Comparative Freeway Study

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Thirty-three sections (200 mi) of freeways with widely divergent accident rates were analyzed. A total of 11,384 accidents were included. These accidents occurred during the course of 9,198 million vehicle-miles (MVM) of travel. The average accident rate for the 33 sections is 1.24 accidents per MVM. The accident rates for the individual sections range from 4.52 to 0.60 accidents per MVM.

The primary purpose of the first part of the study was to obtain information concerning freeway design characteristics as related to accident frequency. The emphasis is on the relative safety value of the various design features. Human factors were considered homogeneous throughout the sections unless they obviously played an unusual role in a section's accident history. The second part attempted to analyze each section and explain why that section had an unusually good or poor accident history.

•FOR STUDY purposes, freeways are broken down into various lengths called sections. These sections are either geographically separate or section breaks are established by virtue of a change in traffic volume, accident rate, design characteristics, or year built.

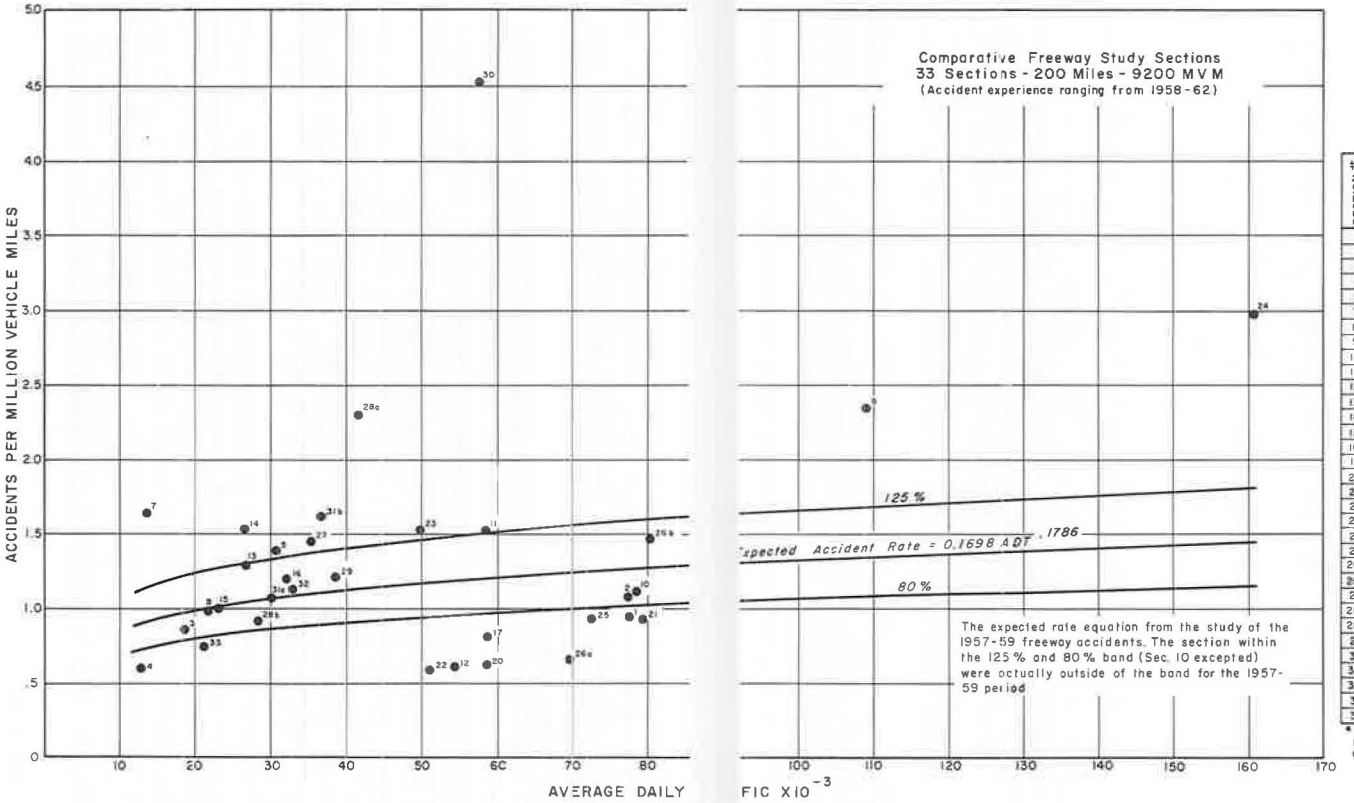
Many sections of freeway have accident rates that vary significantly from the expected rate. This was discovered by a freeway accident-rate study by this Department in 1961, using data for 1957 to 1959, inclusive (1). In the previous study the expected accident rate was defined by the equation $R = 0.17 V^{0.18}$, where R is the expected rate and V is the average daily traffic. If a freeway accident rate fell within 25 percent above or 20 percent below the expected rate, it was considered average. Those sections of freeway with accident rates that did not fall within these limits were considered to have a significant variation and were taken as subject matter for this comparative freeway study (Figs. 1 and 2).

The study reported here was initiated as an attempt to learn what factors in the non-average freeway sections were responsible for the higher or lower accident rates. Human factors were considered homogeneous throughout the sections unless they obviously played an unusual role in a section's accident history. In this report the emphasis is on the relative safety value of various design features.

A pilot study, involving sections 1 to 14, inclusive, was first made to determine the best approach to the study problems. A 3-yr period of accident experience, 1958 to 1960, was used. On completion of the pilot study, more recent data were available for the remaining sections and the period 1959 to 1961 was used with the exception of sections 16, 29, 30, 31, and 33 (Table 1).

The earlier study revealed 31 out of 94 sections as non-average. Accident rates based on the more recent data showed eleven of these sections actually possessed average accident rates according to the expected rate equation. That is to say, eleven of the sections that had been thought widely variant actually turned out to be normal, when greater experience became available. Even among the other 20 sections, the low rates increased and the high rates decreased, approaching the average as more experience accrued. The "expected-rate" equation was calculated from 1957 to 1959 data

Paper sponsored by Committee on Highway Safety.



SECTION #	1957-1959 DATA			STUDY PERIOD DATA		
	ACTUAL ACC./MVM	EXPECTED ACC./MVM	% OF EXPECTED	ACTUAL ACC./MVM	EXPECTED ACC./MVM	% OF EXPECTED
1	0.79	1.30	61	0.95	1.26	75
2	0.73	1.30	56	1.09	1.26	86
3	0.73	0.95	77	0.86	0.98	87
4	0.66	0.90	73	0.80	0.90	67
5	1.53	1.10	139	1.38	1.07	129
7	1.65	0.90	183	1.64	0.92	178
8	0.63	1.10	57	0.98	1.00	98
9	1.96	1.30	151	2.35	1.35	174
10	1.48	1.25	118*	1.12	1.26	89
11				1.51	1.20	126
12	0.46	1.20	38	0.62	1.18	52
13	1.78	1.10	178	1.29	1.03	125
14	1.72	1.10	156	1.52	1.03	148
15	0.51	1.00	51	1.00	1.01	99
16	0.48	1.00	48	1.20	1.07	112
17	0.74	1.20	62	0.82	1.20	68
20	0.51	1.20	43	0.63	1.20	53
21	0.58	1.20	48	0.94	1.27	74
22	0.38	1.20	32	0.60	1.17	51
23	1.54	1.20	128	1.52	1.16	131
24	1.45	0.95	153	2.98	1.44	206
25				0.94	1.25	75
26a	0.77	1.25	62	0.66	1.24	53
26b				1.47	1.27	116
27	1.49	1.10	135	1.45	1.10	132
28a	1.88	1.10	171	2.30	1.13	204
28b				0.91	1.05	87
29	0.58	1.10	53	1.21	1.12	108
30	2.08	1.20	173	4.52	1.20	376
31a	1.42	1.10	142	1.07	1.06	101
31b				1.62	1.10	147
32	1.55	1.10	141	1.13	1.08	104
33	0.33	0.95	32	0.75	0.99	76

* This portion included in study due to the known unusual nature of the alignment.

Figure 1. Accide ate vs average daily traffic.

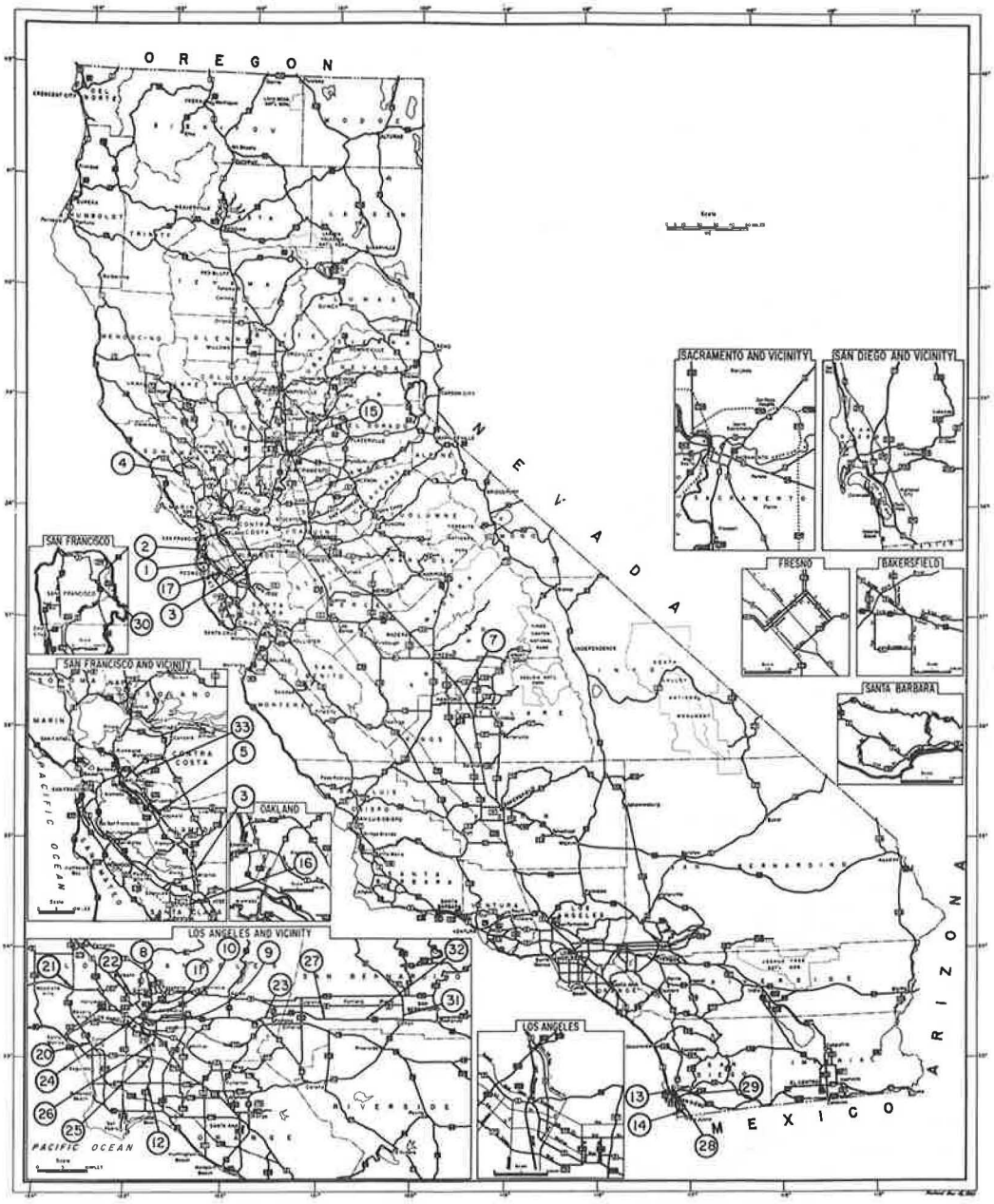


Figure 2. Study section locations.

and it is understandable that some of the sections possess accident rates that fluctuate from year to year in this manner. Some of these sections were completed and open to traffic for only a short time during the 1957 to 1959 period.

The study is divided into two parts. The first is intended as a guide to the type and range of variables encountered in a study of this nature. The various tables and graphs represented only the sections which are encompassed by this study. The limitations will no doubt be evident as each concept presented could well be a major study in its own right. The intent here is to point out some of the variables and develop a broad

TABLE 1

COMPARATIVE FREEWAY STUDY SECTIONS

Section No.	Description	Study Period	Comments
1	Bayshore Fwy.; SM-68-Var Bransten Rd. to N.C.L. of S. San Francisco	1958-1959-1960	
2	Bayshore Fwy.; SM, SF-68-Var. N.C.L. of S. San Francisco to 3rd St. in San Francisco	1958-1959-1960	
3	Nimitz Fwy.; Ala, SCl-69-SJs, A Rt. 68/69 separation to Warm Springs separation (Rt. 5)	1958-1959-1960	
4	Petaluma Fwy.; Son-1-F, C 2.23 mi N. of Marin Co. line to S.C.L. of Santa Rosa	1958-1959-1960	
5	Castro Valley Link; Ala-228-A, SLn. Rt. 69 to jct. Rt. 5	1958-1959-1960	
6	No section		
7	U.S. 99; Tul-4-F Visalia Airport interchange to 1 mi N. of Goshen	1958-1959-1960	
8	Colorado Fwy.; LA-161-LA, Pas, S.Pas Eagle Vista Dr. to Holly St.	1958-1959-1960	
9	Pasadena Fwy.; LA-165-LA 4-level structure to jct. Rt. 205	1958-1959-1960	
10	Pasadena Fwy.; LA-205-Pas, S.Pas. Jct. Rt. 165 to Ave. 64	1958-1959-1960	
11	Pasadena Fwy.; LA-205-Pas, S.Pas. Ave. 64 to Orange Grove Ave. interchange	1958-1959-1960	
12	Long Beach Fwy.; LA-167-LBch, A, Com, Lyn, SGt. Pacific Coast Highway to Atlantic Blvd.	1958-1959-1960	
13	Balboa Bypass; SD-2-SD 1 mi. S. of Balboa Ave. to 0.65 mi. N. of Balboa Ave.	1958-1959-1960	
14	Montgomery Fwy.; SD-2-SD, ChV, G, NatC. San Ysidro junction to S.C.L. of National City	1958-1959-1960	
15	Roseville Fwy.; Sac;Pla-3;3, 17-B;A, A, Rsv. Howe Ave. in Sac. Co. to N. of Atlantic St. in Placer Co.	1959-1960-1961	Portion of section open Jan. 1960 (2,000 ft E. of Folsom Rd. to N. of Atlantic St.), 1.7 mi
16	Los Gatos Fwy.; SCl-5;239-LGts, D, Cmb, SJs;D, SJs. Santa Cruz Ave. to The Alameda	1960-1961	Not open full year of 1959; portion of section open June 1960 (Bascom Ave. to The Alameda), 1.0 mi.
17	Bayshore Fwy.; SM-68-D, MlP, RdwC. Santa Clara Co. line to Bransten Rd.	1959-1960-1961	
18	No Section		
19	No section		
20	San Diego Fwy.; LA-158-ClC, LA, A Approx. 0.2 mi N. of Venice Blvd. to Ovada Pl.	1959-1960-1961	Most of section open Feb. 1959 (0.2 mi N. of Venice Blvd. to 0.5 mi N. of
22	Golden State Fwy.; LA-161;4-LA;Gndl, LA Glendale Blvd. to Burbank Blvd.	1959-1960-1961	Part of section opened Aug. 1959 (Alameda St. to Burbank Blvd.), 1.3 mi
23	San Bernardino Fwy.; LA-26-Cla, Pom, C, W.Cov. San Bernardino Co. line to Citrus Ave.	1959-1960-1961	
24	Harbor Fwy.; LA-165-LA 30th St. to 4-level structure	1959-1960-1961	
25	Long Beach Fwy.; LA-167-Com, A, Lyn, SGt. Atlantic Ave. to Firestone Blvd.	1959-1960-1961	
26a	Long Beach Fwy.; LA-167-Bell, B, Ver. Firestone Blvd. to N. jct. Atlantic Blvd.	1959-1960-1961	
26b	Long Beach Fwy.; LA-167-Bell, B, Ver, Cmrc. N. jct. Atlantic Blvd. to Olympic Blvd.	1959-1960-1961	
27	San Bernardino Fwy.; SBd-26-Mcl, Upl, Ont, D Live Oak Ave. to Los Angeles Co. line	1959-1960-1961	Part of section open Aug. 1959 (500 ft W. of Turner Ave. to 800 ft W. of Milliken Ave.), 1.7 mi
28a	U.S. 395; SD-77-SD N. of jct. Rt. 200 to Genesee Ave.	1959-1960-1961	
28b	U.S. 395; SD-77-SD Genesee Ave. to Clairmont Mesa Blvd.	1959-1960-1961	
29	S.S. Rt. 94; SD-200-SD, A W. of 25th St. O.C. to E. of Palm Ave.	1960-1961-1962	1959 data not used because part of section (W. of 25th St. to 32nd St.) not open until Dec. 1959, 1.9 mi
30	Central Fwy.; SF-2-SF Jct. Rt. 68 to Turk St.	1960-1961	Not open full year of 1959
31a	Riverside; SBd-43-F, Col, SBd. Riverside Co. line to jct. Rt. 26 & 650 ft S. of Mill St. to jct. Rt. 31	1960-1961	Not open full year of 1959
31b	Riverside Fwy.; SBd-43-F, Col, SBd. Jct. Rt. 26 (San Bernardino Fwy.) to 650 ft S. of Mill St.	1960-1961	Not open full year of 1959
32	San Bernardino Fwy.; SBd-26-D, Ria, Col. 5th St. in Colton to Live Oak Ave.	1960-1961	Not open full year of 1959; 2.1 mi portion (Live Oak Ave. to Cypress Ave.) not open until March 1960
33	Warren Fwy; Ala-227-Oak Redwood Rd. to Thornhill Dr.	1960-1961	Portion of section not open until March 1960 (Lincoln Ave. to Redwood Rd.), 0.97 mi

TABLE 2 - SUMMARY OF DATA

Group	Section	Freeway	Location	Length (mi.)	ADT	No. of Lanes	Lane Width	Median Width	Paved Shldr. Lt.	Paved Shldr. Rt.	Total Acc.	MVM	Actual Acc/MVM	Expected Acc/MVM	% of Expected
HIGH ACCIDENT SECTIONS	50	Central	SF-2-SF Jct. Rte. 68 to Turk St.	1.47	57,800	4 & 8	12'	Double Deck	2'	2'	280	62	4.52	1.20	376
	24	Harbor	LA-165-LA 30th St. to 4-Level	3.20	160,700	8	12'	Curbed 12-16'	2'	6'	1675	563	2.98	1.44	206
	26a	U.S. 395	SD-77-SD No. of Jct. Rte. 200 to Genesee Ave.	4.75	41,300	4	12'	12 & 16' Curb to 34'	2'	6'	494	215	2.30	1.13	204
	7	U.S. 99	Tul-4-F Visalia Airport Interchange to 1 mi. No. of Goshen	3.67	13,700	4	12'	46'	2'	6'	90	55	1.64	0.92	178
	9	Pasadena	LA-165-LA 4-Level St. to Jct. Rte. 205	1.90	106,100	4 & 6	4-12' 2-11' / 4-11' 4-10'	4' Sep. Ave.	2'	Some 5' [illegible]	533	227	2.35	1.35	174
	14	Montgomery	SD-2-SD, ChV, C, NatC San Ysidro Jct. to S.C.L. National City	9.16	26,300	4	12'	36-40'	5'	8'	400	264	1.52	1.03	148
	31b	Riverside	SBd-43-F Col, SBd Jct. Rte. 26 (Ebd. Fwy) to 650' So. of Mill St.	2.25	36,500	4	12'	44'	2'	10'	97	60	1.62	1.10	147
	27	San Bernardino	SBd-26-Mtl, Upl, Ont, O Live Oak Ave. to L.A.-S.B. Co. Line	13.56	35,100	4	12'	16-46'	2-8'	8-10'	757	522	1.45	1.10	132
	23	San Bernardino	LA-26-Cts, Pom, C, W.Cov S.B. Co. Line to [illegible] St.	11.12	46,900	8	12'	16'	2'	8'	922	606	1.52	1.16	131
	5	Castro Valley Link	Ala-228-A, SLe Rte. 68 to Jct. Rte. 5	2.05	30,700	4	12'	Curbed 16'	2'	8'	95	69	1.38	1.07	129
	11	Pasadena	LA-205-Pas, S Pas Ave. 64 to Orange Grove Ave. Interch.	1.10	58,100	6	4-11' 2-10'	6'	2'	2'	106	70	1.51	1.20	126
	13	Balboa Bypass	SD-2-SD [illegible] to 0.65 mi. No. of Balboa Ave.	1.65	26,600	4	12'	Variable	2'	8'	82	65	1.29	1.03	125
		Total or Average		55.90							3511	2763	1.99		
AVERAGE ACCIDENT SECTIONS	269	Long Beach	LA-167-Bell, B, Ver, CmrC No. Jct. Atlantic Blvd. to Olympic Blvd.	1.54	80,000	6	12'	40'	2'	8'	199	135	1.47	1.27	116
	16	Los Gatos	SCl-5,239-LGts, [illegible] Santa Cruz Ave. to [illegible]	10.20	32,000	4	12'	34-46'	2'	8'	286	238	1.20	1.07	112
	29	S.S.R. 94	SD-200-SD, a West of 29th St. O.C. to E. of Palm Ave.	8.52	36,800	6	12'	66'	2-8'	8-10'	449	372	1.21	1.12	108
	32	San Bernardino	SBd-26-[illegible] to Live Oak Ave.	8.23	33,000	4	12'	46-64'	2'	8'	222	197	1.13	1.08	104
	31a	Riverside	SBd-43-F Col, SBd Riverside Co. Line to Jct. Rte. 26 & 650' So. of Mill St. to Jct. Rte. 31	6.30	30,000	4 & 6	12'	56'	2'	10'	148	138	1.07	1.06	101
	15	Roseville	Sac, Pla-3,4,17-[illegible] Hawk Ave. in Sac. Co. to No. of Atlantic St.	14.40	23,000	4	12'	36'	2'	8'	359	359	1.00	1.01	99
	8	Colorado	LA-161-LA, Pas, S Pas Eagle Vista Dr. to Holly St.	2.00	21,900	4	12'	12' Curb to 36'	2'	8'	47	48	0.98	1.00	98
	10	Pasadena	LA-205-Pas, S Pas Jct. Rte. 165 to Ave. 64	3.50	78,500	6	11'	6'	2'	2'	337	301	1.12	1.26	89
	26b	U.S. 395	SD-77-SD Genesee Ave. to Clairemont Mesa Blvd.	3.75	28,200	4	12'	12 & 16' Curb to 34'	2'	6'	106	116	0.91	1.05	87
	3	Nimitz	Ala, SCl-69-SLe, A Rte. 58/105 Sep. to Warm Springs Sep.	7.75	18,300	4	12'	40'	2'	8'	134	155	0.86	0.98	87
	2	Bayshore	SM, SF-68-Ver N.C.L. of So. San Francisco to 3rd St. in S.F.	3.20	77,100	6	12'	12' Curb to 38'	2-5'	8'	294	270	1.09	1.26	87
		Total or Average		69.39							2581	2329	1.11		
LOW ACCIDENT SECTIONS	33	Warren	Ala-227-Oak Redwood Rd. to Thornhill Rd.	2.64	21,000	4	12'	36-40'	2-5'	8'	30	40	0.75	0.99	76
	1	Bayshore	SM-68-Ver Broadway Rd. to N.C.L. of So. San Francisco	13.80	77,500	6	12'	36'	2-6'	8'	1271	1341	0.95	1.26	75
	23	Long Beach	LA-167-Com, A, Lyn, SGF Atlantic Ave. to Firestone Blvd.	4.98	72,400	8	12'	40'	2'	6'	370	393	0.94	1.25	75
	21	Ventura	LA-2-LA Jct. Rte. 158 (S.D. Fwy) to Louise Ave.	2.73	79,300	6	12'	22'	8'	8'	222	237	0.94	1.27	74
	17	Bayshore	SM-68-[illegible] Santa Clara Co. Line to Bransten Rd.	7.90	58,800	6	12'	60'	2'	8'	415	509	0.82	1.20	68
	4	Petaluma	Son-1-P, C 2.23 mi. No. of Mrn. Co. Line to S.C.L. of Santa Rosa	20.10	12,900	4	12'	44'	5'	8'	171	284	0.60	0.90	67
	26a	Long Beach	LA-167-Bell, B, Ver Firestone Blvd. to No. Jct. Atlantic Blvd.	3.22	69,800	6	12'	40'	2'	8'	163	246	0.66	1.24	53
	20	San Diego	LA-158-CIC, LA, A [illegible] mi. No. of Venice Blvd. to [illegible]	5.00	38,500	8	12'	22'	6'	10'	200	320	0.63	1.20	53
	12	Long Beach	LA-167-[illegible] Pacific Coast Hwy. to Atlantic Blvd.	6.83	54,300	6	12'	16' Curb to 43'	2'	8'	250	405	0.62	1.18	53
	22	Golden State	LA-161-A-LA, Glen, LA Glendale Blvd. to Burbank Blvd.	5.98	51,000	6 & 8	12'	22'	6'	10'	200	331	0.60	1.17	51
		Total or Average		75.16							3292	4106	0.80		
		Grand Total or Average		200.45							11,384	9158	1.24		

Section	RAMPS: On Ramps No. of Ramps	On Acc.	On MV	On Acc./MV	Off Ramps No. of Ramps	Off Acc.	Off MV	Off Acc./MV	Total Ramps	Total Acc.	Total MV	Total Acc./MV	WITHIN INTERCHANGE: Length	% of Total	Total Acc.	Ramp Acc.	Main Line Acc.	MVM	M. Line Acc./MVM	BETWEEN INTERCHANGE: Acc.	MVM	Acc./MVM	ALIGNMENT: % Align. on Curve Under 5000' R	% Align. on Grade Over 2%	Min. Curve Radius	Max. Grade (%)
50	4	22	51.2	0.43	2	31	28.6	1.08	6	53	79.8	0.66	Not Readily Available										30		600	
24	13	105	186.5	0.56	11	203	185.6	1.11	24	308	372.1	0.83											34	26	2000	5
26a	16	72	69.7	1.03	15	63	79.5	0.79	31	135	149.2	0.90	1.99	41.9	432	135	297	114	2.61	62	101	0.61	41	71	800	6
7	8	10	11.2	0.89	8	11	5.3	2.08	16	21	16.5	1.27	1.82	49.6	67	21	46	27	1.70	23	26	0.82	43	—	—	—
9	9	38	63.3	0.60	8	148	63.5	2.33	17	186	126.8	1.47	—	—	—	—	—	—	—	—	—	—	33	—	—	—
14	22	28	31.5	0.89	21	32	27.4	1.17	43	60	58.9	1.02	4.06	44.3	186	60	126	115	1.10	214	149	1.44	14	—	—	—
31b	8	5	13.9	0.36	8	37	14.7	2.52	16	42	28.6	1.47	—	—	—	—	—	—	—	—	—	—	42	22	2500	4
27	21	46	30.2	1.52	22	44	31.4	1.40	43	90	61.6	1.46	—	—	—	—	—	—	—	—	—	—	13	9	3500	4.5
23	22	81	42.4	1.91	23	49	49.4	0.99	45	130	91.8	1.42	4.56	41.2	550	130	420	260	1.65	364	348	1.05	27	35	2000	5.8
5	4	2	10.3	0.19	5	14	13.7	1.02	9	16	24.0	0.67	0.77	37.6	39	16	23	26	0.88	56	43	1.30	36	—	—	—
11	1	0	0.7	0	2	0	2.0	0	3	0	2.7	0	—	—	—	—	—	—	—	—	—	—	38	—	—	—
13	3	2	3.8	0.53	4	8	11.6	0.69	7	10	15.4	0.65	—	—	—	—	—	—	—	—	—	—		—	—	—
Total or Average	131	411	516.7	0.80	129	640	510.7	1.25	260	1051	1027.4	1.02	13.22	42.9	1282	362	920	542	1.70	718	669	1.07	25	28		
269	3	14	35.0	0.40	3	41	28.9	1.42	6	55	63.9	0.86	0.39	64.3	96	55	41	79	0.54	103	59	1.75	23	45	1200	2.7
16	23	30	40.6	0.74	19	39	39.5	0.99	42	69	80.1	0.86	2.97	29.1	154	69	85	68	1.23	132	169	0.78	31	16	2000	3
29	27	45	62.2	0.72	26	79	60.8	1.30	53	124	123.0	1.01	5.40	63.4	336	124	212	241	0.88	113	131	0.86	26	33	1500	3.5
32	11	6	8.4	0.71	12	10	10.4	0.96	23	16	18.8	0.85	—	—	—	—	—	—	—	—	—	—	7	2	4000	3
31a	17	22	24.4	0.90	15	27	23.1	1.17	32	49	47.5	1.03	—	—	—	—	—	—	—	—	—	—	10	22	4000	3.5
15	23	24	43.0	0.56	22	27	37.0	0.73	45	51	80.0	0.64	4.13	28.7	183	51	132	110	1.20	176	249	0.71	10	2	3000	3
8	5	5	22.3	0.22	5	8	19.3	0.41	10	13	41.6	0.31	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10	8	10	11.2	0.89	9	9	20.0	0.45	17	19	31.2	0.61	—	—	—	—	—	—	—	—	—	—	47	—	—	—
26b	5	15	20.0	0.75	6	30	21.7	1.38	11	45	41.7	1.08	1.47	38.2	71	45	26	24	1.08	35	92	0.38	—	—	—	—
3	8	8	12.0	0.67	8	9	11.6	0.78	16	17	23.6	0.72	1.00	12.9	34	17	17	18	0.94	100	137	0.73	10	—	—	—
2	2	9	12.2	0.74	2	8	11.6	0.69	4	17	23.8	0.71	0.45	14.1	78	17	61	38	1.61	216	232	0.93	36	—	—	—
Total or Average	132	188	292.3	0.64	127	287	283.9	1.01	259	475	576.2	0.83	16.41	31.0	952	378	574	576	1.00	875	1069	0.82	19	15		
33	4	0	3.7	0.0	4	3	4.1	0.73	8	3	7.8	0.38	—	—	—	—	—	—	—	—	—	—	20	100	2000	6
1	29	66	114.5	0.58	32	94	116.8	0.82	61	160	229.3	0.70	7.00	44.3	658	160	498	558	0.89	613	783	0.78	15	Basically Flat		
23	15	35	61.0	0.57	15	43	58.6	0.73	30	78	119.6	0.65	2.80	56.3	236	78	158	219	0.72	134	174	0.77	33	12	2500	3
21	6	14	25.3	0.55	6	34	24.4	1.39	12	48	49.7	0.97	1.41	51.6	157	48	109	135	0.81	65	102	0.64	42	8	1500	3
17	13	27	47.5	0.57	14	34	46.4	0.73	27	61	93.9	0.65	2.14	27.1	162	61	101	146	0.69	253	363	0.70	4	4	3500	3
4	23	8	13.4	0.60	22	20	13.8	1.45	45	28	27.2	1.03	4.43	22.0	76	28	48	65	0.74	95	221	0.43	15	—	—	—
26a	6	15	27.3	0.55	7	17	31.0	0.55	13	32	58.3	0.55	1.40	43.5	104	32	72	111	0.65	59	135	0.44	8	—	2000	—
20	12	19	60.7	0.31	13	26	60.3	0.43	25	45	121.0	0.37	2.21	44.2	103	45	58	153	0.38	97	167	0.58	27	24	2400	4
12	16	22	57.1	0.38	18	37	57.9	0.64	34	59	115.0	0.51	2.30	33.7	138	59	79	138	0.57	112	267	0.42	36	5	—	—
22	16	29	58.2	0.50	17	38	55.6	0.68	33	67	113.8	0.59	2.66	44.5	142	67	75	157	0.48	58	174	0.33	37	11	1800	3
Total or Average	140	235	468.7	0.50	148	346	466.9	0.74	288	581	935.6	0.62	26.35	36.0	1776	578	1198	1680	0.71	1496	2386	0.62	20	11		
Grand Total or Average	403	834	1277.7	0.65	404	1273	1261.5	1.01	807	2107	2539.2	0.83	55.98	36.0	4010	1318	2692	2798	0.96	3080	4124	0.75				

concept of the interwoven factors which apparently have an effect on accident rates. The second part is a discussion of individual sections, bringing forth facts concerning each section and making an attempt to isolate those factors which give it the accident experience it possesses.

In the development of the first part, many extremely interesting facets of the relationship between design factors and accident rates were glimpsed but not fully explored. Among these were ramp terminal shapes, bridge widths, type of interchange, and interchange spacing. But perhaps most important was the tentative finding that accident rates rise sharply with average lane volume, so that additional lanes may be justified on the basis of accident reduction even as much as on the basis of free-flow service volumes.

The present report does not provide a full understanding of how these additional facets may have affected accident rates. Research is being continued in an effort to develop facts concerning the unknowns brought out in this report. This research is a portion of the Highway Transportation Agency's 5-yr Safety Research Program, in cooperation with the U.S. Bureau of Public Roads.

SUMMARY OF DATA

Table 2 is a summary of accident, exposure, and design data for each of the study sections. The freeway sections are arranged into three groups and the data are summarized or averaged for each group. Twelve of the sections totaling 55.90 mi had significantly above average accident rates (referred to as high accident sections). Ten of the sections totaling 75.16 mi had significantly below average accident rates (referred to as low accident sections). Eleven of the sections totaling 69.39 mi had average accident rates.

Three of the sections in Table 2 have been split or designated as part a and part b because when these sections were under preliminary study, it was found that they had portions with accident concentration quite dissimilar to the remainder of the section.

The data listed in the table represent a 3-yr aggregate with the exception of sections

miles of travel (MVM). The exposure for ramps is essentially related to the number of vehicles entering or leaving without regard to the distance traveled, and therefore, is simply million vehicles (MV).

The term "within interchange area" is used in Table 2 and throughout this report. The area referred to is that encompassing the main line, ramps and structures from the end of the farthest speed change lane taper on one end of an interchange to the end of the farthest speed change lane taper on the other end of the interchange. An acceleration lane length is measured from the gore nose to the end of the lane taper. A deceleration lane length is measured from the start of the lane taper to the beginning of the first ramp curve.

INVESTIGATION OF ALIGNMENT AND GRADE

A representative sample of eight sections (1, 15, 16, 17, 20, 23, 28, and 29) from the original 31 was taken for this investigation. The eight sections total 81 mi with 3,935 MVM of exposure. The freeways ranged in ADT between 20,000 and 100,000 and had between four and eight traffic lanes. Grades ranged from 2 to 6 percent and curves from 1,500 to 5,000 ft in radius. (A curve with a radius of 5,000 ft or greater was considered a tangent section for this study. A grade of 2 percent or less was considered level.)

The accident data for sections 1, 15, 16, and 17 were taken from accident profiles where accidents are plotted to the nearest 100 ft but there is no designation as to direction of travel. The accident data for sections 20, 23, 28, and 29 were taken from large-scale collision diagrams where accidents are plotted as accurately as possible on a scale likeness of the freeway.

The alignment was categorized by type into the following groups: straight level, straight grade, curved level, and curved grade. A further breakdown by direction upgrade or downgrade was possible for sections 20, 23, 28, and 29 because the information was plotted on collision diagrams. Table 3 gives accident data for the eight sec-

TABLE 3

EFFECT OF ALIGNMENT ON FREEWAY ACCIDENT RATES

Alignment	PDO	Inj.	Fat.	Tot.	MVM	Total Acc./MVM	Inj. & Fat. Acc./MVM
(a) Sections 1, 15, 16, 17, 20, 23, 28 & 29							
Straight level (a)	1,358	915	47	2,320	2,767	0.84	0.35
Straight grade (b)	261	131	4	396	333	1.19	0.41
Curved level (c)	393	231	8	632	560	1.13	0.43
Curved grade (d)	339	165	8	512	275	1.86	0.63
Straight (ab)	1,619	1,046	51	2,716	3,100	0.88	0.35
Curved (cd)	732	396	16	1,144	835	1.37	0.49
Grade (bd)	600	296	12	908	608	1.50	0.51
Level (ac)	1,751	1,146	55	2,952	3,327	0.89	0.36
Total	2,351	1,442	67	3,860	3,935	0.98	0.38
(b) Sections 20, 23, 28 & 29[a]							
Straight upgrade	81	52	2	135	144	0.94	0.38
Straight downgrade	110	52	1	163	144	1.13	0.37
Curved upgrade	141	74	7	222	127	1.75	0.64
Curved downgrade	174	81	1	256	127	2.02	0.65
Total	506	259	11	776	542	1.43	0.50

[a]This further breakdown of grade classifications available for these sections only.

TABLE 4

EFFECT OF TRUCK TRAFFIC ON ACCIDENT RATES

Alignment	PDO	Inj.	Fat.	Tot.	MVM	Total Acc./MVM	Inj. & Fat. Acc./MVM
(a) Section 23—Truck Traffic 11 Percent							
Straight level (a)	223	117	8	348	310	1.12	0.40
Straight upgrade (b)	33	29	0	62	41	1.51	0.71
Straight downgrade (c)	35	17	1	53	41	1.29	0.44
Curved level (d)	144	72	3	219	120	1.83	0.63
Curved upgrade (e)	39	39	3	81	48	1.69	0.88
Curved downgrade (f)	52	37	1	90	48	1.88	0.79
Straight (abc)	291	163	9	463	392	1.18	0.44
Curved (def)	235	148	7	390	216	1.81	0.72
Grade (bcef)	159	122	5	286	178	1.61	0.71
Level (ad)	367	189	11	567	430	1.32	0.47
Total	526	311	16	853	608	1.40	0.54
(b) Section 20, 28, 29—Truck Traffic 4 to 5 Percent							
Straight level (a)	277	96	3	376	446	0.84	0.22
Straight upgrade (b)	48	23	2	73	103	0.71	0.24
Straight downgrade (c)	75	35	0	110	103	1.07	0.34
Curved level (d)	42	32	4	78	91	0.86	0.40
Curved upgrade (e)	102	35	4	141	79	1.78	0.50
Curved downgrade (f)	122	44	0	166	79	2.10	0.56
Straight (abc)	400	154	5	559	652	0.86	0.24
Curved (def)	266	111	8	385	249	1.55	0.48
Grade (bcef)	347	137	6	490	364	1.35	0.39
Level (ad)	319	128	7	454	537	0.85	0.25
Total	666	265	13	944	901	1.05	0.31

tions combined, as well as a further breakdown for sections 20, 23, 28, and 29. Table 4 indicates truck influence.

Section 23, a high accident section and also a high truck traffic section (11 percent) appears by itself in Table 4. This analysis is not meant to imply that truck traffic is the sole cause of the high accident rate. However, this is probably a major contributing factor since this section has 35 percent of its alignment on grades greater than 2 per-

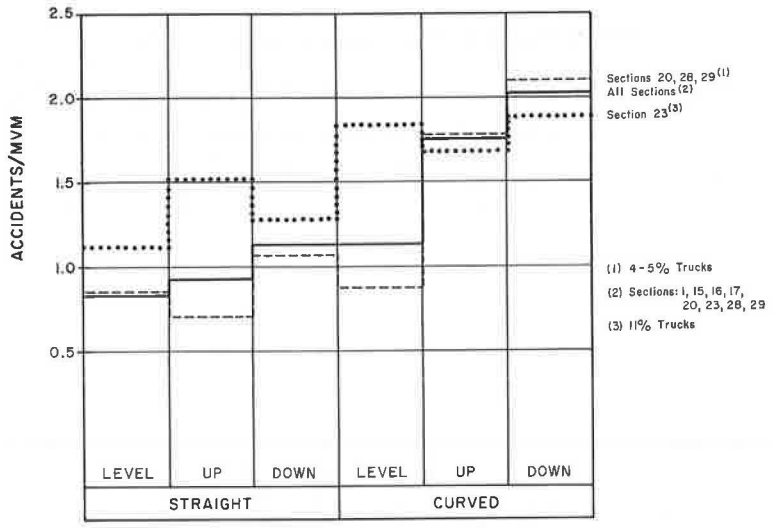


Figure 3. Accident rates by alignment type.

cent. The combination of trucks and grades will normally produce adverse conditions. This section has 41.2 percent of its alignment within interchange areas and 27 percent of its alignment on curves under 5,000-ft radius. The section is relatively old (opened 1955-1957). All of these factors contribute adversely to the accident rate.

Tables 3 and 4, and Figure 3 indicate that:

1. Straight level alignment has the lowest rates

affect accident rates; curved grade is the greatest offender.

3. Moderate truck traffic (4 to 5 percent) appears to have little effect on accident rates, whereas heavy truck traffic (11 percent) appears to affect rates adversely on the straight upgrade and curved level alignment.

FIXED OBJECTS

Fixed objects present a major problem in both accident frequency and severity. A recent freeway fatal accident study (2) revealed that 32 percent of the 660 freeway fatal accidents in 1961 and 1962 involved fixed objects. An analysis of all types of accidents revealed that 28 percent of 36,171 freeway accidents involved fixed objects; 8.5 percent of the accidents involved fixed objects in the median and 19.5 percent involved fixed objects to the right of the traveled way. A further breakdown is given in Table 5. A field inventory of fixed objects on ten sections of freeway is given in Table 6.

TABLE 5

ACCIDENTS INVOLVING FIXED OBJECTS

Fixed Object	% of All Accidents	% of Fixed-Object Accidents
Guardrail	7	25
Fence	5	18
Signs	4	14
Pier, abutment or bridge rail	4	14
Light standard	2	7
Curbed island	2	7
Miscellaneous	4	15
Total	28	100

In an attempt to gain information as to the most vulnerable type of fixed object, the freeway accident percentages for guardrail, signs, light standards, piers, abutments, and bridge rail were adjusted in proportion so that the combined total would equal 100 percent. The resulting

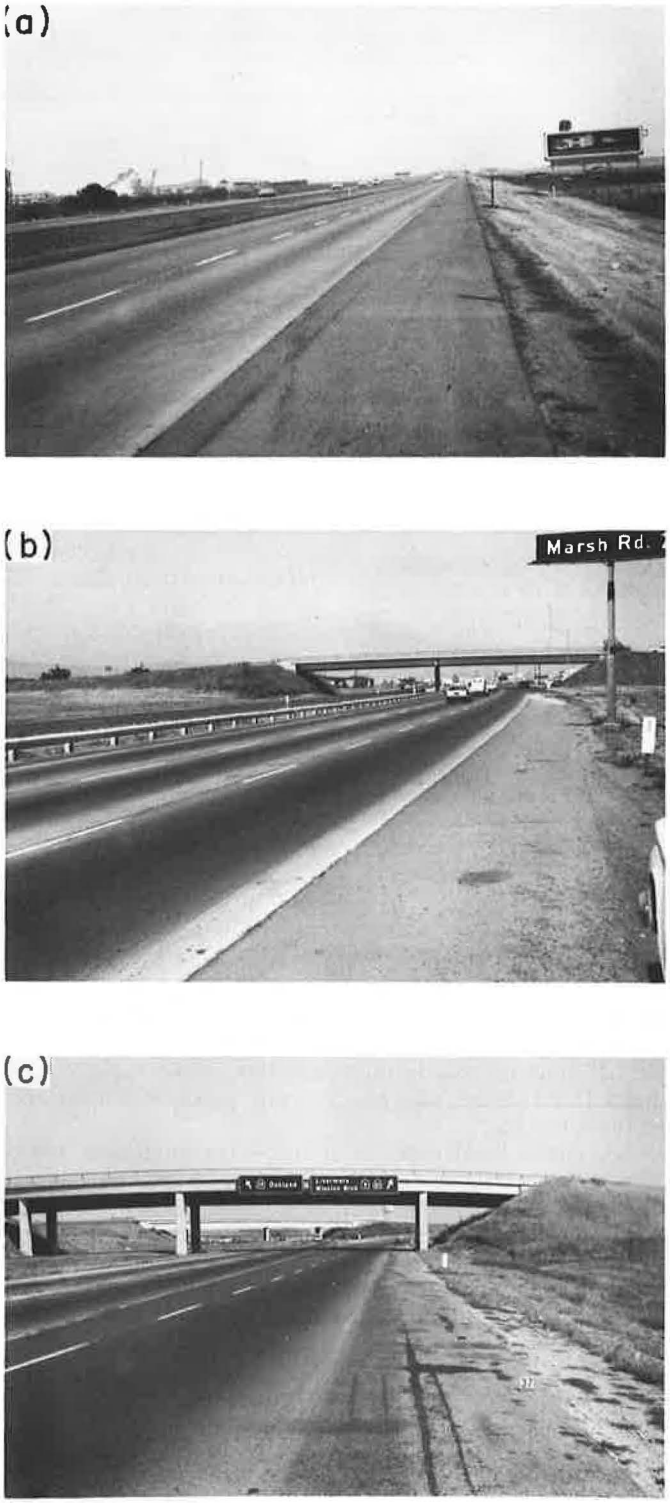


Figure 4. (a) Clear, firm roadside; (b) no pier at shoulder edge (but with sign pole); and (c) pier at shoulder edge.

TABLE 6

SUMMARY OF FIXED OBJECTS IN SECTIONS 17, 20, 21, 22, 23, 27, 28, 29, 31, 33

Fixed Objects	Areas					
	Interchange			Between Interchanges	Total	% of Total Fixed Objects
	Off-Ramps	On-Ramps	Main Line			
Guardrail[a]	602	533	206	453	1,794	46.1
Light standard	502	402	95	26	1,025	26.3
Signs[b]	237	71	112	245	665	17.1
Pillars, abutments, bridge rail	53	72	189	94	408	10.5
Total	1,394	1,078	602	818	3,892	100.0
% of total fixed objects	35.8	27.7	15.5	21.0	100.0	-

[a]Guardrail was counted in 50-ft lengths as one fixed object.
[b]Includes wood or steel posts, with or without guardrail.

TABLE 7

ACCIDENTS INVOLVING FIXED OBJECTS VS TOTAL FIXED OBJECTS IN PLACE

Fixed Object	% of Fixed-Object Accidents Involved	% of Total Fixed Objects	Ratio
Piers, abutments, bridge rail	23.5	10.5	2.24
Signs	23.5	17.1	1.37
Guardrail	41.2	46.1	0.89

percentage of accidents involved was then compared to the percentage of fixed objects actually in place. The results are given in Table 7.

The validity of this comparison may well be in question due to the lack of exposure data and the selection of a definite length of guardrail as one fixed object. At most, the comparison is an approximation which points to pillars, abutments and bridge rail as being placed in the most freeway mileage in California but represent 26 percent of "unit" objects and account for 12 percent of fixed object collisions.

Figure 4 shows an example of clear, firm roadside area and two examples of fixed objects adjacent to the roadbed. The guardrail in the median (Fig. 4b) was placed to prevent U-turns across the median at the interchange, but it can easily be struck by a vehicle drifting off the traveled way. The bridge pier (Fig. 4c) could have been inclosed in the overcrossing fill cone or totally eliminated as in the case of the bridge in Figure 4b, thus eliminating a fixed object that could easily produce a fatal accident if a vehicle should drift off the traveled way.

It is difficult to determine what percent of roll-over accidents are caused by fixed objects. It has been shown mathematically and experimentally (3) that it is virtually impossible for a standard automobile which is skidding to overturn unless it strikes a fixed object (such as curbs or dikes) or its wheels are embedded in soft material. The tires simply cannot develop enough friction to produce the moment required to overturn the auto. Some fixed objects act as fulcrums when struck by the wheels of a sliding vehicle. In other instances, roll-over accidents occur when the wheels of an out-of-control vehicle imbed themselves in loose material in the median or to the right of the shoulder. Many serious accidents may well have been minor accidents or might not have been reportable accidents at all had the victims been able simply to ride them out in an upright manner ("spin").

LONG BRIDGES

There are nine exceptionally long bridges (average 1,000 ft) within the study sections. Table 8 gives the bridge descriptions along with a 3-yr accident history (1959 to 1961).

TABLE 8

LONG BRIDGES, 1959-1960-1961 DATA

Section	Description	Length Incl. Guardrail	MVM	PDO Acc.	Inj.	Fat.	Total Acc.	Acc. Involving Guardrail or Br. Rail	Acc. Involving Stalled Veh.
	(a) Without Shoulders								
1	SM-68-Bsbn, Sierra Pt. O.H. Br. No. 35-130	1,000	15.2	18	3	1	22	0	0
17	SM-68-RdwC, Redwood Cr. Br. No. 35-145	700	8.6	2	9	1	12	0	0
25	LA-167-SGt, Los Angeles Riv. Br. No. 53-828	675	11.0	8	6	2	16	9	4
23	LA-26-Pom, Rt. 26/19 Sep. Str. Br. No. 53-855	900	8.5	12	8	1	21	9	0
26	LA-167-Ver, Hobart Yard O.H. Br. No. 53-940	1,300	15.7	12	5	1	18	5	1
26	LA-167-Cmrc, East Yard O.H. Br. No. 53-842	1,600	22.4	20	9	0	29	15	2
28	SD-77-SD, San Diego Riv. Br. No. 57-126	1,000	10.6	12	6	0	18	6	2
	Total	7,175	92.0	84	46	6	136	44	9
	(b) With Shoulders								
22	LA-4-LA, Gndl, LA Riv. & Sep. Br. No. 53-1075	675	7.3	2	2	0	4	0	0
22	LA-4-Brb, Providentia Ave. Br. No. 53-1085	850	7.1	0	2	1	3	2	0
	Total	1,525	14.4	2	4	1	7	2	0

TABLE 9

Bridges	MVM	Accidents	Bridge Acc. Rate	Avg. Freeway Rate[a]	% of Avg.
Without shoulders	92.0	136	1.48	1.10	134
With shoulders	14.4	7	0.49	0.51	96

[a]Average accident rate of sections containing bridges.

Seven of the bridges had three lanes in one direction with no shoulders and 40-ft (curb-to-curb) cross-sections. The other two bridges had four lanes in one direction with shoulders and 58-ft (curb-to-curb) cross-sections. The accident data concerning the no-shoulder vs shoulder bridges are summarized in Table 9.

The bridges without shoulders show a 34 percent increase in accident rate over the rate of the freeways which they serve. Although the exposure is extremely small, the indication is that the bridges with shoulders operate at about the same accident rate as the freeways they serve. One logical explanation for this may be that a bridge without shoulders does not provide an emergency parking area. Nine of the 136 (7 percent) no-shoulder bridge accidents involved parked or stalled vehicles, whereas none of the accidents on the bridges with shoulders involved a parked or stalled vehicle. The bridge rail or guardrail was involved in 33 percent of the no-shoulder bridge accidents and 29 percent of the shouldered bridge accidents.

NUMBER OF TRAFFIC LANES

At the beginning of this study, the expected accident rate curve set the standard for determining what would constitute a good or bad section. The combined data of 4-, 6-, and 8-lane freeways were used in calculating the expected rate equation.

During the course of this study, it became evident that a 4-lane freeway usually had a higher accident rate than a 6- or 8-lane facility with the same ADT. This situation suggested an investigation to see if the accident rate vs ADT curve for the 4-lane freeways would actually show a higher average rate than the 6- or 8-lane freeways. The use of the study section data for this type of investigation was avoided in this report because many of the study sections actually pick up and drop lanes throughout their lengths and the number of lanes would not be homogeneous. To continue the investigation, freeway sections with homogeneous lane characteristics were chosen and the accident rate vs ADT curves were calculated. The investigation is not yet complete but there is a definite indication that for any given ADT a 4-lane freeway would have a higher accident rate than a 6-lane, and a 6-lane would have a higher rate than an 8-lane. When complete, the findings of the investigation will be published in a separate report.

NORMAL STATISTICS

The statistics concerning each study section are discussed in the next part of this report. These statistics are compared with an estimate of the average or normal for

TABLE 10

NORMAL ACCIDENT STATISTICS, ALL CALIFORNIA FREEWAYS, 1958-1961

Condition	% Total Acc.	Acc. Rate
No. veh. involved:		
1	28	0.36
2	53	0.69
3	15	0.19
≥4	4	0.05
Driver violation:		
Following too close	18	0.23
Unsafe lane change	6	0.08
Improper turn	7	0.09
Exceeding safe speed	24	0.31
Wrong side of road	1	0.01
Improper parking	1	0.01
Other	9	0.12
None	34	0.44
Movements:		
Rear-end	29	0.37
Passing side swipe	18	0.23
Cross-median	6	0.08
Stopped or backing up	14	0.18
Other movements	33	0.43
Weather:		
Clear	81	-
Cloudy	9	-
Raining	6	-
Fog	3	-
Other	1	-
Dusk or dawn	3	-
Dark—no street lights	25	-
Dark—street lights	20	-
Alignment and grade:		
Straight level	64	-
Straight hillcrest	2	-
Straight grade	14	-
Curved level	9	-
Curved hillcrest	2	-
Curved grade	9	-
Speed of driver causing accident (mph):		
0	9	-
1-10	5	-
11-20	6	-
21-30	8	-
31-40	13	-
41-50	23	-
51-60	24	-
61-70	9	-
≥71	3	-
Age of vehicle causing accident (yr):		
0-2	39	-
2-5	36	-
5-10	19	-
≥11	6	

Condition	% Total Acc.
Residence of driver causing accident:	
California—local	82
California—not local	13
Out of California	3
Not stated	2
Age of driver causing accident (yr):	
<15	6
15-26	25
27-36	28
37-46	22
47-56	14
57-66	7
≥67	3
Driver's condition:	
Had been drinking	14
Sleep	5
Other defects	3
No defect	78
Vehicle condition:	
Defective	10
Not defective	90
Fixed object involvement:	
Hit fixed objects (8.5% to left	
Time of day:	
2400-0100 (midnight to 1 a.m.)	4
0100-0200	4
0200-0300	5
0300-0400	3
0400-0500	2
0500-0600	2
0600-0700	3
0700-0800	6
0800-0900	4
0900-1000	3
1000-1100	3
1100-1200	4
1200-1300	3
1300-1400	3
1400-1500	4
1500-1600	5
1600-1700	7
1700-1800	8
1800-1900	7
1900-2000	5
2000-2100	4
2100-2200	4
2200-2300	3
2300-2400	4

freeways. The estimate is based on a computer analysis of 36,171 accidents which occurred on all California freeways during the 1958 through 1961 period. The accident rate for this period was 1.29 accidents per MVM. A summary of the analysis is given in Table 10.

In Table 10, accident rates are tabulated for the single- and multiple-vehicle category. A simple ratio was used to calculate the rates; i.e., the percentage of total accidents is to 100 as the accident rate is to the total rate of 1.29. The accident rates for the other categories were not listed due to the unknown nature of travel involvement for these categories. For example, we know that there is more travel generated during clear weather than during rainy weather but it is difficult to determine what proportion of the total travel should be assigned to each type. An attempt of this sort was made in the alignment portion of this report, but the rates determined are not tabulated as normal because the data were drawn from the study sections and not all freeways.

The drivers' violation category shows 18 percent of the accidents involved following too close violations. When accidents are involved, this type of violation represents a large percentage, but if accidents are not involved, the percentage is relatively small. It is hard to tell when a driver is following too close unless he has an accident. Some authorities believe that following too far is more hazardous than following too close, because it is more difficult for the following driver to perceive the closing rate, or differential speed of the car ahead, and also because the large differential speed in following too far accidents results in a much greater severity when an accident does occur.

Studies of traffic flow (4) show that at design hourly volume of 1,500 vph/lane, 50 percent of all drivers choose headways of 1.8 sec or less (the average headway is, of course, 3,600/1,500 = 2.4 sec), center to center. The clear headway is less than this by the amount of the car-length: speed quotient. At 2,000 vph/lane, which is often attained on urban freeways, the 50 percentile headway is 1.5 sec (average 1.8 sec), and 85 percent of all drivers choose a headway of 2.6 sec or less. Although it may seem from the foregoing that high volume automatically results in short "unsafe" headways, at an hourly volume of 1,000 vph/lane, which is considered acceptable for long-distance rural travel and is associated with free-running speeds of 60 to 65 mph, the average headway is 3.6 sec but 15 percent still choose headways of 1.0 sec or less. No wonder that a patrolman has difficulty deciding whether a driver is following too close or not, until the driver has an accident.

As stated before, these statistics are used in the discussion of the individual sections. All of the conditions have been analyzed for each section, but only those pertinent to that particular section or those that vary significantly from the normal have been included in the tables found in the discussions.

This Department is presently engaged in a study of ramp geometry as related to accident frequency. The study is in a rough draft state and the analysis is not yet completed. However, evidence analyzed to date indicates the following:

1. On-ramps have a normal accident rate of about 0.60 per million ramp vehicles; off-ramps have a normal accident rate of about 1.00 per million ramp vehicles.
2. Downhill on-ramps are the best type of on-ramp; uphill off-ramps are the best type of off-ramp.
3. Ramps associated with diamond-type interchanges are apparently the safest type. The left-hand ramps (enters or leaves the freeway at high-speed lane) experience the highest accident rates.

THE SAN FRANCISCO AREA

Section 30—SF-2-SF (New Route 80, 101)

This is the Central Skyway in San Francisco, a 1.47-mi portion of Rt. 2 between the junction of Rt. 68 and Turk St. Facts about the section are as follows:

1. 57,800 ADT, 62 MVM (1960-61), 280 accidents.
2. Accident rates—expected, 1.20; actual, 4.52 or 375 percent of expected rate.
3. The section is basically six lanes with a short portion of eight lanes. It is an

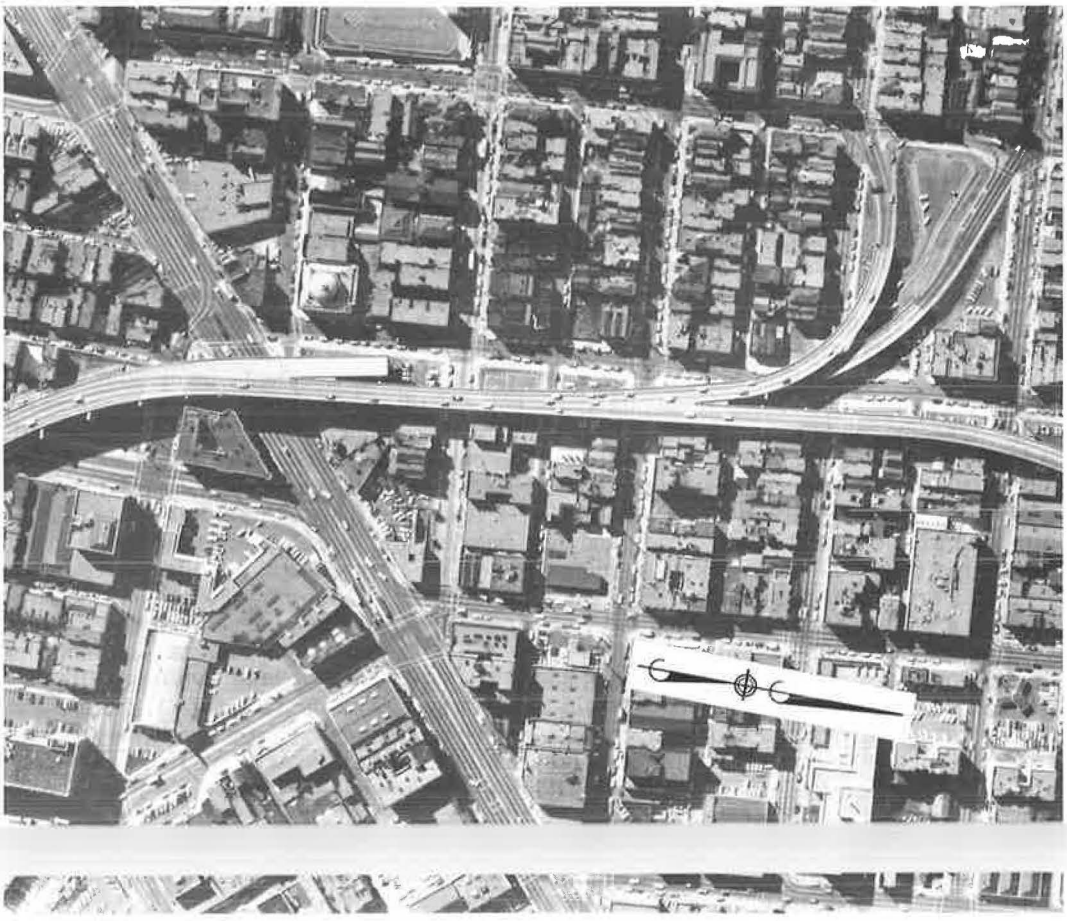


Figure 5. Central Skyway, San Francisco.

TABLE 11

ACCIDENT DATA, CENTRAL SKYWAY

Condition	% Acc.	
	Section 30	Normal[a]
Driver's condition:		
H. B. D.	3	14
Sleep	0	5
Violation—following too close	11	18
Movement—rear end	30	29
Time of day—afternoon peak		
4-6 p. m.	13	15
Speed (mph):		
0	13	9
1-10	4	5
11-20	6	6
21-30	11	8
31-40	27	13
41-50	28	23
51-60	10	24
61-70	1	9
≥71	0	3

[a]Normal statistics from Table 10.

elevated viaduct, 40 ft curb to curb (no shoulders) on each roadway. About half of the section is single deck and the remainder is double deck (Fig. 5).

4. Thirty percent of the alignment is on curves between 600- and 1,000-ft radii.

5. The ramps are all two lanes and have average accident rates.

The limited design standards imposed by the elevated viaduct section create a high accident rate problem. For instance, the Embarcadero Skyway in San Francisco is similar to the Central Skyway. The Embarcadero has an accident rate of 3.05 with an ADT of 30,000. The Viaduct portion of the James Lick Freeway has better alignment (1,200-ft minimum radius curve) but still has an accident rate of 2.32 with an ADT of 130,000. The Nimitz

TABLE 12

ACCIDENT DATA, SECTION 1

Condition	% Acc.	
	Section 1	Normal
Residence—Calif., local	91	82
Weather—raining	15	6
Driver's condition—H. B. D.	17	14
Movement—rear end	57	29

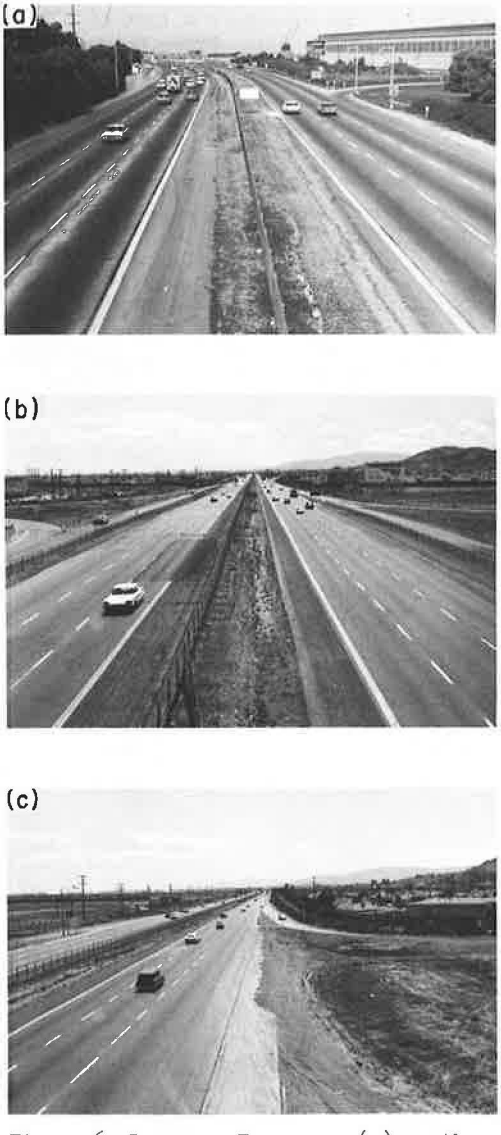


Figure 6. Bayshore Freeway: (a) north end section 1, Butler Rd. O.C., rate 1.06; (b) center section 1, 19th Ave. O.C., rate 0.79; south end section 1, East Hillsdale Ave., rate 0.61.

Freeway viaduct section has mostly tangent alignment with cross-section similar to the Central Skyway. The Nimitz Viaduct has an accident rate of 1.57 with an ADT of 75,000.

Table 11 indicates that the motorists using this section are better than average from the standpoint of drinking or dozing. Violation, movement, and peak hour accidents are relatively average. Stopped vehicles show a slightly higher than normal percentage because disabled vehicles have no place to park safely. A larger percentage of accidents occurred at lower speeds than normal; however, with short radius alignment, the average speed is less than normal. When driving on an elevated freeway such as the Central, the stable objects around the driver are not as apparent as they are on a ground-level freeway. Some people believe that this sensation subconsciously increases driving speed. In other words, the sense of speed is lost much as it is when riding in an airplane. This section does not seem to bear this out; however, the speed may actually be excessive for the existing design standards. A more detailed study of viaducts involving a much larger sample may be of some value.

Apparently, the lack of shoulders and the lack of off-the-traveled-way maneuverability combined with the short radius curves play an important role in this section's high accident rate.

Section 1—SM-68-Var (New Route 101)

This is a 15.8-mi portion of the Bayshore Freeway (Rt. 68) between the north city limits of South San Francisco and Bransten Rd. in Redwood City. Facts about the section include:

1. 77,500 ADT, 1,341 MVM (1958-60), 1,271 accidents.
2. Accident rates—expected, 1.26; actual, 0.95 or 75 percent of expected rate.
3. Six lanes (a 6-mi portion was widened to eight lanes between mid-1960 and the end of 1961), 36-ft median (some median barrier installed in May 1960), and 8-ft shoulders.
4. Fifteen percent of the horizontal alignment is on curve, vertical alignment is basically flat.

Traveling south from the start of the section at the north city limits of South San Francisco to a point 10.3 mi south,

Figure 7. The Bayshore Freeway, section 17.

TABLE 13

DATA FROM SECTION 17

Condition	% Acc.	
	Section 17	Normal
Residence—Calif., local	88	82
Weather—raining	8	6
Driver's condition—H. B. D.	24	14
Movement—rear end	23	29

the freeway has an accident rate of 1.06 (expected rate, 1.27). From that point (3rd and 4th St. interchange in San Mateo), and for the next 2¼ mi, it has a rate of 0.79 (expected rate, 1.26). The remaining 3¼-mi section has a rate of 0.61 (expected rate, 1.25) (Fig. 6).

The first 10 mi of this section has a clearance to the nearest fixed object (in many places) of approximately 6 ft to the right from the edge of the shoulder; the rest has approximately 56 ft of clearance.

Figure 8. Willow Rd. interchange.

The congestion problem is evident by the large percentage of rear-end accidents (Table 12). This problem is typical of the Bayshore Freeway.

Section 17—SM-68-D, M1P, RdwC. (New Route 101)

This is a 7.9-mi portion of the Bayshore Freeway between Bransten Rd. in Redwood City and the San Mateo—Santa Clara Co. line. Facts about the section include:

1. 58,800 ADT, 509 MVM (1959-61), 415 accidents.
2. Accident rates—expected, 1.20; actual, 0.82 or 68 percent of expected rate.
3. Six-lane, 40-ft traversable median (except where median barrier is placed), 8-ft shoulders, approximately 12-ft clearance on the right where frontage roads exist and 60 ft to the right-of-way line where there are no frontage roads.
4. Alignment (Fig. 7) is relatively flat and straight with only 4 percent on curves under 5,000-ft radius (3,500-ft minimum radius) and 4 percent on grade over 2 percent (3 percent maximum).

This freeway section has a 42 percent higher accident rate southbound (0.95) than northbound (0.67). The major increase in accidents occurred between 11 p.m. and 2 a.m. During these 3 hr, there were 53 accidents southbound and only 16 accidents northbound. Table 13 shows an abnormal (24 percent) number of accidents involving drinking drivers.

The Willow Rd. interchange is a four-quadrant clover leaf without collector distributor roads (Fig. 8). The ramps have a rate of 1.54 accidents per MV. These ramps are responsible for 50 percent of the total ramp accidents in the section but carry only 20 percent of the ramp traffic. The acceleration and deceleration lanes average 550 and 350 ft, respectively. The increase in ramp accident rate is divided equally between the on- and off-ramps.

Although sections 1 and 17 are both Bayshore Freeway sections, the percentage of rear-end accidents is greater in section 1 (57 percent) than in section 17 (23 percent). Section 1 carried one-third to two-thirds more traffic than section 17 with generally the same number of lanes. The accident rates for sections 17, 1, and 2 are 0.82, 0.95, and 1.09, respectively, and the ramp rates are 0.65, 0.70 and 0.71, respectively.

In general, the alignment (especially ramps) is forced into a more restricted area as the freeway proceeds from south to north (from section 17, through 1 to 2), apparently due to increasing right-of-way cost when approaching the densely populated area. The more restricted area decreases off-the-traveled-way maneuverability. At the same time, the average daily traffic increases and peak hour traffic is heavier. Vehicles in trouble have no escape route and vehicles entering or leaving the freeway must negotiate tight ramp patterns.

THE SAN DIEGO, VENTURA, AND GOLDEN STATE FREEWAYS

Section 20—LA-158-C1C, LA, A (New Route 405)

This 5-mi section of Rt. 158 (San Diego Freeway), between Venice Blvd. U.C. in Culver City and Ovada Pl. Pedestrian U.C. near Santa Monica, displays the following characteristics:

1. 58,500 ADT, 320 MVM (1959-61), 200 accidents.
2. Accident rates—expected, 1.20; actual, 0.63 or 53 percent of expected rate.
3. Eight lanes, 22-ft median, 10-ft shoulder outside, 8-ft shoulder inside.
4. Alignment (Fig. 9) is good with 24 percent of the vertical alignment on grade over 2 percent (4 percent maximum) and 27 percent of the horizontal alignment on curve of under 5,000-ft radius (2,400-ft minimum).
5. Ramps have much lower than average rates (0.37 actual vs 0.80 expected); ramp acceleration and deceleration lane lengths both average 700 ft.

The success of this section may be attributed to better than average ramps, fairly liberal design standards, and an ADT which produces low lane densities for an eight-lane freeway. At a low lane density, emergency maneuvers can be made on the traveled way. As the lane density increases, emergency maneuvers must be made elsewhere to avoid collision with another vehicle. This section is primarily elevated and in most

Figure 9. San Diego Freeway.

places the 10-ft shoulder is the limit to safe off-the-traveled-way maneuvers. Table 14 gives the ADT and the accident rate for each year of the 5-yr period of 1959 to 1963.

Table 15 indicates that rear-end accidents accounted for 13 percent of the total accidents in this section, whereas the normal is 29 percent. Fifty-one percent of the accidents were single-vehicle accidents (28 percent is normal). The lack of rear-end accidents and the high percentage of single-vehicle accidents indicate that congestion is not a major problem. The fact that 51 percent of accidents were single vehicle against a normal of 28 percent does not show that this freeway is more susceptible to single-vehicle accidents, but that it is less susceptible to other types.

TABLE 14

ACCIDENT RATES, SECTION 20

Year	ADT	Actual Acc. Rate	Expected Acc. Rate	% of Expected
1959	50,000	0.56	1.16	48
1960	59,000	0.51	1.21	42
1961	68,000	0.67	1.23	60
1962	75,000	0.78	1.25	62
1963	114,000[a]	1.13	1.35	84

[a]Freeway sections on both sides of study section opened to traffic during this period, causing sharp increase in ADT.

TABLE 15

Type of Accident	Rate (per MVM)	%	Rate (per MVM)	%
Single vehicle	0.36	28	0.32	51
Multiple vehicle	0.93	72	0.31	49
Total	1.29	100	0.63	100
Rear end	0.37	29	0.08	13
All other	0.92	71	0.55	87
Total	1.29	100	0.63	100

Figure 10. Ventura Freeway.

Section 21—LA-2-LA (New Route 101)

This 2.73-mi portion of Rt. 2 (Ventura Freeway), between the junction of the San Diego Freeway and Louise Ave., is an elevated freeway. Facts about the section include:

1. 79,300 ADT, 237 MVM (1959-61), 222 accidents.
2. Accident rates—expected, 1.27;

chain link barrier, and 8-ft shoulders.

4. Alignment (Fig. 10) is flat with only eight percent of the vertical alignment on grade over 2 percent but 42 percent of the horizontal alignment on curves between 2,000- and 2,500-ft radius.
5. Ramp rates are slightly high (0.97); acceleration and deceleration lengths average 500 and 800 ft, respectively.

During the first half of the study period, this section had an ADT of only 50,000. The freeway sections to the east and west of this section were not opened to traffic until mid-1960. As soon as the completed gaps in the freeway were opened, the ADT jumped from 50,000 to 110,000. The accident rate for this section was disproportionately low when the freeway had a volume that would produce low lane densities, but when the lane densities reached normal levels, the accident rate rose to the expected rate. A summary of accident rates for the 2.73-mi study section is given in Table 16.

TABLE 16

ACCIDENT RATES, SECTION 21

Year	ADT	Actual Acc. Rate	Expected Acc. Rate	% of Expected
1959	49,000	0.40	1.16	35
1960	79,000	0.98	1.27	77
1961	103,000	1.12	1.32	85
1962	121,000	1.10	1.36	81
1963	128,000	1.58	1.38	115

Figure 11. Golden State Freeway.

TABLE 17

ACCIDENT RATES, SECTION 22

Year	ADT	Actual Acc. Rate	Expected Acc. Rate	% of Expected
1959	41,000	0.60	1.13	53
1960	51,000	0.46	1.17	39
1961	64,000	0.60	1.23	49
1962	113,000	0.68	1.36	50
1963	114,000	0.85	1.36	63

TABLE 18

Condition	% Acc.		Acc. Rate per MVM	
	Section 22	Normal	Section 22	Normal
Violation:				
Unsafe lane change	20	6	0.12	0.08
Improper turn	25	7	0.15	0.09
Movement:				
Rear end	17	29	0.10	0.37
Passing sideswipe	32	18	0.19	0.23

Apparently, as the lane density increases, it becomes more difficult to avoid conflicting vehicle movements on the traveled way. Vehicles are thus forced to leave the traveled way in an emergency situation or conflict with other vehicles on the traveled way.

In most places, this section has only the 8-ft shoulder for emergency off-the-traveled-way maneuvers on the right. The median barrier on the left restricts the space for emergency maneuvering to 11 ft.

Section 22—LA-161/4-LA;Gndl, LA (New Route 5)

This 5.98-mi portion of Rt. 161 and 4 (Golden State Freeway), between Glendale Blvd. in Griffith Park and Cypress Ave. in the City of Burbank, displays the following characteristics:

1. 51,000 ADT, 331 MVM (1959-61), 200 accidents.
2. Accident rates—expected, 1.17; actual, 0.60 or 51 percent of expected rate.
3. Eight lanes (except for a short six-lane portion between Western and Alameda Ave.), 22-ft traversable median, 10-ft outside shoulders and 8-ft inside shoulders.
4. The ramps have better than average rates (0.59); the acceleration and deceleration lanes average 800 ft in length.

Thirty percent of this section is elevated and 70 percent is at ground level (Fig. 11). Clearance to the right within the ground level portion is fairly good (20 to 40 ft). Clearance to the right on the elevated portion is limited to 10 ft between interchanges but is approximately 30 ft within interchange areas due to the 20-ft traversable divider between the main lanes and the collector-distributor roads. The liberal design of this section is further demonstrated with shoulders on the long bridge sections, two-lane collector-distributor roads, and ramp shoulders continuing across overcrossing structures.

The favorable record of this section may be attributed to liberal design standards, better than average ramp design, and good capabilities for emergency off-the-traveled-way maneuvers.

As indicated by Table 17, the accident rate in this section did not rise more than expected when the volume increased. This could be due to good off-the-traveled-way clearance allowing emergency maneuvers at higher lane densities. This section also has a low percentage of rear-end accidents (lack of congestion) but high percentages of improper turn and unsafe lane-change violations (Table 18).

LONG BEACH FREEWAY

Section 12—LA-167-LBch, A, Com, Lyn, SGt. (New Route 7)

The 6.83-mi portion of Rt. 167 (Long Beach Freeway), between the Pacific Coast Highway and Atlantic Ave. (south crossing in Compton), displays the following characteristics:

1. 54,200 ADT, 405 MVM (1958-60), 250 accidents.
2. Accident rates—expected, 1.18; actual, 0.62 or 52 percent of expected rate.
3. Six lanes, 16-ft curbed median on the south half of the section, and 40-ft traversable median on the north half of the section.
4. Thirty-six percent of the horizontal alignment is on curves under 5,000-ft radius and only 5 percent of the vertical alignment is on grade over 2 percent (Fig. 12).
5. Off-the-road clearance is good (20 to 40 ft).

The favorable record of this section is most probably a result of fairly liberal cross-section design, good alignment and good off-the-traveled-way maneuverability. Table 19 gives accident data for the section that differs measurably from the normal. This table indicates a high percentage of high-speed accidents, out-of-state residence drivers, and drivers who had been drinking.

Despite the low overall accident rate of this section, a ¾-mi portion has a comparatively poor accident record (1.80 accidents per MVM). Within the poor portion is the cloverleaf interchange at Del Amo Blvd. (Figs. 13 and 14). This interchange is on a crest vertical curve and has steep ramp grades and low visibility. This ¾-mi portion is responsible for 32 percent of all the accidents within the 6.83-mi section but has only 11 percent of the total exposure.

Section 25—LA-167-Com, A, Lyn, SGt (New Route 7)

The 4.96-mi portion of Rt. 167 (Long Beach Freeway), between Atlantic Ave. (south crossing in Compton) and Firestone Blvd., displays the following characteristics:

3. Six lanes, 40-ft traversable median, 2-ft inside shoulders, and 8-ft outside shoulders.
4. Thirty-three percent of horizontal alignment on curve with radius less than 5,000 ft (mostly 2,500-ft radius) and 12 percent of the vertical alignment on grade greater than 2 percent (3 percent maximum).
5. A large part of this section is elevated and has guardrail protection on the right. Potential off-the-traveled-way maneuverability is good in the median but is limited on the right due to the guardrail.

This section operates at 75 percent of the expected rate, probably due to its fairly liberal design standards. The only major point of accident concentration is

Figure 12. Long Beach Freeway.

TABLE 19

ACCIDENT DATA, SECTION 12

Condition	% Acc.	
	Section 12	Normal
Weather:		
Rain	2	6
Fog	8	3
Residence—Calif., local	73	82
Driver's condition—H. B. D.	25	14
Speed—61 mph	25	12
Time of day (6 to 9 a.m.)	21	13
Cross-median	12	6

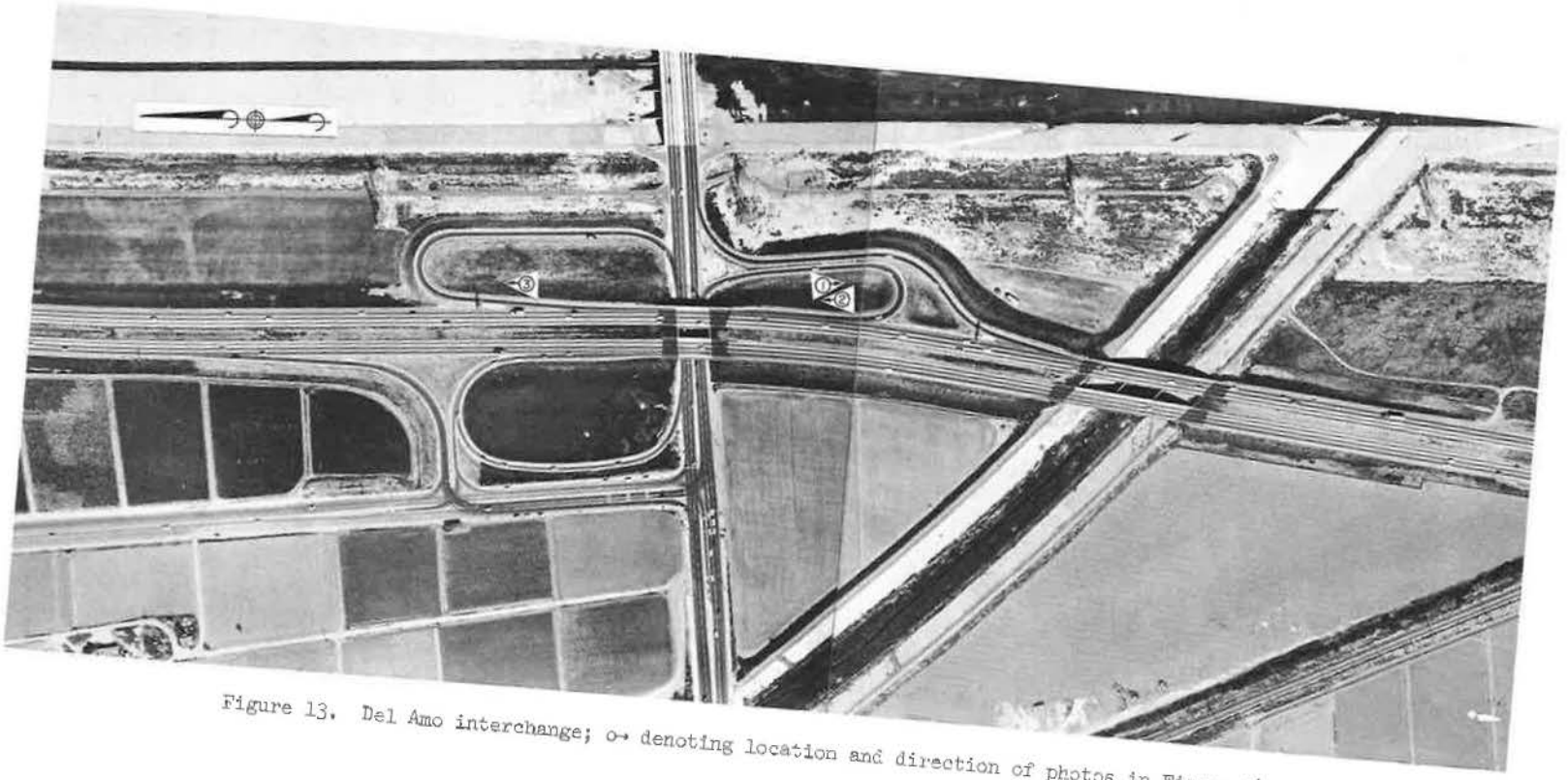


Figure 13. Del Amo interchange; ⟶ denoting location and direction of photos in Figure 14.

Figure 14. Del Amo interchange.

TABLE 20

ACCIDENT DATA, SECTION 25

Condition	% Acc.	
	Section 25	Normal
Weather:		
Rain	2	6
Fog	5	3
Speed—≥61 mph	23	12
Residence—Calif., local	89	82
Driver's condition—H.B.D.	25	14
Time of day (morning peak—6 to 8 a.m.)	21	13

at a 700-ft long, 40- ft wide (curb-to-curb) bridge with no shoulders. This 700-ft portion has an accident rate of 1.52. Accident data that differ measurably from the average are summarized in Table 20.

Section 26—LA-167-Bell, B, Ver. (New Route 7)

This 4.76-mi portion of Rt. 167 (Long Beach Freeway) lies between Firestone Blvd. and Olympic Blvd. in Compton. Facts about the section include:

1. 74,500 ADT, 381 MVM (1959-61), 362 accidents.
2. Accident rates—expected, 1.25; actual, 0.95 or 76 percent of expected rate.
3. Six lanes, 40-ft traversable median, 2-ft inside shoulders, and 8-ft outside shoulders.

The 3.22-mi portion from Firestone Blvd. to Atlantic Blvd. (north crossing in Vernon) is designated in Table 2 as section 26a. The next 1.54 mi from Atlantic Blvd. (north crossing in Vernon) to Olympic Blvd. is designated as sec-

[illegible] alignment in section 26a is on curve with radii less than 5,000 ft (3,000 ft minimum), whereas 33 percent of section 26b has alignment under the 5,000-ft standard (1,200 ft minimum). Section 26a is mostly at ground level with good potential off-the-traveled-way maneuverability for approximately 40 ft on the right and in the median. It has no grades over 2 percent. Section 26b has 45 percent of its vertical alignment on grades between 2 and 3 percent. The section is primarily elevated with little or no potential for off-the-traveled-way maneuvering. The section also has two 40-ft curb-to-curb bridge sections totaling 3,000

TABLE 21

RAMP RATES

Section	On-Ramps	Off-Ramps	All Ramps
26a	0.55	0.55	0.55
26b	0.40	1.42	0.86
Normal	0.60	1.00	0.80

TABLE 22

ACCIDENT RATES, LONG BEACH FREEWAY

Section	Mi	ADT	Actual Acc. Rate	Expected Acc. Rate	% of Expected
12	6.83	54,200	0.62	1.18	52
25	4.96	72,400	0.94	1.25	75
26a	3.22	69,800	0.66	1.24	53
26b	1.54	80,100	1.47	1.27	116

ft in length. The ramps in section 26b have less liberal design characteristics than those in section 26a. The section 26b ramps have only about half as much acceleration and deceleration length and sharper radius curves. The ramp rates for the two sections are given in Table 21.

A summary of accident rates for the Long Beach Freeway sections, given in Table 22, indicates a general increase in ADT from section 12 to section 26b, yet the design standards, if anything, have decreased.

HARBOR AND PASADENA FREEWAYS

Section 24—LA-165-LA (New Route 11)

The 3.2-mi portion of Rt. 165 (Harbor Freeway), between the four-level interchange and 30th St., displays the following characteristics:

1. 160,700 ADT, 563 MVM (1959-61), 1,675 accidents.
2. Accident rates—expected, 1.44; actual, 2.98 or 206 percent of expected rate.
3. Eight lanes basic with the following variations: (a) four-level interchange to 2nd St., 10 lanes (weaving section) for 0.5 mi; (b) 2nd St. to Wilshire Blvd., 0.55 mi, six lanes with two-lane collector-distributor roads in each direction; (c) Wilshire Blvd. to 11th St., 0.6 mi, four-lane southbound, three-lane northbound with the two-lane collector-distributor road continued for the northbound traffic; and (d) 11th to 30th St., 1.55 mi, eight lanes. A ½-mi portion was detoured for the first 11 mo of the study period, during the construction of the Santa Monica interchange structures.
4. Thirty-four of the horizontal alignment (Fig. 15) is on curves under 5,000-ft radius (minimum curves 2,000-ft radius) and 26 percent of the alignment is on grade greater than 2 percent (5 percent maximum).
5. Fills and concrete walls limit off-the-traveled-way maneuverability to the 8-ft shoulders.

This section has an ADT ranging from 125,000 to 180,000 veh/day. There are 24 ramps within the 3.2-mi section for an average of 7.5 ramps per mile. The ramp ADT's range from 4,000 to 25,000 veh/day and the northbound to westbound and northbound to eastbound freeway-to-freeway connections at the four-level interchange each accommodate more than 70,000 veh/day. In spite of the high volumes, the on-ramps have an average accident rate of 0.56 (normal, 0.60) and the off-ramps have an average rate of 1.11 (normal, 1.00).

Figure 15. Harbor Freeway.

The reader should, for the time being, avoid the conclusion that the interchange spacing is necessarily a causative factor in the higher than average accident rate on this section. The 24 ramps in 3.2 mi

are the equivalent of six full interchanges, which would mean an average spacing of 0.53 mi. Other freeway sections with closely spaced interchanges (in this range) do not have excessive rates. The ramp accident study now under way will shed more light on this subject.

There are two major freeway-to-freeway interchanges in the section of the Harbor Freeway being considered here. There are also three two-lane collector-distributor road terminals, in addition to the freeway interchange ramp terminals, which are also two-lane ramps. The tremendous volumes using these ramps and the jockeying for position associated with these volumes are undoubtedly contributing factors in the accident rate. However, placing the ramps farther apart would not reduce these volumes but might increase them. As a matter of fact, an attempt was made to space the ramps at a greater distance by incorporating them with long collector-distributor roads, and this may be part of the problem, since it causes most of the ramp traffic to have two decisions instead of one for each entry or exit vehicle. (The accident rates shown here include accidents on the collector-distributor roads and ramps as well as those on the main line).

The staggering main line volume and the limited cross-section design with little or no off-the-traveled-way maneuverability makes this freeway section very susceptible to accidents. The accident rate would most likely be even higher if it were not for the fairly good horizontal alignment.

Table 23 compares data from Section 24 with the normal data from Table 10. The peak hours are not involved in the unusually high percentage of the total accidents within the section. One explanation for this is that the staggering main line volume causes congestion during many hours of the day.

It is interesting to note that although there are huge and notorious weaving volumes on this section of the Harbor Freeway (e.g., the weave in 1,800 ft between the Hollywood interchange and 1st St. is 3,700 vph during the morning peak hour), the number of accidents attributed to sideswiping which should be associated with weaving is no higher than average. A greater than average percentage of accidents seem to be occurring at the lower speeds. Rear-end accidents and following-too-close violations are apparently better than average within this section.

TABLE 23

ACCIDENT DATA, SECTION 24

Condition	% Total Acc.	
	Section 24	Normal
Driver's condition:		
H.B.D.	7	14
Sleep	1	5
Time of day—(afternoon peak 4-6 p.m.)	17	15
Violation—following too close	51	18
Movement—rear end	37	29
Sideswipe	20	18
Speed (mph):		
0	3	9
1-10	6	5
11-20	14	6
21-30	17	8
31-40	20.5	13
41-50	25	23
51-60	12	24
61-70	2	9
≥ 71	0.5	3

Section 9—LA-165-LA (New Route 11)

The 1.9-mi portion of Rt. 165 (Pasadena Freeway) lies between the four-level structure and the junction of Rt. 205. Facts about the section are as follows:

1. 109,000 ADT, 227 MVM (1958-60), 533 accidents.
2. Accident rates—expected, 1.35; actual, 2.35 or 174 percent of expected rate.
3. Six lanes from the 4-level interchange to the Castelar St. overcrossing (0.9 mi), primarily four 12-ft lanes and two 11-ft lanes; eight lanes through the remainder of the section (1.0 mi), primarily four 11-ft lanes and four 10-ft lanes; 6-ft curbed median with a portion of the section on separate roadways, and no shoulders with the exception of some 5-ft portions behind the rolled gutter-type curb.

This section is the northerly extension of the Harbor Freeway (section 24). Both

Figure 16. Eastbound on Pasadena Freeway, showing left-hand off-ramp to Golden State Freeway.

TABLE 24

ACCIDENT DATA, SECTION 9

Condition	% Acc.	
	Section 9	Normal
Violation—unsafe lane change	22	6
Movement—rear end	45	29
Hit fixed object	37	28
Defective vehicle	5	10
Residence—Calif., local	90	82
Driver's condition—H.B.D.; sleep, and other	11	22

sections experience the problems which are associated with extremely high volumes. Section 9 is old (completed in 1948) and the lower design standards to which it was built increases the accident probability already augmented by the high volume. Thirty-three percent of the horizontal alignment is on curve with radii less than 5,000 ft. The lane widths are substandard; the median is narrow and at places replaced by a concrete wall. There are no shoulders with the exception of some 5-ft portions behind the rolled gutter-type curb. The section has four tunnels without shoulders where off-the-traveled-way maneuverability is impossible. The ramps possess short or no speed change lanes.

Also contributing to this higher accident rate is the presence of three low-standard, high-volume, left-hand off-ramps (Fig. 16). These ramps are located at Castelar St. (Hill St.), Riverside Dr. and Figueroa St. The southbound ramp at Castelar St. is a continuation of the main line tangent alignment as the freeway curves to the right. The other two ramps have sharp curves to the left with mainline downhill grade. All three of these ramps have high accident rates and account for 64 percent (118 out of 186) of all ramp accidents in the section although carrying only 23 percent of the ramp volume. The average ramp rate for the three off-ramps is 4.04; the normal rate for off-ramps is 1.00.

There is one low volume (300 veh/day) left-hand on-ramp at Amador St. that does not have a poor accident record.

Table 24 indicates that drivers using this freeway section are more responsible than normal. Drivers involved in accidents had fewer defects, such as drinking or fatigue, and the vehicles they were driving were in better condition. The percentage of accidents involving fixed objects is high because of the lack of shoulders and the large number of fixed objects close to the traveled way, including continuous lighting. A congestion problem is suggested by the high percentage of unsafe lane change violations and rear-end accidents.

Section 10—LA-205-Pas, S.Pas. (New Route 11)

The 3.5-mi portion of Rt. 205 (Pasadena Freeway), between the junction of Rt. 165 and Ave. 64 (Marmion Way) interchange, displays the following characteristics:

1. 78,500 ADT, 301 MVM (1958-60), 337 accidents.
2. Accident rates—expected, 1.26; actual, 1.12 or 89 percent of expected rate.
3. Six 11-ft lanes, 6-ft curbed median (median barrier in place after July 1961), and no shoulders on the right with the exception of a few emergency parking areas.

This section is a continuation of the Pasadena Freeway to the east of section 9. It was completed in 1940 and is California's first freeway. The alignment is poor with

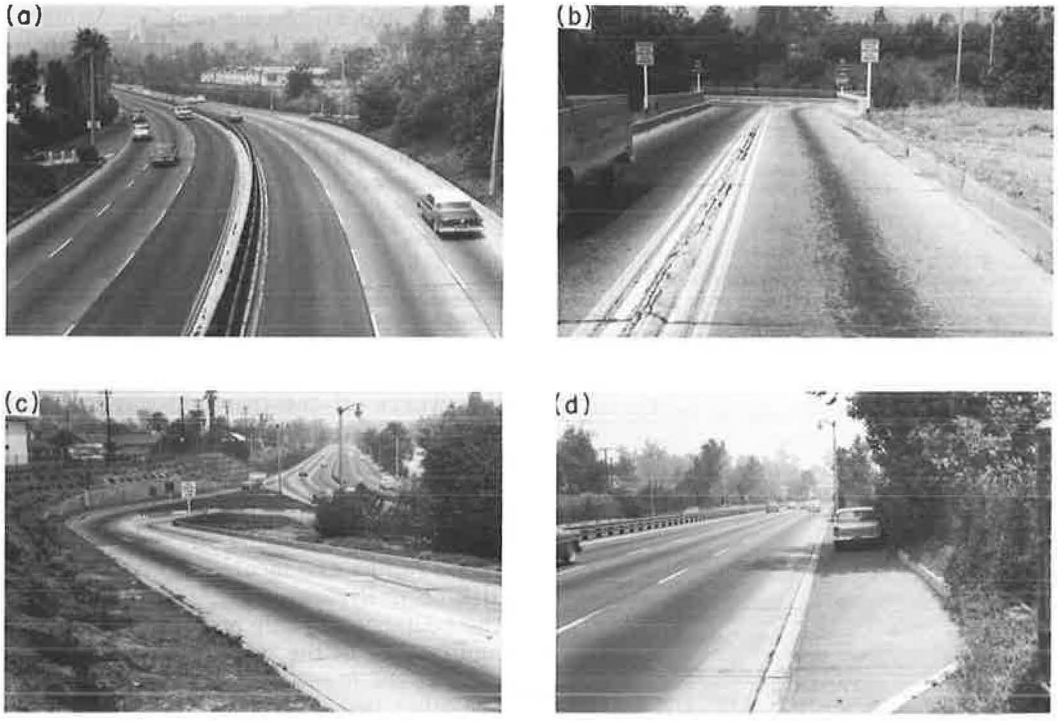


Figure 17. Section 17: (a) Pasadena Freeway; (b) northbound off- and on-ramp at Ave. 43; (c) southbound off- and on-ramp at Ave. 43; and (d) emergency parking area.

grades up to 5 percent. Forty-seven percent of the horizontal alignment is on curves with less than 5,000-ft radius (Fig. 17a). Ramp acceleration and deceleration lanes are far below present standards with some on-ramps having stop signs at the nose (Fig. 17b and c). Figure 17d shows one of the emergency parking areas which are almost the only possibility for off-the-traveled-way maneuvering. In spite of the apparent design deficiencies, this section operates with an average accident rate (Table 25).

Section 11—LA-205-Pas, S.Pas (New Route 11)

The 1.1-mi portion of Rt. 205 (Pasadena Freeway), between the Marmion Way interchange and the Orange Grove Ave. interchange, displays the following characteristics:

1. 58,100 ADT, 70 MVM (1958-60), 106 accidents.
2. Accident rates—expected, 1.20; actual, 1.51 or 126 percent of expected rate.
3. Six lanes (2- to 10-ft lanes and 4- to 11-ft lanes), 6-ft curbed median (barrier in place after July 1961), and no shoulders with the exception of the emergency parking area.

This section is the continuation of the Pasadena Freeway to the east of section 10 and the design situation is practically the same (Fig. 18), with the major difference being the reduction of two-lane widths from 11 to 10 ft. Section 11 has 38 percent of its alignment on curves with radii less than 5,000 ft, whereas section 10 has 47 percent of its alignment on curves with radii less than 5,000 ft.

Section 11 operates at only 126 percent of the expected rate in spite of the apparent

TABLE 25

ACCIDENT DATA, SECTION 10

Study Period	Actual Acc. Rate	Expected Acc. Rate	% of Expected
1958, 1959, 1960	1.12	1.26	89
1961	1.41	1.25	113
1962	1.49	1.25	119

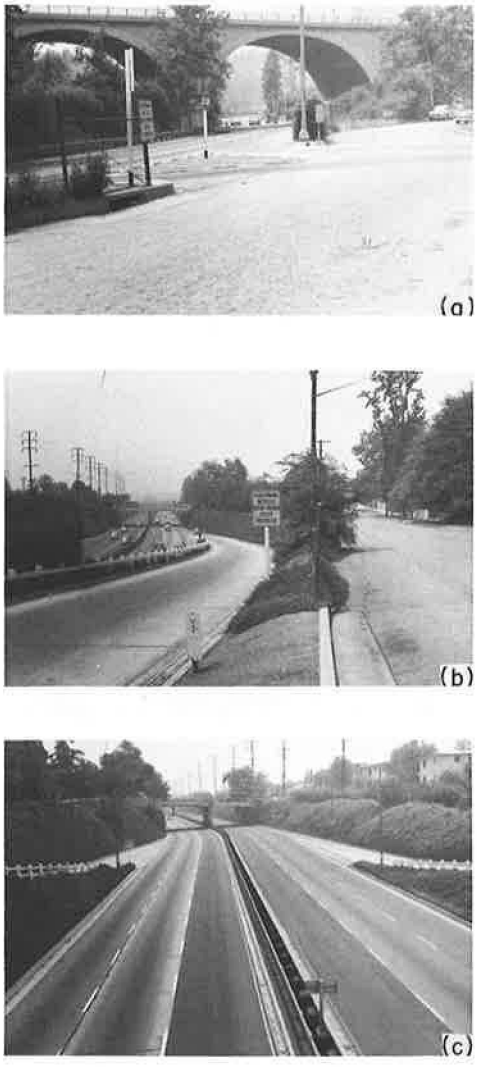


Figure 18. Section 11: (a) at Salonica Ave.; (b) southbound on-ramp at Orange Grove Ave., with stop sign; and (c) northbound on-ramp, with stop sign, and southbound off-ramp at Orange Grove Ave.

TABLE 26

ACCIDENT DATA, SECTIONS 10 AND 11

Condition	% Acc.	
	Sections	Normal
Hit fixed object	55	28
Movement—rear end	27	29
Violation—unsafe lane change	15	6
Defective vehicle	4	10
Residence—Calif., local	88	82
Driver's condition—H.B.D., sleep, and other	9	22

design deficiencies. Both sections 10 and 11 are lacking in potential off-the-traveled-way maneuverability as indicated by the high percentage of accidents which involved fixed objects (Table 26).

Apparently congestion is not a major problem within these sections. As pointed out before, sections 9, 10 and 11 are continuous on the Pasadena Freeway from the four-level structure to the Orange Grove Ave. interchange. The design standards are quite similar, yet section 9 has an ADT greater than 100,000; 45 percent of the accidents were of the rear-end type and 37 percent involved fixed objects. Sections 10 and 11 have two-thirds the ADT with only 27 percent rear-end accidents but 55 percent of the accidents involving fixed objects. Apparently the vehicles in the high-volume area are hitting each other and in the low-volume area they hit fixed objects.

SAN BERNARDINO AND RIVERSIDE FREEWAYS

Section 23—LA-26-Cla, Pom, C, WCov (New Route 10)

The 11.12-mi portion of Rt. 26 (San Bernardino Freeway), between Citrus St. in the City of Covina and the Los Angeles-San Bernardino Co. line, displays the following characteristics:

1. 49,900 ADT, 608 MVM (1959-61), 922 accidents.
2. Accident rates—expected, 1.16; actual, 1.52 or 131 percent of expected rate.
3. The west half of this section has six lanes and a 16-ft curbed median with median barrier installed in December 1961. The east half was widened from four to six lanes in December 1960. It has a 16-ft traversable median with no median barrier during the study period (Fig. 19).

This section has an ADT range of from 60,000 on the west end to 45,000 on the east end. The west half of the section, which includes the Kellogg Hill portion, had an accident rate of 2.0 with an expected rate of 1.20. The high accident rate in this west portion is probably due to the greater differential in speeds be-

Figure 19. San Bernardino Freeway.

Figure 20. On-ramps, section 23, showing lack of merging distance.

tween truck and automobile traffic. Trucks can only average about 16 mph on the 4 to 6 percent upgrade portion (3.5 mi long), whereas cars have no trouble maintaining normal highway speeds of 55 to 65 mph. The truck traffic in this section is 11 percent and the average for freeways is about 6 to 8 percent. In general, the west half of this section has lower design standards than the east half. The west half has 55 percent of its vertical alignment on 4 to 6 percent grade and 30 percent of its horizontal alignment on curve (between 2,000- and 3,500-ft radius). The east half has 14 percent of its vertical alignment on 2 to 3 percent grade and 11 percent of its horizontal alignment on curve (between 3,000- and 5,000-ft radius).

The east half of the section had an accident rate of 1.3 with an expected rate of 1.1. It had an accident rate of 1.45 during the 2-yr period before conversion to six lanes and a rate of 1.15 for the year after conversion. The construction operation (from four to six lanes) did not cause a severe accident problem. Approximately 20 accidents could be partially attributed to the construction operation.

The four diamond interchanges on the far east end of this section have extremely short acceleration lanes, averaging 260 ft from nose to end of taper (Fig. 20). These on-ramps were designed in accordance with the acceleration distance theory (5), that long straight ramp roadways provide enough distance to accelerate to 0.7 of freeway design speed and, therefore, no merging distance is necessary. The seven on-ramps accounted for 46 accidents during the study period for a ramp accident rate of 3.33 (normal, 0.60). The ramp rate for the entire section is 1.42 and if these seven ramps were excluded, the rate would be 1.03. Apparently, the ramp terminals are too short to allow proper merging and the entering vehicles must slow or stop, which in turn causes many rear-end accidents.

Section 27—SBd-26-Mcl, Upl, Ont, D (New Route 10)

The 13.58-mi portion of Rt. 26 (San Bernardino Freeway) lies between the San Bernardino-Los Angeles Co. line and Live Oak Ave. near the City of Fontana. Facts about the section include:

1. 35,100 ADT, 522 MVM (1959-61), 757 accidents.
2. Accident rates—expected, 1.10; actual, 1.45 or 132 percent of expected rate.
3. This section had four lanes for all except the last month of the 3-yr study period, at which time the easterly 6 mi of the section were opened for six lanes of traffic. The freeway was widened on the inside (median side) between January and December 1961. There was little increase in accident rates during the construction period. The section has a 16- to 46-ft median, 10-ft shoulders, 8 percent of its length on fill section, 10 percent on cut section, and 82 percent constructed at ground level.
4. This section has good alignment (Fig. 21) with only 13 percent of its horizontal alignment on curve under 5,000-ft radius (3,500-ft minimum) and only 9 percent of its vertical on grade over 2 percent (4.5 percent maximum).

This section has an ADT range of from 45,000 at the west end to 29,000 at the east end. The section also experiences an exceptionally high Sunday afternoon volume which is a result of weekend travelers returning home from trips into the Imperial Valley, the Palm Springs area, and the Salton Sea area. This volume is at its greatest peak during the months of October through April when the temperature is mild in the desert area.

Twenty-five percent of the total accidents in this section occurred westbound between 3:00 and 9:00 p.m. on Sundays in these seven months. During this period, there was only 16 MVM of travel for an accident rate of 11.9. This situation is most critical in the western 3-mi portion of this section, within which are three diamond interchanges similar to and immediately east of the ones mentioned in section 23. Within the 3-mi section and during the critical period, 80 accidents occurred with only 4 MVM of travel for an accident rate of 20.0. Here again the ramp merging areas were apparently too short to accommodate merging vehicles without causing a bottleneck in the already critical traffic flow.

Many of the accidents which occurred during this critical period were rear-end accidents at fairly high speeds (following too far). As a result, the injuries per accident (0.89) and the vehicles per accident (2.7) were higher than normal, which is about 0.76 and 1.9, respectively. Many of the accidents were a result of further congestion caused by other accidents.

The volumes during this critical period ranged between 1,000 and 1,500 vph/lane. Apparently the higher accident rates occurred when the volumes were between 1,200 and 1,500 vph/lane for a period of from 1 to 3 hr.

At lane volumes of less than 750 vph, speeds are almost independent of volume. Between 1,000 and 1,500 vph/lane, average speed drops from about 55 to 45 mph, owing to lack of passing opportunities. The westbound traffic coming from the Palm Springs area had been driving for a distance of 20 to 30 mi in a stream of high-speed characteristics, with volumes less than 1,000 vph/lane. When they catch up with the upstream end of the moving queue which forms as the volume and density build up and the speed drops, they have the sun in their eyes and are possible fatigued and irritable at having

to go home after the weekend in the desert. As a result, they apparently have trouble perceiving the fact that a significant change in speed of the cars ahead has taken place. Once one accident has happened, of course, traffic stops and then the situation is compounded, with secondary collisions (counted as separate accidents) occurring at the upstream end of the stopped queue.

If the 6-hr period on Sunday had had an average accident rate, the total section would have had an accident rate of 1.05 with an expected rate of 1.10.

The most probable solution to this accident problem may be to increase the freeway capacity by adding additional lanes. The 5-mi portion of freeway between Vineyard Ave. and the county line was widened to six lanes and opened for traffic in December of 1961. This portion had an accident rate of 0.96 in 1962 with an expected rate of 1.13. The on-ramp acceleration lanes at the diamond interchanges were also lengthened during the widening project.

Section 23 (adjacent to section 27 to the west) experienced only a mild degree of the 6-hr Sunday afternoon congestion problem. Only 10 percent of the accidents in section 23 occurred during the critical period with approximately 5 percent of the vehicle miles. Apparently the six-lane portion in that section did alleviate the congestion or the upstream end of the high-density flow was generally farther east.

Section 32—SBd-26-D, Ria, Col (New Route 10)

The 8.23-mi portion of the San Bernardino Freeway, between Live Oak Ave. near the City of Fontana and 5th St. in Colton, displayed the following characteristics:

1. 33,000 ADT, 197 MVM (1960-61), 222 accidents.
2. Accident rates—expected, 1.08; actual, 1.13 or 104 percent of expected rate.
3. Four lanes, median mostly traversable (46- to 66-ft variable) with only a ½-mi section of 12-ft curbed median, good potential off-the-traveled-way maneuverability with clearance to fixed objects of 30 to 60 ft on the right in most places.
4. Alignment (Fig. 22) is good with only 7 percent of the horizontal alignment on curves under 5,000 ft (4,000-ft minimum) and 2 percent of the vertical alignment on grade greater than 2 percent (3 percent maximum). The on-ramp acceleration lanes

Considering the design aspects and the ADT of this section, it would be expected that the overall accident rate would be lower than average. In actuality, this section is subject to the same Sunday congestion problem experienced by the adjacent section 27.

Twenty-four percent of the accidents occurring in this section happened westbound between 3:00 and 8:00 p.m. on Sunday during the months of January, February, March, October and November. Seventy percent of these Sunday accidents occurred in a 2-hr period between 5:00 and 7:00 p.m. The accident rate for this 2-hr period is 23.0. If the 5-hr period on Sunday had had an average accident rate, this section would have had an accident rate of 0.90 with an expected rate of 1.08. A six-lane section may well relieve this problem as illustrated in sections 23 and 27.

Figure 22. San Bernardino Freeway.

Section 31—SBd-43-F, Col, SBd. (New Route 395 and 15)

This 8.55-mi portion of Rt. 43, which includes parts of the Riverside and San Bernardino Freeways, lies between the Los Angeles-Riverside Co. line and the junction of Rt. 31 in San Bernardino. Facts about the section include:

1. 32,000 ADT, 198 MVM (1960-61), 245 accidents.
2. Accident rates—expected, 1.07; actual, 1.19 or 111 percent of expected rate.

TABLE 27

STATISTICS, SECTION 31

Location	ADT	No. Lanes	Median (ft)	% Curve <5,000-Ft Radius	% Grade >2%	Off-Traveled-Way Maneuverability	No. Left-Hand Ramps	Actual Acc. Rate	Expected Acc. Rate	% of Expected Rate
Co. line to jct. Rt. 26	25,000	4	46	11	29	Good	0	1.07	1.02	105
Jct. Rt. 26 to Mill St.	36,500	4	42	42	22	Fair	2	1.62	1.10	147
Mill St. to jct. Rt. 31	37,000	6	22, Sep. Rdw.	10	15	Fair-Poor	5	1.07	1.10	97

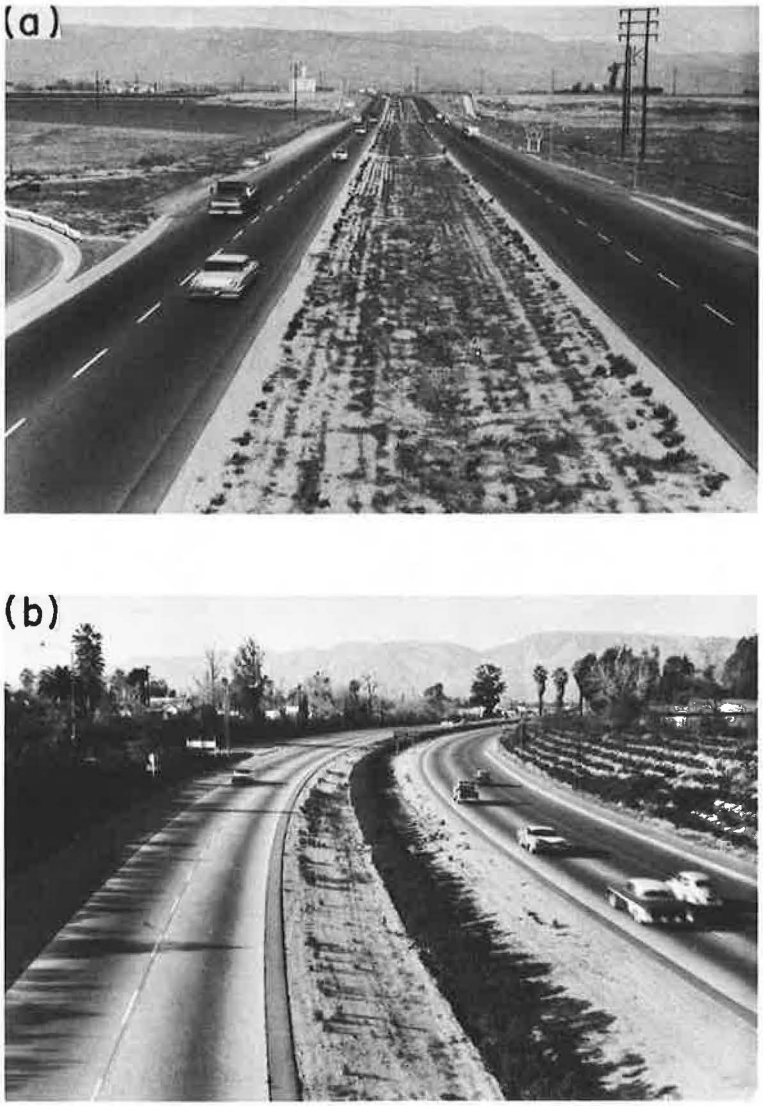


Figure 23. Section 31: (a) near south city limits of Colton (accident rate, 1.07); and (b) near Colton Ave. (accident rate, 1.62).

The 2.25-mi portion from the junction of Rt. 26 to Mill St. (Table 2, section 31b) has an above average accident rate. The remainder of the section (Table 2, section 31a) is about average (Table 27, Fig. 23).

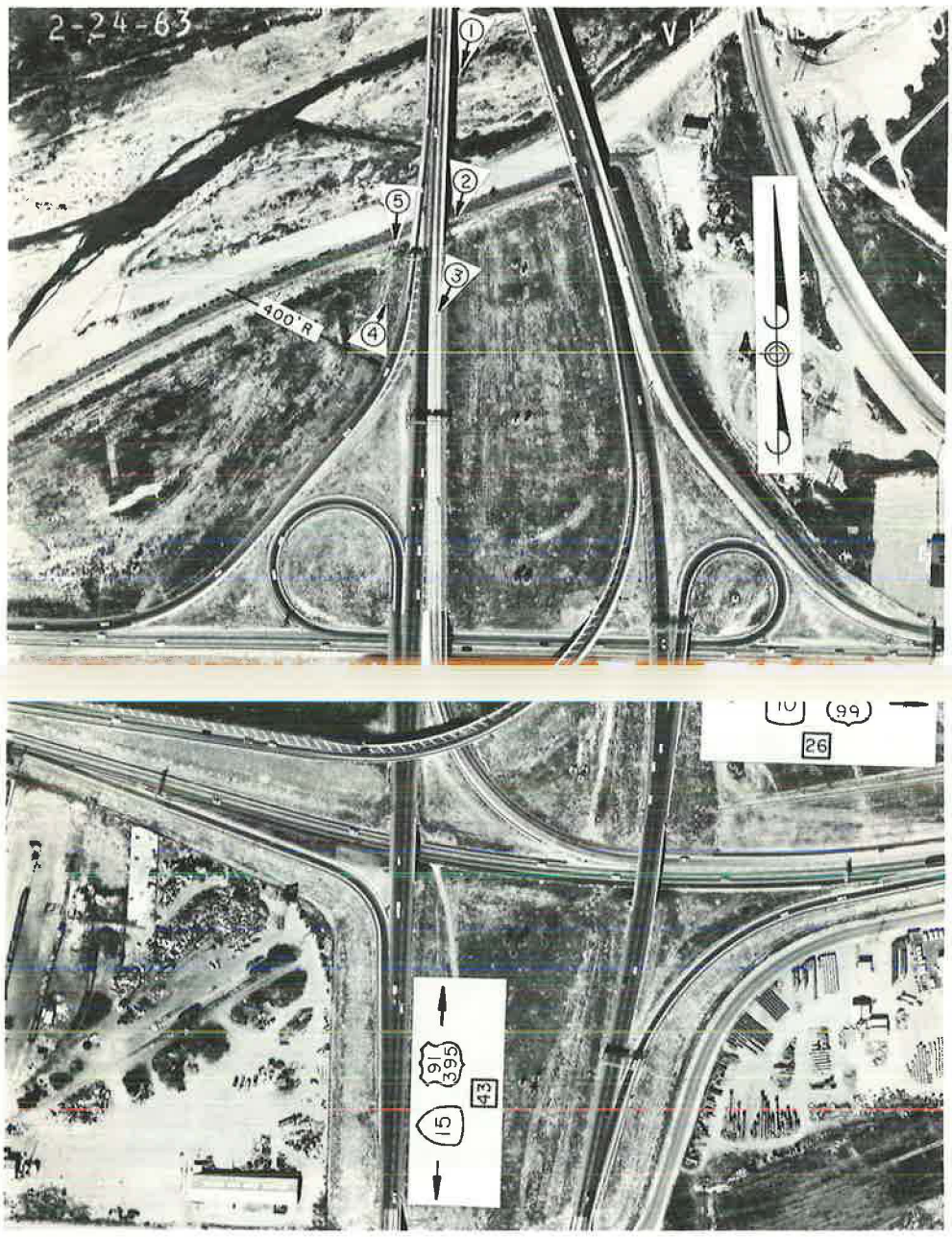


Figure 24. Junctions San Bernardino and Riverside Freeways; ↔ location and direction of photos in Figures 25 and 26.

Figure 25. Drivers' view of off-ramp, southbound Rt. 43 to westbound Rt. 26.

Figure 26. Construction of new ramp; southbound on US 91 to westbound on San Bernardino Freeway in Colton.

The southbound Rt. 43 to westbound Rt. 26 off-ramp is a major contributor to the high accident rate of section 31b (Fig. 24). The ramp accounted for 21 accidents with 5.3 MV entering (actual rate of 3.96 vs expected rate of 1.00). The vehicles apparently entered the ramp at too great a speed to negotiate the 400-ft ramp curve. The ramp is signed for 40 mph, but it has the appearance of being a higher speed ramp. The main line type overhead signing for the southbound-westbound turn may also contribute to the illusion. Figure 25 illustrates the drivers' view. Construction has begun on a new structure that will bypass this ramp and provide a high-speed freeway-to-freeway connection (Fig. 26).

FREEWAYS IN THE SAN DIEGO AREA

Section 28—SD-77-SD (New Route 395)

This section is on the Cabrillo Freeway and is the 8.5-mi portion of Rt. 77 north of Rt. 200 (A St.) to Clairmont Mesa Blvd. Facts about the section include:

1. 35,600 ADT, 331 MVM (1959-61), 600 accidents.
2. Accident rates—expected, 1.10; actual, 1.82 or 165 percent of expected rate.
3. Four lanes (with the exception of a ½-mi portion of eight lanes), 12- and 16-ft curbed median variable to 54-ft traversable, 2-ft shoulders on the left and 8-ft shoulders on the right.

TABLE 28

Section	Length (ft)	ADT	Actual Acc. Rate	Expected Acc. Rate	% of Expected
28a	4.75	41,300	2.30	1.13	204
28b	3.75	28,200	0.91	1.05	87

Figure 27. Section 28a.

This section has been split and designated as section 28a (A St. to Genesee Ave.) and section 28b (Genesee Ave. to Clairmont Mesa Blvd.) in Table 2. Section 28a was built in 1948 to considerably lower design standards than Section 28b which was built in 1956 and 1958. The accident problem is concentrated in the southerly 4.75-mi section as illustrated in Table 28.

Traveling from south to north, the first mile of section 28a has an accident rate of 1.25 and an expected rate of 1.00. It has a 54-ft traversable median, grades under 2 percent and over 1,400-ft radius curves. Off-the-traveled-way maneuverability to the right is poor and median traversability is hampered by trees (Fig. 27).

Figure 28. Washington St. interchange; o→ location and direction of photos in Figure 29.

Figure 29. Washington St. interchange.

Figure 30. Section 28b; actual accident rate, 0.91; expected accident rate, 1.05.

TABLE 29

ACCIDENT DATA, SECTION 28

Condition	% Acc.	
	Section	Normal
Driver's condition:		
H. B. D.	15	14
Sleep	3	5
Violation—following too close	33	18
Movement—rear end	35	29
Speed—31-40 mph	16	13
Time of day—afternoon peak 4 to 6 p. m.	32	15

The next 2.5-mi portion of section 28a has an accident rate of 3.0 with an expected rate of 1.10. It has a 6- to 16-ft curbed median, 76 percent of its vertical alignment on grade of from 4 to 6 percent and 54 percent of its horizontal alignment on curves between 600- and 4,000-ft radius. Within this 2.5-mi portion is the Washington St. interchange (Figs. 28 and 29). The ½-mi portion which includes this interchange has an accident rate of 5.6. The interchange area is situated on a 600-ft radius horizontal curve with a +4 percent grade entering and a -6 percent grade leaving. There is a 12-ft curbed median, little or no off-the-traveled-way maneuverability to the left or right; the situation is further complicated by six high-volume (4,000 ADT average) ramps.

The next 1.25 mi of section 28a has an accident rate of 1.60 with an expected rate of 1.10. It has a 5 percent maximum grade, 3,000-ft minimum radius horizontal curve and a 1,000-ft bridge with no shoulders at the San Diego River. The bridge has an accident rate of 1.7.

The on-ramps within section 28a have an average acceleration lane length of 300 ft and an average ramp accident rate of 1.03 accidents per million ramp vehicles as compared to a normal of about 0.80.

The next 3.75 mi (section 28b) have an accident rate of 0.91 with an expected rate of 1.05. The horizontal alignment is primarily tangent and the grades are less than 2 percent. Off-the-traveled-way maneuverability is good in most places (Fig. 30). The two interchanges within this section have the main lane shoulders carried through the interchange area. The ramp acceleration lanes have an average length of 720 ft. The combined ramp rate is 1.08 with the major offenders being the off-ramps (average rate, 1.38).

TABLE 30

ACCIDENT DATA, SECTION 13

Condition	% Acc.	
	Section 13	Normal
Single vehicle	52	28
Vehicle age (yr):		
0-2	24	39
5-10	39	19
Driver's age—15-26 yr	46	25
Driver's condition		
H. B. D.	14	14
Sleep and other	30	8
Violation		
Following too close	24	18
Unsafe lane change	14	6
Movement		
Rear end	44	29
Passing sideswipe	2	18
Hit fixed object	44	28
Light conditions—daylight	37	52

Figure 31. Montgomery Freeway.

TABLE 31

ACCIDENT DATA, SECTION 14

Condition	% Acc.	
	Section	Normal
Single-vehicle accidents	39	28
Speed—41-50 mph	40	23
Light condition—daylight	35	52
Time of day—12:00 to 7:00 a.m.	48	23
Residence—Calif., local	71	82
Driver's age—15-26 yr	43	25
Driver's condition:		
H. B. D.	43	14
Sleep and other	9	8
Automobile age (yr):		
0-2	40	39
5-10	32	19
Violation:		
Following too close	12	18
Unsafe lane change	6	6
Movement:		
Rear end	42	29
Passing sideswipe	9	18
Hit fixed object	36	28

Section 28, as a whole, has a peak hour congestion problem; Table 29 indicates a high percentage of peak hour accidents followed by the high percent of following-too-close violations and rear-end type accidents.

The rear-end type accident is more frequent in section 28a (41,300 ADT) than in section 28b (28,200 ADT). Figure 30 is typical of the northern portion of this study section.

Section 13—SD-2-SD (New Route 5)

This section is on the Balboa bypass, from 1 mi south of Balboa Ave. to 0.65 mi north of Balboa Ave. on Rt. 2 in San Diego. Facts about the section include:

1. 26,600 ADT, 48 MVM (1958-60), 62 accidents.
2. Accident rates—expected, 1.03; actual, 1.29 or 125 percent of expected rate.
3. Four lanes, variable median width, 2-ft inside shoulders and 8-ft outside shoulders.

This section of freeway operates at 125 percent of the expected rate, has fair to good off-the-traveled-way maneuverability, and is located in the heart of the Balboa-La

of young drivers, including a large percentage of servicemen, frequent this area. As Table 30 indicates, the accidents involved a large percentage of young, inexperienced, irresponsible, fatigued drivers in old cars speeding in early morning hours.

Section 14—SD-2-SD, ChV, G, NatC. (New Route 5)

The 9.16-mi portion of Rt. 2 (Montgomery Freeway) between the San Ysidro junction and the south city limits of National City. Facts about the section include:

1. 26,300 ADT, 264 MVM (1958-60), 400 accidents.
2. Accident rates—expected, 1.03; actual, 1.52 or 148 percent of expected rate.
3. Four lanes, 36- to 40-ft deterring earth median, 14 percent of horizontal alignment on curve under 5,000-ft radius (Fig. 31).

This section of US 101 is the major route between San Diego and Tijuana,

Figure 32. Otay River bridge, showing northbound lanes looking south; guardrail on other end of bridge.

Figure 33. Off-ramp to National Ave.

Mexico. Tijuana is a typical border city with scores of bars and night clubs operating on a 7-day-a-week, 24-hr-a-day basis and providing popular entertainment for thousands of sailors and marines in the San Diego and Oceanside areas.

As Table 31 indicates, there was a high percentage of accidents involving young drivers and drivers who had been drinking. There was a high percentage of early morning, single-vehicle accidents involving older automobiles. A high percentage of rear-end type accidents is usually indicative of a congestion problem; however, this section has a relatively low ADT and peak hour accidents are not excessive.

There are four relatively narrow bridges within this section. Two are located at the Sweetwater River Channel and two are at the Otay River. They are two lane, 26 ft in width (curb to curb) and have flared guardrail approaches (Fig. 32).

Thirty-one percent of the total accidents occurring in this section were concentrated within the 5,400-ft length that includes the bridges. This portion carried only 16 percent of the MVM for an accident rate of 2.94. If the 5,400-ft portion were excluded, the remaining 8.14 mi would have an accident rate of 1.24 with an expected rate of 1.03.

There are two ramps within this section that seem to have some degree of accident concentration. The first is a two-lane, left-hand on-ramp from eastbound Rt. 199 to northbound Rt. 2 at Palm City. This ramp has an accident rate of 1.16 which is about twice normal for an on-ramp. The second ramp is the northbound off-ramp to National Ave. It is a buttonhook-type ramp with a 250-ft deceleration lane which ends with a 70-ft radius curve that has a 37° delta (Fig. 33).

In July 1958, a shoulder stripe was installed in advance of the off-ramp. In August 1958, the ramp was fog sealed for color contrast with the main line, and the plywood fence with black and white zebra stripes was installed in the head-on position down the deceleration lane. In 1959, there were 9 ramp accidents with only 0.29 MV entering. In January 1960, the shoulder stripe was lengthened in advance of the deceleration lane and under the structure. There were 4 accidents in 1960, 4 in 1961, and 3 in 1962 with approximately 0.32 MV entering per year.

MISCELLANEOUS LOCATIONS

Section 4—Son-1-F, C (New Route 101)

This 20.1-mi portion of Rt. 1 between Petaluma and Santa Rosa (Petaluma-Santa Rosa Freeway) displays the following characteristics:

1. 12,900 ADT, 284 MVM (1958-60), 171 accidents.
2. Accident rates—expected, 0.90; actual, 0.60 or 67 percent of expected rate.
3. Four lanes, 46-ft traversable median, 8-ft outside shoulders, and 5-ft inside shoulders.
4. Off-the-traveled-way clearance is good with 40- to 60-ft clearance to the right-of-way line.
5. Only 15 percent of the total alignment within this section is on curve.

Figure 34. Petaluma—Santa Rosa Freeway.

The success of this section in accident experience can be attributed to good alignment standards, liberal cross-section design, good off-the-traveled-way emergency maneuverability and low volume even for a four-lane freeway (Fig. 34).

As Table 32 indicates, accidents in this section involved more driver defects, greater speeds and a high percentage of single-vehicle accidents. Yet in spite of the high percentage of driver defect-caused accidents, the overall rate is very low due to the high geometric standards.

TABLE 32

ACCIDENT DATA, SECTION 4

Condition	% Acc.	
	Section	Normal
Weather		
Rain	9	0
Fog	7	3
Speed—> 60 mph	26	12
Driver's condition		
H.B.D.	22	14
Sleep	18	5

Section 7—Tul-4-F (New Route 99)

This section is the 3.67-mi portion of the US 99 freeway from the Visalia Airport interchange to 1 mi north of Goshen. Facts about the section are as follows:

1. 13,700 ADT, 55 MVM (1958-60), 90 accidents.
2. Accident rates—expected, 0.92; actual, 1.64 or 178 percent of expected rate.
3. Four 12-ft traffic lanes, 8-ft shoulders on right, 2-ft shoulders on left and 46-ft traversable median (Fig. 35).

The Visalia Airport interchange is a major contributor to the high accident rate

Figure 35. Section 7.

0.85 mi long or 23 percent of the total section accounted for 60 percent of the accidents in the total section. Of the 54 accidents occurring in the interchange, 20 were directly attributed to the 7 ramps within the interchange. Two of these ramps (F & G) accounted for 13 of the 20 ramp accidents (Fig. 36). These accidents were all weaving accidents occurring in the weave between the two ramps (F & G) which is a two-lane weave across the main lane northbound freeway traffic. Some of the accidents occurred when vehicles in the outside main lane attempted to cross the inside lane into the left-hand off-ramp (G). Ramp (G) is a two-lane PCC left side off-ramp and it is confusing to the main line traffic as to which actually is the continuation of the main lanes (Fig. 37).

All traffic from Visalia to Hanford must weave with the freeway traffic. Traffic from Hanford to Visalia does not have to weave across freeway traffic; however, there is an element of surprise at the off-ramp (B) (Fig. 38). The ramp is hidden from view by the underpass until the motorist is almost too close to the ramp nose to make the turn decision. Southbound freeway traffic going to Visalia expreiences the same sensation. The left-hand off-ramp from Visalia to southbound on the freeway (Ramp A) is also confusing because of the limited visibility (Fig. 39).

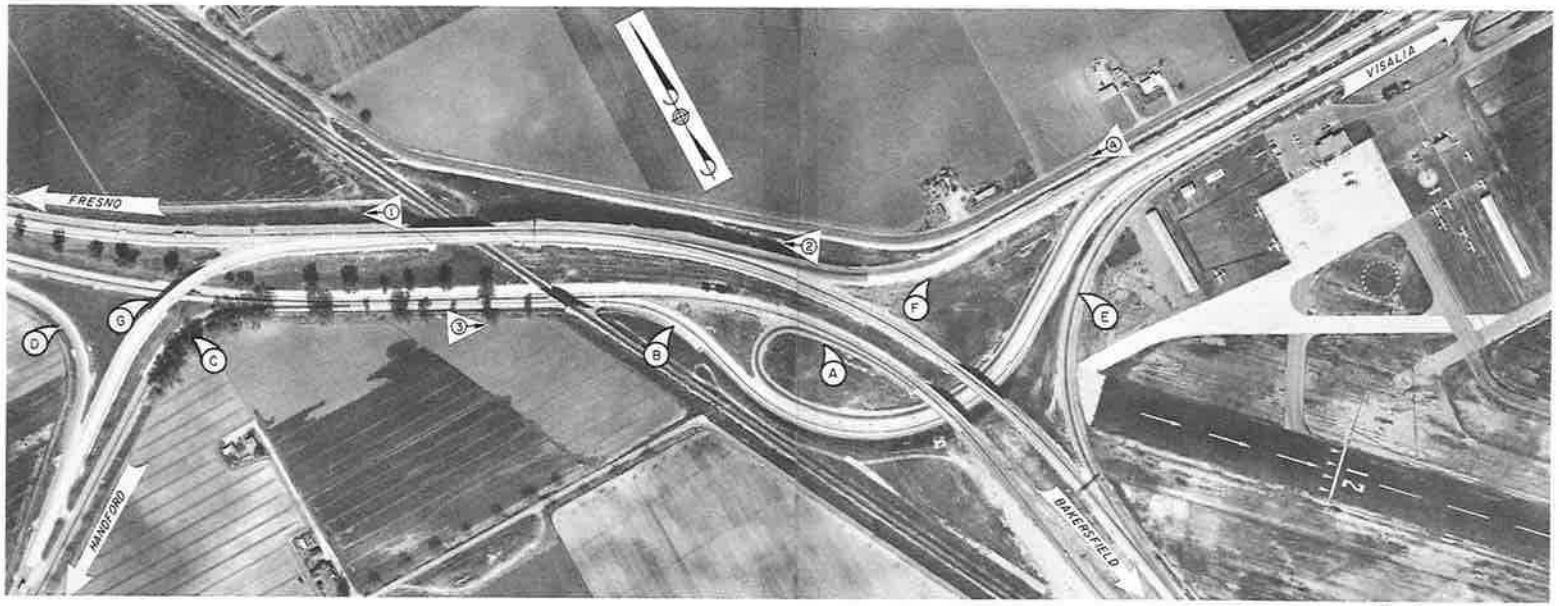


Figure 36. Visalia Airport interchange; ⊶ location and direction of photos in Figures 37 and 38.

Figure 37. Ramps, Visalia Airport interchange.

Figure 38.

TABLE 33

DATA FROM VISALIA FREEWAY SECTION

Condition	% Acc.	
	Section 7	Normal
Single vehicle	39	28
Light—daytime	44	52
Alignment—straight level	42	64
Residence—Calif., local	42	82
Driver's condition—sleep	15	5
Defective vehicle	15	10
Hit fixed object	37	28
Movement:		
Rear end	16	29
Passing sideswipe	24	18
Violation:		
Following too close	6	18
Unsafe lane change	14	6

Figure 40. Hamilton Ave. interchange, southern portion.

The 2.82-mi portion of the freeway section which excludes the airport interchange has an accident rate of only 0.80. This portion includes the two interchanges at Goshen.

The comparisons given in Table 33 point to the factors which were perhaps the major contributors to the total section's accident rate. There were fewer local drivers and more fatigued drivers involved than normal. The single-vehicle accidents generally involved the fatigued or sleepy driver hitting fixed objects during the evening hours.

Figure 41. Hamilton Ave. interchange; o→ location and direction of photo in Figure 40.

The table indicates only 42 percent for straight level alignment accidents; however, this section has 43 percent of its alignment on curve.

Section 16—SC1-5;239-LGts, D, Cmb, SJs;D, SJs (New Route 17 & 280)

The San Jose-Los Gatos Freeway, a 10.2-mi portion of Rt. 5 between San Jose and Los Gatos, displays the following characteristics:

1. 32,000 ADT, 238 MVM (1960-61), 268 accidents.
2. Accident rates—expected, 1.07; actual, 1.20 or 112 percent of expected rate.
3. Four lanes, 34- to 46-ft traversable median, and 8-ft shoulders.

This freeway section has an average accident rate. Off-the-traveled-way maneuverability is fair. Thirty-one percent of the alignment is on curves under 5,000-ft radius and 16 percent is on grade greater than 2 percent.

Figure 40 is a view of the southern portion of the Hamilton Ave. interchange, looking south. Figure 41 is an aerial view of the entire interchange. The ½-mi section that includes the interchange has an unusually high accident rate of 2.6. Immediately preceding the interchange, the northbound traffic must negotiate a 2,300-ft radius curve on a -3 percent grade. There are two 150-ft long, 30-ft curb-to-curb (each direction) bridges within the curve.

The northbound off-ramp to Hamilton Ave. has the appearance of the traveled way extended at the end of the curve. The ramp has a 260-ft radius curve with a deceleration length of 500 ft. It has an accident rate of 4.5 with 2 million vehicles entering.

The interchange is partially hidden from view by the railroad overhead when northbound and by a crest vertical curve preceding the interchange when southbound.

Other Sections

Sections 2, 3, 5, 8, 15, 29 and 33 operate relatively close to the expected accident rate and present no new concept or design feature for discussion. The sections were not abnormally hindered by the careless or drinking driver, and the designs could best

SUMMARY AND CONCLUSIONS

Thirty-three sections (200 mi) of freeways with widely divergent accident rates and a total of 11,384 accidents were analyzed. The accidents occurred during the course of 9,198 MVM of travel, to yield an average accident rate of 1.24 accidents per MVM. The accident rates for the individual sections range from 4.52 to 0.60 accidents per MVM.

The first part of the study indicated that some design features were associated with higher accident rates than others. The trends which developed are as follows:

1. The alignment was broken down into 6 types which are, in order of low to high accident type, straight level, straight upgrade, straight downgrade, curved level, curved upgrade, and curved downgrade. With heavy truck traffic, the straight upgrade is apparently more detrimental than the straight downgrade and all of the curved classifications are practically the same.
2. Fixed objects are involved in about 28 percent of all freeway accidents. Piers, abutments and bridge rails are apparently the most vulnerable, with signs, guardrails, and light standards following in that order. Curbs, dikes and drainage structures frequently act as fulcrums to convert simple skidding into roll-over accidents.
3. Long bridges with shoulders have better accident rates than long bridges without shoulders.
4. Ramps associated with diamond-type interchanges are apparently the safest type. On-ramps generally have better accident rates than off-ramps. The downhill on-ramp is the best type of on-ramp and the uphill off-ramp is the best type off-ramp. The left-hand ramp (enters or leaves the freeway at high-speed lane) has a higher accident rate than any other class.

5. For any given ADT, a four-lane freeway has a higher accident rate than a six-lane freeway and a six-lane freeway has a higher accident rate than an eight-lane.

The second part of the study indicated, in general, that the high accident sections possessed the lower alignment standards. They had an average of 25 percent of their horizontal alignment on curves with radii less than 5,000 ft, whereas the low accident sections averaged 20 percent. The vertical alignment of the high accident sections averaged 28 percent on grades greater than 2 percent. The low accident sections averaged 11 percent.

Forty-three percent of the high accident sections' total length was within interchange areas as compared to 36 percent for the low accident sections. The interchange on a horizontal or vertical curve was more apt to be found in the high accident sections.

The high accident sections had an average ramp accident rate of 1.02 accidents per MV, whereas the low accident sections had an average ramp rate of 0.62. The high ramp rates were associated with the left-hand connections, tight ramp turns and short speed change lanes.

The high accident sections possessed more narrow bridges and less clearance to fixed objects. Narrow curbed medians were characteristic of the high accident sections and the wide traversable medians were generally associated with the low accident sections.

A few of the high accident sections experience congestion of short duration (weekend traffic) that resulted in extremely high accident rates during those periods. Two of the high accident sections experienced an unusual proportion of accidents involving irresponsible or drinking drivers.

The low accident sections were characterized by open-type roadside which would allow the driver to maneuver safely off the traveled way in the case of emergency. Some of the low accident sections did not provide good off-the-traveled-way clearance, but in every case the lane density (ADT/lane) was low enough to allow sufficient maneuvering on the traveled way.

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