California Method of Assigning Diverted Traffic to Proposed Freeways

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California has developed a set of curves showing percent of freeway usage as a function of both time and distance differentials. The primary features of this chart are that it shows: (a) as long as some time is saved, there will be some users of the freeway route no matter how far out of direction they must go; (b) as long as some distance is lost, there will be some "non-users", no matter how much time is saved; (c) in between there is a gray area where people do not know how much time or distance is saved or lost, or whether it is saved or lost.

The area between the limiting boundaries described in (a) and (b) was filled by a systematic set of usage curves and the coefficients were determined by observation of two existing freeways; i.e., by interviewing the users and comparing with total interzone transfers. The chart was then tested against the Shirley Highway data reported by D.L. Trueblood in HRB Bulletin 61, and was found to fit relatively well. At least the California curves fit the Shirley data far better than the time-ratio curves fit the California data.

In California, whenever a route study involves new location or more than one alternate solution, a complete economic analysis is made, showing user costs for the common set of trips whether made via any one of the proposed alternates or via remaining roads. This work is done in conjunction with the assignment, by punch card machines. The manual coding necessary consists of coding the distance via existing network for each interzone transfer, the distance to and from each freeway alternate for each interzone transfer, and the distance between access points along the line of each freeway alternate. The assignment curves are expressed as a formula,

$$P = 50 + \frac{50(d+\frac{1}{2}t)}{\sqrt{(d-\frac{1}{2}t)^2+4.5}}$$

for the purpose of machine manipulation.

● MOST of the cities in California lie on principal state highways that are being projected as freeways. The larger cities, of course, will be served by several freeways in each.

Whenever a route study or project report for one of these freeways involves alternate locations, an economic analysis accounting for road-users' operating costs and benefits as well as highway costs is made. The economic analysis takes into consideration those items that can be reduced to financial terms with a minimum amount of surmise or opinion, but often there are other factors which cannot be stated in dollars which might outweigh the formal analysis. These must be resolved by judgment.

Many engineers are prone to regard economic analyses as "theoretical", using the word in a manner that implies that theory is antithetic to practice. These engineers are reminded that whenever one says "this line will do the most good for the money," he has made an economic analysis. Whether it is formalized and computed or merely based on a mental process involving long experience, judgment, and art, the analysis is made. The difference is that when a formal analysis is made, it can be laid down in black and white for all to see, and the engineer can say "these are the facts". This is a very valuable thing to be able to say if controversy arises regarding a route location, and the other man says "this is my opinion."

For many years, in California practice, trips were assigned to a proposed route on the basis of least cost (1). In this method, the cost per trip, including time value, was computed via the proposed route and via the remaining road network, and the whole transfer between zones was assigned to the route resulting in the least cost per trip. This method usually produced results which looked reasonable from a subjective point of view, and had a distinct advantage in that trips which would "lose money" by using

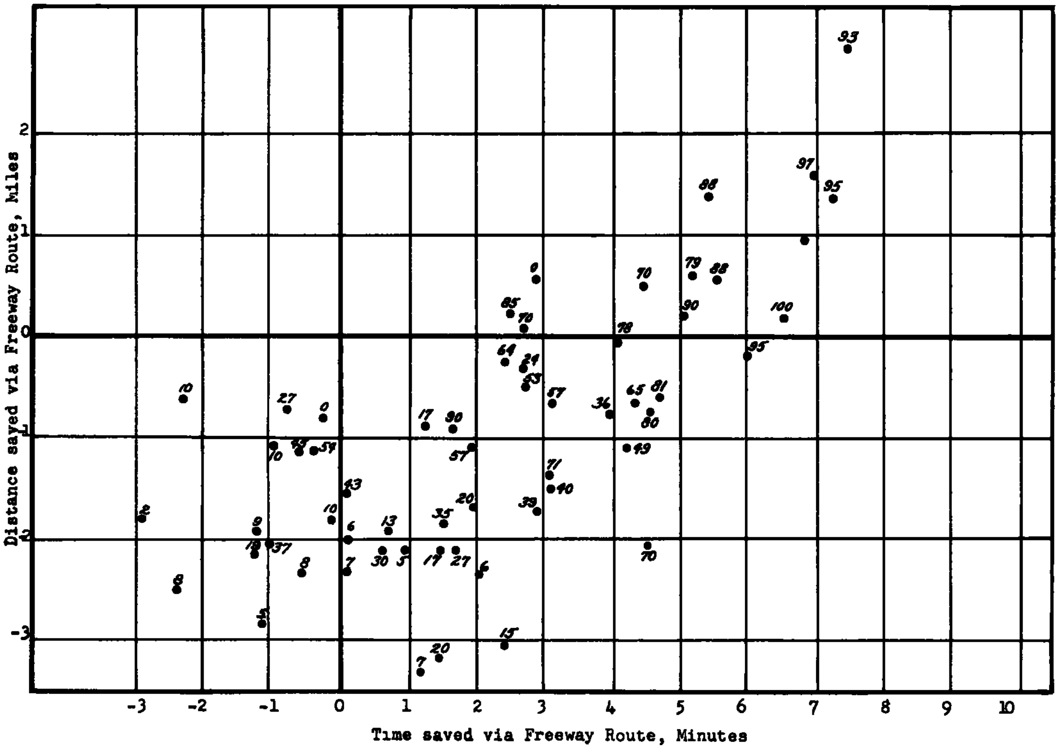


Figure 1. Percent usage related to time saved and distance saved-Alvarado Expressway.

the freeway were not assigned to it, thereby reducing its benefits. The reason for putting "lose money" in quotations here is that, if the proper values are assigned to time saved, and to driver's preference, he does not lose by choosing one route or the other. He may spend more, but he gets what he considers his money's worth, or he would have gone the other way. Inasmuch as a practical method of assigning different values to time for various individual users of a facility has not come to our attention, the "least cost" procedure has considerable merit.

It was known, that all of the drivers involved in a given transfer would not choose the same route, but it was hoped that the overs would offset the unders. In 1953, however, this procedure was revealed to have some serious flaws.

In one city, moving a proposed access point from H Street to J Street changed the ADT on the freeway by about 40 percent. In another city, the far bypass alternate which skirted the town about $1\frac{1}{2}$ miles from the main intersection, was found to have practically the same projected traffic volume as the near by-pass. This was because trips destined to the central business district saved a bare fraction of a cent by using the freeway in the case of the far by-pass, and although the saving per trip was much greater on the near by-pass, all of the trips involved in this large transfer were assigned to both alternates.

In a third city (San Diego), a similar situation arose but here there was a completed expressway upon which an origin-destination survey had just been completed. To obviate the difficulty, which was caused by the assumption that either 100 percent or none of a given transfer would use the proposed facility, it was decided that a curve of graduated percent usage would be used. The time-ratio curve in D. L. Trueblood's paper "Effect of Travel Time and Distance on Freeway Usage" (2) was tested against the known data on the Alvarado expressway. It was found that this curve would result in assigning 39,000 trips per day to the expressway, whereas only 24,000 trips a day were using the expressway. It was then decided to do some independent analysis of the San Diego Origin-Destination data in conjunction with known usage of the two freeways in that city.

DEVELOPMENT OF ASSIGNMENT CURVES

Driver preference for one route or another is a function of many factors. The simplest ones to measure and express numerically are travel-time and travel-distance. It is believed that orientation, or sense of direction, in itself is also extremely important. It is very difficult to persuade a motorist to start out in a northerly direction when he knows his destination in southerly. Fortunately, nearly all trips which are out of direction in this sense involve extra travel distance, which can be measured.

From Trueblood (2) was derived the idea of plotting time, distance, and percent usage on one graph. It was thought that some iso-usage curves could be developed by interpolation or smoothing of the values observed. If distance is of no weight, the iso-usage curves would come out parallel to the time ordinates. The results of observations on the two expressways in San Diego are shown in Figures 1 and 2, and in Tables 1 and 2. It was practically impossible to discern a pattern, and so deductive reasoning was resorted to. This reasoning went like this:

1. There are other factors besides time and distance, but they will be ignored because they can't be measured and because they cannot be forecast.

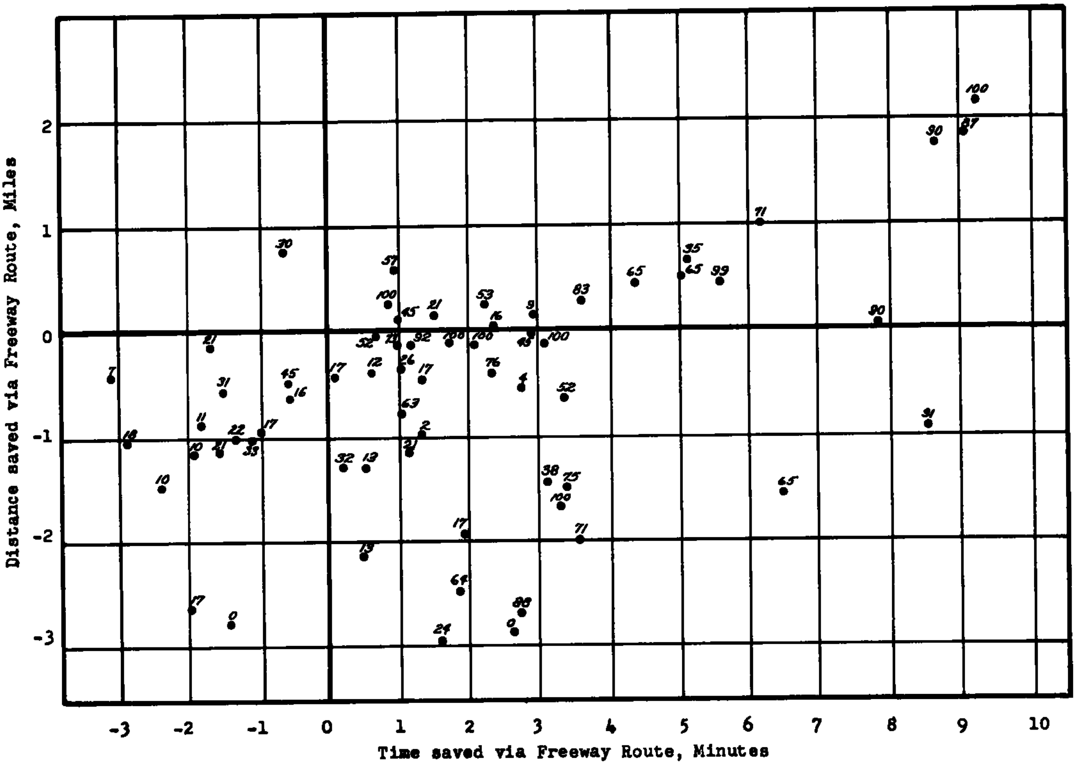


Figure 2. Percent usage related to time saved and distance saved-Cabrillo Freeway.

2. For the purpose of forecasting, it is essential that a systematic, or regular, pattern be used. If idiosyncrasies of a particular route or street system affect the pattern, they are impossible to extrapolate from the observed case or cases to the problem at

TABLE 1

ALVARADO-MISSION VALLEY EXPRESSWAY USE STUDY

From Zone	To Zone	Total Trip Transfer Between Zones	No. of Trips on Expressway	Percent of Trips on Expressway	Time Via Expressway (Min.)	Time Via Alternate Route (Min.)	Distance Via Expressway (Miles)	Distance Via Alternate Route (Miles)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
76	51	1323	1126	85	11.39	18.13	8.37	9.31
51	76	1125	912	81	11.39	18.13	8.37	9.31
76	52	260	249	96	18.61	24.68	12.25	12.04
52	76	271	255	94	18.61	24.68	12.25	12.04
76	53	874	651	74	12.62	16.90	9.40	8.28
53	76	775	533	69	12.62	16.90	9.40	8.28
76	54	293	224	76	12.62	16.90	9.40	8.28
54	76	279	169	61	12.62	16.90	9.40	8.28
76	55	423	389	92	11.39	18.13	8.37	9.31
55	76	337	312	93	11.39	18.13	8.37	9.31
76	56	558	386	69	12.62	16.90	9.40	8.28
56	76	501	266	53	12.62	16.90	9.40	8.28
76	57	807	515	64	12.62	16.90	9.40	8.28
57	76	867	470	54	12.62	16.90	9.40	8.28
76	58	2212	1196	54	18.08	20.71	12.07	10.32
58	76	1861	959	52	18.08	20.71	12.07	10.32
76	59	523	130	25	19.38	19.41	12.57	9.82
59	76	581	137	24	19.38	19.41	12.57	9.82
76	60	301	33	11	11.89	10.66	7.32	5.19
60	76	278	36	13	11.89	10.66	7.32	5.19
76	61	513	95	18	12.47	13.16	8.34	6.39
61	76	578	132	23	12.47	13.16	8.34	6.39
76	62	1004	263	26	11.89	10.66	7.32	5.19
62	76	1157	271	23	11.89	10.66	7.32	5.19
76	63	73	41	56	9.92	12.63	6.50	6.01
63	76	65	50	77	9.92	12.63	6.50	6.01
75	51	156	133	85	9.95	15.51	7.37	7.92
51	75	225	177	79	9.95	15.51	7.37	7.92
75	52	40	37	93	17.17	22.06	11.25	10.65
52	75	23	19	83	17.17	22.06	11.25	10.65
75	53	172	66	38	11.18	14.28	8.40	6.89
53	75	117	52	44	11.18	14.28	8.40	6.89
75	54	82	20	24	11.18	14.28	8.40	6.89
54	75	37	13	35	11.18	14.28	8.40	6.89
75	55	76	76	100	9.95	15.51	7.37	7.92
55	75	101	94	93	9.95	15.51	7.37	7.92
75	56	138	55	40	11.18	14.28	8.40	6.89
56	75	135	35	26	11.18	14.28	8.40	6.89
75	57	169	67	40	11.18	14.28	8.40	6.89
57	75	126	50	40	11.18	14.28	8.40	6.89
75	58	507	138	27	19.36	21.30	12.38	10.69

TABLE 1 (Cont'd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
58	75	532	116	22	19.36	21.30	12.38	10.69
75	59	100	12	12	20.66	20.00	12.88	10.19
59	75	113	23	20	20.66	20.00	12.88	10.19
75	60	68	6	9	14.20	12.07	8.01	5.15
60	75	53	0	0	14.20	12.07	8.01	5.15
75	61	125	19	15	11.03	10.54	7.34	5.00
61	75	165	7	4	11.03	10.54	7.34	5.00
75	62	381	47	12	10.45	8.04	6.32	3.80
62	75	368	36	10	10.45	8.04	6.32	3.80
75	63	28	3	11	8.48	10.01	5.50	4.62
63	75	21	13	62	8.48	10.01	5.50	4.62
74	51	251	199	79	11.39	18.13	8.37	9.31
51	74	288	235	82	11.39	18.13	8.37	9.31
74	52	50	32	64	25.06	29.56	15.22	14.54
52	74	33	22	67	25.06	29.56	15.22	14.54
74	53	255	54	21	12.62	16.90	9.40	8.28
53	74	247	58	23	12.62	16.90	9.40	8.28
74	54	117	7	6	23.33	25.36	13.81	11.48
54	74	102	6	6	23.33	25.36	13.81	11.48
74	55	84	82	98	11.39	18.13	8.37	9.31
55	74	86	73	85	11.39	18.13	8.37	9.31
74	56	143	63	44	12.62	16.90	9.40	8.28
56	74	130	56	43	12.62	16.90	9.40	8.28
74	57	213	42	20	18.90	20.43	12.99	9.79
57	74	188	38	20	18.90	20.43	12.99	9.79
74	58	607	36	6	21.38	17.95	13.52	9.26
58	74	700	75	11	21.38	17.95	13.52	9.26
74	59	184	3	2	22.68	16.65	14.02	8.76
59	74	214	6	3	22.68	16.65	14.02	8.76
74	60	59	0	0	15.19	12.35	8.77	6.98
60	74	79	3	4	15.19	12.35	8.77	6.98
74	61	147	7	5	12.47	13.16	8.34	6.39
61	74	109	3	3	12.47	13.16	8.34	6.39
74	62	304	38	13	11.89	10.66	7.32	5.19
62	74	244	30	12	11.89	10.66	7.32	5.19
74	63	27	9	33	9.92	12.63	6.50	6.01
63	74	31	9	29	9.92	12.63	6.50	6.01
73	51	211	152	72	10.14	12.69	6.89	6.63
51	73	200	131	65	10.14	12.69	6.89	6.63
73	52	43	31	72	19.15	23.82	12.18	10.12
52	73	60	40	67	19.15	23.82	12.18	10.12
73	53	215	51	24	13.34	15.76	9.47	6.40
53	73	181	39	22	13.34	15.76	9.47	6.40
73	54	71	9	13	13.34	15.76	9.47	6.40
54	73	102	6	6	13.34	15.76	9.47	6.40
73	55	76	58	76	11.93	16.07	8.30	8.25
55	73	44	36	82	11.93	16.07	8.30	8.25
73	56	196	39	20	13.16	14.84	9.33	7.22
56	73	148	23	16	13.16	14.84	9.33	7.22

TABLE 1 (Cont'd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
73	57	202	33	16	13.16	14.84	9.33	7.22
57	73	206	76	37	13.16	14.84	9.33	7.22
73	58	711	68	10	18.62	16.30	12.00	8.37
58	73	641	47	7	18.62	16.30	12.00	8.37
73	59	184	2	1	19.92	15.00	12.50	7.87
59	73	164	3	2	19.92	15.00	12.50	7.87
73	60	70	3	4	16.88	10.70	10.10	6.09
60	73	91	3	3	16.88	10.70	10.10	6.09
73	61	211	9	4	15.21	12.47	8.32	4.92
61	73	206	17	8	15.21	12.47	8.32	4.92
73	62	467	7	1	12.43	8.60	7.25	4.13
62	73	377	6	2	12.43	8.60	7.25	4.13
73	63	13	3	23	9.86	11.17	6.14	5.24
63	73	28	3	11	9.86	11.17	6.14	5.24
72	51	219	166	76	9.95	15.51	7.37	7.92
51	72	169	137	81	9.95	15.51	7.37	7.92
72	52	48	33	69	17.17	22.06	11.25	10.65
52	72	58	46	79	17.17	22.06	11.25	10.65
72	53	188	51	27	11.18	14.28	8.40	6.89
53	72	165	58	35	11.18	14.28	8.40	6.89
72	54	67	36	54	11.18	14.28	8.40	6.89
54	72	53	23	43	11.18	14.28	8.40	6.89
72	55	59	59	100	9.95	15.51	7.37	7.92
55	72	92	74	80	9.95	15.51	7.37	7.92
72	56	140	40	29	11.18	14.28	8.40	6.89
56	72	76	27	36	11.18	14.28	8.40	6.89
72	57	197	52	26	11.18	14.28	8.40	6.89
57	72	152	45	30	11.18	14.28	8.40	6.89
72	58	403	73	18	16.64	18.09	11.07	8.93
58	72	308	77	25	16.64	18.09	11.07	8.93
72	59	136	23	17	17.94	16.79	11.57	8.43
59	72	89	7	8	17.94	16.79	11.57	8.43
72	60	52	3	6	10.45	8.04	6.32	3.80
60	72	39	3	8	10.45	8.04	6.32	3.80
72	61	142	13	9	11.75	10.54	6.94	5.00
61	72	153	13	9	11.75	10.54	6.94	5.00
72	62	409	13	3	10.45	8.04	6.32	3.80
62	72	382	12	3	10.45	8.04	6.32	3.80
72	63	53	10	19	7.88	10.61	5.21	4.91
63	72	35	10	29	7.88	10.61	5.21	4.91
71	51	144	132	92	9.12	16.34	6.98	8.31
51	71	117	113	97	9.12	16.34	6.98	8.31
71	52	17	17	100	16.34	22.89	10.86	11.04
52	71	26	26	100	16.34	22.89	10.86	11.04
71	53	104	88	85	10.35	15.11	8.01	7.28
53	71	63	58	92	10.35	15.11	8.01	7.28
71	54	40	31	77	10.35	15.11	8.01	7.28
54	71	31	26	84	10.35	15.11	8.01	7.28
71	55	39	39	100	9.12	16.34	6.98	8.31

TABLE 1 (Cont'd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
55	71	41	37	90	9.12	16.34	6.98	8.31
71	56	61	50	82	10.35	15.11	8.01	7.28
56	71	60	41	68	10.35	15.11	8.01	7.28
71	57	75	61	81	10.35	15.11	8.01	7.28
57	71	73	64	88	10.35	15.11	8.01	7.28
71	58	285	222	78	15.81	18.92	10.76	9.32
58	71	211	151	72	15.81	18.92	10.76	9.32
71	59	42	28	67	17.11	17.62	11.26	8.82
59	71	45	29	64	17.11	17.62	11.26	8.82
71	60	35	0	0	9.62	8.87	5.93	4.19
60	71	49	13	27	9.62	8.87	5.93	4.19
71	61	57	22	39	10.92	11.37	6.55	5.39
61	71	38	19	50	10.92	11.37	6.55	5.39
71	62	142	56	39	9.62	8.87	5.93	5.19
62	71	127	69	54	9.62	8.87	5.93	5.19
70	51	120	100	83	8.59	14.21	5.91	7.30
51	70	108	91	84	8.59	14.21	5.91	7.30
70	52	51	45	88	15.81	20.76	9.79	10.03
52	70	43	39	91	15.81	20.76	9.79	10.03
70	53	84	50	60	9.82	12.98	6.94	6.27
53	70	83	65	78	9.82	12.98	6.94	6.27
70	54	33	16	49	9.82	12.98	6.94	6.27
54	70	17	6	35	9.82	12.98	6.94	6.27
70	55	50	46	92	8.59	14.21	5.91	7.30
55	70	38	29	76	8.59	14.21	5.91	7.30
70	56	54	24	44	9.82	12.98	6.94	6.27
56	70	57	19	33	9.82	12.98	6.94	6.27
70	57	114	66	58	9.82	12.98	6.94	6.27
57	70	91	45	49	9.82	12.98	6.94	6.27
70	58	338	172	51	12.80	16.79	9.08	8.31
58	70	247	111	45	12.80	16.79	9.08	8.31
70	59	66	14	21	14.10	15.49	9.58	7.81
59	70	50	16	32	14.10	15.49	9.58	7.81
70	60	54	0	0	9.09	6.74	4.86	3.18
60	70	51	0	0	9.09	6.74	4.86	3.18
70	61	126	6	5	10.39	9.24	5.48	4.38
61	70	101	13	13	10.39	9.24	5.48	4.38
70	62	210	39	19	9.09	6.74	4.86	3.13
62	70	187	9	5	9.09	6.74	4.86	3.13
69	51	431	237	55	10.11	12.69	6.58	6.63
51	69	365	194	53	10.11	12.69	6.58	6.63
69	52	68	39	57	17.33	19.24	10.46	9.36
52	69	62	36	58	17.33	19.24	10.46	9.36
69	53	321	19	6	11.34	11.46	7.61	5.60
53	69	246	30	12	11.34	11.46	7.61	5.60
69	54	106	4	4	11.34	11.46	7.61	5.60
54	69	67	0	0	11.34	11.46	7.61	5.60
69	55	120	103	86	10.11	12.69	6.58	6.63
55	69	106	83	78	10.11	12.69	6.58	6.63

TABLE 1 (Cont'd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
69	56	335	33	10	11.34	11.46	7.61	5.60
56	69	336	23	7	11.34	11.46	7.61	5.60
69	57	456	27	6	11.34	11.46	7.61	5.60
57	69	382	42	11	11.34	11.46	7.61	5.60
69	58	1041	53	5	14.32	15.27	9.75	7.64
58	69	979	88	9	14.32	15.27	9.75	7.64
69	59	252	5	2	15.62	13.97	10.25	7.14
59	69	272	4	1	15.62	13.97	10.25	7.14
69	60	140	4	3	10.61	5.22	5.53	2.51
60	69	170	0	0	10.61	5.22	5.53	2.51
69	61	310	6	2	11.91	7.72	6.15	4.57
61	69	330	0	0	11.91	7.72	6.15	4.57
69	62	934	0	0	10.61	5.22	5.53	2.51
62	69	835	10	1	10.61	5.22	5.53	2.51
69	63	75	0	0	8.04	7.79	4.42	3.62
63	69	60	0	0	8.04	7.79	4.42	3.62
68	51	922	467	51	10.14	12.69	6.89	6.63
51	68	892	457	51	10.14	12.69	6.89	6.63
68	52	222	57	26	24.16	24.76	14.18	12.06
52	68	258	79	31	24.16	24.76	14.18	12.06
68	53	835	52	6	13.00	13.83	8.68	5.40
53	68	785	62	8	13.00	13.83	8.68	5.40
68	54	349	6	2	22.43	20.56	12.77	9.00
54	68	317	20	6	22.43	20.56	12.77	9.00
68	55	354	267	76	10.14	12.69	6.89	6.63
55	68	388	262	68	10.14	12.69	6.89	6.63
68	56	542	28	5	11.37	11.46	7.92	5.60
56	68	487	38	8	11.37	11.46	7.92	5.60
68	57	882	14	2	18.00	15.63	11.95	7.31
57	68	782	20	3	18.00	15.63	11.95	7.31
68	58	2888	26	1	20.48	13.15	12.48	6.78
58	68	2838	45	2	20.48	13.15	12.48	6.78
68	59	1110	14	1	21.78	11.85	12.98	6.28
59	68	995	20	2	21.78	11.85	12.98	6.28
68	60	449	0	0	18.74	7.55	10.58	4.50
60	68	459	3	1	18.74	7.55	10.58	4.50
68	61	757	17	2	14.87	10.54	7.53	3.92
61	68	839	7	1	14.87	10.54	7.53	3.92
68	62	1802	14	1	10.64	5.22	5.84	2.51
62	68	1548	7	0	10.64	5.22	5.84	2.51
68	63	123	4	3	8.07	7.79	4.73	3.62
63	68	134	10	7	8.07	7.79	4.73	3.62
67	51	512	109	21	10.03	10.05	5.90	4.35
51	67	509	131	26	10.03	10.05	5.90	4.35
67	52	80	15	19	23.60	19.36	12.72	8.94
52	67	86	23	27	23.60	19.36	12.72	8.94
67	53	416	9	2	11.44	8.64	7.07	3.18
53	67	390	3	1	11.44	8.64	7.07	3.18
67	54	130	9	7	21.87	15.16	11.31	5.88

TABLE 1 (Cont'd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
54	67	97	0	0	21.87	15.16	11.31	5.88
67	55	156	101	65	10.03	10.05	5.90	4.35
55	67	159	92	58	10.03	10.05	5.90	4.35
67	56	243	13	5	11.26	8.82	6.93	3.32
56	67	222	20	9	11.26	8.82	6.93	3.32
67	57	353	0	0	14.24	10.23	9.07	4.19
57	67	278	0	0	14.24	10.23	9.07	4.19
67	58	1118	7	1	16.72	7.75	9.60	3.66
58	67	1159	3	0	16.72	7.75	9.60	3.66
67	59	420	0	0	16.72	7.75	9.60	3.66
59	67	499	0	0	16.72	7.75	9.60	3.66
66	51	703	285	40	8.90	8.57	5.53	4.61
51	66	664	284	43	8.90	8.57	5.53	4.61
66	52	132	42	32	16.12	15.12	9.41	7.34
52	66	122	50	41	16.12	15.12	9.41	7.34
66	53	551	22	4	10.13	7.34	6.56	3.58
53	66	492	35	7	10.13	7.34	6.56	3.58
66	54	157	0	0	10.13	7.34	6.56	3.58
54	66	156	3	2	10.13	7.34	6.56	3.58
66	55	156	106	68	8.90	8.57	5.53	4.61
55	66	238	156	66	8.90	8.57	5.53	4.61
66	56	500	31	6	10.13	7.34	6.56	3.58
56	66	496	28	6	10.13	7.34	6.56	3.58
66	57	647	12	2	10.13	7.34	6.56	3.58
57	66	678	22	3	10.13	7.34	6.56	3.58
66	58	1686	33	2	15.59	12.08	9.23	5.45
58	66	1528	39	3	15.59	12.08	9.23	5.45
66	59	461	7	2	16.89	10.78	9.73	4.95
59	66	414	3	1	16.89	10.78	9.73	4.95
65	51	108	77	71	7.54	9.93	4.95	5.19
51	65	69	47	68	7.54	9.93	4.95	5.19
65	52	19	19	100	14.76	16.48	8.83	7.92
52	65	17	13	77	14.76	16.48	8.83	7.92
65	53	50	0	0	8.77	8.70	5.98	4.16
53	65	44	0	0	8.77	8.70	5.98	4.16
65	55	5	5	100	7.54	9.93	4.95	5.19
55	65	16	13	81	7.54	9.93	4.95	5.19
65	56	74	8	11	8.77	8.70	5.98	4.16
56	65	65	13	20	8.77	8.70	5.98	4.16
65	57	107	4	4	8.77	8.70	5.98	4.16
57	65	78	3	4	8.77	8.70	5.98	4.16
65	58	282	7	2	14.23	13.44	8.65	6.03
58	65	223	16	7	14.23	13.44	8.65	6.03
65	59	38	0	0	15.53	12.14	9.15	5.53
59	65	47	0	0	15.53	12.14	9.15	5.53
64	51	491	439	89	4.98	12.49	3.72	6.42
51	64	579	535	93	4.98	12.49	3.72	6.42
64	52	72	72	100	12.20	19.04	7.60	9.15
52	64	71	66	93	12.20	19.04	7.60	9.15

TABLE 1 (Cont'd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
64	53	69	45	65	6.21	11.26	4.75	5.39
53	64	91	53	58	6.21	11.26	4.75	5.39
64	54	11	11	100	6.21	11.26	4.75	5.39
54	64	10	10	100	6.21	11.26	4.75	5.39
64	55	146	134	92	4.98	12.49	3.72	6.42
55	64	137	132	96	4.98	12.49	3.72	6.42
64	56	119	78	66	6.21	11.26	4.75	5.39
56	64	194	117	60	6.21	11.26	4.75	5.39
64	57	102	66	65	6.21	11.26	4.75	5.39
57	64	84	63	75	6.21	11.26	4.75	5.39
64	58	194	102	53	11.67	15.07	7.42	7.43
58	64	132	75	57	11.67	15.07	7.42	7.43
64	59	36	12	33	12.97	13.77	7.92	6.93
59	64	23	6	26	12.97	13.77	7.92	6.93
64	60	55	7	13	5.48	5.02	2.67	2.30
60	64	48	6	13	5.48	5.02	2.67	2.30
64	61	191	29	15	4.88	5.62	2.38	2.59
61	64	201	28	14	4.88	5.62	2.38	2.59
64	62	234	46	20	5.48	5.02	2.67	2.30
62	64	257	45	18	5.48	5.02	2.67	2.30
64	63	26	7	27	2.91	4.26	1.56	2.05
63	64	13	6	46	2.91	4.26	1.56	2.05
		103,333	23,913					

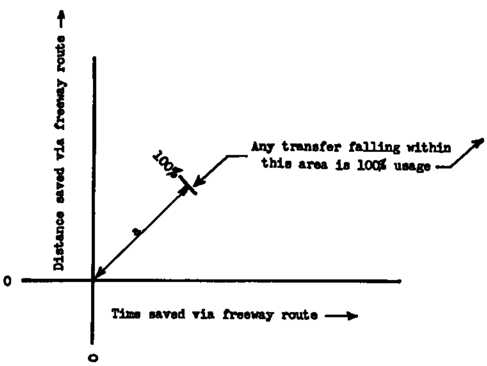


Figure 3.

hand. Regularity is assured if the shape of the curve is expressed by a mathematical equation.

3. The more time saved, the greater will be the percent usage.

4. The more distance saved (or the less that is lost), the greater will be the percent usage.

5. When either time or distance saved is small, there will be doubt in the motorists' minds as to whether it is saved or lost, and some motorists will resolve it one way and some the other.

6. Some motorists will drive any amount of distance to save time, and a few motorists will choose the shortest route no matter how much time this route consumes.

100 Percent Usage Boundary

Starting with the above reasoning, the upper right-hand quadrant of the graph was examined first (see Figure 3). Any trip which plots in this quadrant saves both time and distance. As a first approximation it might be said that the axes of zero distance and zero time would be the 100 percent usage boundary.

However, near the origin the time and distance differences are so small that many motorists in planning a trip will think that the trip lies in another quadrant; i.e., they will not know that the freeway route saves both time and distance or either. This applies even to habitual users (commuters), since they seldom record the actual time or

TABLE 2

CABRILLO FREEWAY USE STUDY

From Zone	To Zone	Total Trip Transfer Between Zones	No. of Trips on Expressway	Percent of Trips on Expressway	Time Via Expressway (Min.)	Time Via Alternate Route (Min.)	Distance Via Expressway (Miles)	Distance Via Alternate Route (Miles)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2	17	440	40	9	12.29	9.19	5.24	4.81
	18,19	440	160	36	4.09	5.14	2.57	2.19
	23	260	80	31	5.97	7.20	2.84	2.39
	25	1120	0	0	13.15	11.86	7.05	4.27
	27	380	380	100	11.60	17.21	6.05	6.96
	28	540	500	92	7.03	8.20	3.22	3.06
	29	400	280	70	4.45	5.46	3.12	2.35
	30	280	120	43	4.45	5.46	3.12	2.35
	31	480	160	33	11.70	10.22	5.78	5.19
	32	100	100	100	10.47	13.50	6.98	6.84
	33	180	140	78	18.09	20.87	12.45	9.75
	34	280	240	86	19.88	23.53	13.38	11.39
3	17	820	80	10	12.29	9.19	5.24	4.81
	18,19	840	260	31	4.09	5.14	2.57	2.19
	20	180	100	56	5.03	6.14	2.28	2.39
	21	180	100	56	3.49	5.74	2.27	2.49
	22	160	20	13	5.08	5.80	2.09	1.69
	23	420	40	10	5.97	7.20	2.84	2.39
	25	1700	220	13	12.24	12.73	6.77	4.60
	27	580	520	90	10.14	18.67	5.63	7.38
	28	440	440	100	6.01	8.00	2.95	2.79
	29	720	480	67	4.45	5.46	3.12	2.35
	30	700	400	57	4.45	5.46	3.12	2.35
	31	1760	660	37	11.70	10.22	5.78	5.19
	32	180	180	100	10.47	13.50	6.98	6.84
	33	220	200	91	18.09	20.87	12.45	9.75
	34	620	420	68	19.88	23.53	13.38	11.39
4	19	380	80	21	6.83	6.33	3.26	2.64
	21	180	100	55	6.23	6.93	2.96	2.94
	23	120	100	83	5.15	8.02	2.63	2.60
	25	840	400	48	10.90	14.00	6.37	4.91
	26	100	100	100	7.17	12.13	3.60	4.14
	27	460	460	100	9.74	19.07	5.42	7.59
	28	500	500	100	5.19	8.82	2.74	3.00
	29	780	200	26	5.47	4.44	3.25	2.22
	30	380	180	47	9.86	10.08	5.06	3.73
	31	1120	240	21	12.35	9.57	6.03	4.94
	32	400	300	75	10.87	13.10	7.10	6.72
	33	100	20	20	19.02	20.82	12.68	9.74
	34	480	300	63	20.81	22.60	13.61	11.16
5	21	80	40	50	7.03	6.51	3.21	2.91
	23	360	160	44	5.15	8.02	2.63	2.60
	25	280	100	36	10.90	14.00	6.37	4.91
	27	180	180	100	9.74	19.07	5.42	7.59

TABLE 2 (Con'td.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	28	240	180	75	5.19	8.82	2.74	3.00
	29	200	20	10	5.47	4.44	3.25	2.22
	31	480	80	17	13.65	8.27	6.53	4.44
6	21	320	160	50	7.03	6.51	3.21	2.91
	25	1340	340	25	10.90	14.00	6.37	4.91
	27	500	500	100	9.74	19.07	5.42	7.59
	28	680	540	80	5.19	8.82	2.74	3.00
	29	380	60	16	5.47	4.44	3.25	2.22
8	23	260	80	31	5.15	8.02	2.63	2.60
	25	240	180	75	10.90	14.00	6.37	4.91
	27	160	160	100	9.74	19.07	5.42	7.59
	28	660	480	73	5.19	8.82	2.74	3.00
9	21	220	120	55	5.29	4.72	2.87	2.36
	23	140	140	100	2.94	4.60	2.05	1.92
	25	640	360	56	8.66	11.98	5.84	4.33
	27	320	320	100	7.26	16.59	4.89	7.06
	28	260	260	100	2.98	5.40	2.16	2.42
	29	440	160	36	5.47	4.44	3.25	2.22
	30	360	40	11	9.72	7.89	4.41	3.06
	31	660	160	24	11.82	10.13	5.56	5.41
10	17	800	320	40	11.08	10.40	4.66	5.39
	18,19	1460	240	16	4.09	5.14	2.57	2.19
	20	480	140	29	2.82	4.42	1.70	1.83
	21	640	340	53	3.49	5.74	2.27	2.49
	23	920	180	20	3.67	3.87	2.26	1.81
	24	900	20	2	7.29	8.54	3.83	2.85
	25	3540	600	17	9.39	11.25	6.05	4.11
	26	800	40	5	6.09	9.74	3.23	3.45
	27	780	680	87	7.84	17.09	5.05	6.90
	28	1160	820	71	3.71	4.67	2.37	2.21
	29	1380	940	68	4.45	5.46	3.12	2.35
	30	1400	1040	74	4.45	5.46	3.12	2.35
	31	2460	1600	65	10.49	11.43	5.20	5.77
	32	420	380	90	8.26	14.05	6.40	6.44
	33	600	360	60	16.88	23.08	11.87	10.33
	34	960	760	79	17.50	26.01	12.85	11.92
11	17	420	100	24	11.08	10.40	4.66	5.39
	18,19	460	60	13	4.09	5.14	2.57	2.19
	25	1940	0	0	11.65	8.99	6.52	3.64
	26	360	40	11	7.68	8.15	4.28	2.98
	27	400	280	70	9.43	15.50	5.52	6.43
	28	460	380	83	3.71	4.67	2.37	2.21
	29	600	280	47	4.45	5.46	3.12	2.35
	30	600	420	70	4.45	5.46	3.12	2.35
	31	1180	440	37	10.49	11.43	5.20	5.77
	32	500	460	92	8.26	14.05	6.40	6.44
	33	200	160	80	16.88	23.08	11.87	10.33
	34	680	680	100	17.50	26.01	12.85	11.92
13	18	420	40	10	6.07	4.20	3.28	2.10
	23	580	60	10	4.92	2.62	2.76	1.31
	25	940	180	19	10.64	8.89	6.55	3.91
	27	440	280	64	9.69	14.06	5.85	6.29
	28	620	120	19	4.96	3.42	2.87	1.71

TABLE 2 (Cont'd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	29	360	20	6	6.43	5.38	3.83	2.69
	30	600	160	27	6.43	5.38	3.83	2.69
	31	840	220	26	6.43	5.38	3.83	2.69
	32	180	100	56	10.24	13.45	7.11	6.47

distance used. The time also varies from day to day, and besides this, the assumed time for the particular interzone transfer can be wrong for an individual trip which begins within a zone at some distance from the centroid of that zone. Therefore, the 100 percent boundary is to be plotted at some distance, a, from the origin. The distance will be determined experimentally.

The next question is what direction the 100 percent boundary will take starting from the point established in Figure 3. In Figure 4 are shown four possibilities. Line (1) would be the boundary if distance is ignored. Lines (2) and (3) imply that a given sum of time and distance saved (i.e., $ax+by=C$) will insure 100 percent usage. But even Line (3) says that if a certain amount of time is saved, not just most, but all drivers will go out of their way to use the freeway. This violates rule No. 6, "a few motorists will choose the shortest route no matter how much time this route consumes". These motorists are called freeway-haters. In order to allow for them, the 100 percent boundary cannot cross the zero-distance axis. However, it is clear that as the time saved becomes larger and larger, it becomes harder and harder to hate the freeway and the number of non-users will decrease.

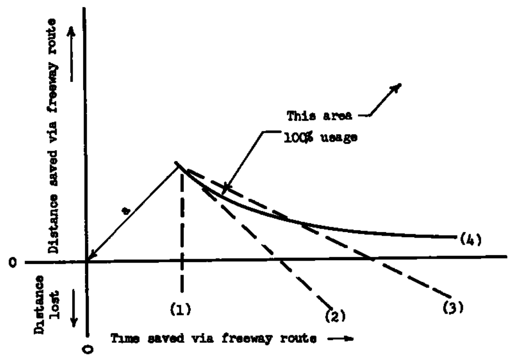


Figure 4.

Curve (4) answers these stipulations: it approaches the zero-distance axis closer and closer as time saved becomes greater, but it never crosses it. In other words, it is asymptotic to the zero-distance axis. One of the simplest curves which has asymptotes is a hyperbola. It was therefore decided to use a hyperbola.

0 Percent Usage Boundary

Next, the lower left-hand quadrant was examined. The planner of any trip which falls in this quadrant would be foolish to use the freeway route, but near the origin it is not certain, in the mind of the motorist, that his trip does fall in the quadrant. Furthermore, it has been stipulated that no matter how much distance is lost by traveling on the freeway, there will always be a few drivers who will use it provided they can save some time. That is to say, the boundary of the zero usage line cannot cross the zero time axis, but comes asymptotic to it as the excess distance increases. This gives us the other branch of the hyperbola set up for the 100 percent boundary (see Figure 5).

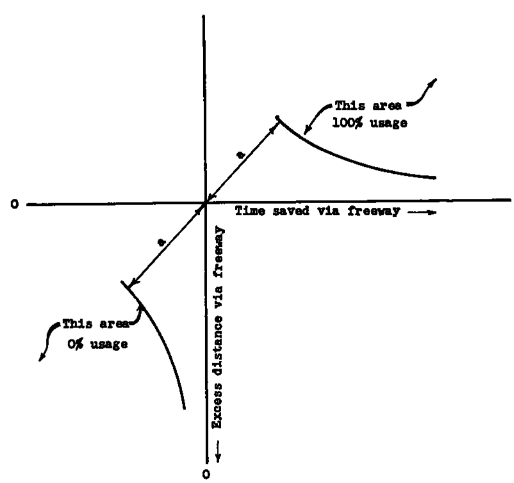


Figure 5.

Filling in Between the Boundaries

Rule No. 2 says that the pattern must be systematic if it is to be worth anything for prognosticating purposes. In other words, if the observed data on existing freeways results in an irregular pattern because of local idiosyncrasies, they must be regularized for use elsewhere, where these idiosyncrasies do not exist.

It was decided that a family of hyperbolas with a common conjugate axis would be the simplest systematic way of filling in the surface between the boundaries.

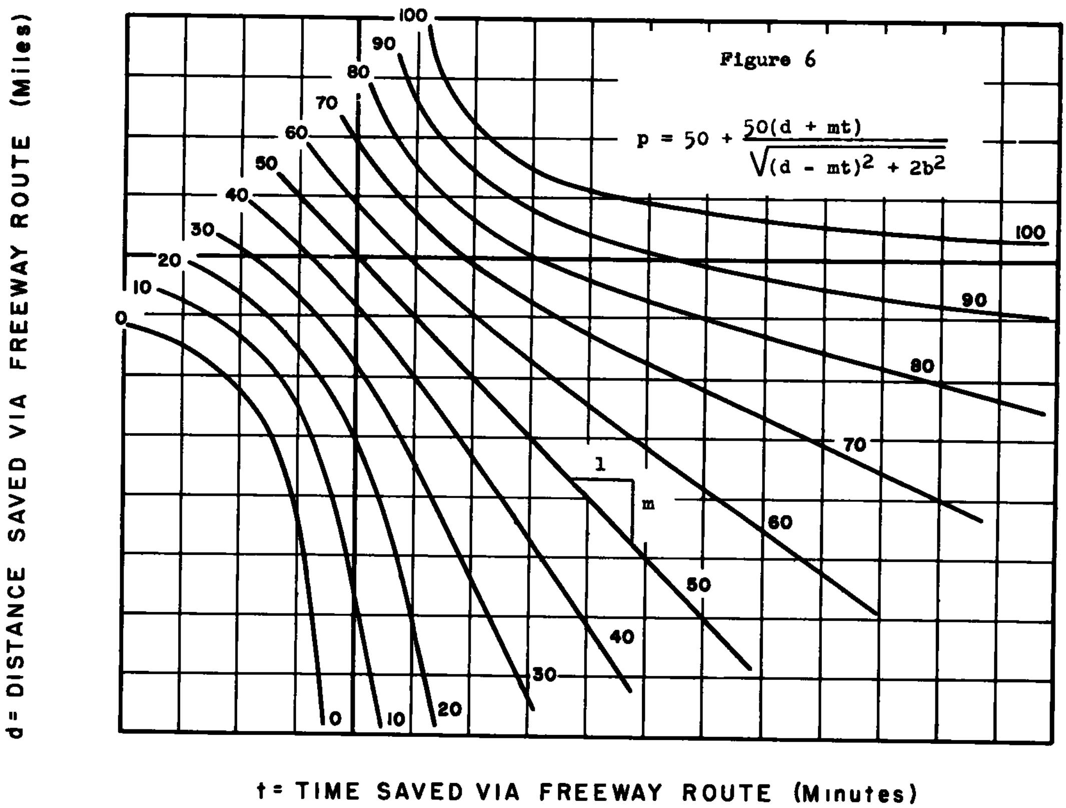


Figure 6.

This set of curves is shown in Figure 6. The equation is $P = 50 + \frac{50\,(d + mt)}{\sqrt{(d - mt)^2 + 2b^2}}$

Where p = percent usage,

d = distance saved in miles,

t = time saved in minutes,

m = a coefficient relating the value of a mile saved to a minute lost; in other words, a scale value for the x ordinate for a given scale on the y ordinate,

and b = a coefficient determining how far the vertices of the 100 percent and 0 percent boundaries are from the origin.

Having developed a rational framework, it remained to determine experimentally the values of m and b which would result in the "best fit". This probably could have been done by the method of least squares, but the partial derivatives of the expression are somewhat awkward to work with, and a trial-and-error method was used instead.

For the Cabrillo and Alvarado freeways in San Diego it was found that for b = 1.5, the best value of m is between 0.4 and 0.5. It was also found that for various values of m, b = 1.5 is pretty fair, although the results are much more sensitive to changes in m than in b.

It will be noted that m is the slope of the 50 percent usage line, or, put in another way, m is the number of extra miles which 50 percent of the drivers will go in order to save one minute of time. It had previously been determined by the California Division of Highways, using AASHO(3) values for passenger car operating costs at various

TABLE 3

RESULTS OBTAINED BY VARIOUS ASSIGNMENT FORMULAS

	Name of Highway ⟶	Alvarado Expressway			Cabrillo Freeway			Shirley Highway		
	Observed Usage ⟶	23,868 trips per day			28,400 trips per day			8,152 trips per day		
Fig ↓	Formula ↓	Trips assigned by formula	Ratio as'gd vol to obs'd vol	Std. error, percent (n=154)	Trips assigned by formula	Ratio as'gd vol. to obs'd vol.	Std. error, percent (n=105)	Trips assigned by formula	Ratio as'gd vol. to obs'd vol	Std error percent (n=87)
6.	$p = 50 + \frac{50(d+mt)}{\sqrt{(d-mt)^2+4\ 5}}$									
	where m=0 4	24,628	1.03	17 1	28,909	1.02	23.2	6,730	0 83	15.3
	where m=0.5	25.403	1 07	17.8	29,880	1 05	23.2	6,695	0 82	15.1
	where m=0.55	26,084	1 09	18.1	30,202	1 07	23 3	6,726	0 83	15 1
	where m=0 67				31,380	1.10	23.6			
7.	$\frac{100}{\frac{p}{0}} = 50 + 6\ 25(2.6t + 4\ 7d)$	24,661	1 03	21.8	30,020	1.06	27 2	6,508	0 80	19.0
8	$\overset{p=0}{0 >} (2.6t + 4.7d) \overset{p=100}{> 0}$	24,375	1 02	31 3	30,020	1.06	44 0	6,133	0.75	30 9
9.	Trueblood time ratio curve	39,007	1.64	29.0	38,379	1.35	28.0	8,258	1 01	9.4

speeds, that the median driver spends 2.6 cents for every minute he saves by driving 53 mph. for 4.7 cents per mile, i.e. the value he places on a minute is 0.55 of that which he spends on a mile. This means that if the 50 percent line were drawn so that m = 0.55, 50 percent of the potential customers would go each way when the "cost" per

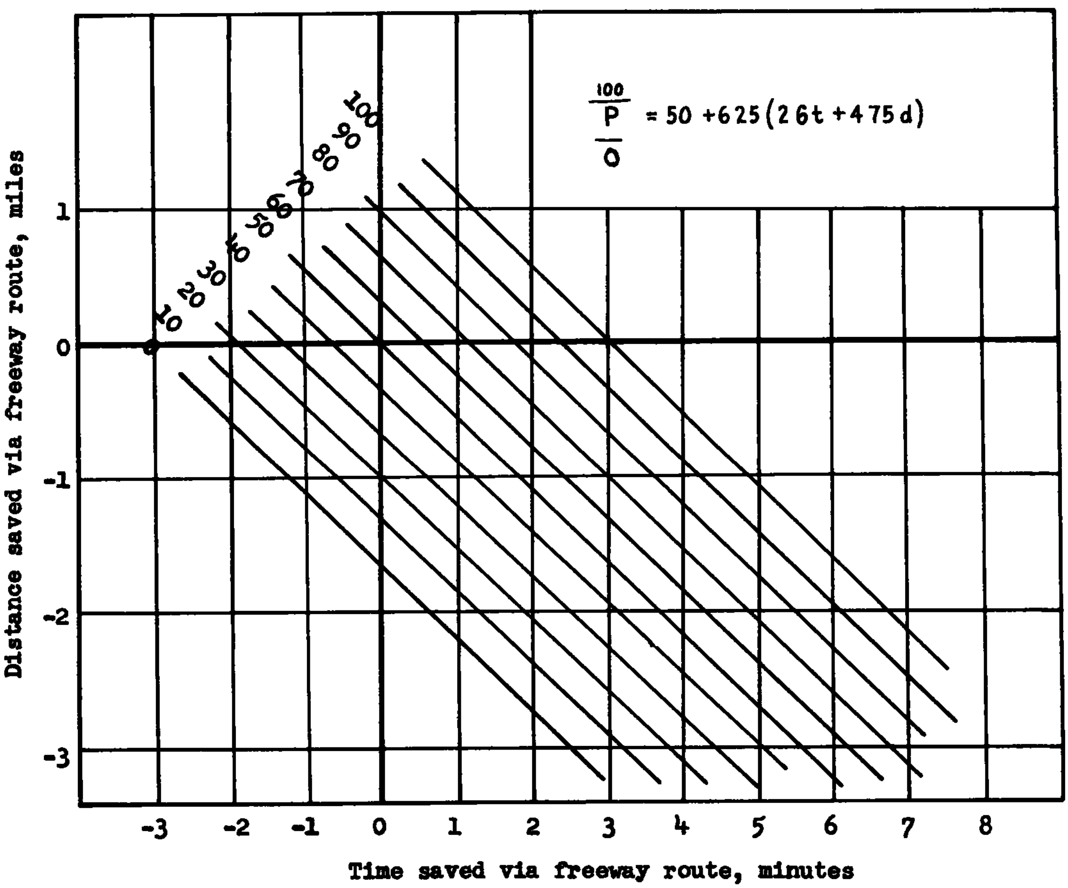


Figure 7.

trip (operating cost plus time value) was equal on either route. This would be a convenient thing for the purpose of computing the economic benefits of a proposed route.

TABLE 4

INTERZONE TRIP DATA - OCEANSIDE-CARLSBAD

From Zone (1)	To Zone (2)	Total Trip Transfer Between Zones (3)	No of Trips on Expressway (4)	Percent of Trips on Expressway Actual (5a)	Percent of Trips on Expressway Theoretical (5b)	Time Via Expressway (Min) (6)	Time Via Alternate Route (Min.) (7)	Distance Via Expressway (Miles) (8)	Distance Via Alternate Route (Miles) (9)
3	N	700	584	83	85	2.18	3.63	1.12	1.77
5	N	219	11	5	20 (0)	3.52	2.80	1.77	1.12
6	N	278	2	1	0	4.23	1.59	2.03	0.86
7	N	1338	105	8	25 (8)	3.40	2.42	1.73	1.16
8	N	48	25	52	42 (37)	3 00	2.82	1.53	1.36
9	N	119	32	27	42 (37)	3.67	3.50	1.81	1.61
10	N	386	23	6	25 (8)	4.33	3 35	2.08	1.51
11	N	345	43	12	25 (8)	5.77	4.79	2.64	2.07
12	N	54	40	75	100	2.93	7.94	2.49	3.31
13	N	71	63	89	90	3.70	7.17	2.78	3.02
14	N	62	56	90	60	4.63	6.90	3.13	2 92
15	N	299	82	27	50	4.80	6.07	3.20	2.60
16	N	98	40	41	63	4.94	7.25	3.78	3.25
17	N	43	29	68	87	4.24	7.95	3.43	3.60
18	N	32	24	75	100	3.70	8.49	3 16	3.87
19	N	32	32	100	100	4.17	10.28	3.58	4.69
20	N	33	21	64	63	6.32	8.63	4.47	3.94
21	N	14	11	79	85	5.42	9.03	4.11	4.16
22	N	31	19	61	100	5.44	11 98	4.12	5.41
23	N	62	45	74	92	5 66	10.35	4.52	4.73
24	N	103	45	44	63	6 48	9.53	4.86	4.39
25	N	62	53	85	68	7 68	10.73	5.48	5.01
26	N	53	44	83	92	6.56	11.25	4.89	5 10
27	N	54	45	83	100	5.91	12 22	4.71	5 60
28	N	43	37	86	100	5 84	12.76	5.06	5.87
29	N	23	17	74	72	7.39	11 21	5.71	5.22
S	N	5160	5000	97	95	8 35	14 85	7.38	7.46
1	S	69	46	46	73	9.55	13.50	7.28	6 84
2	S	26	23	88	85	8.67	13.38	6.87	6.82
3	S	185	169	91	94	7.68	13.24	6.65	6.80
4	S	5	5	100	90	7.91	12.94	6.55	6.65
5	S	71	39	55	75	8.74	12 85	6.96	6.55
6	S	95	57	60	68	9.48	13.03	7.22	6.58
7	S	485	227	47	68	8.65	12.20	6.92	6.28
8	S	50	42	84	80	8.25	12.60	6.72	6.48
9	S	51	35	68	48	10.29	11.45	6.66	6.01
10	S	157	51	33	48	9.86	11.01	6.48	5.83
11	S	193	91	47	48	8.68	9.83	6.02	5.37
12	S	50	42	84	100	5.19	9.39	4.49	5.04
13	S	23	21	91	75	5.57	9.01	4.65	4.88
14	S	28	28	100	68	6.10	8.48	4.87	4.66
15	S	189	104	55	44	6.58	8.00	5.07	4.46
16	S	61	42	69	48	6.00	7.15	4.85	4.20
17	S	24	22	92	78	5.30	7.85	4.50	4.55
18	S	25	23	92	98	4.90	8.25	4.30	4.75
20	S	52	9	17	35	6.08	6.22	4.25	3.52
21	S	13	7	54	73	5.03	7 10	3.74	3.81
22	S	18	13	72	95	3 74	6.76	3.20	3.67
23	S	142	78	55	58	4.36	6.14	3.46	3.41
24	S	128	18	14	35	5.18	5.32	3.80	3.07
25	S	45	8	18	32	4.59	4.42	3.09	2.56
26	S	46	36	78	68	4.18	6.21	2.94	3.27
27	S	35	32	91	89	4.24	6.61	2.94	3.47
28	S	36	27	75	89	2.74	5.11	2.32	2.85
N	S	6175	5860	95	87	8.35	14.35	7.38	7.20

Usage curves which depend on time ratio, disregarding distance, have a tendency to assign "money-losing" trips to a freeway and thus reduce the benefits, or even wipe them out.

Starting with a value for m of 0.67 (based on the 1948 California values of 3 cents per mile and 2 cents per minute) and working through 0.55 (based on current values) down to 0.4, trials were made with results shown in Table 3. The item called "Standard Error" in this table was computed as follows:

$$S.E. = \sqrt{\frac{\Sigma d^2}{n}}$$

where d = p - p'
(p = computed percent usage for a given interzone transfer
(p' = observed percent usage for the same transfer
and n = number of interzone transfers

Table 3 also shows results obtained by other formulas. Graphs of these other formulas are shown in Figures 7, 8 and 9.

It was decided that a coefficient of 0.5 would be as close to right as the data warrant, and that formula was adopted. The final graph is shown in Figure 10. This graph appears in the California Planning Manual, Part 8 (Traffic).

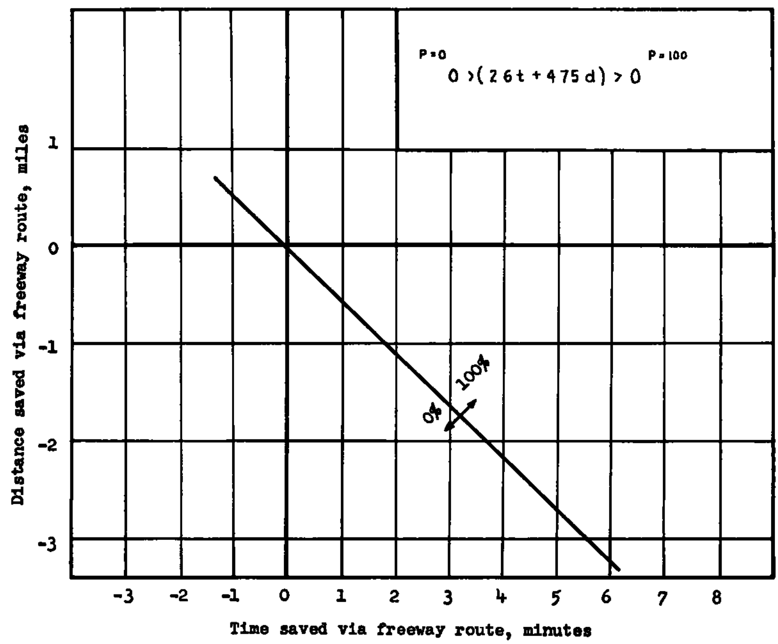


Figure 8.

USAGE OF SMALL CITY BY-PASSES

Origin and destination surveys were made in two small cities in California, Oceanside-Carlsbad (population 25,541), and Tulare (population 13,253), where freeway by-passes had been built. All of the external-internal traffic was interviewed, whether using the freeway or the old road. The through traffic was not interviewed, and internal traffic was interviewed only when it used the freeway. The internal traffic using other streets was not interviewed and it is therefore not known what percentage usage obtained for these transfers.

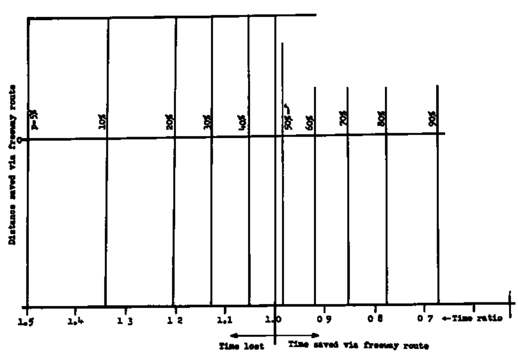
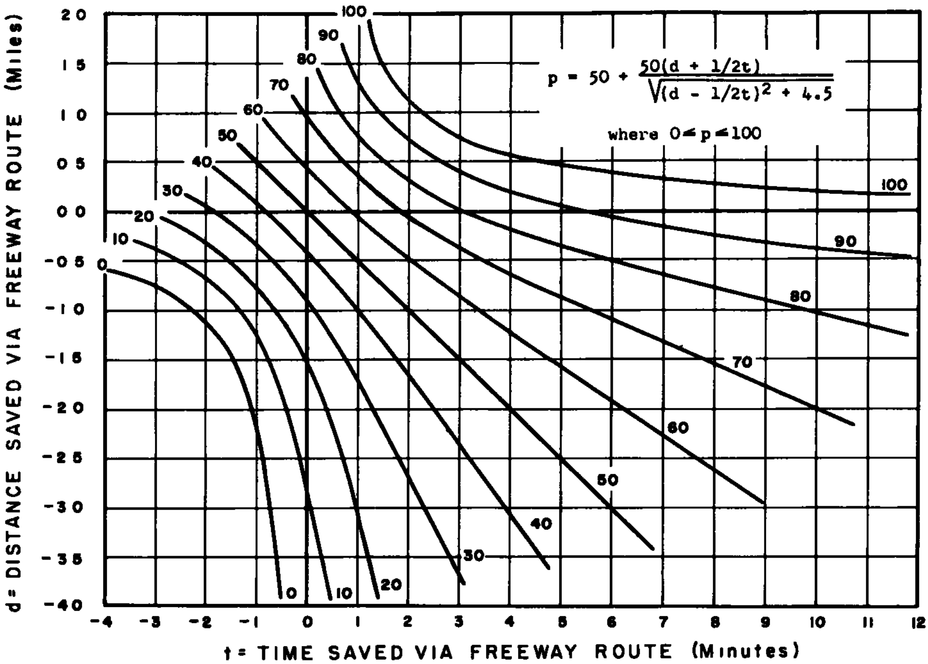


Figure 9. Trueblood time ratio curve.

The results of the Oceanside survey are

shown in Table 4 and those of the Tulare survey in Table 5. The column headed "Theoretical percent usage" shows the percent that would be read directly from Figure



PROCEDURE FOR USE OF THE CHART

1. a. Determine distance between points by best available freeway route (d_f) and by best available alternate (d_a). The distance saved, d, is d_a minus d_f.

b. Determine travel time between points by best available freeway route (t_f) and by best available alternate route (t_a). The time saved, t, is t_a minus t_f.

When determining d_a and t_a, do not overlook the fact that when the freeway obliterates part of the existing road net, d_a and t_a may include some freeway travel. In this case, the "non-users" will be users of the freeway for the portions of the trip where no alternate route is available.

2. Enter chart at appropriate values of d and t and read p, the percentage of trips between the given points which will use the freeway route.

3. Multiply p by the number of trips between the given points. Assign this number of trips to the appropriate portion of the freeway. Assign the balance to the alternate route.

4. When $p < 50$ and $L < 2.0$ miles, the following modification should be applied:

$$p_1 = p + (p - 50)\times(1.5 - 0.75L)$$

where
p_1 = modified percent assignment
p = original percent assignment
L = Length of freeway (between points of choice of trip routing) used via the best available freeway route (d_f)

5. When both ends of a trip are on the freeway, as in the case of a through trip, then assign 100% to the freeway.

Figure 10, Percent of traffic diversion to freeway in relation to time and distance saved.

10 for each interzone transfer. In parentheses are shown the percent usage after applying a secondary formula which is explained below. With this adjustment, the theoretical and actual usage compare as shown in Table 6.

Adjustment for Short Trips

In developing the hyperbolic curves, it was reasoned that when the time and distance differences were small, there would be doubt in the minds of trip planners which route saves time or distance and which loses. It was for this reason that transfers plotting

TABLE 5

INTERZONE TRIP DATA (TULARE)

From Zone	To Zone	Total Trip Transfer Between Zones	No. of Trips on Expressway	Percent of Trips on Expressway: Actual	Percent of Trips on Expressway: Theoretical	Time Via Expressway (Min.)	Time Via Alternate Route (Min.)	Distance Via Expressway (Miles)	Distance Via Alternate Route (Miles)
(1)	(2)	(3)	(4)	(5a)	(5b)	(6)	(7)	(8)	(9)
				%	%				
5	N	414	15	4.0	0	7.22	5.25	4.93	3.64
N	5	367	16						
6	N	152	27	14.0	14	6.72	5.75	4.78	3.79
N	6	110	9						
7	N	44	13	33	61	5.64	6.83	4.34	4.24
N	7	44	16						
20	N	256	234	92	93	4.75	7.62	3.98	4.60
N	20	250	232						
5	S	394	16	4.0	13	7.10	6.25	4.88	3.64
S	5	404	16						
6	S	208	20	9.5	31	6.61	6.75	4.73	3.79
S	6	141	13						
9	S	50	25	42.0	83	5.30	8.05	4.14	4.38
S	9	57	20						
10	S	45	4	20.0	60	5.70	7.65	4.46	4.06
S	10	56	16						
11	S	115	4	2	13	7.10	6.25	4.88	3.64
S	11	96	0						
14	S	28	5	21	57	6.60	8.00	4.70	4.39
S	14	39	9						
20	S	471	418	90	100	4.37	9.10	3.87	4.60
S	20	550	502						
N	S	4,000	3,940	98.4	-a	8.20	11.50	7.54	7.29
S	N	4,075	4,000						

a Would be assigned 100 percent by virtue of being a through trip.

TABLE 6

RESULTS AS APPLIED TO EXTERNAL-INTERNAL TRIPS ON SMALL CITY BY-PASSES

	Oceanside Trips	Oceanside S.E. (Percent)	Tulare Trips	Tulare S.E. (Percent)
Actual Usage	2823		244	
Parabolic Formula (Modified)	3137	16.3	516	25.9
Time Ratio Curve	3840	22.5	892	39.7
All or Nothing (Least Cost)	3295	32.8	363	48.0

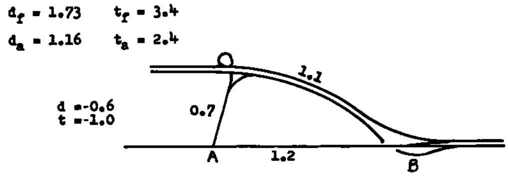


Figure 11.

near the intersection of the zero distance and zero time axes were made other than 100 percent or 0 percent. However, in a geographic situation like that shown in Figure 11, there can be no doubt which is the better route from A to B. The parabolic chart would show 25 percent users of the freeway because the differences are small, and this is obviously an error.

The case shown in Figure 11 is likely to arise in small city by-passes, and did arise at Oceanside. It was necessary to develop a systematic way of taking care of this situation.[1] It was decided that the correction should be a function of the length of ride on the freeway, and that it should apply only to ridiculous trips. Now obviously a ridiculous trip will not plot more than 50 percent usage. Therefore the correction where p=50 would be zero, increasing to a maximum at p=0. This statement is expressed

$$\overline{p_1}\,\Big|_{0}^{50} = \overline{p}\,\Big|_{0}^{50} + a(p - 50),$$ where p_1 is the adjusted percent usage.

For determining "a", several graphs were drawn in the shape of Figure 12 and the one which gave the best results was chosen. This was the one showing

$$a = 1.5 - \tfrac{3}{4}L$$

The adjusted formula for short trips (where $L < 2.0$ miles) is then,

$$p_1 = p + (1.5 - \tfrac{3}{4}L)(p - 50),$$ where L is length of freeway ride, and must be less than 2.0, and $p < 50$.

This formula reduces the percent usage of transfer A - B in Figure 11 from 25 percent to 8 percent. Strangely enough, 8 percent of the people in Oceanside going from A to B do use the freeway route.

Reasons for Choice of Route

In connection with the Oceanside and Tulare surveys, an attempt was made to determine the subjective factors which influence individual motorists in choosing one route or the other.

This information was obtained by having the interviewer asking as a last question

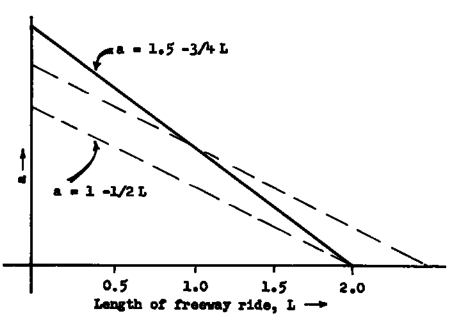


Figure 12.

[1] The time-ratio curve would show 8 percent users. It may have been noted that the question of time or distance ratio vs time or distance difference has been avoided. It is not proposed to open that question here. Good reasons were had for using the difference form.

"Why did you choose the freeway instead of the old road to reach your destination?" The phrasing of the question, of course, depended on the location of the interview station. When the interviewing was on the old road the question was reversed and drivers

ROUTE COMPARISON CARD

TS 91

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Alternate	Trip type	Card No	Between Zones: Low No	Between Zones: High No	No of Trips (year) 1955 ADT	Access Points Used: Low No	A or B	L or R	High No	A or B	L or R	Distance approaching (miles) at Speed 1	at Speed 2	at Speed 3	Distance leaving (miles) at Speed 1	at Speed 2	at Speed 3
X	1		01	15	5,750							4.50					
A	2		01	15		01			02		R				325		
A	3		01	15		01			03		R				1.50		
B	2		01	15		01			02		R				450		
B	3		01	15		01			03		R				175		

NOTES

1. The figures in this form and in form TS 9 2 refer to the example in Fig. 8-321.2. The notes for that figure are also pertinent to this form.

2. Trip type codes are.
   1 - existing system
   2 - "Basic" (non-user) route for comparison with user route.
   3 - Freeway user route.

   Where trip type 2 is identical to trip type 1, trip type 2 need not be shown.

3. Card No. - Where more than one freeway is used additional lines (cards) must be used to describe a routing. Each line or card must be numbered. 1 for the first line, 2 for the second and so on. In the example all routings can be described on one line hence this column is left blank.

4. "Number of trips" need be entered for the existing routing only. The A or B designation need not be entered since the Low number access point will always be A and the High number access point will be B.

5. Three speeds will be allowed for surface street travel. They should be noted on the first page. No particular order in listing routings is required. It may be desirable to list all trip type 3 on one set of sheets, trip type 2's on another and so on.

Figure 13.

were asked why they used the old road instead of the freeway. The interviewers were instructed to leave the question open-ended; that is, not to put answers in the drivers' mouths. The interviewer entered a code number in the appropriate column of the interview sheet depending on the response. The numbers used in the field were:

1. Because of signs
2. Because it's shorter (closer)
3. Because it's faster
4. Have no reason, or don't know
5. Didn't know about freeway or unfamiliar with the area
6. Other (to be written in, time permitting)
7. The only way out.

The interviewers were encouraged to write in as many of the respondents' remarks as possible. In the following analyses the first answer was always used. After the survey other code numbers were assigned to some of the more commonly used reasons and this information was put on punch cards.

The question surprised and seemed to stun a lot of people judging from the number of blank looks. It had one unexpected usefulness in that the driver usually left smiling.

A common reply was an answer which indicated that the driver made a stop in addition to the one he previously gave as his last stop. There would be answers such as "I went this way to get gas" and "To go to the drugstore." This would necessitate changing the last stop on the interview sheet and re-asking the question as to choice of route from the last stop. This type of interview consumed a lot of time and the correct answer to choice of route was not always obtained.

In general, people that used the freeway knew why they went that way and had a ready answer. The people interviewed on the old highway were usually the ones who had to think about why they went that way. The non-users had many varied reasons for choosing their routing in contrast to the few reasons given by freeway users.

In addition to trips discussed in this analysis there were several thousand trips on the Oceanside freeway that were internal trips. That is, they would enter the freeway but leave before they reached the end. These were left out of previous analyses since the non-user portion of the internal traffic was unknown. An interesting occurrence was the high praise the freeway received, especially from the internal traffic on the

TABLE 7

NUMBER OF PEOPLE GIVING VARIOUS REASONS FOR USING EITHER THE FREEWAY ROUTE OR THE OTHER ROUTE (OCEANSIDE-CARLSBAD)

Type of trip from engineer's viewpoint		Distance saved via freeway	Over 1/2 mile		Up to 1/2 mile		Lose up to 1/2 mile		Lose more than 1/2 mile		Lose both distance and time		Through Traffic (non-stop)		Totals other than through traffic	
		Time saved via freeway	Over 5 minutes		Up to 5 minutes		Save more than 2 minutes		Save up to 2 minutes							
Type of trip from users' and non-users' viewpoints			Obviously save both time and distance	Obviously lose both time and distance	Obviously save time Probably save distance too	Obviously lose time Maybe lose distance too	Lose some distance, but definitely save time	Gain some distance but probably lose time	obviously lose distance Probably save some time	Obviously save distance Maybe lose time	Obviously lose distance Maybe lose time	Obviously save distance Probably save time	Dist fwy. old rd lose / Time fwy. old rd gain	7 38 / 7 20 / 0 18 mi / 8 35 / 14 35 / 6 00 min		
Reasons given when asked why you used the freeway instead of the old road (or vice versa)			Users	Non-Users	Users	Non-Users	Users	Non-Users	Users	Non-Users	Users	Non-Users	Users	Non-Users	Users	Non-Users
Orientation	1	Signing	0	6	0	3	16	19	2	18	0	160		38		
	2	Only way	4	12	2	20	7	31	3	71	13	775		38		
	3	Best way, logical	3	0	C	0	3	0	0	5	0	6		16		
	4	Required route	2	0	0	0	0	10	2	6	0	5		0		
	5	Habit	0	2	0	0	6	27	0	58	6	58		0		
	6	Meant to stop but didn't	0	0	0	0	0	0	0	0	0	0		11		
	7	See city or scenic	1	10	0	0	0	65	0	62	0	15		2		
	8	Lost or missed freeway	0	2	0	2	3	8	0	11	1	12		168		
	9	Unfamiliar	3	2	0	0	6	63	0	38	4	119		31		
		Subtotal	13	34	2	25	41	223	7	269	24	1,150		68 / 334	87	1,701
Distance	10	Shorter	122	31	30	14	86	125	55	245	53	729		23		
	11	Direct Route	2	0	0	0	6	10	2	11	2	34		2		
		Subtotal	124	31	30	14	92	135	57	256	55	763		25	358	1,199
Time	12	Faster	239	8	160	2	405	26	359	54	118	188		21		
	13	Shorter and Faster	34	0	16	0	20	2	12	0	2	0		0		
		Subtotal	273	8	176	2	425	28	371	54	120	188		21	1,365	280
Comfort and Convenience	14	Less Congestion	6	0	5	0	12	0	5	0	2	3		0		
	15	Less Traffic	22	0	7	0	21	5	16	5	6	12		4		
	16	No stops or signals	4	0	3	0	21	0	11	2	2	0		0		
	17	Easier, simpler	3	0	2	0	20	5	5	25	4	38		2		
	18	Convenient, handier	14	0	3	0	5	6	2	16	6	65		6		
	19	Just like it better	3	0	0	0	6	3	3	5	2	0		2		
	20	Safer	9	0	2	0	13	0	9	3	4	0		0		
	21	Better road	4	0	2	0	0	0	5	0	2	6		0		
	22	Don't like freeways	0	0	0	0	0	8	0	10	0	0		6		
		Subtotal	65	0	24	0	98	27	56	66	28	124		20	271	217
Least Cost	23	Cheaper	2	0	0	0	0	0	0	0	0	0		0	2	0
	24	Don't know why	2	16	6	3	8	20	8	31	8	131		15		
	25	Other	5	2	2	0	8	8	11	15	4	36		14		
	26	Didn't ask or interviewer error	55	11	2	25	17	75	1	70	2	145		46		
		Subtotal	62	29	10	28	33	103	20	116	14	312		75	139	588
		Total	539	102	242	69	689	516	511	761	241	2,537	10,860	475	2,222	3,985
		Actual percent usage	85		78		57		40		9		96		36	
		Chart percent usage	90 to 100		60 to 92		60 to 85		35 to 58		0 to 35				42	

freeway. There was almost no adverse comment, except for some that were afraid to drive on the freeway, and some complaining about signing. Many in Oceanside or Carlsbad were trying to find US 395. Many of the non-users even commented on how nice it

TIME AND DISTANCE BETWEEN ACCESS POINTS

Barstow Study Feb 19 55 TS 92 Page 1 Alternate A

Access points		Distance * (miles)	Time * (minutes)	Access points		Distance * (miles)	Time * (minutes)
Low No	High No			Low No	High No		
01	02	1.35	1.91				
	03	4.05	4.97				

* Includes penalty time and distance where applicable

Figure 14.

was to drive on the old road now that the freeway was there. This attitude is in marked contrast to the extreme pressure applied in 1948 to have the freeway built a considerably greater distance to the east of Oceanside and by-pass the city completely. If the Oceanside freeway had been built at that location, there would be no local traffic using it.

The results are given in Table 7. There are six general categories, but the original 26 reasons are reproduced here to avoid unconscious bias on the part of the author.

The table speaks for itself. It is obvious that both time and distance are considered, although it is probable that when both time and distance are favorable to one route, the word "shorter" covers both. The large number of respondents saying "it's the only way" when they would lose both time and distance if they went the other way indicates that a time-ratio curve should come close to showing no usage when the time ratio is greater than 1.0. In fact, except for scattering exceptions, the only people who use a freeway when they lose time are those who mistakenly believe they are saving time (or distance). This "only way" response also indicates that people are map conscious. The most logical way of providing for this phenomenon is to record the extra distance incurred by the round-about route.

ASSIGNMENT PROCEDURE

Data are coded for punched cards unless specific approval for manual tabulation is obtained from Headquarters Traffic Department. The reasons for this are: (a) although it sometimes seems quicker and simper to hand-tally the trips into the few groups necessary for one localized problem, it frequently happens that they need to be regrouped for another alternate or problem; (b) once the data are on cards, much tedious sorting, regrouping, calculating and summation can be done mechanically; (c) machine tabulations provide a systematic way of filing the calculations and furnishing copies where needed. (d) if the machine makes a mistake in handling one item, it makes the same mistake in every item. Additionally, internal checks are usually available in the machine process. On the other hand, spot checks of manual calculations may show that the method is correct, but among hundreds or even thousands of repetitive calculations it is very hard to spot a mistake. (e) Much labor is saved and engineering personnel may be utilized to a better advantage on other needed projects.

For convenience in this discussion, trips will be classified in two categories: users and non-users. Users are defined as those trips who find it desirable to use a proposed freeway line in preference to other routes. Non-users are those who, when they have a choice, decide not to use the freeway. Under certain circumstances, non-users do use short portions of freeway where the old road is obliterated by new construction.

Since upon completion of construction there will be only one plan available to the road user, the question of which trips will use which portions of the proposed plan is answered by comparison with the remaining streets and highways available for travel (not by comparison with alternative plans). The streets and highways available for travel by non-users upon completion of any proposed improvement will be called the basic system. The streets and highways over which the trips are now being made will be called the existing system. The only difference between the existing system and the basic system will be where portions of the existing system are obliterated by the proposed improvement.

Whether based on an O & D survey of any type, or upon other methods of estimating traffic movements, the set of trips is first broken down into transfers between zones, or points of choice. Each transfer is then subject to the following treatment. (a) Time and distance via the existing system are determined; (b) time and distance via basic system are determined; (c) time and distance via Plan A are determined; (d) access points and quadrants for the freeway portion of the transfer are recorded for later summation; (e) based on a comparison of items (b) and (c), a percent usage is determined; (f) the number of users is determined by multiplying the percent usage by the number of trips in the whole transfer. The number of non-users is recorded for later use in the economic comparison. (g) The number of users for this transfer is added to the users for all other transfers having a common access point and quadrant. This is done twice: once for each of the two access points used by any one trip.

Steps (b) to (g) are repeated for each alternate being studied. Steps (f) and (g) are repeated for future traffic if the several transfers have different growth factors.

In order to accomplish the above steps on punch card machines, the original data, consisting of the distance of various speeds for each interzone transfer, are entered on forms T.S. 9.1 and T.S. 9.2 (Figures 13 and 14).

The lettered steps in the preceding paragraph are then accomplished by electric business machines for each interzone transfer, as follows: (a) time and distance via existing system. Distance is key-punched from T.S. 9.1, time is computed according to distance in each speed column; (b) time and distance via basic system (trip type 2).

If this is different from (a), the distance on freeway is picked up by merging corresponding access points with cards T.S. 9.2, then total time and distance via basic system are computed and punched. (c) Time and distance via plan A. The distance on city streets from each zone centroid to and from the freeway is key-punched. Time is computed and punched in electric computing machine. Distance and time on freeway are ganged from merged T.S. 9.2 cards. Total distance and time then computed and punched; (d) access point numbers and quadrants were key punched from T.S. 9.1. (e) A new card is made showing (b) and (c) on same card. p is then computed in electronic calculating machine, using formula. If L on freeway is less than 2.0 miles and p is less than 50, a "modified percent" is computed by second formula; (f) the p or p_1 determined in step (e) is multiplied by number of trips in transfer (this was key-punched from T.S. 9.1). The result is automatically punched in the "freeway card" and marked U (for user). The difference is punched into the "basic card" and marked N (for non-user); (g) cards are sorted down by entry access point and the number of trips entering freeway at each access point is tabulated. Then they are sorted by exit access point and the number of trips exiting at each access point is tabulated. The traffic engineer takes these tables and prepares a flow diagram by algebraic addition of trips entering and leaving freeway at each point.

Since the data are also to be used for economic comparisons of alternate routes, the number of vehicle-miles and vehicle-minutes, both users and non-users, for each alternate is also multiplied out on the electronic calculator, punched, and tabulated in the same tabulations.

Further information, including punch card forms, wiring diagrams and instructions to machine operators, is contained in a "Manual of Procedure for Punched Card Processing of Freeway Traffic Assignment Studies" by the California Division of Highways, Highway Planning Survey (June 29, 1955).

WORK TO BE DONE

Some experimenting with a procedure that does not require hand coding of each transfer, but only each zone, has been done. In a large metropolitan area with several freeways, there are so many access points available to each zone, depending on where the other zone of the transfer is, that it is quite prolix to have the machines select the proper access points for each transfer. It is hoped that this can still be done, however, and at the same time maintain some human control of where the trips go. Physical controls such as bridges and "only route available" situations are hard to systematize for machine processing.

In the Alvarado study, the alternate route used for determining distance and time differences was the "best" city street route, "best" being determined by eyeball inspection of the map. However, in working with the data it was noted that drivers use many routes in going between a given pair of zones. A good method of selecting which street route to use for the basic routing has not been developed. The preferred solution would be to develop an assignment curve which would not compare just two routes, but would compare all available routes and assign a percentage to each. This does not seem very practical, but it is important nonetheless.

When two or three freeway routes are available in addition to the surface street route, our procedure has been: (a) Compute p for each freeway with respect to "eyeball best" surface route. The freeway having highest p is considered the best freeway route. (b) Assign (100 - p) to the surface route, where p is the highest p in step (a). (c) Recompute p for the best freeway with respect to the second-best freeway. Divide the users between the two freeways according to this split. (d) Repeat (c) for best and third best, etc. This procedure is tiresome, complex, and leaves much to be desired. Perhaps the best way is to adopt the practical rules: If it is in a metropolitan area, make it eight lanes. In small areas, the short route is always the best route, and in metropolitan areas the straight routes are the best.

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