Effect of Traffic Volumes and Number of Lanes On Freeway Accident Rates

RICHARD A. LUNDY, California Division of Highways

Three years of experience on 659 mi of four-, six-, and eight-lane freeways have revealed that the accident rates for each classification will normally increase with an increasing ADT. The rate of increase per 10,000-veh increase in ADT is four-lane, 0.240 accidents/MVM; six-lane, 0.094 accidents/MVM; and eight-lane, 0.078 accidents/MVM. For any given ADT, the four-lane freeways have a higher accident rate than the six-lane, and six-lane freeways have a higher rate than the eight-lane. Therefore, as the ADT increases, the difference in rates between the three classifications becomes greater. This relationship introduces the possiblity of significantly reducing the total number of freeway accidents by increasing the number of traffic lanes, even though the increase is not required by traffic volumes.

•A RECENT REPORT (1) by the California Division of Highways indicated that the accident rates on freeways increase as the traffic volumes increase, and for a given

The present study analyzes in more detail the accident rate vs volume relationship reported in the comparative freeway study report. It is based on a 3-yr observation (1960-1962) of 659 mi of freeway on which 26,152 million vehicle miles (MVM) were traveled and 35,675 accidents occurred.

All freeway sections in existence during the study period were classified into three categories: four, six, and eight lanes. Sections having more lanes in one direction of travel than in the other and sections with less than 30 MVM/yr of travel were eliminated. The requirement of a minimum amount of travel of 30 MVM was imposed since it was felt that with this amount of travel, the element of chance variation in the accident rate would be significantly reduced and fairly stable accident rates would result. The number of sections meeting these requirements are indicated in Table 1.

TABLE 1

FREEWAY SECTIONS MEETING REQUIREMENTS FOR STUDY

Year	No. of Sections			
	4-Lane	6-Lane	8-Lane	Total
1960	24	21	10	55
1961	35	30	17	82
1962	42	35	20	97
Total	101	86	47	234

For each lane classification, the curve best representing the accident rate vs ADT relationship was calculated by the

Paper sponsored by Committee on Highway Safety.

TABLE 2

1960 ADT AND ACCIDENT RATES, GROUP AVERAGES

GROUP NO.	ADT CLASS INTERVAL	4 LANES					6 LANES					8 LANES				
		Miles	No of Acc.	MVM	Acc./MVM	Avg. ADT for Group*	Miles	No. of Acc.	MVM	Acc./MVM	Avg. ADT for Group*	Miles	No. of Acc.	MVM	Acc./MVM	Avg. ADT for Group*
I	Less than 7,000															
II	7,000 to 9,999															
III	10,000 to 14,999	82.79	327	379	0.86	12.5										
IV	15,000 to 21,499	40.03	210	246	0.85	18.5										
V	21,500 to 31,599	103.96	1268	982	1.29	26.2	6.69	58	65	0.89	26.8					
VI	31,600 to 46,499	12.47	283	165	1.72	37.0	28.32	322	361	0.89	36.5					
VII	46,500 to 67,999	4.17	172	95	1.81	62.6	43.59	980	881	1.11	56.9	17.78	218	231	0.94	50.7
VIII	68,000 to 99,999						47.30	2005	1372	1.46	82.6	5.51	358	174	2.06	82.4
IX	100,000 to 120,000						18.69	940	706	1.33	107.1	12.72	621	469	1.32	110.4
X	Over 120,000						1.75	108	88	1.23	137.9	8.72	1011	525	1.93	160.8
	TOTALS	243.42	2260	1867	1.21	24.4	146.34	4413	3473	1.27	66.3	44.73	2208	1399	1.58	102.0

*ADT in thousands

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1961 ADT AND ACCID RATES, GROUP AVERAGES

GROUP NO.	ADT CLASS INTERVAL	4 LANES					6 LANES					8 LANES				
		Miles	No. of Acc.	MVM	Acc./MVM	Avg. AI for Grou	Miles	No. of Acc	MVM	Acc./MVM	Avg. ADT for Group*	Miles	No. of Acc.	MVM	Acc./MVM	Avg. ADT for Group*
I	Less than 7,000															
II	7,000 to 9,999															
III	10,000 to 14,999	99.93	384	431	0.78	13.3										
IV	15,000 to 21,499	52.66	302	324	0.93	18.4										
V	21,500 to 31,599	69.70	685	623	1.10	24.5	12.88	114	121	0.94	27.3					
VI	31,600 to 46,499	62.75	1172	879	1.33	38.7	32.37	443	478	0.93	41.4	3.27	25	38	0.66	35.3
VII	46,500 to 67,999	8.43	327	169	1.94	55.0	29.25	663	582	1.14	54.7	22.35	378	478	0.79	60.8
VIII	68,000 to 99,999						46.97	1532	1350	1.13	83.7	11.00	508	355	1.43	87.8
IX	100,000 to 120,000						30.75	2263	1194	1.90	110.4	23.38	1254	952	1.32	109.0
X	Over 120,000											15.52	1479	864	1.71	146.3
	TOTALS	293.47	2870	2496	1.15	27.4	152.22	5015	3725	1.35	66.8	75.52	3644	2687	1.36	94.2

*ADT in thousands

TABLE 4

1962 ADT AND ACCIDENT RATES, GROUP AVERAGES

GROUP NO.	ADT CLASS INTERVAL	4 LANES					6 LANES					8 LANES				
		Miles	No. of Acc.	MVM	Acc./MVM	Avg. ADT for Group*	Miles	No. of Acc.	MVM	Acc./MVM	Avg. ADT for Group*	Miles	No. of Acc.	MVM	Acc./MVM	Avg. ADT for Group*
I	Less than 7,000	24.14	57	55	1.04	6.2										
II	7,000 to 9,999	31.58	146	97	1.51	8.9										
III	10,000 to 14,999	94.62	374	399	0.94	13.8										
IV	15,000 to 21,499	69.41	412	400	1.03	17.2	5.81	45	44	1.02	20.8					
V	21,500 to 31,599	75.65	767	701	1.09	25.3	18.22	165	152	1.09	25.4					
VI	31,600 to 46,499	75.44	1510	1008	1.50	38.4	30.79	526	453	1.16	40.3	12.03	178	158	1.13	45.6
VII	46,500 to 67,999	12.17	496	226	2.19	50.6	46.07	1172	878	1.33	53.5	10.24	164	170	0.96	59.9
VIII	68,000 to 99,999	4.27	263	107	2.46	68.4	56.56	2696	1702	1.58	83.8	20.37	641	626	1.02	85.9
IX	100,000 to 120,000						14.75	1074	609	1.76	110.4	11.53	562	444	1.27	106.3
X	Over 120,000						10.61	987	490	2.01	127.5	35.13	3030	1796	1.69	144.7
	TOTALS	387.28	4025	2993	1.34	27.5	182.81	6665	4328	1.54	68.2	89.30	4575	3194	1.43	98.7

* ADT in thousands

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1960 TO 1962 ADT AND A DENT RATES, GROUP AVERAGES

GROUP NO.	ADT CLASS INTERVAL	4 LANES					6 LANES					8 LANES				
		Miles	No. of Acc.	MVM	Acc./MVM	Avg. AD for Grou	/iles	No. of Acc.	MVM	Acc./MVM	Avg. ADT for Group*	Miles	No. of Acc.	MVM	Acc./MVM	Avg. ADT for Group*
I	Less than 7,000	24.14	57	55	1.04	6.2										
II	7,000 to 9,999	31.58	146	97	1.51	8.9										
III	10,000 to 14,999	277.34	1085	1269	0.86	13.2										
IV	15,000 to 21,499	162.10	924	970	0.95	17.9	5.81	45	44	1.02	20.8					
V	21,500 to 31,599	249.31	2720	2306	1.18	25.4	37.79	337	338	1.00	26.5					
VI	31,600 to 46,499	150.66	2965	2051	1.45	38.4	91.48	1291	1292	1.00	39.7	15.30	203	196	1.04	42.1
VII	46,500 to 67,999	24.77	995	491	2.03	54.1	18.91	2815	2341	1.20	54.8	50.37	760	879	0.86	57.8
VIII	68,000 to 99,999	4.27	263	107	2.46	68.4	50.83	6233	4424	1.41	83.5	36.88	1507	1155	1.30	85.9
IX	100,000 to 120,000						54.19	4277	2509	1.70	109.6	47.63	2437	1865	1.31	108.3
X	Over 20,000						12.36	1095	578	1.89	130.1	59.37	5520	3185	1.73	148.9
	TOTALS	924.17	9155	7346	1.25	26.7	81.37	16,093	11,526	1.40	67.2	209.55	10,427	7280	1.43	97.8

*ADT in thousands

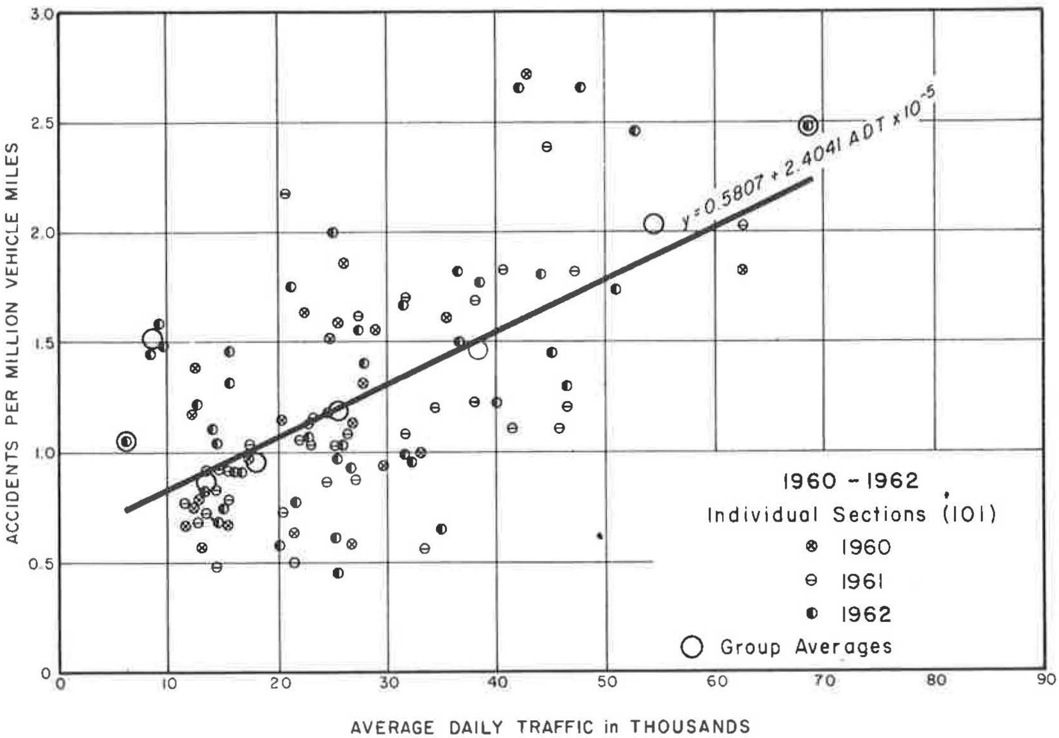

Figure 1. 1960 to 1962 four-lane accident rate vs ADT (9,155 accidents, 7,346 MVM).

TABLE 6

STANDARD ERROR OF ESTIMATE FOR ACCIDENT RATE VS ADT CURVES (Least Squares Program)

YEAR	NUMBER of LANES	TYPE of CURVE				
		Linear $y = a + bx$	Exponential $y = a(b)^x$	Semi Log 1 $\log_e y = a + bx$	Semi Log 2 $y = a + b \log_e x$	Log Log $y = a(x)^b$
1960	4 Lanes	0.397	0.410	0.422	0.395	0.398
1961	4 Lanes	0.358	0.360	0.364	0.363	0.364
1962	4 Lanes	0.463	0.447	0.464	0.510	0.519
1960-1962	4 Lanes	0.419	0.415	0.422	0.446	0.447
1960	6 Lanes	0.495	0.481	0.498	0.463	0.473
1961	6 Lanes	0.359	0.353	0.357	0.378	0.374
1962	6 Lanes	0.412	0.412	0.415	0.420	0.421
1960-1962	6 Lanes	0.424	0.426	0.430	0.430	0.431
1960	8 Lanes	0.455	0.479	0.487	0.480	0.489
1961	8 Lanes	0.391	0.395	0.412	0.392	0.403
1962	8 Lanes	0.401	0.395	0.401	0.415	0.414
1960-1962	8 Lanes	0.438	0.436	0.446	0.447	0.451

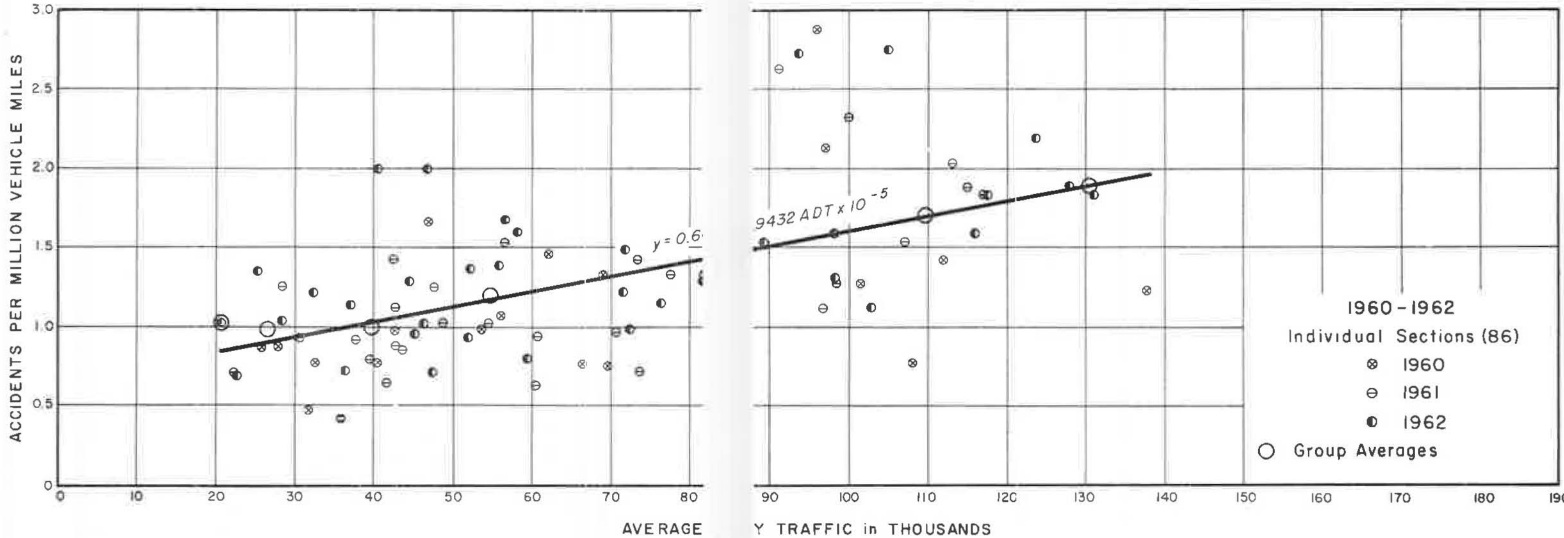

Figure 2. 1960 to 1962 six-lane ac ent rate vs ADT (16,093 accidents, 11,526 MVM).

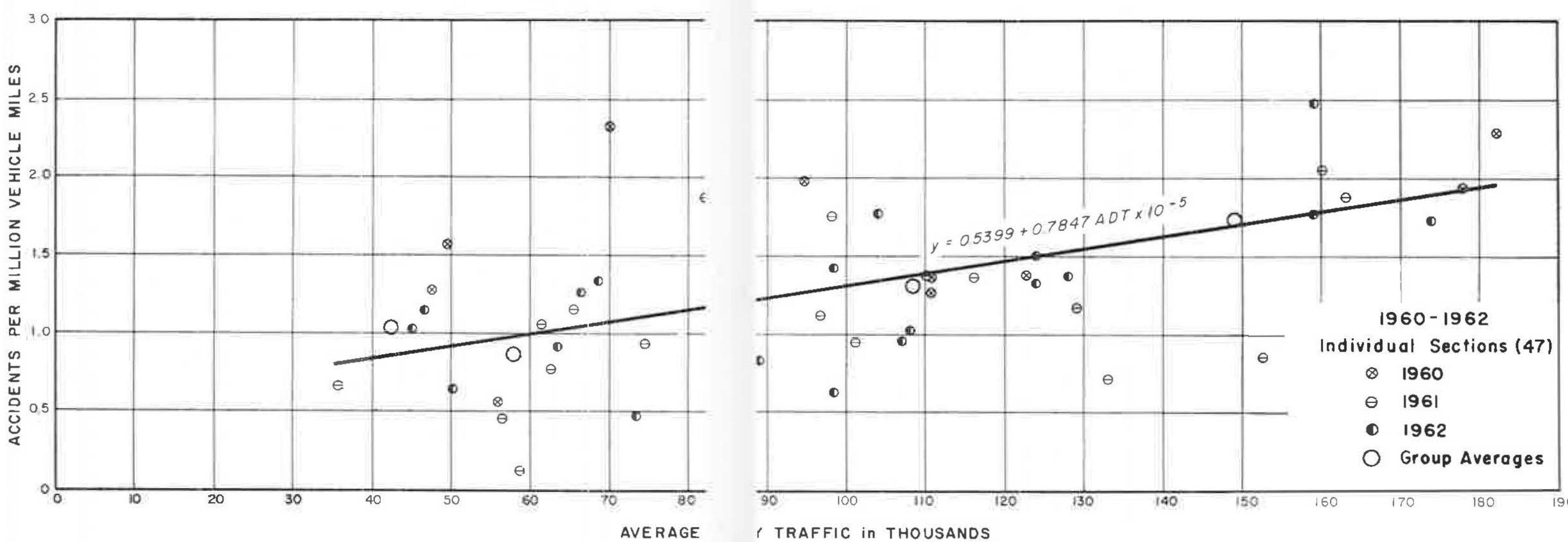

Figure 3. 1960 to 1962 eight-lane dent rate vs ADT (10,427 accidents, 7,280 MVM).

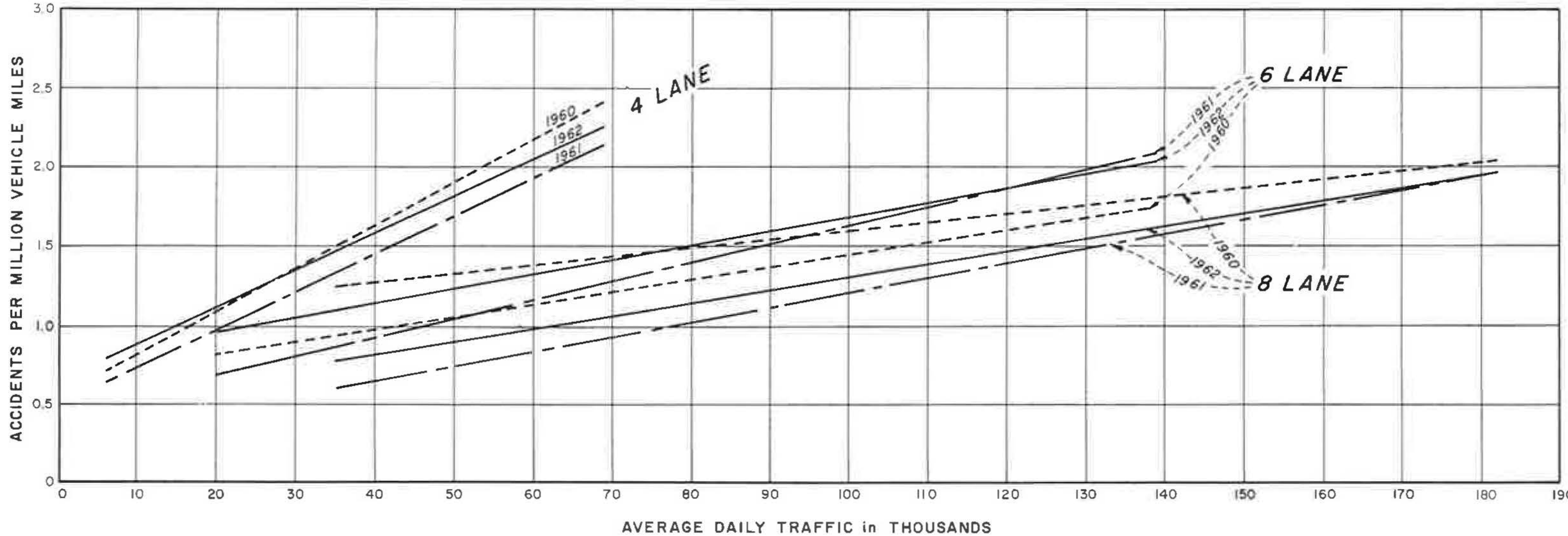

Figure 4. Four-, six-, and eight-lane linear fits for 1960, 1961, and 1962.

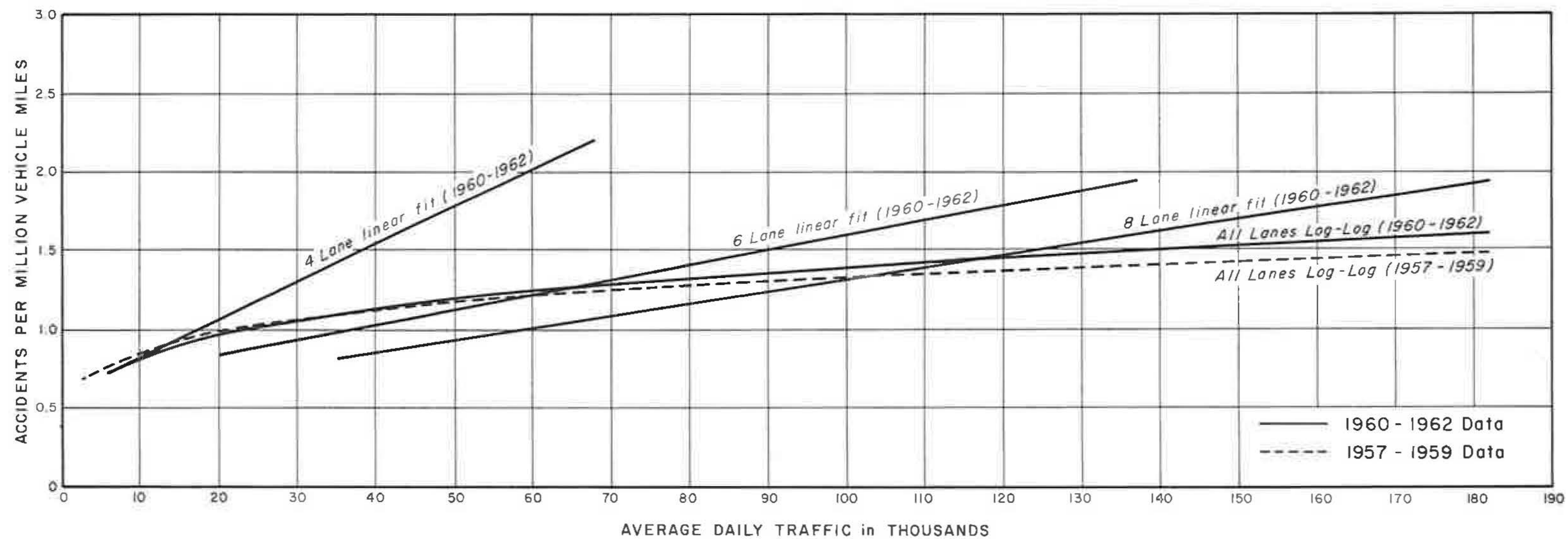

Figure 5. Linear fits (1960-1962) for all four, six, and eight lanes and log-log fits for all lanes (1960-1962 and 1957-1959).

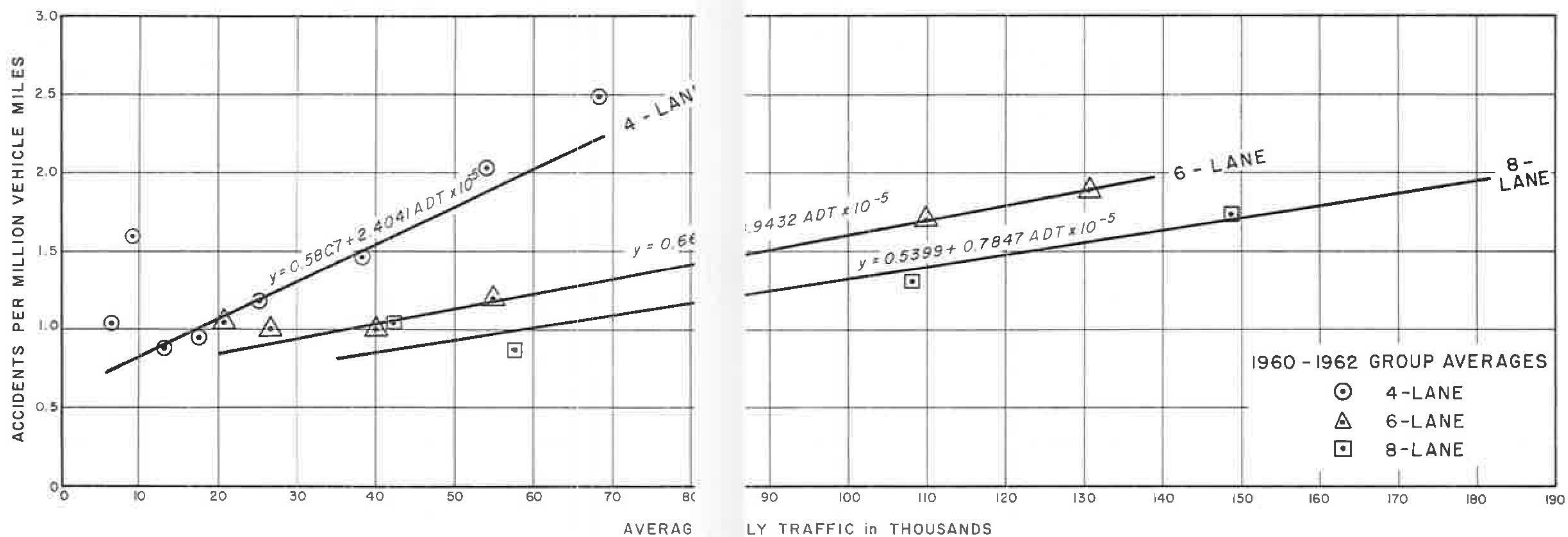

Figure 6. Linear fits and group averages 60-1962) for four-, six-, and eight-lane freeways.

method of least squares, using each individual freeway segment as a pair of coordinates (y = accident rate, x = ADT). Group average accident rates for several ADT groups (or class intervals of ADT) were superimposed on these curves for purposes of inspection.

Tables 2 through 4 are group average accident rates for each volume class and number of lanes. Each year is tabulated separately and then the 3 yr are combined in Table 5. The ADT class intervals are the same as those used in "Accidents on Freeways in California" (2). The original selection of the class intervals was such as to present six uniform intervals on the logarithmic scale between traffic volumes of 10,000 and 100,000 veh/day.

Figures 1 through 4 show the linear fits obtained through the results of a computer program. The program used also provided fits for four other types of curves along with the standard error of estimate for each type. Table 6 indicates the curve types and the standard errors. For all practical purposes, the linear fit proved as good as any other type and is by far the easiest to understand and work with.

The original curve (2) showing accident rate vs ADT was a log-log equation ($y = ax^b$) that combined the four-, six-, and eight-lane data (1957-1959) and provided the single curve shown in Figure 5. The (1960-1962) log-log equation is also plotted on Figure 5 along with the 1960-1962 four-, six-, and eight-lane linear fits. The lines tilt up when sorted by number of lanes, yet as a group they still approximate the original log-log form.

Figure 6 is a summary of all 3 yr of experience. The two most significant points of interest are apparent:

1. All other things being equal, the accident rate for a four-, six-, or eight-lane freeway will normally increase with an increasing ADT.
2. For any given ADT, a four-lane freeway would be expected to have a higher accident rate than a six-lane freeway and a six-lane a higher rate than an eight-lane freeway.

This phenomenon is apparently characteristic of total accident rates, but not of fatal accident rates. The curves or relationships between fatal accident rates and traffic volumes are not yet available. However, the trends seem to show a slight decrease in the fatal accident rate as the ADT increases.

If the future relationship remains consistent with the past, a sizable reduction in total accidents could be realized by providing more lanes. For example, if a proposed freeway has an estimated future ADT of 60,000 veh/day, it would generate about 22 MVM/mi/yr. Figure 6 shows a probable accident rate of 2.00 accidents per MVM for a four-lane freeway at this ADT. In raw numbers, this reduces to $22 \times 2 = 44$ accidents per mile per year. The six-lane accident rate at 60,000 would be about 1.23, or $1.23 \times 22 = 27$ accidents per mile per year. In other words, 17 accidents per mile per year could be prevented by building a six-lane freeway instead of a four-lane freeway. At this rate, the extra lanes would prevent $20 \times 17 = 340$ accidents per mile in 20 yr.

In this study alone, there were 92 mi of four-lane freeway in the 31,600 to 68,500 ADT range by 1962. If these freeways had been six-lane and if Figure 6 may be used to predict the probable accident rate, there would have been 1,425 accidents in 1962 as compared to the 2,269 accidents which actually occurred. If this rate were to continue for 20 yr (it is more likely to increase since the ADT is constantly increasing), there may be a possiblity of preventing 16,880 accidents in the 20-yr period by adding two lanes to the 92 mi of four-lane freeways.

The number of traffic lanes of a freeway is only one of many factors affecting the accident rate on the freeway. However, increasing the number of lanes, although not necessarily initially required by traffic volume demands, does reduce significantly the number of accidents on the freeway during its lifetime. Therefore, the possibility of providing the ultimate number of lanes on freeways should always be considered for initial construction whenever stage-type construction is contemplated.

REFERENCES

1. The Comparative Freeway Study. Calif. Div. of Highways, April 1964.
2. Accidents on Freeways in California. Theme IV. World Traffic Eng. Conf., 1961.

Discussion

JOHN VERSACE, Ford Motor Co.—The results of this study imply that freeway accidents can be reduced by increasing the number of lanes, even if the traffic volume does not call for such an increase. The accident rate on the larger freeways was less than might be expected because the traffic volume per lane was not reduced that much. However, these results may reflect the peculiarities of the sample as much as anything, so we should be conservative about the conclusions until there is independent evidence.

Although the data have been classified according to whether the freeway had four, six, or eight lanes, we must not rule out the possibility that other factors which covary with the size of freeway might be major causes of the results given. Is it certain that the freeways compared are similar in all respects other than the number of lanes? Is there any way in which the traffic is consistently different for the three types of freeway, as might result from urban vs suburban differences? Were the speeds comparable, on the average, for all the roads? Was the distribution of cars and trucks uniform? And most importantly, was the number of accesses per mile comparable?

It may be useful to scrutinize the data more completely by selecting matched triplets of four-, six-, and eight-lane segments, with the matching based on factors such as these. Or, if all else can be construed as remaining essentially equal, we could compare the before-and-after accident experience of roads that have been widened.

However, the results as they stand do invite some commentary. Why was there

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be one or more factors in addition to the mere change in traffic volume per lane. Traffic volume is a carrier, as it were, of traffic accidents; the more volume, the more opportunities for the conflicts and frictions which lead to accidents. But traffic friction can be caused by other things as well, and previous evidence indicates that the number of accidents increases where there are more conflicts or friction points.

The addition of the third lane produces a qualitiative change in driving behavior by increasing the driver's flexibility. However, additional lanes also increase the opportunities for friction by providing more opportunities for lane crossovers. Furthermore, brief spells of mental confusion and disorientation are more likely to occur to drivers who find themselves embedded in a sea of cars without the fixation point, or focus of orientation, provided by a nearby road edge.

The further reduction in accident rate on the eight-lane freeways was very small and statistically unreliable. The six-lane freeway may be the optimum size. Improvements in both volume and accident reduction might be better realized by multiplying the number of six-lane freeways, even if they are parallel and contiguous but not interacting, rather than by adding more lanes. Channeled traffic, which restricts passing and merging, is an important consideration and should be studied in terms of speed fluctuations.

Finally, this was a cross-sectional study which compared the accident rates on existing freeways. The implication that increasing the number of lanes on existing freeways will reduce accidents is an interpretation. The results of the study are perhaps necessary for such a conclusion, but they are not sufficient. Among other things, a widened freeway encourages greater use, thereby at least partially defeating itself.

STANLEY R. BYINGTON, U. S. Bureau of Public Roads. —In 1906, Sir Oliver Lodge noted in Easy Mathematics, "An equation is the most serious and important thing in mathematics." This review shows how important equations are in understanding relationships such as those described by Mr. Lundy. Treated here is an extension of Mr. Lundy's analysis including the effect on the accident-ADT relationships when a third parameter is introduced.

Recent research on a National Cooperative Highway Research Project (3) hypothesized and confirmed that the MVM rate does not adequately portray the risks associated with traveling along differently designed two-lane highways. The MVM rate does not eliminate the effect of mileage on crude accident data for conventional (uncontrolled-access) two-lane highways. In fact, it was shown that omission of the consideration of study segment length within ADT groupings does distort the MVM rate vs ADT relationship. Reported findings of the research showed that for segments of constant length, the true relationship is a slight decrease of rate with increased ADT, whereas the apparent relationship showed the reverse, i. e., an increase of the rate with increased ADT.

Because regression analysis, which excludes a segment length parameter, can influence and distort the MVM rate vs ADT relationship, an analysis similar to that conducted in the NCHRP study has been applied to Mr. Lundy's data. Regression equations were developed from already prepared computer programs to define a surface in log-log-log space that would pass through the data. The form of the regression equations utilized is actually an extension of the log-log equation ($y = ax^b$) plotted in Figure 5 of Mr. Lundy's report. The statistical relationship of segment length and traffic volume on the number of accidents was determined from the logarithmic transformation of the equation:

$$y = a x_1^{b_1} x_2^{b_2} \tag{1}$$

where

- x_1 = segment length (mi);
- x_2 = ADT (thousands of veh/day);
- y = number of accidents per year per segment; and
- a, b_1, b_2 = constants determined from data by method of least squares.

The regression calculations gave the estimate of the coefficients, a, b_1, and b_2 indicated in Table 7. The length elasticity coefficient b_1, is nearly the same and is less than unity, regardless of the number of freeway lanes. What this means is that for every 1 percent difference in segment length, there is a smaller percent difference in the number of accidents. For example, on 5-mi road segments, there are less than 5 times the number of accidents as on 1-mi road segments. This finding implies that inclusion of segment length in the denominator of an accident rate does not actually remove the effect of length. This is true unless segment lengths and their distribution are nearly the same for all ADT groupings. A question arises concerning what effect the coefficients given in Table 7 have on Mr. Lundy's statement that "... accident rates on freeways increase as the traffic volumes increase, and for a given traffic volume, the accident rates decrease as the number of lanes increase." The summary of the effects of the elasticity coefficients on the MVM rate is best shown pictorially.

TABLE 7

VALUES OF LOGARITHMIC EQUATION COEFFICIENTS[a]

No. of Lanes	a	b_1	b_2
4	-0.544	0.816	1.231
6	-1.139	0.856	1.483
8	-2.074	0.878	1.891

[a]Lundy's data.

Figure 7 illustrates that when the segment length is held constant and ADT increases, the MVM rate also increases.

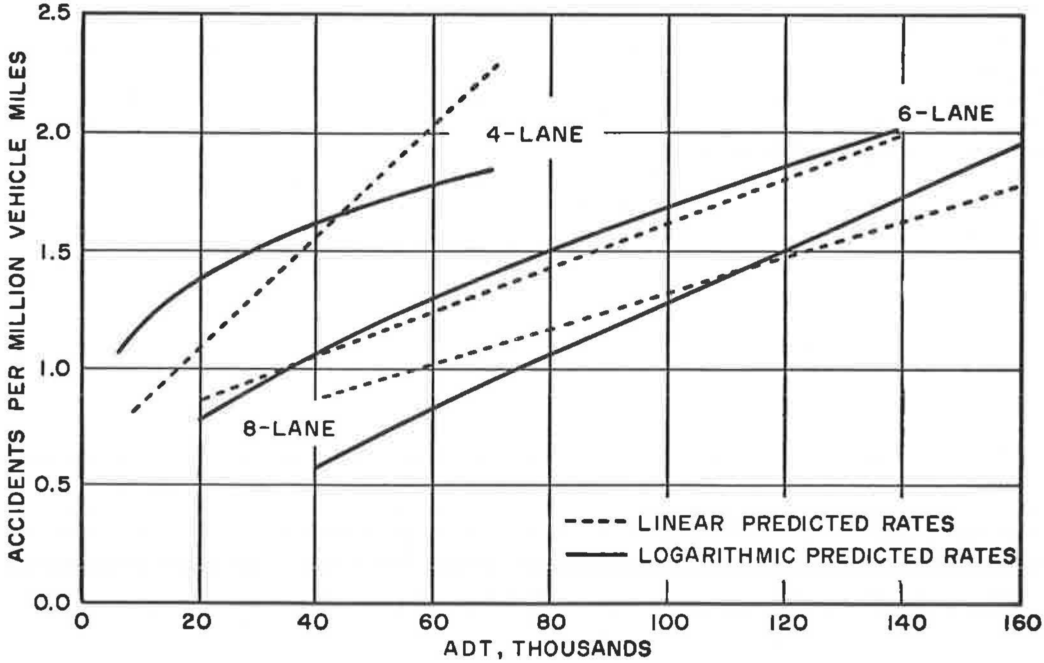

Figure 7. Accidents per MVM vs ADT, Lundy's data (2-mi study segments).

TABLE 8

AVERAGE SEGMENT LENGTHS BY TRAFFIC VOLUME AND NUMBER OF LANES[a]

Traffic Vol. (1,000)	Mean Segment Length (mi)	Frequency of Section	Traffic Vol. (1,000)	Mean Segment Length (mi)	Frequency of Section	Traffic Vol. (1,000)	Mean Segment Length (mi)	Frequency of Section
6-13.9	15.7	16	20-39.9	5.1	16	45- 66.9	4.4	11
14-17.9	14.7	16	40-52.9	5.3	17	67- 98.9	3.1	12
18-24.9	6.8	17	53-72.9	7.7	17	99-127.9	5.0	12
25-29.9	8.7	17	73-98.9	5.7	17	128+	4.7	10
30-40.9	7.6	16	99+	5.0	15			
41+	3.6	16						

[a]Lundy's data.

TABLE 9

LOGARITHMIC PREDICTED ACCIDENT RATES PER MVM, SIX- AND EIGHT-LANE FREEWAYS[a]

Segment Length (mi)	Accidents per MVM[b]							
	Six Lanes				Eight Lanes			
	25 ADT	50 ADT	75 ADT	100 ADT	60 ADT	90 ADT	120 ADT	150 ADT
2	85	119	145	167	81	116	150	184
4	77	108	132	150	75	107	138	179
6	72	101	124	142	71	102	131	161
8	70	98	119	137	68	98	127	155

[a]Lundy's data. [b]For ADT groups in thousands.

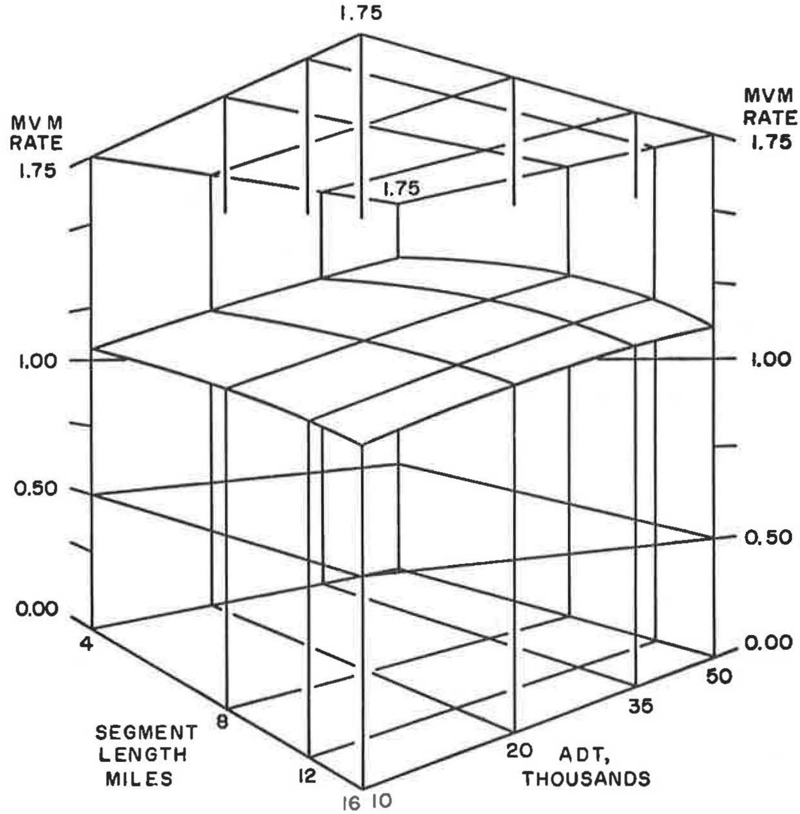

Figure 8. Logarithmic predicted accident rate per MVM, four-lane freeways, Lundy's data.

This figure also shows that for the same segment length and for a given traffic volume, the accident rate decreases as the number of lanes increase. Using Mr. Lundy's example of a proposed freeway with an estimated future ADT of 60,000 veh, Figure 7 indicates that for four- and six-lane highways the logarithmic regression curves predict probable accident rates of 1. 77 and 1. 30 accidents per MVM, respectively. The accident savings would then be 10 accidents per mile per year [(1. 77 - 1. 30) accid. / MVM × 22 MVM] rather than the 17 found by Mr. Lundy. As the logarithmic curves in Figure 7 are for constant segment lengths of 2 mi, there is the problem of how the accident savings vary when other segment lengths are used. For 4-, 8-, and 12-mi segments, the computed savings amounted to 8, 7 and 6 accidents per mile per year, respectively. Resultant differences in accident savings as predicted by the linear and logarithmic equations decrease for ADT values less than that used in this example. Thus, Mr. Lundy's statements on the effect of the number of lanes and ADT on accident rates are sufficiently accurate for those volumes below which additional lanes are not normally justified by the traffic volume demand, i. e., 50, 000 ADT for four lanes and 75, 000 for six lanes.

Two additional observations can be derived from Figure 7. First, regardless of the length segment, the accident savings predicted by the logarithmic equations remain nearly constant for all ADT values. Second, this figure shows the effect of unequal segment lengths within different ADT groupings: whereas the logarithmic curves closely approximate the linear curves for the six- and eight-lane freeways, there is an evident difference between the four-lane freeway curves. This is explained by the data given in Table 8, the ADT groupings of which were selected to yield as equal a frequency of study segments as possible. There is a distinct decreasing of average segment lengths for the four-lane freeway segments studied by Mr. Lundy, whereas the segment lengths are nearly the same for all ADT groups of six- and eight-lane freeway segments studied.

Because Figure 7 offers a limited view of the combined effect of segment length and ADT on the MVM rate, Figure 8 is presented to show for four-lane freeways the MVM rate as a surface above an ADT-length base. The height of the surface above a set of segment length-ADT coordinates indicates the accident rate; the higher the surface, the higher is the rate. This figure reveals that the accident rate decreases with increased segment length and increases with ADT. Table 9 indicates that figures for six- and eight-lane freeways would have produced similar surfaces.

Reference

3. Kihlberg, J. A., Campbell, B. J., and Tharp, K. J. Analysis of Motor Vehicle Accident Data as Related to Highway Classes and Design Elements. Cornell Aeronautical Lab., Aug. 1964.

JOSEPH S. CHAMPAGNE, Port of New York Authority. —Many factors contribute to accidents on our highways. Generally these are alignment, cross-section, access control, the driver, the weather, and highway capacity. Mr. Lundy has pointed out that accident rates increase with increased traffic volume and that accidents are proportional to traffic volumes. The signficant difference between a four-, six-, or eight-lane freeway is the rate at which the accident rates increase. Four lanes had a rate of increase of 0.24 accidents per MVM, six lanes of 0.094 accidents per MVM, and eight lanes of 0.078 accidents per MVM.

[illegible]

This is due to the number of traffic lanes and the other factors previously mentioned. Also, passing opportunities are more frequent on six- and eight-lane highways than on the four-lane highway, which in part contribute to lower accident rates on the six- and eight-lane highways. The additional lanes reduce the motorist's need to take unnecessary risks.

Going one step further, I compared accident rate and ADT to highway capacity (Figs. 9 and 10, Table 10). The basic data were obtained from Figure 6.

In Mr. Lundy's example of a freeway with an estimated future ADT of 60,000 veh/day, the four-lane facility was estimated at 100 percent capacity and the six- and eight-lane facilities were estimated at 65 percent and 50 percent of capacity, respectively. It is assumed that 10 percent of ADT volume is equivalent to the peak hour volume and the practical capacity is 1,500 veh/lane/hr (4). Tables 11, 12 and 13 give accident numbers and rates when all the facilities have reached 100 percent capacity and when the four-lane facilities are at 100, 65 and 50 percent of capacity.

The results of the example, given in Table 11, indicate fewer accidents on the six- and eight-lane facilities than on the four-lane. But the six- and eight-lane facilities are only operating at 65 and 55 percent of capacity. Table 12 indicates that when facilities are operating at 100 percent capacity, there is little difference in the number of accidents per mile per year. Table 13 gives the effect on accidents when the four-lane facilities are operating at and below capacity. The accident rate is virtually the same for the six- and eight-lane facilities when they are operating at the same percent of capacity.

Mr. Lundy's paper emphasizes the fact that we should not wait for a facility to become a parking lot before we decide to expand. We should continually monitor our facilities whether they be two, four, six, eight or ten lanes and be prepared to act before the accident rate increases above the 100 percent capacity rate. As his example

TABLE 10

DATA ON FOUR-, SIX-, AND EIGHT-LANE HIGHWAYS[a]

ADT (1,000)	Four Lanes		Six Lanes		Eight Lanes	
	Capacity (%)	Accident Rate per MVM	Capacity (%)	Accident Rate per MVM	Capacity (%)	Accident Rate per MVM
10	16.6	0.82	11.1	-	8.3	-
20	33.20	1.08	22.2	0.86	16.6	-
30	49.80	1.31	33.3	0.94	24.9	-
40	66.40	1.55	44.4	1.04	33.2	0.85
50	83	1.80	55.5	1.13	41.5	0.94
60	99.60	2.03	66.6	1.23	49.8	1.02
70	116.20	2.27	77.7	1.32	57.5	1.09
80	132.80	-	88.8	1.41	66.4	1.16
90	149.40	-	99.9	1.50	74.7	1.24
100	166	-	111.0	1.60	83	1.31
110	182.60	-	122.1	1.70	91.3	1.40
120	199.20	-	133.2	1.80	99.6	1.48
130	215.80	-	144	1.88	108	1.56
140	232	-	156	1.98	116.2	1.63
150	249.0	-	167	-	124.5	1.71
160	265.6	-	178	-	132.8	1.78
170	282.2	-	189	-	142	1.87
180	298	-	200	-	150	1.94

[a]ADT and accident rate taken from Figure 6 of Lundy's report.

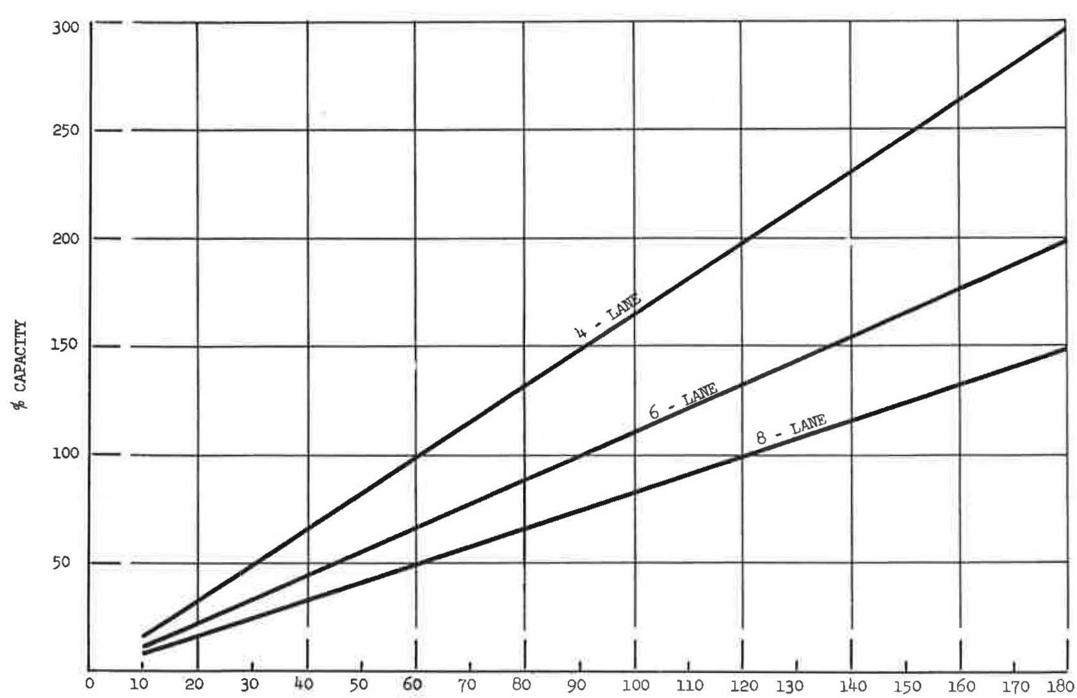

Figure 9. Percent capacity vs ADT for four-, six-, and eight-lane freeways.

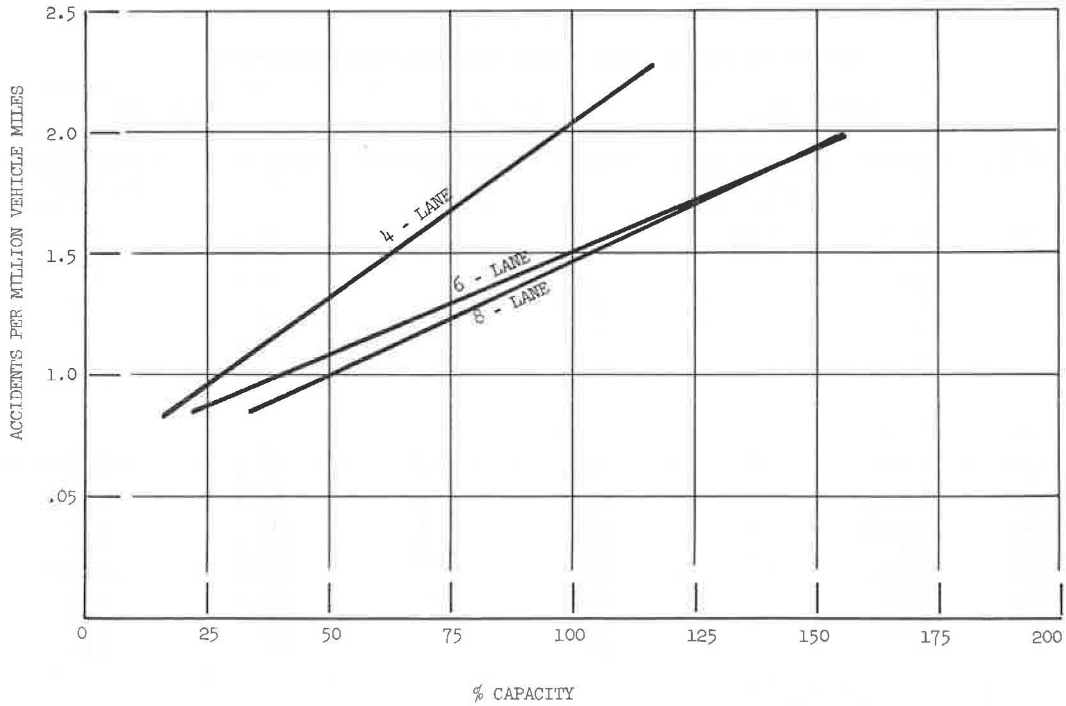

Figure 10. Accidents per MVM vs capacity for four-, six-, and eight-lane freeways.

No. of Lanes	Capacity (%)	Accident Rate	No. Accidents/Mi/Yr
4	100	2.2	44
6	65	1.2	14
8	50	1.15	13

[a] ADT = 60,000 veh, 22 veh-mi/mi/yr.

No. of Lanes	ADT (1,000)	Accident Rate	MVM/Mi/Yr	No. Accidents/Mi/Yr
4	60	2.2	22	44
6	90	1.5	32	48
8	120	1.45	43	62

TABLE 13

FOUR-LANE HIGHWAY AT VARIOUS CAPACITIES

Capacity (%)	ADT (1,000)	Rate	MVM/Mi/Yr	No. Accidents/Mi/Yr
100	60	2.2	22	44
65	40	1.5	14.6	21
50	30	1.0	11	11

shows, we should not permit highways to exceed capacity because of the increase in the number of accidents and also because of the increase in delays and the inability of the facility to handle unusual increases in peak hour volumes.

Reference

4. Geometric Highway Design. Table II-9, p. 86. AASHO.

R. A. LUNDY, Closure—Mr. Versace, Mr. Byington, and Mr. Champagne have presented interesting and valuable discussions of this report. These ideas will serve as useful reference in future research of this nature.

One of the questions raised by Mr. Versace concerns the basic data used in the study. It is granted, as Mr. Versace explained, that the freeways studied were not exactly equal in every respect other than in the number of lanes; however, from a practical standpoint, it would be difficult to say that they are significantly different. Every effort was made to exclude abnormalities from the data.

It was suggested that matched triplets of four-, six-, and eight-lane segments be studied in lieu of massing data which was the method of this study. These triplets, matched in design, volume content, weather conditions, driver traits, etc., are extremely difficult to find and in the final analysis it would probably be necessary to build models to specifications, which, of course, is impractical. If the models did exist, they would be equal in ADT and hence no ADT vs rate relationship would be obtained.

Mr. Versace surmised that the six-lane freeway may be the optimum size. This interpretation cannot be drawn from the California report; the evidence points to exceptionally low accident rates on eight-lane freeways and there is no evidence that drivers become "lost in a sea of cars" when operating on an eight-lane facility. On the contrary, eight-lane freeways provide far more passing opportunities (hence, less lane blockage) and greater areas for emergency maneuvers. If these lanes were channelized with curbing or some other physical barrier, this advantage would be lost and accident concentrations would no doubt occur at those locations where cross-over is permitted.

The National Cooperative Highway Research Project (3), which formed the backbone of Mr. Byington's discussion, utilized 1961-1962 California (conventional two-lane) data in the development of the accident rate vs segment length relationship. These data were obtained from routine annual tabulations (TS-5.0 tables) produced by the California Division of Highways. In October 1964, the division was asked to comment on the project and those comments pertinent to the accident rate vs segment length relationship were as follows:

> Each highway segment shown in the TS-5.0 tabulations is homogeneous in respect to number of lanes, access control, and whether divided or not; but it is not necessarily homogeneous in respect to traffic volume; i.e., the range of traffic volume within a section may be very large. Since one of the primary factors that the Laboratory, and we independently, have found to affect accident rates or numbers is the magnitude of traffic volumes, the Laboratory findings in this respect may have large errors. The magnitude or direction of these probable errors are unknown and a great deal of analysis would be required to determine them.
>
> The Laboratory further found that the accident rate and accident numbers are related to the segment length. This is undoubtedly true and as the Laboratory pointed out, it is probably due to the fact that the shorter homogeneous highway sections usually contain those roadside and highway geometry features which are normally associated with accident causation. In using the relationships that have been established for the prediction of accidents for a particular section of highway, one must remember to enter the report graphs or tables with the maximum highway segment length which is homogeneous in all respects and which includes the piece of highway under consideration. Otherwise, if the length of the piece under consideration only is used, the curves or tables will be entered at an accident rate portion of the data which is too high.

These comments were, of course, based on the study containing only two-lane conventional highway data. Mr. Byington's application utilized four-, six- and eight-lane California freeway data and the ADT is quite stable within these segment lengths; however, the segment lengths were created for a number of reasons besides ADT, including legislative boundaries which certainly do not affect the accident rate. Many of the sections do, however, terminate at some distinctly different type of facility or the break is introduced at a point of major volume change. These end conditions could, and probably do, affect the accident rate on shorter sections. However, the California data must be reworked and broken into nonbiased sections before accurate distance coefficients can be calculated.

Mr. Champagne's application of the study data is interesting and informative. The significance of his comment, "Table 12 indicates that when all facilities are operating at 100 percent capacity, there is little difference in the number of accidents per mile per year," is not clear. The statement is correct; however, it should be pointed out that the six-lane freeway is allowing 50 percent (and the eight-lane, 100 percent) more vehicles to use the freeway without accident.