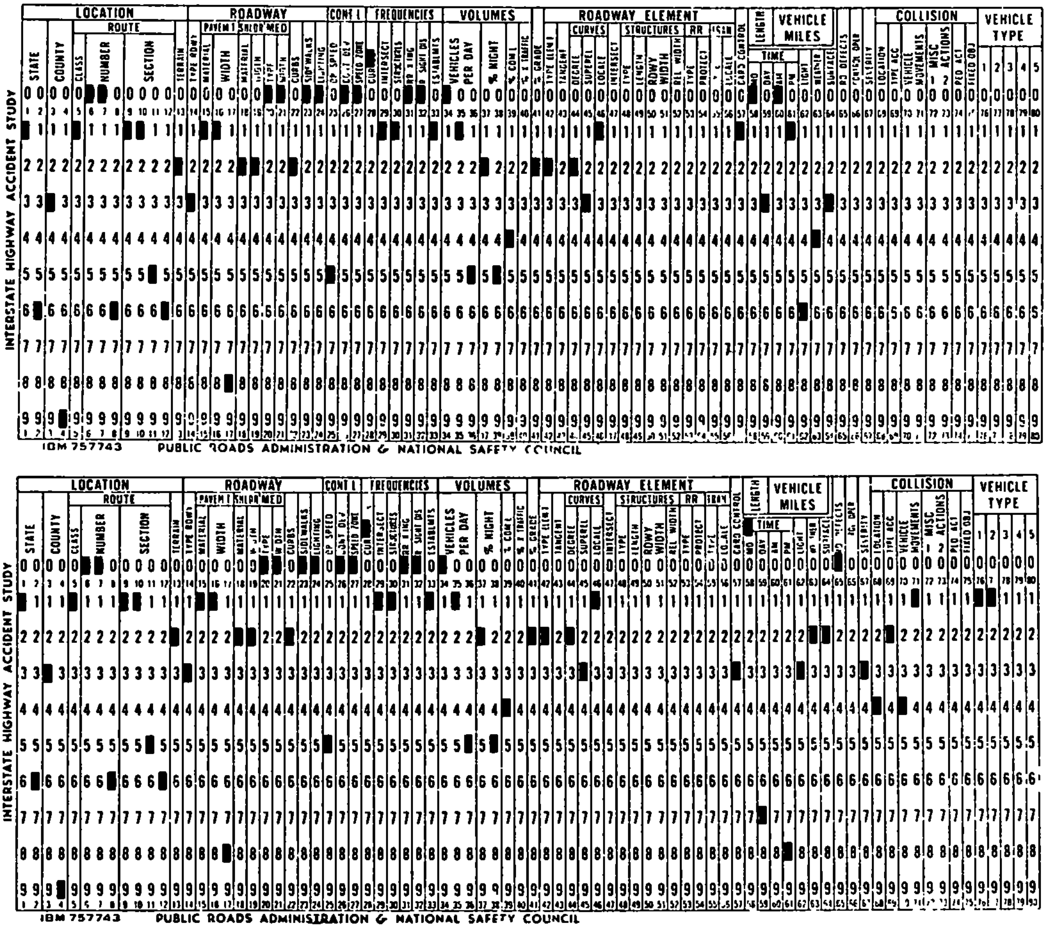


Figure 2. A highway card (above) and an accident card (below) on the same highway section.

when the cross traffic is well below 10 percent.

Another important intersection characteristic is the number of approaches. Three-way intersections (T's and Y's) have mardekly lower accident rates than four-way crossings. This is not necessarily an argument for staggering all crossings, however, as the increased number of intersections and the additional turning and weaving might easily nullify the apparent advantage.

Wide roadways are desirable at two-lane bridges and underpasses, and they should be several feet wider than the approach pavements. Of the two types of structures, underpasses are considerably more hazardous.

A number of roadway features did not appear to have any consistent effect on the accident rates. These include grade, pavement and shoulder widths, frequency of curves, frequency of sight restrictions, and the percentages of commercial and night traffic.

Technique of Study

To make it possible to study a large number of different highway features, the roads included in the study were divided into short homogeneous sections. Each of these sections was substantially uniform in grade, pavement width, shoulder width, degree of curvature, traffic volume, etc. Any place where a change occurred in any of these characteristics was made a dividing line between one section and another. Intersections and structures were also regarded as sections, because of their special characteristics, e.g., volume of traffic on the intersecting road, relative width of bridge roadway and adjoining pavement. The presence of an intersection of a structure was treated as a break between highway sections. Each accident was assigned to the highway section where it occurred.

TABLE 2

NUMBER OF HIGHWAY SECTIONS, BY TYPE OF ROADWAY ELEMENT

State	Tan	Curves	Inter-sections	Struc-tures	Railroad cross-ings	Other	Total
Colorado	1,239	571	604	207	13	2	2,636
Conn 1941	1,634	1,356	1,027	311	9	106	4,443
Conn 1946	1,628	1,317	1,020	329	9	106	4,409
Georgia	160	84	16	6			266
Iowa	1,434	493	686	293	13		2,919
Louisiana	333	148	108	64	19	11	683
Minnesota	1,402	533	612	54	13	2	2,616
Nebraska	2,683	559	1,107	298	34		4,681
New Mexico	416	77	16	58			567
Oregon	626	771	322	122	9		1,850
Pennsylvania	338	239	12	203		11	803
Utah	896	530	276	51	18	27	1,798
Virginia	832	240	263	92	2	14	1,443
Washington	1,093	610	537	83	17		2,340
Wisconsin	232	69	91	16	2	2	412
Wyoming	132	58	30	4	1		225
Total	15,078	7,655	6,727	2,191	159	281	32,091

The basic techniques for the study were devised by the National Safety Council in cooperation with the Bureau of Public Roads in 1945, following a pilot study on US 1 in Virginia.

All 48 states were invited to participate in the study, using as data the 1941 accidents on rural sections of the Interstate Highway System.[1] Only 15 states were able to do so, although a number of others expressed interest in the project. The chief obstacles to wider participation by the state highway departments were insufficient manpower to prepare the strip maps and the coding sheets, inability to locate accidents accurately, and incomplete accident reporting, in the sense that too many accidents went unreported. Two brief reports of preliminary findings have already been published.[2]

The participating states are given in Figure 1 and Table 1. For each state the table gives the year for which accidents were submitted[3], the number of miles of

[1]1941 was selected as the most-recent year in which driving conditions were normal A few of the states used other years (see Table 1), and some main rural highways were used which are not part of the Interstate Highway System

[2]C F McCormack, "A Plan for Relating Traffic Accidents to Highway Elements," AASHO Convention Group Meetings, 1944, pp 117-119 D M Baldwin, "The Relation of Highway Design to Traffic Accident Experience," AASHO Convention Group Meetings, 1946, pp. 103-109

[3]In addition to 1941, Pennsylvania submitted cards for accidents in the first 5 mo of 1942 These cards have not been used in any of the analyses covered in this report

roadway included in the study, and the total amount of travel on those roads during the study year.

The data were recorded on punch cards. The original coding procedure called for two sets of cards.[4] One set, called highway cards, contains a card for each highway section. The second set, called accident cards, contains a card for each accident. In Figure 2, the upper picture is of a typical highway card; below it is an accident card representing an accident on the same highway section. The first 56 columns, which identify and describe the highway section, are identical on the two cards. This makes it possible to classify accidents according to various highway features without having to refer to the highway cards.

The punch in Column 57 indicates which type of card it is. The remaining columns serve different purposes on the two types of cards. On a highway card they give the length of the section and the annual vehicle-mileage of travel on it. On an accident card these columns contain information about the circumstances of the accident.

TABLE 3

NUMBER OF ACCIDENTS, BY TYPE OF ROADWAY ELEMENT

State	Tan	Curves	Inter-sections	Struc-tures	Railroad cross-ings	Other	Total
Colorado	676	130	225	80			1,111
Conn 1941	1,374	560	426	11		16	2,387
Conn 1946	1,223	439	287	81	1	67	2,098
Georgia	64	32	17	8			121
Iowa	461	100	98	20	1		680
Louisiana	531	39	107	14	2		693
Minnesota	254	46	170	13	5		488
Nebraska	638	77	121	29	6		871
New Mexico	89	10	9	1			109
Oregon	926	106	366	118			1,516
Pennsylvania	265	140	22	19		55	501
Utah	447	120	116	16	7		706
Virginia	648	164	250	51		2	1,115
Washington	1,962	509	1,119	86	17	1	3,694
Wisconsin	197	7	68	2			274
Wyoming	45	4	8				57
Total	9,800	2,483	3,409	549	39	141	16,421

A third type of card, the summary card, has recently been punched and used in some of the later analyses. There is one of these cards for each highway section, with the columns at the end of the card containing information about the number of accidents on the section.

Tables 2 to 4 indicate the size of the study. Table 2 shows the number of highway sections in each state, subdivided by

[4]An outline of the punching code is presented in the appendix

types of roadway elements. Nearly half of the 32,091 highway cards represent tangent sections, and one fourth represent curve sections. About two thirds of the remainder represent intersections. The rest are for structures, railroad crossings, toll stations, and transitions of various kinds.

TABLE 4

NUMBER OF ACCIDENTS, BY SEVERITY, AND RATIOS AND ADJUSTMENT FACTORS

State	Number of Accidents				Ratio			Adjustment factor[1]
	Fatal	Injury	Other	Total	Total to fatal	Total to fatal-plus-injury	Injury to fatal	
Colorado	46	382	683	1,111	24 2	2 60	8 3	2 07
Conn 1941	51	1,018	1,318	2,387	46 8	2 23	20 0	1 07
Conn 1946	42	758	1,298	2,098	50 0	2 62	18 0	1 00
Georgia	8	47	66	121	15 1	2 20	5 9	3 31
Iowa	30	274	376	680	22 7	2 24	9 1	2 20
Louisiana	22	260	411	693	31 5	2 46	11 8	1 59
Minnesota	10	178	300	488	48 8	2 60	17 8	1 02
Nebraska	46	406	419	871	18 9	1 93	8 8	2 65
New Mexico	11	59	39	109	9 9	1 56	5 4	5 05
Oregon	39	288	1,189	1,516	38 9	4 64	7 4	1 29
Pennsylvania	20	193	288	501	25 0	2 35	9 7	2 00
Utah	33	283	390	706	21 4	2 23	8 6	2 34
Virginia	102	434	579	1,115	10 9	2 24	4 3	4 59
Washington	84	975	2,635	3,694	44 0	3 49	11 6	1 14
Wisconsin	9	89	176	274	30 4	2 80	9 9	1 64
Wyoming	4	27	26	57	14 2	1 84	6 8	3 52
Total	557	5,671	10,193	16,421	29 5	2 64	10 2	

[1]50 divided by the total-to-fatal ratio These adjustment factors are used in computing the type 1 accident rates

Table 3 shows similar information regarding the accident cards. In all, there were 16,421 accidents, of which 60 percent were on tangents and 16 percent on curves.

Table 4 classifies the accident cards by severity within each state. There are cards for 557 fatal accidents, 5,671 personal-injury accidents, and 10,193 property-damage accidents.

Table 4 also lists certain ratios for each state. The ratio of the total number of accidents to the number of fatal accidents is a rough measure of the completeness of accident reporting. It has its limitations, however, for while all fatal accidents are probably reported, it is most unlikely that the true total-to-fatal ratio is the same in every state. In any event, this ratio is the basis of an adjustment which is used in some of the rate computations.

The ratio of all accidents to those involving either deaths or injuries has a similar interest. It might also be used for adjustments, but this has not been done so far. This ratio varies much less among the different states than does the total-to-fatal ratio.

The table also shows the ratio of the number of injury accidents to the number of fatal accidents in each state, and the last column lists the adjustment factors based on the total-to-fatal ratio.

METHOD OF ANALYSIS

It was difficult to decide how to combine the detailed data from different states. The reporting requirements vary, and it cannot be assumed that the reporting laws are fully complied with in every state. There are three essentially different ways of dealing with this problem. One way is to use a system of weights involving an adjustment factor for each state. A state which is believed to report only half its accidents would have an adjustment factor of 2, so that each reported accident would count as two adjusted accidents. This is substantially the approach that was used by McCormack and Baldwin in their earlier reports of preliminary findings from this study. The trouble with adjustments is that they give the most weight to the least reliable data, and that the adjustment factors are computed on the basis of a dubious assumption.

A second approach would dispense with adjustments but would use only the data from states whose reporting meets a certain standard. This avoids the distortions caused by the adjustment process, but it has the drawback of reducing the amount of usable data. A variation of this approach would use only the fatal accidents (in all the states), or only the fatal and injury accidents. To use only fatal accidents is impractical, however, for it would reduce the study to only 557 accidents. The use of both fatal and injury accidents has more to commend it, but there would still be a heavy reduction in the amount of data available for analysis. Moreover, it is doubtful that fatal (or fatal and injury) accidents are affected by highway features in the same way as accidents of all degrees of severity combined.

The third approach is to ignore the problem altogether and simply count up all the accidents in all the participating states, irrespective of the variation in reporting standards For all its crudeness, this method turns out to be generally superior to the other two.

All three of these approaches have been used. (The choice among them is explained in the final section of the report.) In the ensuing discussion they will be called

Type 1 rates, Type 2 rates, and Type 3 rates respectively. The Type 1 rates use all the participating states, with the number of accidents in each state multiplied by the adjustment factor given in the last column of Table 4.[5] The Type 2 rates do not use adjustments, and use only those states having a total-to-fatal ratio of at least 25. The Type 3 rates use all the participating states, without adjustment.

Once it has been decided which material to use and whether the count should be of actual or of adjusted accidents, the puted and examined to see if there is a steady trend or other close relation between accident rate and grade. If the rates show indications of a trend but are somewhat irregular, it is possible to make a statistical test of whether or not a trend really exists.

The slope of the "best" straight line — the regression coefficient — is computed, with each rate weighted in proportion to the amount of travel on which it is based. Also computed are the confidence limits of this slope, from which one can tell at

TABLE 5

ACCIDENT RATES ON TANGENTS, BY GRADE AND ROADWAY TYPE

Grade	Two-lane roads		Three-lane roads		Four-lane roads: Undivided		Four-lane roads: Divided[1]		Four-lane roads: Controlled access	
	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles
Type 1 accident rates (All states, using adjustment factors)										
Percent										
Less than 3	5,442	3 7	194	6 1	1,043	6 0	827	4 7	504	2.2
3 - 3 99	321	4 0	18	5 6	136	7 1	83	3 4	139	2 9
4 - 4 99	253	3 6	6	7 7	65	6 8	56	4 4	59	1 6
5 - 5 99	322	4 4	3	4 4	49	6 8	9	3 6	46	2 1
6 - 6 99	86	4 0	1	10 0	29	10 2	1	1 4	13	1 7
7 or more	49	3 9	5	14 4	26	10 1	6	15 6	13	1 5
Less than 3	5,442	3 7	194	6 1	1,043	6 0	827	4 7	504	2 2
3 or more	1,031	4 0	33	6 8	305	7 5	155	4 1	270	2 3
Type 2 accident rates (Selected states,[2] without adjustment)										
Less than 3	3,507	3 0	100	6 5	644	3 3	701	3 0	504	1.6
3 - 3 99	219	3 3	14	3 4	78	3 5	78	2 5	139	1 7
4 - 4 99	175	2 7	1	1 2	12	2 0	43	3 0	59	1 5
5 - 5 99	259	4 2	0	0 0	18	3 7	6	1 8	46	1 4
6 - 6 99	50	2 9	0	-	0	-	1	2 5	13	1 6
7 or more	48	3 7	0	-	5	6 3	0	-	13	1 5
Less than 3	3,507	3 0	100	6 5	644	3 3	701	3 0	504	1 6
3 or more	751	3 4	15	2 7	113	3 4	128	2 6	270	1 6
Type 3 accident rates (All states, without adjustment)										
Less than 3	5,442	2 2	194	2.6	1,043	2 7	827	2 9	504	1 6
3 - 3 99	321	2 3	18	2 5	136	2 8	83	2 5	139	1 7
4 - 4 99	253	2 2	6	2 3	65	2 0	56	2 6	59	1.5
5 - 5 99	322	3 1	3	0 9	49	2 3	9	1 8	46	1 4
6 - 6 99	86	2 2	1	2 0	29	2 4	1	1 4	13	1.6
7 or more	49	3 7	5	3.1	26	2 6	6	3.3	13	1.5
Less than 3	5,442	2 2	194	2 6	1,043	2 7	827	2 9	504	1.6
3 or more	1,031	2 5	33	2 2	305	2 4	155	2 5	270	1 6

[1]Excluding highways with controlled access This applies to all the tables
[2]States having a total-to-fatal ratio of 25 or more This applies to all the tables

process of computing a rate involves (1) counting the total number of accidents on sections in a particular category, (2) adding up the total vehicle-mileage on these sections, and (3) dividing the former sum by the latter to get the rate in terms of accidents per million vehicle-miles. To study the effect of grade, for example, the highway sections are divided into several groups on the basis of their grades. Then the rates for these groups are computed a glance how reliable the estimated slope is and whether or not it is significantly different from zero. These quantities are presented in those cases where they will aid in understanding the analyses.[6]

[5]Use of these adjustment factors involves the assumption that the total-to-fatal ratio would be the same in every state if the reporting standards were identical There is at least one state in the present study for which this assumption is clearly unreasonable See Footnote 12

[6]For those to whom the correlation coefficient is more familiar than the regression coefficient, it should be pointed out that the two are closely related ($b = r\,\sigma_y/\sigma_x$, where b is the regression coefficient, r the correlation coefficient, and σ_y and σ_x the standard deviations of y and x respectively) The significance of the departure of b from zero is the same as that for r The use of b has two advantages, however, over the use of r (1) it is of more inherent interest, since it may be more important to know about a relationship of steep slope with low reliability than one of small slope with high reliability, (2) if the true relationship is a straight line, the estimated value of b is normally distributed while that of r is highly skewed So the estimate of b is much less affected by sample size than that of r

RESULTS: ACCIDENT RATES VERSUS HIGHWAY FEATURES

For study purposes the highway sections have been classified as tangents, curves, intersections, structures, and miscellaneous (railroad grade crossings, toll stations, and transitions in width of roadway or median). These are further subdivided according to the number of lanes on the study route.

Some of the material is presented in tables, some in bar graphs. Most of the tables present the three types of accident rates already described. As a guide to the reliability of the various rates, there is presented, along with each rate, the actual number of accidents on which it is based.

The graphs, with one exception, show only the Type 3 rates, i. e., the ones which use accidents from all the states without any adjustments. On these graphs the bars differ in width according to the number of vehicle-miles on which each rate is based.

TANGENTS: EFFECT OF GRADE

Two-Lane Roads

Table 5 shows how the accident rates on tangents vary with the gradient of the highway. On two-lane roads there does not appear to be any particular relation between accident rate and grade, no matter which of the three rate types is considered.[7] For each of the three types the slope (regression coefficient) is positive, i. e., the accident rate tends, on the average, to increase as the grade increases. However, none of the three slopes is significantly different from zero at the 5-percent level of significance.[8] This means that the amount of scatter is such that there is more than a 5-percent chance that the true slope may be zero or negative.

The three types of accident rates differ considerably. The Type 1 rate is the highest, because it includes accidents which are assumed to have occurred without being reported. The Type 3 rate is the lowest, because it uses only the accidents that were actually reported and includes states in which the reporting is known to be poor. The Type 2 rate is in between. It might be thought that this rate would be the most reliable, because it includes only the accidents actually reported in states where reporting is presumed to be good; but it suffers from being based on a smaller sample than the other two types of rates.

A disturbing feature in all three types of rates is the large amount of apparently meaningless fluctuation. For example, the Type 2 rate takes the values 3. 0, 3. 3, 2. 7, 4. 2, 2. 9, and 3. 7 as the grades increase steadily. These fluctuations are too large to be due to sampling variation. They cannot be a result of the adjustment process, for they are just as prominent in the unadjusted rates (Type 2 and 3) as in the adjusted one; anyway, the same effect is found within individual states. Nor are they peculiar to the effect of grade; similar fluctuations occur with most other highway features. They may be due to the oversimplification caused by studying only one or two features at a time while ignoring all the rest, or they may be a result of the difficulty in obtaining absolutely accurate data. This could have the effect of obscuring relations which really exist. There is some evidence to support the latter belief.[9]

To sum up, the accident rate on two-lane tangents does not appear to be significantly affected by grade.

Three-Lane Roads

On three-lane tangents, as on the two-lane tangents, most of the travel was on roads of less than 3-percent grade, large fluctuations are present in the accident rates, and no reliable relation is found between accident rate and the percent of grade. The slopes for the Types 1 and 3 rates lack statistical significance, as with the two-lane roads. The Type 2 rate has a significant negative slope, with the rate declining as the grades become steeper; but the decline is meaningless, because

[7] This statement refers to the total correlation between accident rate and grade, ignoring all other highway features It may be that, when the appropriate other features are held constant, there is a significant partial correlation All the statements which will be made in connection with single-factor analyses refer to total correlations only

[8] The 5-percent level is widely used in statistical analyses

[9] After submitting the data for the present study, Minnesota conducted another study of the same highway which in some respects parallels the work being described here The collection of data was all new, none of the information being carried over from the earlier work Very great care was used in checking all information, particularly with regard to the exact locations of accidents The value of this care is demonstrated by the greater consistency of the results in their report, "Minnesota Rural Trunk Highway Accident, Access Point and Advertising Sign Study" (1951)

it is due to a peculiar distribution of travel among the different states. The high rate for roads of less than 3-percent grade is caused entirely by the figures from one state, Oregon, which included no roads with higher grades. If Oregon data are excluded from the Type 2 rate, the significant relation disappears.

Four-Lane Roads, Undivided

On four-lane tangents without a median, it seems unlikely that the grade has any effect on the accident rate, even though the Type 1 rate does have a significant upward slope of 0.69 ± 0.48 per percent grade. (This means that the rate increases by about 0.69 for each 1-percent increase in the grade. There is a 95-percent chance that the true slope is between $0.69 - 0.48 = 0.21$ and $0.69 + 0.48 = 1.17$.) The Type 3 rate, which uses the very same accidents and vehicle-mileage, tends to become smaller as the grades increase out in a way which does not indicate a statistically significant trend. The Type 2 rate is irregular but shows a slight tendency to increase as the grades increase.

This is an example of how each type of accident rate can point to a different conclusion. It appears that grades in the range used on main rural highways do not have any appreciable effect on the accident rate for four-lane undivided tangents, especially in view of the fact that the significant rate of increase for the Type 1 rate is due to a peculiar circumstance which distorts the true picture.[10]

Four-Lane Roads, Divided

For four-lane tangents having a median but no control of access, the accident rates are also inconclusive. None of the slopes is statistically significant, but there is some tendency for the rate to decline as the grade increases.

Four-Lane Roads, Divided, with Controlled Access

On these roads, too, the grade does not have any particular effect on the accident rates.

[10] Virginia, whose adjusted accident rate is much higher than that of any of the other states, contributes increasing proportions of the total travel as the grades increase This makes the Type 1 rate appear to increase, even though there is no increase when Virginia is considered by itself or when all the other states are considered with only Virginia excluded See Footnote 12.

Summary

On tangent highway sections there does not appear to be any relation between grade and accident rates. In these analyses the roads have been classified only by grade, so it remains possible that grade may have some effect on the accident rate when the appropriate other features are held constant.

TANGENTS: EFFECT OF VOLUME

Two-Lane Roads

Figure 3 shows how the accident rate on two-lane tangents varies with the average daily traffic when all other characteristics of the highway section are ignored. This is a typical example of the type of bar graph used in this report. Each bar conveys three distinct pieces of information. The height of the bar indicates the Type 3 accident rate for the set of roads which the bar represents. The horizontal position of the bar indicates the average daily traffic volume on the roads represented. The width of the bar indicates the number of vehicle-miles of travel on which the rate is based. No scale is shown for these widths, since it is only the relative widths that matter. The scales are different in each graph.

To be concrete, the first bar in Figure 3 shows that the Type 3 rate is 1.3 for roads carrying from 0 to 900 vehicles per day. The next bar shows the rate to be for 1.6 for roads carrying from 1,000 to 1,900 vehicles per day, and that this rate is based on about five times as much experience as the first rate. And so on.

The graph suggests a definite pattern, which in fact is the same for all three types of rates.[11] The accident rate increases steadily with increasing volume, reaching a maximum for roads carrying 8,000 to 9,000 vehicles per day. Heavier traffic reduces the accident rate somewhat, presumably because the extreme congestion at such high volumes makes it difficult for drivers to engage in passing maneuvers. The latter point is of small interest to the highway designer, who would hardly recommend two-lane construction for a road expected to carry as many as 9,000 vehicles per day.

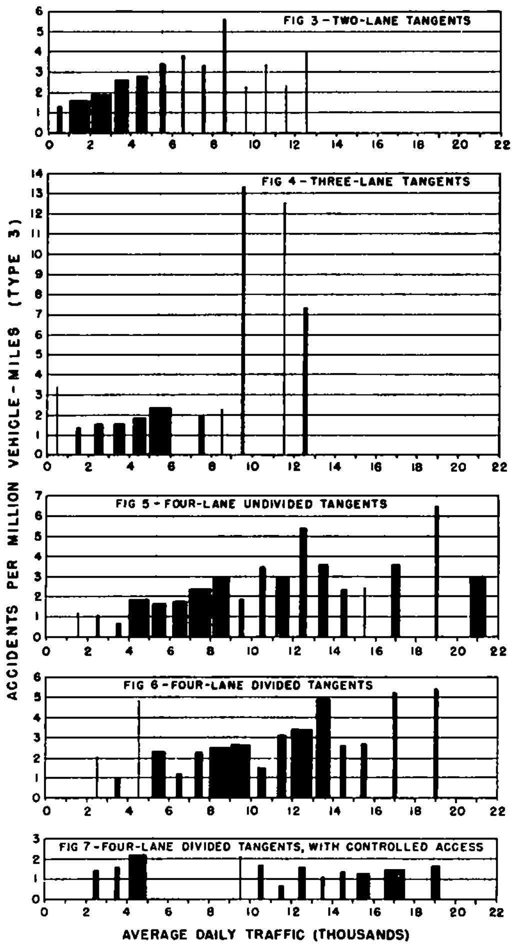
In the range that is of principal interest the relation is simple and straightforward:

[11] Information concerning all three types of rates is presented in Table 6.

higher traffic volumes mean higher accident rates.

Three-Lane Roads

There is a similar increase on three-lane tangents, as shown in Figure 4. The Type 1 and Type 3 rates[11] both increase significantly as the traffic volume becomes larger. The information for the Type 2 rate is too fragmentary to be of much value.



Figures 3-7. Accident rates on tangents, by volume of traffic.

Four-Lane Roads, Undivided

Figure 5 represents the condition on four-lane undivided tangents. All three types of accident rates[11] have a pattern similar to that for the 2-lane tangents: the rate goes up until a certain volume is reached, after which it drops down again. But the three types of rates do not have their maxima at the same traffic volume. The Type 1 rate reaches its peak between 5,000 and 10,000 vehicles per day, while the Type 2 and Type 3 rates are highest for volumes between 15,000 and 20,000. The Type 1 rate would have its peak in this same range if the Virginia figures were omitted.[12]

Four-Lane Roads, Divided

Figure 6 shows the same information for four-lane divided tangents without controlled access. The pattern is the same as before, with the accident rate going up as traffic volume increases. If there is any volume above which the accident rate begins to drop, it is beyond the range of these data, for which the maximum volume is 20,000 vehicles per day.[13]

Four-Lane Roads, Divided, with Controlled Access

The accident rates for these roads are shown in Figure 7. The rates appear to be somewhat lower for high volumes than for low volumes.

The appearance is misleading. The volumes under 5,000 come almost exclusively from Pennsylvania, while the volumes over 5,000 are all from Connecticut. The comparison is not so much between low volumes and high volumes as between Pennsylvania and Connecticut. Pennsylvania's accident rate is higher than Connecticut's, even though the average volumes are 4,000 and 15,000 respectively.

Examination of the trend within each state shows that in Pennsylvania, where the volumes range from 3,000 to 5,000 vehicles per day, the accident rate increases steadily with increasing volume, but it is hard to draw conclusions from such a small range of volumes. In Connecticut the range is wide, and there is no significant trend. The evidence at hand does not indicate that traffic volume has

[12] The Virginia data play a disturbing role in many of the Type 1 rates. They have a low total-to-fatal ratio, with the consequently high adjustment factor of 4.59. Yet this adjustment factor seems excessive, for the adjusted accident rates are usually much higher for Virginia than for the other states. For example, on four-lane undivided tangents carrying between 5,000 and 9,900 v.p.d., the adjusted accident rate for Virginia is 10.4 while it is only 3.7 for all the other states combined. Both rates are based on more than 200 accidents.

[13] The Type 1 rate is higher in the 10,000 to 14,900 group than in the 15,000 to 19,900 group, but this is due to the peculiar effect of Virginia discussed in Footnote 12.

any particular effect on the accident rate on four-lane divided tangents with controlled access.

TABLE 6

ACCIDENT RATES ON TANGENTS, BY VOLUME OF TRAFFIC AND ROADWAY TYPE

Average daily traffic	Two-lane roads		Three-lane roads		Four-lane roads					
					Undivided		Divided		Controlled access	
	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles
Type 1 accident rates (All states using adjustment factors)										
Vehic per day										
0 - 4,900	5,007	3 6	79	5 3	129	5 6	25	3 1	265	4.0
5,000 - 9,900	1,396	4 3	102	6 6	481	7 3	388	4 0	3	2 1
10,000 - 14,900	71	3 6	46	10 4	422	6 9	465	5 3	166	1 4
15,000 or more	0	-	0	-	317	4 1	126	5 1	340	1 5
Type 2 accident rates (Selected states, without adjustment)										
0 - 4,900	2,868	2 9	5	2 0	18	1 4	19	1 4	265	2 0
5,000 - 9,900	1,320	3 8	64	4 8	117	3 2	280	2 4	3	2 1
10,000 - 14,900	71	3 3	46	8 1	309	3 5	380	3 5	166	1.4
15,000 or more	0	-	0	-	314	3 7	126	4 4	340	1 5
Type 3 accident rates (All states, without adjustment)										
0 - 4,900	5,007	2 1	79	1 6	129	1 6	25	1 6	265	2 0
5,000 - 9,900	1,396	3 6	102	2 9	481	2 2	388	2 4	3	2 1
10,000 - 14,900	71	3 3	46	8 1	422	3.5	465	3 4	166	1.4
15,000 or more	0	-	0	-	317	3 6	126	4 4	340	1 5

Summary

The foregoing material is summarized in Table 6. In most cases the average daily traffic has a considerable effect on the accident rate on tangent highway sections. The common pattern is for the accident rate to increase as the volume increases. At very-high volumes the accident rate usually drops somewhat, probably because of congestion.

As between the different types of roads at the same volumes, the conclusions depend on which type of accident rate is examined. Judged by the Type 1 rate, the safest roads at volumes below 10,000 vehicles per day are the four-lane divided roads without controlled access, followed closely by the two-lane roads; the four-lane undivided roads are the worst in this volume range. Above 10,000 vehicles per day the four-lane divided roads with controlled access are far and away the safest, while the three-lane roads have much the highest accident rates.

The Type 3 rates show little difference between road types for volumes under 5,000 v.p.d., while the two-lane roads have the highest Type 3 rate for volumes between 5,000 and 10,000. Above 10,000 the conclusion is the same as before: the three-lane roads are the most hazardous, while the controlled-access four-lane roads are the safest.

The Type 2 rates are still different. Below 5,000 the information is fragmentary. Between 5,000 and 10,000 vehicles per day, the three-lane roads are the worst, while the four-lane divided roads without controlled access are the safest of those for which the samples are adequate. Above 10,000 vehicles per day the conclusion is the same as for the Types 1 and 3 rates.

TWO-LANE TANGENTS: EFFECTS OF OTHER FEATURES

Since traffic volume has a pronounced effect on accident rates, it is desirable to group the roadway sections by volume before studying the effects of other factors. Alternatively, the volume itself can be made one of the independent variables in a multiple regression analysis, a procedure which separates the effects of different factors. Both approaches have been used.

TABLE 7

ACCIDENT RATES ON TWO-LANE TANGENTS, BY WIDTH OF PAVEMENT

Pavement width	Type 1 (All States, using adjustment factors)		Type 2 (Selected States, without adjustment)		Type 3 (All States, without adjustment)	
Feet	Number	Per mil vehic -miles	Number	Per mil vehic -miles	Number	Per mil vehic -miles
16 or less	246	5 5	246	3 3	246	4 3
18	1,795	4 0	742	2 9	1,795	2 1
20	3,263	3 4	2,434	3 0	3,263	2 3
21 or 22	506	4 7	359	3 1	506	2 6
23 or 24	299	3 8	138	3 9	209	1 9
25	45	2 4	38	1 9	45	1 6
26	47	4 0	47	3 6	47	3 3
27	47	3 3	42	3 4	47	2 5
28	132	4 6	132	3 6	132	3 6
29 or more	94	3 1	81	2 8	94	2 5

Grade and Volume Together

With grade and volume as independent variables, the multiple analysis corroborates the earlier conclusion that grade has no statistically significant effect on the accident rate, while volume does.

TABLE 8

ACCIDENT RATES ON TWO-LANE TANGENTS BY WIDTH OF SHOULDERS

Shoulder width	Type 1 (All States using adjustment factors)		Type 2 (Selected States without adjustment)		Type 3 (All States, without adjustment)	
Feet	Number	Per mil vehic -miles	Number	Per mil vehic -miles	Number	Per mil vehic -miles
Curb	10	2 9	3	0 8	10	1 4
0 - 4 9	2 673	3 9	2,012	3 1	2,673	2 6
5 - 7 9	2 789	3 6	1 556	3 1	2 789	2 0
8 - 9 9	525	3 6	338	3 0	525	2 4
10 or more	476	4 1	350	3 3	476	2 8

Pavement Width Alone

If the two-lane tangents are classified solely according to their pavement width, irrespective of traffic volume, shoulder width, or other factors, the results are as shown in Table 7. The evidence is confusing. It is not even clear whether 24-ft. pavements are safer than 20-ft. pavements; the Type 3 rate suggests that they are, while the Types 1 and 2 rates indicate that they are not. Neither is it definitely established that very narrow pavements have the highest accident rates. The Types 1 and 3 rates indicate that they do, but the Type 2 rate shows pavements of 16 ft. as having a lower accident rate than those of 24 ft.

Shoulder Width Alone

Similar information about the effect of shoulder width is presented in Table 8. There is no indication that shoulder width, considered alone, has any bearing on the accident rates.

Pavement Width, Shoulder Width, and Volume

With the roads grouped according to traffic volume in 5,000 v.p.d. intervals, a multiple analysis has been made in each group, using pavement width and shoulder width as the independent variables. The complete table is too complicated for inclusion here, but a condensed version is given as Table 9.

None of the effects is statistically significant. In neither the 0-to-4,900 nor the 5,000-to-9,900 volume group is there a statistically significant effect on either the Type 1 or the Type 3 accident rate due to

TABLE 9

ACCIDENT RATES (TYPE 3) ON TWO-LANE TANGENTS, BY VOLUME OF TRAFFIC, PAVEMENT WIDTH, and SHOULDER WIDTH

Pavement width	Less than 5 feet		5 - 7 9 feet		8 - 9 9 feet		10 feet or more		Total	
	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles
0 - 4,900 vehicles per day										
Feet										
16 or less	97	2 8	96	5 2	0	-	1	3 3	194	3 6
18	679	2 0	871	2 1	82	2 0	58	3 8	1,690	2 1
20	991	2 7	1,027	1 6	223	1 8	66	1 6	2,307	2 0
21-22	193	2 4	25	1 4	65	2 5	117	2 9	400	2 4
23-24	67	2 5	167	1 5	16	2 1	9	2 7	259	1 7
25 or more	35	2 3	61	1 6	0	-	55	2 6	151	2 1
Total	2,062	2 4	2,247	1 8	386	2 0	306	2 5	5,001	2 1
5,000 - 9,900 vehicles per day										
16 or less	4	4 0	48	20 0	0	-	0	-	52	15 3
18	14	1 7	73	3 5	12	2 0	2	2 5	101	2 8
20	469	3 5	237	3 0	104	7 9	71	2 9	881	3 5
21-22	49	3 0	29	2 7	23	11 5	5	1 7	106	3 3
23-24	13	9 3	27	7 3	0	0 0	0	-	40	6 8
25 or more	33	3 9	88	2 9	0	-	92	4 4	213	3 6
Total	582	3 4	502	3 4	139	6 3	170	3.5	1,393	3 6
All volumes										
16 or less	101	2 8	144	7 0	0	-	1	3 3	246	4 3
18	693	2.0	944	2 1	94	2 0	60	3 7	1,791	2 1
20	1,497	2 9	1,297	1 8	327	2 4	137	2 1	3,258	2 3
21-22	242	2 5	54	1 9	88	3 2	122	2 8	506	2.6
23-24	80	2 8	194	1 7	16	1 9	9	2.7	299	1 9
25 or more	68	2 8	150	2 2	0	-	147	3 5	365	2 7
Total	2,681	2 6	2,783	2 0	525	2 4	476	2 8	6,465	2 2

Note: in Table 9 the column groups fall under the heading "Shoulder width".

(1) pavement width, for constant shoulder width; (2) shoulder width, for constant pavement width; or (3) pavement width and shoulder width acting together.[14] That is, the material in this study indicates that

TABLE 10

ACCIDENT RATES ON TWO-LANE TANGENTS BY FREQUENCY OF CURVES

Frequency of curves	Type 1 (All States, using adjustment factors)		Type 2 (Selected States without adjustment)		Type 3 (All States, without adjustment)	
No. per mile	Number	Per mil vehic -miles	Number	Per mil vehic -miles	Number	Per mil vehic -miles
0 - 0 4	1,251	4 0	442	3 1	1,251	1 7
0 5 - 0 9	1,463	3 9	649	3 4	1 463	2 1
1 0 - 1 4	580	3 4	329	2 7	580	2 0
1 5 - 1 9	771	3 4	573	2 4	771	2 2
2 0 - 2 9	588	4 2	492	3 8	588	3 1
3 0 - 3 9	552	3 1	508	3 0	552	2 6
4 0 - 4 9	806	3 8	806	3 5	806	3 5
5 0 - 5 9	405	3 2	405	3 0	405	3 0
6 0 - 6 9	55	5 5	55	4 3	55	4 3
7 or more	0	-	0	-	0	-

neither pavement width nor shoulder width nor any combination of them has a determinable effect on the accident rates on two-lane tangents.

Frequency of Curves

In the belief that driver behavior and accident experience might be affected by the frequencies of occurrence of curves, intersections, and other such features, the study routes have been divided into "frequency sections" averaging 10 to 15 mi. in length. Every card contains all the frequency information for the frequency section to which it belongs.

Table 10 shows how the accident rates on two-lane tangents vary with the average number of curves per mile. As usual, the result depends on which figures are examined. The only rates with a significant trend are the Type 3 rates, which go up as the curves become more frequent. The Types 1 and 2 rates suggest an opposite conclusion, that the tangent sections interspersed with one or two curves per mile are safer than those in places where curves are quite rare. Either conclusion, once established, has a plausible explanation, but the figures are confusing. Even the simple fact that all three types of rates have their highest values for curve frequencies of six or more curves per mile is not so simple as it seems, for the state which supplied all these sections, Oregon, has a still higher accident rate for frequencies between 4.0 and 4.9.

TABLE 11

ACCIDENT RATES (TYPE 3) ON TWO-LANE TANGENTS, BY VOLUME OF TRAFFIC, FREQUENCY OF CURVES, AND LENGTH OF TANGENT

Frequency of curves	Less than 1 mile		1 - 1 9 miles		2 - 2 9 miles		3 miles or more		Total	
	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles
0 - 4,900 vehicles per day										
Number per mile										
Less than 0 5	66	1 9	64	1 5	135	2 5	881	1 6	1,146	1 7
0 5 - 0 9	213	1 9	279	2 2	197	2 0	466	1 5	1,155	1 8
1 - 1 9	492	2 0	232	1 7	75	1 5	231	2 6	1,030	2 0
2 - 2 9	342	2 7	51	2 8	4	1 0	7	3 3	404	2 7
3 or more	1,071	2 9	95	2 4	26	2 8	26	4 9	1,218	2 9
Total	2,184	2 5	721	2 0	437	2 0	1,611	1 7	4,953	2 0
5,000 - 9,900 vehicles per day										
Less than 0 5	16	8 4	0	-	0	-	68	4 0	84	4 4
0 5 - 0 9	88	4 7	17	3 5	119	4 9	63	3 8	287	4 5
1 - 1 9	190	2 9	33	1.4	0	0 0	45	3 8	268	2 6
2 - 2.9	128	4.1	51	5 3	0	-	0	-	179	4 3
3 or more	408	3 2	93	4 8	19	5 3	31	8 4	551	3 6
Total	830	3 4	194	3 4	138	4 8	207	4 2	1,369	3 6
All volumes										
Less than 0 5	82	2 2	64	1 5	135	2 5	949	1 6	1,230	1 7
0 5 - 0 9	301	2 3	296	2 2	316	2 6	529	1 6	1,442	2 0
1 - 1 9	714	2 2	265	1 7	75	1 5	276	2 8	1,330	2 1
2 - 2 9	470	3 0	102	3 7	4	1 0	7	3.3	583	3 1
3 or more	1,488	2 9	188	3 7	73	4 1	57	6 3	1,806	3 1
Total	3,055	2 7	915	2 2	603	2.4	1,818	1 8	6,391	2 3

Curve Frequency, Tangent Length, and Volume

Table 11 gives a multiple breakdown of the Type 3 accident rates by curve frequency, tangent length, and traffic volume. The length is that of the entire

[14] For (1) and (2) the statistical tests are t tests of the partial regression coefficients For (3) they are F tests of the multiple correlation coefficients The two types of tests are equivalent when there is only one independent variable

TABLE 12

ACCIDENT RATES (TYPE 3) ON TWO-LANE TANGENTS, BY VOLUME OF TRAFFIC, FREQUENCY OF INTERSECTIONS, AND FREQUENCY OF STRUCTURES

Frequency of intersections	Number of structures per mile					
	Less than one		One or more		Total	
No. per mile	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles
0 - 4,900 vehicles per day						
Less than 0 5	357	1 8	19	1 9	376	1 8
0 5 - 0 9	798	1 9	47	1 3	845	1 8
1 - 1 9	2,425	1 9	280	2 2	2,705	1 9
2 - 2 9	675	2 8	28	7 6	703	2 9
3 or more	359	2 7	13	5 9	372	2 7
Total	4,614	2 0	387	2 2	5,001	2 1
5,000 - 9,900 vehicles per day						
Less than 0 5	23	5 0	0	-	23	5 0
0 5 - 0 9	23	11 5	0	-	23	11 5
1 - 1 9	382	4 3	87	4 0	469	4 2
2 - 2 9	553	3 5	48	20 0	601	3 8
3 or more	278	2 5	0	-	278	2 5
Total	1,259	3 5	135	5 6	1,394	3 6
All volumes						
Less than 0 5	380	1 9	19	1 9	399	1 9
0 5 - 0 9	821	1 9	47	1 3	868	1 9
1 - 1 9	2,835	2 1	367	2 5	3,202	2 1
2 - 2 9	1,262	3 1	76	12 5	1,338	3 2
3 or more	646	2 6	13	5 9	659	2 6
Total	5,944	2 2	522	2 6	6,466	2 3

TABLE 13

ACCIDENT RATES ON TWO-LANE TANGENTS, BY FREQUENCY OF ROADSIDE ESTABLISHMENTS (INCLUDING DWELLINGS)

Frequency of establishments	Type 1 (All States, using adjustment factors)		Type 2 (Selected States, without adjustment)		Type 3 (All States, without adjustment)	
No. per mile	Number	Per mil vehic -miles	Number	Per mil vehic -miles	Number	Per mil vehic -miles
0 - 0 9	650	4 3	220	5 3	650	1 8
1 0 - 4 9	2,131	3 4	904	2 6	2,131	1 8
5 0 - 9 9	1,567	4 4	1,205	3 3	1,567	2 9
10 0 - 19 9	1,770	3 5	1,637	3 2	1,770	2 9
20 0 - 49 9	356	4 0	293	2 9	356	3 1
50 or more	0	0 0	0	0 0	0	0 0

TABLE 14

ACCIDENT RATES ON TWO-LANE TANGENTS, BY FREQUENCY OF SIGHT-DISTANCE RESTRICTIONS

Frequency of restrictions	Type 1 (All States, using adjustment factors)		Type 2 (Selected States, without adjustment)		Type 3 (All States, without adjustment)	
No per mile	Number	Per mil vehic -miles	Number	Per mil vehic -miles	Number	Per mil vehic -miles
0 - 0 9	3,472	3 7	1,833	2 8	3,472	2 0
1 0 - 1 9	1,061	4 3	588	4 0	1,061	2 5
2 0 - 2 9	891	4 1	811	3 4	891	3 1
3 0 - 3 9	684	3 3	661	3 0	684	3 0
4 0 - 4 9	354	3 1	354	2 9	354	3 0
5 0 - 5 9	12	2 7	12	2 7	12	2 7

TABLE 15

ACCIDENT RATES (TYPE 3) ON TWO-LANE TANGENTS, BY VOLUME OF TRAFFIC, PERCENT COMMERCIAL TRAFFIC, AND PERCENT NIGHT TRAFFIC

Commercial traffic	Night traffic							
	0 - 19 percent		20 - 29 percent		30 - 39 percent		Total	
	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles
0 - 4,900 vehicles per day								
Percent								
0 - 9.9	1	5.0	0	-	108	2.8	109	2.8
10 - 14.9	786	3 0	281	2.1	503	2.7	1,570	2.7
15 - 19.9	249	3.7	564	1.6	470	2.5	1,283	2.1
20 - 24.9	8	1.3	866	2.2	850	1.4	1,724	1.7
25 or more	0	-	221	1.7	94	1 3	315	1.6
Total	1,044	3.1	1,932	1.9	2,025	1.8	5,001	2.1
5,000 - 9,900 vehicles per day								
0 - 9 9	0	-	0	-	68	2.5	68	2.5
10 - 14 9	303	6.4	183	4.2	194	2.8	680	4.2
15 - 19.9	204	6.8	0	0.0	235	2.7	439	3.8
20 - 24.9	0	-	72	3.5	111	2.3	183	2.7
25 or more	0	-	9	1.4	15	1.9	24	1.7
Total	507	6.5	264	3.8	623	2.6	1,394	3.6
All volumes								
0 - 9.9	1	5.0	0	-	176	2.7	177	2.7
10 - 14.9	1,117	3.6	464	2.6	697	2.8	2,278	3.1
15 - 19.9	453	4.7	564	1.6	739	2.6	1,756	2.4
20 - 24.9	8	1.3	938	2.3	970	1.5	1,916	1.8
25 or more	0	-	230	1.7	109	1.4	339	1.6
Total	1,579	3.8	2,196	2.0	2,691	2.0	6,466	2.3

tangent, even though it may be broken up into a number of shorter sections by the presence of minor intersections or structures. The multiple regression analysis corroborates the confusing conclusions from the analysis of curve frequency alone. In the lowest volume group, the effect of adding curves is to reduce the Type 1 accident rate and to increase the Type 3 rate. There is no significant effect at higher volumes.

The value of the multiple analysis becomes apparent when we examine the effect of tangent length on the Type 3 accident rates for volumes under 5,000 vehicles per day. The totals for all curve frequencies combined indicate a high positive correlation between accident rate and tangent length. Even when the detailed breakdown is used, the simple correlation with tangent length is still statistically significant. Yet it falsifies the truth. For there is a large negative correlation between tangent length and curve frequency, i. e., long tangents have a strong tendency to be associated with low curve frequencies. To determine the effect of different tangent lengths on roads having the same curve frequency we must use the partial correlation coefficient of accident rate with tangent length. This coefficient is not statistically significant for any volume group.

Structure Frequency, Intersection Frequency, and Volume

This breakdown of accident rates is given in Table 12. There are no statistically significant effects of structure frequency or intersection frequency. However, there is some tendency for the Type 3 rates to increase with increasing intersection frequency when the traffic volume is low and to decrease with increasing intersection frequency when the traffic volume is high.

Frequency of Roadside Establishments

Table 13 shows the effect on the accident rates of the frequency of roadside establishments (including dwellings).[15] The results are perplexing. Only the Type 3 rate comes anywhere near showing a significant trend; these figures suggest that adding roadside establishments makes a road more hazardous. The Type 2 rate, on the other hand, seems to indicate that only roads that are particularly bad are those having less than one establishment per mile. The Type 1 rate is quite irregular.

[15] This has been studied in more detail by Minnesota and Michigan The Minnesota study is cited in Footnote 9 supra, while the Michigan study, published in 1952, is entitled "Accident Experience in Relation to Road and Roadside Features "

Frequency of Sight-Distance Restrictions

For this study a restriction has been defined as a stretch of road where the sight distance is less than 600 ft. in flat or rolling terrain, or less than 400 ft. in mountainous terrain.

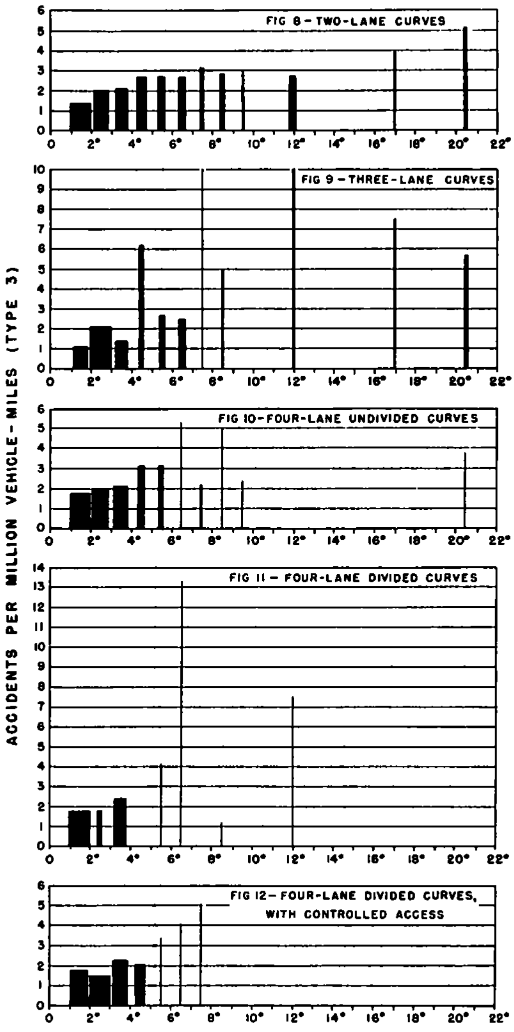
The relation of accident rates to the frequency of sight restrictions is shown in Table 14. The Type 3 rates are the most meaningful. Their slope is statistically significant, with the accident rate rising as the restriction frequency increases from zero up to about three restrictions per mile. The Types 1 and 2 rates have maximums when there are between one and two restrictions per mile; they drop steadily as the frequency of restrictions increases above this number.

Commerical Traffic, Night Traffic, and Volume

Table 15 presents a three-way breakdown of the Type 3 accident rates by traffic volume, the percentage which is commercial traffic, and the percentage of the traffic that flows after dark. The multiple analysis indicates that the accident rate is reduced by increasing the percentage of night traffic when the percentage of commerical traffic remains the same, and it also falls off with increasing commercial traffic when the night traffic is held fixed. Both these effects were unexpected.

Summary

Of all the characteristics studied for their effects on the accident rate on two-lane tangents, traffic volume is the only one whose effect is entirely clear. The effects of the frequencies of curves, intersections, roadside establishments, and sight restrictions are all uncertain, while grade, pavement width, shoulder width, tangent length, and frequency of structures do not have any independent effects on the accident rates. The effects of commercial traffic and night traffic are inconclusive.



Figures 8-12. Accident rates on curves, by degree of curvature.

CURVES: EFFECT OF DEGREE OF CURVATURE

Two-Lane Roads

The Type 3 accident rates on two-lane curves, by degree of curvature, are presented in Figure 8.[16] The relation is clear-cut: the sharper the curve, the higher the accident rate. As a matter of fact, the slopes are highly significant for all three types of rate. In accident-rate units per degree, the slopes are 0.19 ± 0.07 for the Type 1 rate, 0.12 ± 0.05 for the Type 2, and 16 ± 0.05 for the Type 3. Thus, whichever type of accident rate is used, the number of accidents per million vehicle-miles increases by about 0.15 for each additional degree of curvature.

[16]All three types of accident rates are given in Table 16

Three-Lane Roads

Here, too, there seems to be a steady increase in hazard with increasing curvature, though the data are somewhat sparse. Figure 9 shows the rates based on a total of 39 accidents.

Four-Lane Roads, Undivided

Figure 10 gives the corresponding information for four-lane undivided curves. The Type 3 rate has the same upward trend as on the two- and three-lane roads, although the slope is not statistically significant; the Types 1 and 2 rates are more irregular.

Four-Lane Roads, Divided

On these roads, too, the accident rate increases as the curves become sharper. The rates are presented in Figure 11.

Four-Lane Roads, Divided, with Controlled Access

Figure 12 shows the relation of curvature to accident rate for roads of this type. As before, the trend is statistically significant, with the accident rates increasing by about 0.4 for each additional degree of curvature.

Summary

There is a direct relation between curvature and accident rate on all types of highways. Sharp curves have high accident rates, gradual curves have low accident rates, in-between curves have in-between accident rates.

Among different types of roads with the same degree of curvature, the data do not indicate any consistent relation.

Table 17 compares tangents with curves on each type of roadway.[17] There is no clear superiority one way or the other. The Type 3 rates, which are the most con-

[17]These rates are for all the tangent and curve sections included in the study, irrespective of other factors.

TABLE 16

ACCIDENT RATES ON CURVES, BY DEGREE OF CURVATURE AND ROADWAY TYPE

Curvature	Two-lane roads		Three-lane roads		Four-lane roads					
					Undivided		Divided		Controlled access	
	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil vehicle-miles
Type 1 accident rates (All states, using adjustment factors)										
Degrees										
0 - 2.9	504	2.6	11	5 6	98	4 9	95	2.4	180	2.4
3 - 5 9	596	3 6	11	9 8	90	8.4	65	4 2	162	3 4
6 - 9.9	338	3 6	6	14 1	16	7 9	5	11 9	38	5 6
10 or more	354	4 8	11	28 0	3	5 8	12	30 6	0	-
Type 2 accident rates (Selected states, without adjustment)										
0 - 2.9	340	1.8	0	-	43	1.9	33	0 7	180	1.6
3 - 5 9	447	2.5	0	0.0	33	2 1	52	2 7	162	2.3
6 - 9.9	287	2 9	0	-	10	2 9	1	1.2	38	4 5
10 or more	281	3.4	1	10 0	0	-	0	-	0	-
Type 3 accident rates (All states, without adjustment)										
0 - 2 9	504	1 6	11	1.7	98	1 9	95	1 8	180	1 6
3 - 5.9	596	2 5	11	2.8	90	2 6	65	2.4	162	2 3
6 - 9.9	338	2.8	6	3 5	16	3.3	5	3 1	38	4.5
10 or more	354	3.5	11	7.3	3	1 2	12	6 7	0	-

TABLE 17

ACCIDENT RATES ON TANGENTS AND CURVES,[1] BY ROADWAY TYPE

	Two-lane roads		Three-lane roads		Four-lane roads					
					Undivided		Divided		Controlled access	
	Number	Per mil vehicle miles	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles
Type 1 accident rates (All states, using adjustment factors)										
Tangents	6,474	3 7	227	6.1	1,348	6.4	982	4 6	774	2.2
Curves	1,794	3 3	39	10 2	210	6 5	177	3.8	380	2.9
Type 2 accident rates (Selected states, without adjustment)										
Tangents	4,259	3 1	115	5 3	757	3.3	829	2.9	774	1 7
Curves	1,355	2 5	1	2.5	86	1 9	86	1.3	380	2 0
Type 3 accident rates (All states, without adjustment)										
Tangents	6,474	2 3	227	2.5	1,348	2.7	982	2.9	774	1.7
Curves	1,794	2.3	39	2.8	210	2 2	177	2.1	380	2.0

[1]All volumes, grades, curvatures, etc

TABLE 18

ACCIDENT RATES ON CURVES, BY VOLUME OF TRAFFIC AND ROADWAY TYPE

Average daily traffic	Two-lane roads		Three-lane roads		Four-lane roads					
					Undivided		Divided		Controlled access	
	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil. vehicle-miles
Type 1 accident rates (All states, using adjustment factors)										
Vehicles per day										
0 - 4,900	1,387	3 5	21	9 1	25	5 7	1	1.1	140	3 8
5,000 - 9,900	403	3.0	18	11 7	96	7 6	43	4 4	0	0 0
10,000 - 14,900	4	0.6	0	-	69	3.4	117	4 1	45	1 8
15,000 or more	0	-	0	-	20	1 9	27	6 5	63	1.4
Type 2 accident rates (Selected states, without adjustment)										
0 - 4,900	957	2 5	1	2 5	2	0 6	0	0 0	140	1 9
5,000 - 9,900	394	2 7	0	-	20	1.5	18	0 7	0	0 0
10,000 - 14,900	4	0 6	0	-	34	2 0	111	2 9	45	1 8
15,000 or more	0	-	0	-	20	1 8	27	5.9	63	1.3
Type 3 accident rates (All states, without adjustment)										
0 - 4,900	1,387	2 3	21	2 6	25	1 7	1	0 3	140	1.9
5,000 - 9,900	403	2 7	18	3 1	96	2.3	43	1 4	0	0.0
10,000 - 14,900	4	0 6	0	-	69	2 4	117	2 9	45	1 8
15,000 or more	0	-	0	-	20	1 8	27	5.9	63	1.3

sistent, indicate that tangents and curves are equally safe on two-lane roads. Tangents are a little safer than curves on three-lane and controlled-access four-lane-divided roads, while they are somewhat more hazardous on the four-lane roads lacking control of access. None of these differences is large enough to warrant any strong conclusions.

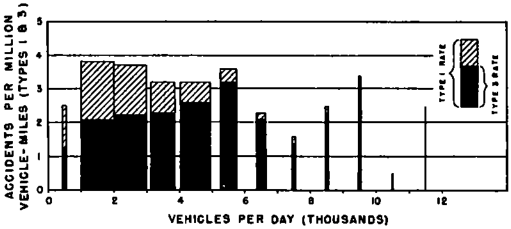


Figure 13. Accident rates on two-lane curves (all degrees), by volume of traffic.

CURVES: EFFECT OF VOLUME

Two-Lane Roads

Table 18 and Figure 13 show how the accident rate on two-lane curves varies with the average daily volume of traffic. The Type 1 rate has a statistically significant tendency to become smaller as the traffic increases. The Types 2 and 3 rates do not vary significantly but have a slight tendency to increase with increasing traffic.

The decline shown by the Type 1 rate was unexpected, but the conclusion which it suggests is almost certainly correct. Table 19 gives a state-by-state breakdown of these rates. This table shows that every state having more than six accidents (actual, not adjusted) at volumes over 5,000 v.p.d. has a lower accident rate for these volumes than for volumes below 5,000. It has also been proved by multiple regression analysis that this decline is not a hidden effect of the degree of curvature.

Why should the accident rate decline with increasing traffic on two-lane curves, when it goes the opposite way on two-lane tangents? Analysis of the types of collisions at different volumes indicates that the distribution of accident types is practically identical for all volume groups. So one can only speculate. Perhaps the extra alertness required for driving on narrow curved roads in heavy traffic is what pulls the accident rate down. A similar decline in accident rate with increasing traffic volume is found at two-lane intersections, where the same alertness factor may be involved. It is not found at curves or intersections on wider roads.

Three-Lane Roads

For three-lane curves the data are pretty meager (see Table 18), but such evidence as there is points to a positive correlation between accident rate and traffic volume.

Four-Lane Roads, Undivided

On four-lane undivided curves, each type of rate increases to a maximum and then falls off gradually as the traffic volume increases. The Type 1 rate has its maximum between 5,000 and 10,000 vehicles per day, the Type 2 has its maximum between 15,000 and 20,000 the Type 3 has its maximum between 10,000 and 15,000. This is similar to the pattern for four-lane undivided tangents.

Four-Lane Roads, Divided

The accident rates on four-lane divided curves show a persistent increase with traffic volume. The information is on the skimpy side, but the trend seems definite. The Types 2 and 3 rates have statistically significant slopes, with the accident rate increasing by about 0.3 of a unit for each additional thousand vehicles per day.

TABLE 19

STATE-BY-STATE ACCIDENT RATES (TYPE 1) ON TWO-LANE CURVES, BY VOLUME OF TRAFFIC

State	0 - 4,900 v p d.			5,000 - 9,900 v p d.		
	Adjusted accidents	Million vehicle-miles	Rate	Adjusted accidents	Million vehicle-miles	Rate
Colorado	238	71 2	3 3	12	1 3	9.2
Conn 1941	269	95.1	2 8	220	80 9	2.7
Conn. 1946	282	112 0	2 5	69	29 2	2 4
Georgia	106	13 7	7 7	0	0	-
Iowa	220	40 5	5 4	0	1.4	0 0
Louisiana	56	27 4	2 0	2	0.2	10 0
Minnesota	41	33 8	1 2	0	0	-
Nebraska	201	54 7	3 7	0	0.4	0 0
New Mexico	50	5 0	10 0	0	0	-
Oregon	108	46 7	2 3	17	8 7	2.0
Utah	206	31 6	6 5	7	1.9	3 7
Virginia	23	3 0	7 7	0	0	-
Washington	294	63 2	4.7	120	27 0	4 4
Wisconsin	11	10.7	1 0	0	0	-
Wyoming	14	4.4	3.2	0	0	-
Total	2,119	613 0	3.5	447	151 0	3.0

Four-Lane Roads, Divided, with Controlled Access

Here the situation is similar to that of the four-lane divided tangents with controlled access. The apparent decline in the accident rate with increasing volume is mainly due to the difference between Pennsylvania and Connecticut. As in the earlier case, the high volumes are all from Connecticut, while practically all of the traffic below 5,000 v.p.d. is from Pennsylvania.

Summary

On all but the two-lane roads, the accident rate on curves varies with volume in much the same way as on tangents. The general tendency is for higher-than-average volumes to cause higher-than-average accident rates, with some decline in the accident rate at extremely high volumes.

The two-lane curves are different. They show a negative correlation between accident rate and traffic volume throughout the volume range. This is thought to be due to the greater care with which people drive under conditions which are obviously dangerous.

TWO-LANE CURVES: EFFECTS OF OTHER FEATURES

Degree and Volume Combined

There are two basically different ways in which curvature and volume together might affect the accident rates. Even if the effects were really independent, there might be intercorrelation between the two factors, i.e., a tendency for the roads having higher-than-average curvature to have either higher-than-average or lower-than-average volume, so that an effect of curvature might appear to be an effect of volume, or vice versa. Multiple regression analysis separates the effects and assigns each to its proper cause.

Or there could be interaction between the two factors. This means the kind of situation in which the effect of volume at low degrees of curvature is different from its effect at high degrees, and the effect of curvature at low volumes is different from that at high volumes.

Both of these possibilities were investigated. The intercorrelation between degree and volume is negligible, and the partial correlations between the Type 1 accident rate and each of the two factors are both statistically significant, with the same signs as the simple correlations. In other words, for roads of the same curvature the average effect of increased volume is to reduce the accident rate by a significant amount, and for roads carrying the same volume the average effect of increased curvature is to increase the accident rate by a significant amount.

The interaction between curvature and volume can be tested by making a two-way classification of the highway sections by both curvature and volume. This is done in Table 20. The Type 1 rate shows no particular interaction, since it drops with increasing volume in each curvature group. The Types 2 and 3 rates do show interaction, and it is exactly the sort one would expect. At low degrees of curvature, i.e., on the curves which are most like tangents,

TABLE 20

ACCIDENT RATES ON TWO-LANE CURVES, BY VOLUME OF TRAFFIC AND DEGREE OF CURVATURE

Curvature	0 - 4,900 v p d.		5,000 v p d or more	
Degrees	Number	Per million vehicle-miles	Number	Per million vehicle-miles
Type 1 accident rates (All States, using adjustment factors)				
0 - 2 9	395	2 7	111	2 1
3 0 - 5 9	423	3.7	173	3.4
6.0 or more	569	4 4	123	3 1
Type 2 accident rates (Selected States, without adjustment)				
0 - 2.9	231	1 8	109	2 0
3 0 - 5.9	278	2 3	169	3 1
6 0 or more	448	3 2	120	2 9
Type 3 accident rates (All States, without adjustment)				
0 - 2 9	395	1 6	111	1 9
3.0 - 5.9	423	2 3	173	3 1
6 0 or more	569	3.2	123	2 8

the hazard increases with volume, just as on the tangent sections. On curves sharper than 6 deg. it is the other way around; here the accident rate is lower when there is more traffic volume.

Another way of looking at this interaction is in terms of the effect of changing the curvature at different fixed volume levels. This effect is the same for all three types of rates. At volumes below 5,000 v.p.d., the accident rate rises steadily with increasing curvature. At volumes over 5,000, the accident rate is lower on sharp curves than on moderate curves.

These facts strengthen the belief that traffic volume affects the accident rate differently on two-lane curves from the way it does on two-lane tangents.

Degree, Grade, and Volume

Table 21 gives the Type 3 accident rates by degree of curvature and grade for two-lane curves carrying various ranges of traffic volume. At low volumes the accident rate goes up with increasing curvature, while the effect of grade is not statistically significant. At higher volumes it is not the curvature but the grade that matters; steeper grades make the accident rates larger.[18]

TABLE 21

ACCIDENT RATES (TYPE 3) ON TWO-LANE CURVES, BY VOLUME OF TRAFFIC, DEGREE OF CURVATURE, AND GRADE

Curvature	Grade: Less than 3%		3% or more		Total	
Degrees	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles
0 - 4,900 vehicles per day						
0 - 2.9	317	1.4	78	2.0	395	1.6
3 - 5.9	317	2.3	106	2.4	423	2.3
6 - 9.9	194	3.0	69	2.3	263	2.8
10 or more	155	3.4	150	3.8	305	3.6
Total	983	2.1	403	2.7	1,386	2.3
5,000 - 9,900 vehicles per day						
0 - 2.9	86	1.9	22	2.9	108	2.0
3 - 5.9	117	2.8	55	4.1	172	3.2
6 - 9.9	51	2.6	22	3.1	73	2.7
10 or more	27	2.5	22	3.9	49	3.0
Total	281	2.4	121	3.6	402	2.7
All volumes						
0 - 2.9	405	1.6	100	2.2	505	1.6
3 - 5.9	434	2.4	161	2.8	595	2.5
6 - 9.9	245	2.9	93	2.5	338	2.8
10 or more	182	3.2	172	3.8	354	3.5
Total	1,266	2.2	526	2.8	1,792	2.3

Degree and Frequency of Curves

Figure 14 shows the accident rates on two-lane curves (of all degrees) as a function of curve frequency. The Type 1 rate is highest when curves are very rare, suggesting that a curve is most hazardous when it is unexpected. The Types 2 and 3 accident rates have their high values when there are more than five curves per mile.

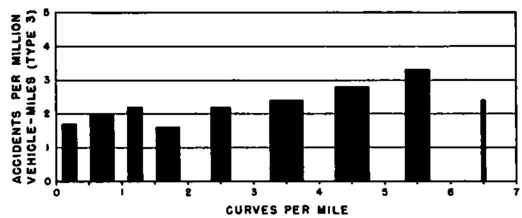


Figure 14. Accident rates on two-lane curves (all degrees), by frequency of curves.

TABLE 22

ACCIDENT RATES ON TWO-LANE CURVES, BY DEGREE OF CURVATURE AND FREQUENCY OF CURVES

Frequency of curves	Curvature: 0 - 2.9°		3° - 5.9°		6° - 9.9°		10° or more	
	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles
Type 1 accident rates (All states, using adjustment factors)								
Number per mile								
0 - 0.9	128	3.0	110	5.4	13	4.2	31	8.9
1.0 - 2.9	178	2.3	163	3.7	96	4.5	53	4.2
3.0 - 4.9	125	2.1	223	2.9	170	3.3	139	4.3
5.0 - 6.9	75	3.3	100	3.2	59	2.8	130	4.6
Type 2 accident rates (Selected states, without adjustment)								
0 - 0.9	42	1.6	47	3.2	2	1.1	4	1.4
1.0 - 2.9	105	1.4	97	2.1	65	2.9	30	2.6
3.0 - 4.9	118	2.0	203	2.5	161	3.2	117	3.3
5.0 - 6.9	75	3.1	100	2.9	59	2.6	130	3.9
Type 3 accident rates (All states, without adjustment)								
0 - 0.9	128	1.4	110	2.7	13	2.0	31	4.3
1.0 - 2.9	178	1.4	163	2.1	96	2.9	53	2.6
3.0 - 4.9	125	1.9	223	2.5	170	2.9	139	3.4
5.0 - 6.9	75	3.1	100	2.9	59	2.6	130	3.9

Table 22 separates the figures into

[18]This peculiar pattern occurs with both the Type 1 and the Type 3 rates (the Type 2 rates were not computed). In the 0 to 4,900 volume group the partial correlation with curvature is the only significant one, while in the 5,000 to 9,900 volume group the partial correlation with grade is the only significant one

TABLE 23

ACCIDENT RATES (TYPE 3) ON TWO-LANE CURVES, BY VOLUME OF TRAFFIC, FREQUENCY OF CURVES, AND FREQUENCY OF SIGHT-DISTANCE RESTRICTIONS

Frequency of curves	Restrictions per mile: Less than 1		1 - 1 9		2 - 2 9		3 or more		Total	
	Number	Per mil vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil. vehicle-miles
0 - 4,900 vehicles per day										
Number per mile										
Less than 0 5	76	1.7	7	1.9	0	0.0	3	7 5	86	1 7
0 5 - 0.9	138	1.8	33	3.2	3	0.9	0	0 0	174	1 9
1 - 1 9	182	1 8	40	1 7	3	0 9	0	-	225	1 7
2 - 2.9	38	1 9	98	2 4	16	1.7	0	0 0	152	2 1
3 or more	9	0.6	41	3 8	181	2 7	518	2.9	749	2 8
Total	443	1 7	219	2.4	203	2.5	521	2 9	1,386	2 3
5,000 - 9,900 vehicles per day										
Less than 0 5	1	1 7	0	-	0	-	0	-	1	1 7
0.5 - 0 9	22	3 5	0	0.0	0	-	0	-	22	3 3
1 - 1 9	72	2.1	3	3.8	0	-	0	-	75	2 1
2 - 2 9	0	0.0	36	2 4	0	-	0	-	36	2.4
3 or more	0	-	4	1 1	131	2 7	133	3.2	268	2.9
Total	95	2 3	43	2.2	131	2 7	133	3 2	402	2 7
All volumes										
Less than 0.5	77	1 7	7	2.2	0	0.0	3	7 5	87	1 7
0 5 - 0 9	160	1.9	33	3 0	3	0 9	0	0 0	196	2 0
1 - 1 9	256	1.8	43	1 7	3	0 9	0	-	302	1 8
2 - 2.9	38	1 9	134	2.4	16	1 7	0	0.0	188	2.2
3 or more	9	0 6	45	3 1	314	2.7	651	2.9	1,019	2 8
Total	540	1 8	262	2.4	336	2 5	654	2 9	1,792	2.3

TABLE 24

ACCIDENT RATES (TYPE 3) ON TWO-LANE CURVES, BY VOLUME OF TRAFFIC, PAVEMENT WIDTH, AND SHOULDER WIDTH

Pavement width	Shoulder width: Less than 5 feet		5 - 7.9 feet		8 - 9 9 feet		10 feet or more		Total	
	Number	Per mil vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil vehicle-miles
0 - 4,900 vehicles per day										
Feet										
16 or less	28	1 5	5	1.1	0	-	0	-	33	1 4
18	257	2 7	153	2 0	4	1 3	1	0.7	415	2.4
20	473	3 0	219	1.9	40	1.4	33	2 2	765	2 4
21-22	58	2.3	5	0.7	2	1 7	26	2.3	91	2.0
23-24	22	2 5	31	1.4	1	0 3	0	0.0	54	1 6
25 or more	15	1 3	5	1 2	0	-	9	4.2	29	1 6
Total	853	2 7	418	1 8	47	1 3	69	2.3	1,387	2 3
5,000 - 9,900 vehicles per day										
16 or less	1	0 9	1	0 7	0	-	0	-	2	0.8
18	7	3 5	12	1 2	5	5 0	0	-	24	1 8
20	230	3.2	84	2 4	3	1 2	10	2 0	327	2 9
21-22	6	2 7	13	2 3	0	-	3	3 3	22	2 5
23-24	0	-	2	0.6	1	3.3	0	-	3	0 8
25 or more	9	4 7	8	2 0	0	-	7	2.8	24	2 9
Total	253	3 2	120	2 0	9	2 4	20	2 4	402	2.7
All volumes										
16 or less	29	1 5	6	1 0	0	-	0	-	35	1.4
18	264	2 7	165	1 9	9	2 2	1	0 7	439	2.3
20	705	3 1	305	2 0	43	1.4	43	2.1	1,096	2 5
21-22	64	2.3	18	1 4	2	1.7	29	2.4	113	2.1
23-24	22	2 5	33	1 3	2	0 6	0	0.0	57	1.5
25 or more	24	1 7	13	1 6	0	-	16	3 6	53	2 0
Total	1,108	2 8	540	1.8	56	1 4	89	2 3	1,793	2 3

several ranges of curvature. At first glance the most prominent feature of this table is that the Types 1 and 3 accident rates have their greatest values for the highest curvature and the lowest frequency. But closer study of the supporting facts shows that this is due to five curves in Iowa which contribute 11 out of the 31 accidents in this group. The other 20 accidents in the group occurred at rates similar to those for other curvatures and frequencies.

The table does not suggest any general conclusions about the effect of curve frequency on the accident rates. The degree of curvature, as before, is positively correlated with the accident rates.

Curve Frequency, Sight-Restriction Frequency, and Volume

Table 23 gives the accident rates on two-lane curves by curve frequency and sight-restriction frequency for various volume groups. There is a high intercorrelation between the two frequencies, so that while high values of both frequencies cause higher accident rates than low values of both frequencies, it is impossible to tell which of the two frequencies is responsible.[19]

Since the preceding section seemed to indicate that curve frequency did not have any consistent effect, it can only be concluded that the effect of curve frequency is not very clear.

TABLE 25

ACCIDENT RATES (TYPE 3) ON TWO-LANE CURVES, BY VOLUME OF TRAFFIC, PERCENT COMMERCIAL TRAFFIC, AND PERCENT NIGHT TRAFFIC

Commercial traffic	Night traffic: 0 - 19 percent		20 - 29 percent		30 - 39 percent		Total	
	Number	Per mil. vehicle-miles	Number	Per mil vehicle-miles	Number	Per mil. vehicle-miles	Number	Per mil. vehicle-miles
0 - 4,900 vehicles per day								
Percent								
0 - 9 9	0	-	0	-	83	3 0	83	3.0
10 - 14 9	297	3.1	79	2.3	188	2 6	564	2.8
15 - 19.9	42	2.9	138	1.9	198	2.5	378	2.2
20 - 24.9	1	1.0	105	1.5	164	1.6	270	1.5
25 or more	0	-	71	2 9	21	2.0	92	2 6
Total	340	3.0	393	1.9	654	2.2	1,387	2.3
5,000 - 9,900 vehicles per day								
0 - 9.9	0	-	0	-	38	3.0	38	3.0
10 - 14.9	88	3.7	11	1.5	92	2.4	191	2.7
15 - 19.9	18	3.5	0	0 0	64	2.1	82	2 1
20 - 24.9	0	-	3	2.5	83	2.9	86	2.9
25 or more	0	-	5	2.9	0	-	5	2.9
Total	106	3.6	19	1.8	277	2.5	402	2.7
All volumes								
0 - 9.9	0	-	0	-	121	3.0	121	3.0
10 - 14.9	385	3.2	90	2.2	280	2.5	755	2 7
15 - 19.9	60	3.1	138	1.8	264	2.3	462	2.2
20 - 24.9	1	1.0	108	1.5	249	1.9	358	1 7
25 or more	0	-	76	2 9	21	2.0	97	2 8
Total	446	3.1	412	1.9	935	2.3	1,793	2 3

Pavement Width, Shoulder Width, and Volume

This breakdown is given in Table 24. On two-lane curves the effect of pavement width is too irregular to be statistically significant, but 24-ft. sections are consistently safer than 20-ft. sections. The partial correlation with shoulder width is significant; the accident rate goes down by about 0.15 of a unit, on the average, for each additional foot of shoulder. These results differ from the situation on two-lane tangents, where neither pavement width nor shoulder width has a consistent effect on the accident rate.

[19] In statistician's language, the multiple correlation is statistically significant, but the partial correlations are not.

Commercial Traffic, Night Traffic, and Volume

Table 25 shows the effects, on two-lane curves, of commercial traffic and night traffic. Neither effect is statistically significant.

Summary

The effect of volume in reducing the accident rate on two-lane curves seems to be stronger for sharp curves than for flat curves. This is logical, for one would expect flat curves to be intermediate, in their accident potential, between sharp curves and tangents.

The frequency of curves does not appear to have any consistent effect on the accident rate, even when the curves are subdivided by degree of curvature. The frequency of sight restrictions has a similarly uncertain effect.

Wide shoulders definitely help to reduce

TABLE 26

ACCIDENT RATES AT INTERSECTIONS AT GRADE[1] ON TWO- AND THREE-LANE ROADS, BY TOTAL VOLUME OF TRAFFIC AND PERCENTAGE OF CROSS TRAFFIC

Cross traffic	Two-lane roads: 0 - 4,900 v p d Number	Per ten million vehicles	5,000 - 9,900 v p d. Number	Per ten million vehicles	10,000 or more v p.d. Number	Per ten million vehicles	Three-lane roads: 0 - 4,900 v.p.d. Number	Per ten million vehicles	5,000 - 9,900 v p d Number	Per ten million vehicles	10,000 or more v p d Number	Per ten million vehicles
Type 1 accident rates (All states, using adjustment factors)												
Percent												
0 - 9	678	3 6	229	2 2	9	0.9	17	4 1	25	9.6	24	34 4
10 - 19	116	11 3	56	6 3	0	0 0	0	0 0	0	-	0	-
20 or more	162	9 2	118	8.7	3	1 9	0	0 0	30	40 8	0	-
Type 2 accident rates (Selected states, without adjustment)												
0 - 9	363	2 0	213	1.8	9	0 8	2	3 3	6	2 1	24	26.7
10 - 19	63	7.1	54	5.5	0	0 0	0	-	0	-	0	-
20 or more	118	6.9	117	8 1	3	1 9	0	-	30	25 0	0	-
Type 3 accident rates (All states, without adjustment)												
0 - 9	678	2.0	229	1.8	9	0 8	1	1.7	25	3 5	24	26 7
10 - 19	116	6.0	56	5.3	0	0 0	0	0.0	0	-	0	-
20 or more	162	6.5	118	7.5	3	1.9	0	0.0	30	25.0	0	-

[1]Excluding rotary intersections

TABLE 27

ACCIDENT RATES AT INTERSECTIONS AT GRADE[1] ON FOUR-LANE ROADS, BY TOTAL VOLUME OF TRAFFIC AND PERCENTAGE OF CROSS TRAFFIC

Cross traffic	Undivided roads: 0 - 4,900 v p d Number	Per ten million vehicles	5,000 - 9,900 v.p.d. Number	Per ten million vehicles	10,000 or more v p d Number	Per ten million vehicles	Divided roads[2]: 0 - 4,900 v p d Number	Per ten million vehicles	5,000 - 9,900 v p.d. Number	Per ten million vehicles	10,000 or more v p.d Number	Per ten million vehicles
Type 1 accident rates (All states, using adjustment factors)												
Percent												
0 - 9	33	8.8	184	9 9	302	4 6	15	3 6	131	5 4	309	7.8
10 - 19	15	22.9	22	48 7	123	32 3	7	17 5	25	10 8	130	28 3
20 or more	0	0 0	34	56 7	236	42 2	0	-	13	13.6	97	22.4
Type 2 accident rates (Selected states, without adjustment)												
0 - 9	13	4 6	62	3 8	255	3 1	15	3.3	91	3.4	238	4 5
10 - 19	14	28.0	8	8 0	123	28 6	7	17.5	25	11 4	130	24.5
20 or more	0	-	15	21.4	227	36 0	0	-	13	11 8	97	19 4
Type 3 accident rates (All states, without adjustment)												
0 - 9	33	3 4	184	3 5	302	3 0	15	3 2	131	3 2	309	4.2
10 - 19	15	21 4	22	14 7	123	28 6	7	17 5	25	10.0	130	24 5
20 or more	0	0 0	34	18.9	236	35 2	0	-	13	11 8	97	19 4

[1]Excluding rotary intersections
[2]Excluding those with controlled access

the accident rate on two-lane curves, and 24-ft. pavements are consistently safer than 20-ft. pavements. This is in contrast to the situation on two-lane tangents, where shoulder width has no particular effect.

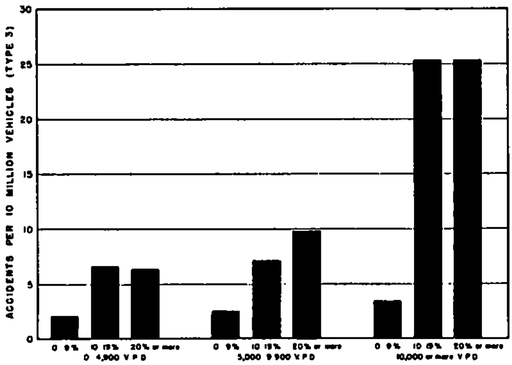


Figure 15. Accident rates at intersections (all roadway types), by total volume and percentage of cross traffic.

The effect of grade is peculiar. At low traffic volumes there is no particular effect, but on roads carrying more than 5,000 v.p.d. the accident rates are higher on roads with steep grades.

Finally, the percentages of commercial and night traffic have no recognizable effect on the accident rates on two-lane curves.

INTERSECTIONS: EFFECT OF TOTAL VOLUME AND CROSS TRAFFIC

The accident rates at intersections are computed somewhat differently than on tangents and curves, since the length of an intersection is not particularly relevant to its accident potential. The base which has been used instead of vehicle mileage is the total number of vehicles using the intersection. To keep the numbers at a manageable size, the accident rates have been expressed in terms of the number of accidents per 10 million vehicles.

The only intersections analyzed have been intersections at grade, excluding rotaries.

Two-Lane Roads

This classification consists of the intersections along the two-lane roads included in the study, irrespective of the number of lanes on the side or cross road. By volume is meant the total number of vehicles entering the intersection from all approaches; the "percentage of cross traffic" is the percentage of this total volume which enters the intersection from roads other than the study route.

Table 26 presents the accident rates at these intersections for various traffic vol-

TABLE 28

ACCIDENT RATES (TYPE 3) AT INTERSECTIONS AT GRADE[1] ON TWO-LANE ROADS, BY TOTAL VOLUME OF TRAFFIC, PERCENTAGE OF CROSS TRAFFIC, TYPE OF INTERSECTION, AND PERCENTAGE OF NIGHT TRAFFIC

Night traffic	0 - 9 percent cross traffic						10 or more percent cross traffic					
	3 -way intersection		4 -way intersection		Total		3 -way intersection		4 -way intersection		Total	
	Number	Per ten million vehicles	Number	Per ten million vehicles	Number	Per ten million vehicles	Number	Per ten million vehicles	Number	Per ten million vehicles	Number	Per ten million vehicles
0 - 4,900 vehicles per day												
Percent												
10 - 19	83	2 9	48	5 0	131	3 4	18	15 0	30	23 1	48	19 2
20 - 29	143	2 0	185	3.9	328	2.8	58	5 4	67	7.1	125	6 2
30 - 39	112	0 9	107	1 8	219	1 2	53	4 5	52	5.3	105	4 9
Total	338	1 5	340	2 9	678	2.0	129	5 4	149	7 2	278	6 3
5,000 - 9,900 vehicles per day												
10 - 19	33	2 8	39	5 2	72	3 7	43	13 4	18	13.8	61	13 6
20 - 29	35	3 3	19	5 0	54	3.8	9	11 2	23	14 4	32	13.3
30 - 39	69	0 9	31	2 2	100	1 1	58	4 3	37	6 1	95	4.8
Total	137	1 3	89	3.5	226	1.8	110	6 3	78	8.7	188	7.1
All volumes												
10 - 19	118	2 8	89	5 1	207	3 5	61	13.9	48	18 5	109	15.6
20 - 29	178	2 2	204	4 0	382	2.9	67	5 8	90	8 1	157	6 9
30 - 39	186	0 9	138	1 9	324	1 1	112	4 3	89	5 4	201	4.7
Total	482	1 4	431	3 0	913	1 9	240	5 7	227	7 5	467	6 5

[1]Excluding rotary intersections, interchanges at grade separations, and intersections with more than four approaches.

umes and percentages of cross traffic. The percentage of cross traffic is of crucial importance. At every volume level where there is an adequate sample, the accident rate is more than twice as high when the cross traffic exceeds 10 percent of the total as when the cross traffic is less than 10 percent. Additional increases in cross traffic to 20 percent or more do not cause appreciable further increases in the accident rates.

TABLE 29

ACCIDENT RATES (TYPE 3) AT INTERSECTIONS AT GRADE[1] ON TWO-LANE ROADS BY TOTAL VOLUME OF TRAFFIC, PERCENTAGE OF CROSS TRAFFIC, AND PERCENTAGE OF COMMERCIAL TRAFFIC

Commercial traffic	0 - 9 percent cross traffic		10 or more percent cross traffic	
Percent	Number	Per ten mil. vehicles	Number	Per ten mil. vehicles
0 - 4,900 vehicles per day				
5 - 9 9	11	0. 6	8	3 3
10 - 14 9	208	2 3	88	6 4
15 - 19 9	174	1 9	121	6 3
20 - 24 9	215	1 8	57	6 0
25 or more	80	3 1	16	9 4
Total	688	2 0	290	6 3
5,000 - 9,900 vehicles per day				
5 - 9 9	6	0. 5	23	6 6
10 - 14 9	128	2 7	83	7 5
15 - 19 9	65	1 7	64	9 1
20 - 24 9	21	0. 8	39	4. 6
25 or more	8	1 9	2	2 9
Total	288	1 7	211	6 9
All volumes				
5 - 9 9	17	0 5	31	5 3
10 - 14 9	340	2 4	172	6 7
15 - 19 9	244	1 8	192	7 0
20 - 24 9	236	1 6	96	5 2
25 or more	88	2 9	18	7 5
Total	925	1 9	509	6. 4

[1]Excluding rotary intersections

The effect of traffic volume on the accident rate is worth noting. Increased volume reduces the accident rate in most cases. This is the same effect that was noted for two-lane curves. The two effects may possibly be related, since neither of them occurs on roads of more than two lanes.

Three-Lane Roads

Table 26 also gives the same information for three-lane roads. The information is meager, but the intersections having less than 10 percent cross traffic appear to be much safer than the others. High volumes are associated with high accident rates.

Four-Lane Roads, Undivided

As with other roadway types, cross traffic between 10 and 19 percent makes an intersection on a four-lane undivided road much more dangerous than if the cross traffic is below 10 percent. Further increases in cross traffic are less important. The total traffic volume has no consistent effect (see Table 27).

TABLE 30

ACCIDENT RATES AT STRUCTURES (ON TWO-LANE ROADS WITH APPROACH PAVEMENTS LESS THAN 30 FEET WIDE), BY RELATIVE WIDTH OF STRUCTURE ROADWAY AND ADJOINING PAVEMENT

Relative Width	Bridges and overpasses		Underpasses	
Feet	Number	Per ten mil vehicles	Number	Per ten mil vehicles
Type 1 accident rates (All States, using adjustment factors)				
Structure narrower by more than 1 ft	21	9 2	0	-
Structure from 1 ft narrower to 1 ft wider	56	5 8	2	2 9
Structure wider by				
1 1 - 3 0	81	7 7	6	6 4
3 1 - 5 0	87	5 2	2	7 5
5 1 - 7 0	17	2 3	5	5 6
7 1 - 9 0	4	0 2	0	0 0
9 1 - 13 0	14	1 0	9	6 0
13 1 - 19 0	4	0 4	0	0 0
19 1 or more	10	1 6	3	2 5
Type 2 accident rates (Selected States, without adjustment)				
Structure narrower by more than 1 ft	15	5 0	0	-
Structure from 1 ft narrower to 1 ft wider	28	4 7	2	3 3
Structure wider by				
1 1 - 3 0	70	4 5	6	6 0
3 1 - 5 0	61	4 1	1	10 0
5 1 - 7 0	10	1 3	2	2 5
7 1 - 9 0	4	0 2	0	0 0
9 1 - 13 0	7	0 5	7	5 0
13 1 - 19.0	4	0. 5	0	-
19 1 or more	10	1 5	2	1 4
Type 3 accident rates (All States, widhout adjustment)				
Structure narrower by more than 1 ft.	21	5 7	0	-
Structure from 1 ft narrower to 1 ft wider	56	3 6	2	2 9
Structure wider by				
1 1 - 3 0	81	4 0	6	5 5
3 1 - 5 0	87	3 1	2	5 0
5 1 - 7 0	17	1 3	5	3 1
7 1 - 9 0	4	0 2	0	0 0
9.1 - 13 0	14	0 6	9	4 5
13 1 - 19.0	4	0 4	0	0 0
19 1 or more	10	1 1	3	1 9

Four-Lane Roads, Divided

On four-lane divided roads without controlled access, the conclusion about cross traffic is again the same. High volume appears to increase the hazard somewhat.

Figure 15[20] presents the accident rates at intersections for all types of roadways combined. The evidence is overwhelming

[20]The bars in Figure 15 are of uniform width In all three volume groups, more than 85 percent of the exposure was at intersections with less than 10 percent cross traffic

that cross traffic in excess of 10 percent of the total traffic makes an intersection much more dangerous than if the cross traffic is less than 10 percent.

When all road types are combined, it appears that the accident rate goes up with increases in the total volume. But the exact opposite is the case for intersections on two-lane roads.

fic control (stop signs, traffic signals, etc.) The question cannot be answered from the data in the present study, because there is too little variety in traffic control at the intersections on the study routes.

STRUCTURES

Structures have been classified accord-

TABLE 31

ACCIDENT RATES (TYPE 3) AT BRIDGES AND OVERPASSES ON TWO - LANE ROADS LESS THAN 30 FEET WIDE, BY RELATIVE WIDTH OF BRIDGE ROADWAY AND ADJOINING PAVEMENT, AND ACTUAL WIDTH OF BRIDGE ROADWAY

Relative width	Width of roadway on bridge									
	Less than 20 feet		20 - 24 feet		25 - 29 feet		30 - 34 feet		35 feet or more	
	Number	Per ten million vehicles	Number	Per ten million vehicles	Number	Per ten million vehicles	Number	Per ten million vehicles	Number	Per ten million vehicles
Feet Bridge narrower by more than 1 foot	17	8 1	4	2.5	0	-	0	-	0	-
From 1 foot narrower to 1 foot wider	28	5 6	27	2 7	1	0 9	0	-	0	-
Bridge wider by										
1 1 - 3 0	5	25 0	76	4 0	0	0 0	0	0 0	0	-
3 1 - 5 0	2	20 0	76	3 1	7	2 6	2	4 0	0	-
5.1 - 7 0	0	-	13	1 6	2	0.5	2	2 0	0	-
more than 7	0	-	0	0 0	4	0 2	14	0.7	14	0.9
Total	52	7 2	196	3 1	14	0.4	18	0 8	14	0 9

TWO-LANE INTERSECTIONS: EFFECTS OF OTHER FEATURES

Intersection Type, Night Traffic, Cross Traffic, and Volume

Three-way intersections are much safer than four-way intersections, according to Table 28. The angle at which the roads intersect does not make any appreciable difference. Increasing the percentage of night traffic reduces the accident rate, as with two-lane tangents.

Commercial Traffic, Cross Traffic, and Volume

This breakdown is given in Table 29. There is some tendency for the accident rate to increase with increasing commercial traffic, but it is not statistically significant.

Summary

The percentage of cross traffic is important, and so is the number of approaches to the intersection. Night traffic reduces the accident rate, while the effect of commercial traffic is not clear.

It would be of interest to know how the accident rate is affected by the type of traf-

ing to the relative width of the roadway at the structure, on the bridge or in the underpass, as compared with the adjoining pavement. Table 30 presents the accident rates on this basis. The table is restricted to two-lane roads with pavements less than 30 ft. wide.

Extra width in relation to the approach pavement definitely reduces the accident hazard on bridges. Table 31 shows that for bridges having the same relative roadway width, the actual width of the bridge pavement also contributes to the safety of the bridge.

There were not enough underpasses in the study to warrant any conclusions about the effect of roadway width in them. Such evidence as there is, based on a total of 28 accidents, indicates that underpasses are considerably more dangerous than overpasses, even though the average extra width of the underpasses in this study is about 2 ft. more than that of the bridges.

CONCLUSIONS

The conclusions fall under two headings: (1) a brief summary of the findings and (2) a critique of the study itself. The latter is as important as the former in guiding future research into the causes of accidents.

A summary of the findings was given near the beginning of this report and will not be repeated here. A number of significant relations were discovered, while others that had been expected to be clear did not turn out as expected.

At the beginning of the analysis, the question was raised as to which type of accident rate would prove most reliable.[21] The Type 3 rate makes the best showing. Of the first 32 analyses to be made, e.g., two-lane tangents by grade, two-lane tangents by volume, the Type 3 rate behaves credibly in 30 of them and is not seriously misleading in any, (though it fails to bring out the effect of traffic volume on two-lane curves). The Type 1 rate, in contrast, is reasonable in only 25 of the analyses, and in two cases gives results which are significant by statistical tests and yet are seriously misleading. The Type 2 rate is misleading in only one case, but there are nine cases in which it is excessively irregular or else contains too little data to give useful results. It would seem that, with the present data at least, one can probably do no better than simply to use all the reported accidents at face value.

The most striking feature of the study is the amount of irregularity in most of the results. Few of the data which have been presented in tables and graphs can be fitted by really smooth curves. There is considerable scatter about the over-all trends, and it is quite likely that some subtle relationships have been masked by these irregularities.

The fluctuations are much larger than one would expect from considerations of the theory of sampling. They may be due, in part, to errors in the data, such as the failure of the original accident reports to specify the accident locations with sufficient accuracy.

But their principal cause is probably the tremendous complexity of the problem itself. Accidents are associated with so many factors, in such a multitude of combinations, that one has to resort to drastic oversimplifications in order to make any kind of order out of a chaotic mass of material. The remarkable thing is not the irregularities in the tabulations but the number of useful conclusions which do emerge. Most of these conclusions were suspected before the present study was begun, but the statistical analyses give them a broader foundation in hard facts than they ever had before.

However, the foundation is not as broad as it ought to be. Too many of the states were unable to provide information of sufficient accuracy and detail for use in this study. While there has been some improvement in this regard since 1941, the situation is still far from satisfactory. If further progress is to be made in understanding the causes of accidents, many of our states will have to make substantial improvements in the quality of their accident reporting.

[21] The three types use (1) adjusted accidents (based on total-to-fatal ratio), all states, (2) actual accidents, selected states (selected for their presumed completeness of reporting), (3) actual accidents, all states

Appendix

OUTLINE OF CARD-PUNCHING CODE

All types of cards (highway, accident, summary)

Cols.	1-2:	State
"	3-4:	County
"	5-8:	Route number
"	9-12:	Section number
"	13:	Terrain (flat, rolling, mountainous)
"	14:	Roadway type (2-lane, 3-lane, etc.)
"	15:	Pavement material
"	16-17:	Pavement width
"	18:	Shoulder material
"	19:	Shoulder width
"	20:	Median type
"	21:	Median width
"	22:	Type of curb
"	23:	Type of sidewalks
"	24:	Type of lighting
"	25:	85-percentile speed
"	26:	Traffic-control devices (reduced speed zone, no-passing zone, signalized intersection, stop sign, etc.)
"	27:	Speed limit
"	28:	Frequency of curves
"	29:	Frequency of intersections
"	30:	" " structures
"	31:	" " railroad crossings at grade
"	32:	" " sight restrictions
"	33:	" " roadside establishments, including dwellings
"	34-36:	Average daily traffic volume
"	37-38:	Percentage of night traffic
"	39:	" " commercial traffic
"	40:	" " cross-road traffic
"	41:	Grade
"	42:	Type element (tangent, curve, intersection, structure, railroad crossing, transition, toll booth)
"	43:	Length of entire tangent of which highway card may be only a part
"	44:	Curvature
"	45:	Superelevation
"	46:	Locality of curve (adjacent to a tangent, part of a compound curve, part of a reverse curve)
"	47:	Type of intersection (right-angled crossing, skew crossing, tee, rotary, etc.)
"	48:	Type of structure (bridge, underpass with center pier, underpass without center pier, tunnel)
"	49:	Length of structure
"	50-51:	Width of roadway on structure
"	52:	Relative width of structure roadway and adjoining pavement
"	53:	Type of railroad grade crossing (single or multiple track, right-angle or skew)
"	54:	Type of protection at railroad crossing
"	55:	Type of transition (in number of lanes, in width of median)
"	56:	Location of transition (at or near structures, on grades with extra truck lane).

The codes given so far apply to all kinds of cards. The identical punching is used in the first 56 columns for (1) the highway card designating a section, (2) each accident card representing an accident on the section, and (3) the summary card representing the section. From here on, however, the coding is different for different types of cards.

Highway cards

Cols. 57:	Type of card (highway card, accident card, summary card)
" 58-59:	Length of section
" 60-64:	Annual vehicle-miles on section

Cols. 65-80 are left blank.

Accident cards

Cols. 57:	Type of card (highway, accident, summary)
" 58:	Month of accident
" 59:	Day of week
" 60-61:	Hour of day
" 62:	Light condition
" 63:	Weather
" 64:	Condition of surface (wet, dry, muddy, etc.)
" 65:	Road defects, if any
" 66:	Traffic control operation (policeman, automatic control operating, automatic control not operating)
" 67:	Severity (fatal, injury, property damage)
" 68:	Location (at intersection, at median opening, between intersections)
" 69:	Type of collision (with pedestrian, with other motor vehicle, with fixed object, ran off roadway, etc.)
" 70-71:	Description of vehicle maneuvers
" 72-73:	Miscellaneous actions (avoiding object in roadway, avoiding other vehicle not involved in collision, etc.) Coded for first two vehicles to collide.
" 74:	Pedestrian's actions
" 75:	Type of fixed object involved (bridge rail, guard rail, trees or shrubs, utility pole, etc.)
" 76-80:	Types of vehicles involved

Summary cards

Cols. 57:	Type of card (highway, accident, summary)
" 58-59:	Length of section
" 60-64:	Annual vehicle-miles on section
" 65-66:	Number of fatal accidents in study year
" 67-68:	Number of injury accidents
" 69-70:	Number of property-damage accidents
" 71-72:	Number of fatal and injury accidents combined
" 73-74:	Total number of accidents in study year
" 75-77:	"Adjusted" number of accidents, using total-to-fatal ratio
" 78-80:	"Adjusted" number of accidents, using total-to-fatal-and-injury ratio

The meaning of the adjustment used in Columns 75 to 80 of the summary cards is explained in the main body of the report.