EFFECT OF TRAVEL TIME AND DISTANCE ON FREEWAY USAGE

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SYNOPSIS

Until recently, little information has been available concerning the factors that influence motorists in choosing routes of travel in urban areas. Although a number of different factors may be involved, the effect of travel time and travel distance seem especially desirable for initial study, because they are items that can be measured with reasonable accuracy on any route and their effect on the action of traffic related to the usage of that route. The relation of these two factors to the usage of the Shirley Highway, a freeway in Arlington and Fairfax Counties, Virginia, is reported in this paper.

The results from this study must be integrated with those from similar studies now underway in other urban areas before definite conclusions can be reached. In general, though, it appears that motorists regard travel time as more important than distance in choosing a route of travel. Of all the trips on the Shirley Highway examined, only 38 percent saved distance while 81 percent saved time.

That motorists are also influenced to some extent by factors other than travel time and distance is evidenced by the fact that 19 percent lost both time and distance. Furthermore, of all the trips studied that could have saved both time and distance on the Shirley Highway, 10 percent used an alternate route instead.

THE NEED for increased capacity of our urban highway systems is recognized equally by the average citizen and the highway engineer, since both are familiar with the continued increases in vehicles and travel, the growing number of accidents, and the economic loss due to traffic congestion. To be really effective, modernization must be on a scale sufficiently generous to permit the safe, rapid flow of the large volumes of traffic that stream daily into and out of our metropolitan areas and move from point to point within these areas. This requires more than minor improvement of existing inadequate streets. In many instances, new controlled-access expressways to provide increased capacity will be needed.

Accepting this as a premise, the highway engineer charged with the responsibility of planning these new systems is immediately confronted with three questions: (1) What is the capacity of the existing street system? (2) How much additional capacity is needed to serve adequately the present and future over-all traffic demand? (3) What new facilities will be required and what volume of traffic may be expected on them?

Data in the Highway Capacity Manual[1/] are available for determining an answer to the first question. The second question can be answered through the use of the origin-and-destination study techniques developed during the past 5 or 6 years, when used in conjunction with estimates of future urban growth. The highway engineer is not so fortunate when it comes to answering the third question, however, for he has not been able to estimate with confidence the amount of traffic a new facility will attract from existing streets. Data upon which to base an answer to this question have been lacking. The delay in undertaking research on this subject may be attributed not to a failure to recognize the need of such information but, rather, to a lack of urban expressways upon which data of an empirical nature can be collected.

With attention focused more directly on the improvement and construction of highway transportation facilities in urban areas during the past few years, more projects suitable for this type of research have become available for study. Interest has recently been stimulated through the efforts of the Subcommittee on Factual Surveys of the American Association of State Highway Officials and studies have now been undertaken in several different cities. Such a study was conducted during the summer of 1950 on the urban portion of the Shirley Highway, a freeway in Arlington and Fairfax Counties, Virginia. The Traffic and Planning Section of the Virginia State Department of Highways assisted in this study by making the field interviews.

CONCLUSIONS

Certain general conclusions are revealed from the data collected and analyzed in this study, but these findings must be integrated with those from similar studies now underway in other urban areas before definite conclusions acceptable for wide application can be reached. Considering all of the passenger car trips between the origins and destinations which might result in freeway usage:

1. A general relation is found between the proportion of trips via the freeway and travel distance ratios, but the variation in usage of the freeway is quite large when the distance by way of the freeway is approximately equal to or slightly greater than that by an alternate route.

2. Although there is some difference in the proportional use of the freeway for trips of different lengths, the difference does not appear to be greatly significant insofar as traffic assignment is concerned.

3. Good correlation is found between the proportion of trips via the freeway and the ratio of travel time via that route to the time via the most favorable alternate route.

4. A slightly better correlation than any other explored was found

1/ - Highway Capacity Manual by the Committee on Highway Capacity, Department of Traffic and Operations, Highway Research Board. Published by the Bureau of Public Roads.

between the proportion of trips via the freeway and the actual time saved or lost in traveling by way of the freeway as compared with that by an alternate route.

5. Motorists, in traveling from one point to another in the study area, apparently regard travel time as more important than distance in selecting a route of travel. Of all the trips examined, only 38 percent saved distance by the freeway, while 81 percent saved time.

THE PROBLEM

The complexity of travel in urban areas is known to all who study city traffic and city planning. Parallel streets offer many alternate routes of travel and motorists in their daily travel do not hesitate to change routes in order to avoid one which has become congested or otherwise unattractive to use. It is common knowledge that they will go considerable distances out of their way in order to reach attractive, free-flowing arterials of modern design.

Origin-and-destination traffic studies provide information concerning the total number of vehicles passing from one zone to another in urban areas but this knowledge, within itself, is not sufficient. It is essential, for purposes of design and for other reasons, to estimate the number that will be attracted to a new arterial route when it is constructed. The making of such traffic-volume estimates is commonly referred to as traffic assignment. Since the major proportion of the traffic that will use a new route will usually consist of vehicles diverted from the existing street system, the extent to which they can be diverted to the new route and the factors which influence that diversion are of vital importance to those who have the responsibility for planning adequate highway facilities.

In the absence of factual data there is, at present, some disagreement among highway engineers regarding the reasons a motorist chooses one route instead of another. Consequently, there is lack of agreement regarding the proper basis upon which to make traffic assignments. Travel time, travel distance, length of trip, ability to keep moving, safety, convenience, economy, habit, and other factors may enter into the choice. Very little is known, as yet, about the individual effect of any one of these factors. Some engineers consider travel time alone to be the most significant; others believe travel time and travel distance to be equally important; opinions concerning the significance of the other factors are usually indefinite and varied.

Although it is possible that a number of different factors may be involved, travel time and travel distance appear the most promising for initial study, because they are measurable items. Both travel time and distance can be determined with reasonable accuracy on any route, even one proposed for construction. Furthermore, if a definite relation exists between either one or a combination of these two factors and the choice of routes, that relation, when established, will provide a practicable basis upon which traffic assignments can be made with confidence. It was, therefore, the effect of these two factors on the usage of the Shirley Highway that was explored in this study. The findings reported here pertain strictly to diverted traffic and are limited to passenger-car travel.

SHIRLEY HIGHWAY SELECTED FOR STUDY

The Henry G. Shirley Memorial Highway extends southwesterly through Arlington and Fairfax Counties in Virginia from a point near the Pentagon. At the north end it connects with a network of expressways serving that building, and via this network, with three bridges crossing the Potomac River to Washington, D. C. Access to either the Shirley Highway or several alternate routes of travel from any one of the three bridges is readily available by way of this network.

The highway is a four-lane, divided freeway with full control of access throughout its entire length. Each lane is 12 ft. wide, and a 30-ft. grass median separates the opposing directions of travel. The posted speed limit for passenger cars in Arlington County is 50 mph. while in Fairfax County it is 55 mph. Through trucks were prohibited from using the route at the time of this study.

The length of the freeway is approximately 18 mi. from its beginning near the Pentagon to the point where it joins US 1, south of Alexandria. Slightly more than 5 mi. at the north end pass through a residential area suitable for a study of this type. Within the 5-mi. section are five traffic interchanges where vehicles may enter or leave the freeway. At the time of this study, the average weekday traffic volume near the middle of the study section was about 30,000 vehicles per day, including both directions of travel.

Figure 1 shows the Shirley Highway from a point just north of the Glebe Road interchange. This picture, taken in September 1950 at 5:30 p.m., shows the heavy outbound movement of traffic during the evening peak period of travel. Figure 2 is a view in the opposite direction, looking south from the Arlington Ridge Road interchange. This picture was taken in April 1950 about 9 a.m., just after the inbound morning peak had passed. Some of the populous residential area served by the freeway is shown in the background.

Figure 1. The Shirley Highway attracts large volumes of traffic. The outbound travel during the evening peak period is shown here.

Figure 2. Inbound travel on the Shirley Highway just after the morning peak has passed.

There are three principal alternate routes of travel, in addition to the Shirley Highway, which serve the area. These are the Mount Vernon Memorial Highway, Jefferson Davis Highway (US 1), and Columbia Pike. The latter two are typical city-street arterials with the usual signalized intersections, commercial development, and accompanying traffic congestion. The Mount Vernon Memorial Highway, being in the nature of a parkway, is more attractive to travel than the other two. There are, of course, many city streets of lesser importance than the three arterials named that also serve the area.

Figure 3 shows the general area of the study and the location of the Shirley Highway in relation to the alternate routes and the city streets serving the area.

STUDY PROCEDURE

The procedure adopted utilizes origin-and-destination data collected in the Washington Metropolitan Area Transportation Survey, combined with those obtained from roadside interviews made at points of exit along the Shirley Highway. With these data at hand, supplemented with travel time and distance measurements, it was possible to relate the percentage of traffic using the freeway between certain origins and destinations with the ratio of travel time or distance by way of the freeway to that by an alternate route.

The Washington transportation survey provided information concerning the total number of passenger cars moving from one zone to another regardless of the route traveled. This survey was conducted during the summer and fall of 1948 by the home-interview method, a 5 percent sample of the dwelling units being interviewed.

In order to adjust for the larger volume of traffic in 1950, the

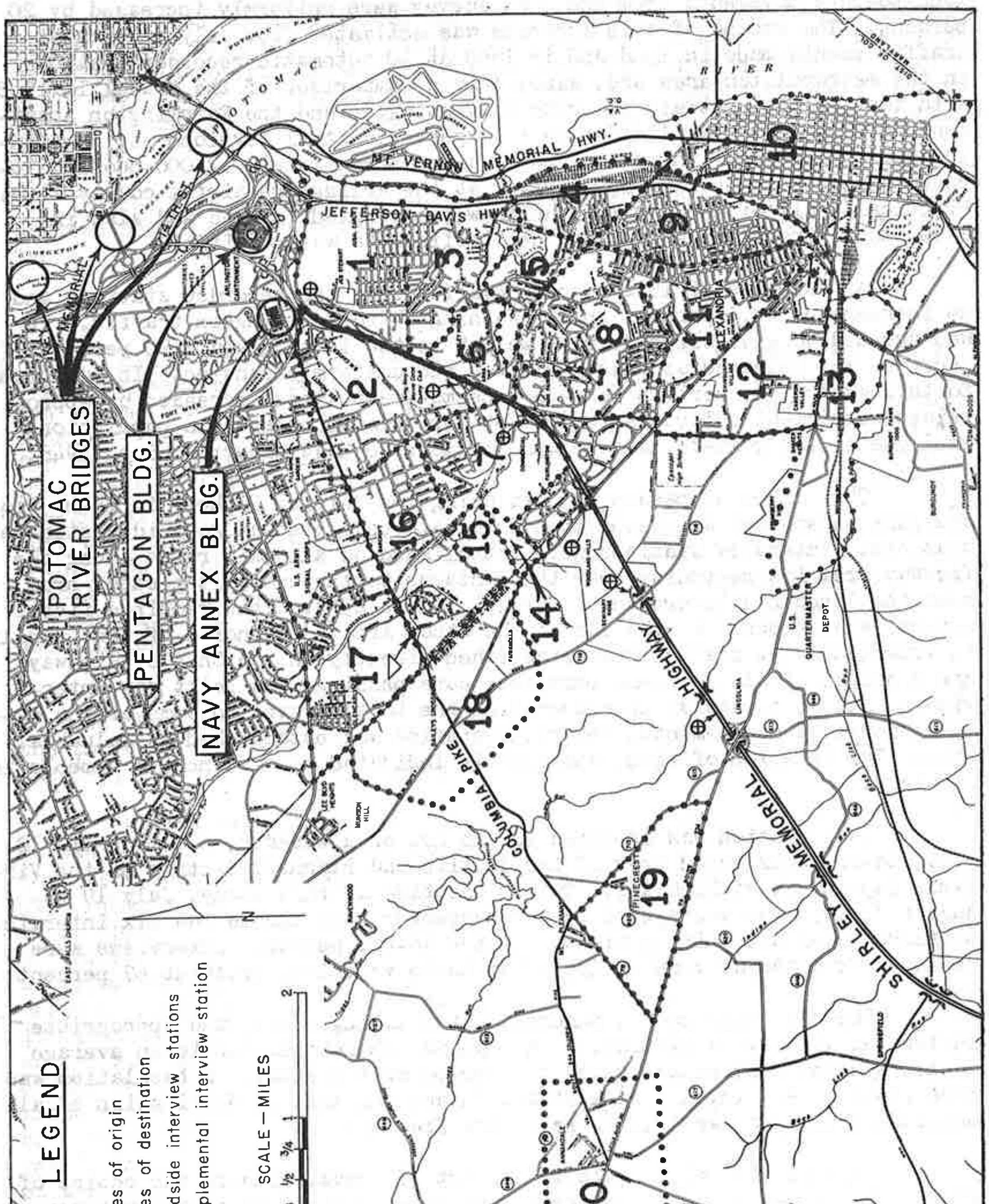

Figure 3. Map of study area.

zone-to-zone movements from the 1948 survey were uniformly increased by 20 percent. The amount of this increase was estimated from July and August traffic counts made in 1948 and in 1950 at 10 automatic recorder stations in the metropolitan area and, also, from a comparison of the travel in 1948 with that in 1950 between the city of Washington and the Fairlington apartment development. Fairlington is a large residential development, containing about 3,600 dwelling units and housing approximately 12,000 people, located directly on the Shirley Highway at the Arlington-Fairfax county line. Practically all of the dwelling units were occupied in 1948 and also in 1950, so a direct comparison of the traffic data was possible.

An increase of 15.2 percent was found at the recorder stations and an increase of 23.1 percent in the Washington-to-Fairlington traffic. It was decided to give slightly more weight to the latter, and a 20 percent increase was selected as reasonable for the uniform expansion. In addition to this expansion, certain zone-to-zone movements were increased by appropriate supplemental factors to account for unusual changes in population, employment, and commercial development known to have occurred since 1948.

The number of passenger cars using the Shirley Highway in going from one zone to another was determined from data collected at roadside interview stations. Interview stations were established on all exit ramps along the freeway from its beginning near the Pentagon to the end of the study area near the Lincolnia interchange (Virginia Route 236). This required five interview stations. At the end of the study area, just north of the Lincolnia interchange, a station was established directly on the Shirley Highway and a sample of all outbound passenger cars passing this point was interviewed. Also, to assist in determining the total travel to some of the outlying zones, a supplemental interview station was established on Columbia Pike. The location of these stations is indicated by distinctive symbols in Figure 3.

Each station was operated for 16 hr. on a weekday, 6 a.m. until 10 p.m., by an experienced crew of the Traffic and Planning Section of the Virginia Department of Highways. During the time of this study, July 19 to August 3, 1950, an average of 23,249 passenger cars passed the six interview stations along the Shirley Highway in the 16-hr. period. Interviews were obtained from the drivers of 15,667 of these vehicles, or about 67 percent.

The data were coded, punched on tabulating cards, and appropriate factors applied by hourly periods to expand the information to an average 24-hr. weekday representative of the period of the study. A tabulation was then prepared showing the zone of origin and the zone of destination of all outbound passenger car drivers using the freeway.

In order to investigate the effect of travel time on the choice of route, it was necessary to determine the time required to travel between points of origin and destination via the freeway and via the alternate routes. A comprehensive travel time map prepared for the Washington transportation survey provided much useful information in this connection. Check runs by the floating-car method were made on the freeway and on the principal alternate routes to test for differences between 1948 and 1950 travel time. The times recorded represent average peak-hour conditions on a weekday and were measured to the center of population of each zone.

As with the travel-time measurements, the distances were measured to the center of population of each zone via the freeway and via the shortest alternate route. In each case the mileage was scaled from a 1:24,000-scale map of the study area. A number of field checks made with a passenger car showed close agreement between the scaled distances and the odometer readings.

The time and distance measurements as well as the traffic volumes between points of origin and destination used in the study are shown in Table 1.

METHOD OF ANALYSIS

Since a part of the basic data for this study was derived from a 5 percent sample of travel, it follows that zone-to-zone movements of very low volume are not suitable for use. For this reason, it was decided to consider the city of Washington and its Maryland suburbs as a single zone for purposes of this study. All trips originating therein and destined to zones in the study area must cross one of the three Potomac River bridges designated in Figure 3. Thus, for purposes of this analysis, these bridges have been considered as points of origin for all trips beginning on the Washington side of the Potomac River. While information relative to the actual bridge crossed was not available, groups of trips were assigned to the most logical crossing according to their zone of origin and zone of destination.

The Pentagon and the Navy Annex Building are major traffic generators on the Virginia side of the Potomac River and these, in addition to the three bridges spanning the Potomac River, (Fourteenth Street, Memorial, and Key) comprise the five points of origin used in the study.

By reviewing the tabulation of passenger cars that used the freeway it was possible to determine the zones in Arlington and Fairfax counties that were destinations of a substantial number of vehicles using that facility. Twenty-one such zones were tentatively selected. The findings reported in this article are based on an analysis of the travel from the 5 points of origin to these 21 zones of destination. In total, 105 different groups of trips were examined, but 15 were found to be unsatisfactory for use because of inadequate samples, uncertainties in adjustment of 1948 travel to 1950, or for some other reason, and these movements were disregarded in the analysis. Also disregarded in the analysis were trips originating outside of the Washington metropolitan area, since it was assumed that a majority of these trips would follow marked routes regardless of the attractiveness of such routes for travel. In Table 1 it will be noted that a few zone-to-zone movements of low volume were used, this being made possible through the use of the data collected at the supplemental roadside interview station on Columbia Pike.

Table 2 summarizes the total number of trips included for study and classifies them according to travel on the freeway, on alternate routes, and those that were not used.

TABLE 1

Origin, Destination, Travel Time, and Travel Distance for Trips Studied.

Zone of destination	Number of trips			Travel time						
	Total	Via Shirley								
		Number	% of total	Via Shirley	Via Alternate	Ratio Shirley to Alternate	Time differential	Via Shirley	Via Alternate	Ratio Shirley to Alternate
				Min.	Min.		Min.	Mi.	Mi.	
Origin at Fourteenth Street Bridge										
1	785	170	21.7	6.3	4.6	1.37	-1.7	2.8	1.9	1.47
2	890	52	5.8	10.3	7.0	1.47	-3.3	4.4	3.3	1.33
3	424	131	30.9	7.0	6.0	1.17	-1.0	3.4	2.4	1.42
4	332	19	5.7	11.0	7.0	1.57	-4.0	5.1	3.1	1.65
5	576	496	86.1	8.0	8.8	0.91	0.8	3.7	3.2	1.16
6	634	370	58.4	7.3	8.3	0.88	1.0	4.0	3.7	1.08
7	1,192	1,172	98.3	6.5	13.5	0.48	7.0	3.9	4.9	0.80
8	860	478	55.6	9.5	10.0	0.95	0.5	4.9	4.2	1.17
9	675	148	21.9	12.2	9.9	1.23	-2.3	5.2	4.3	1.21
10	2,308	188	8.1	18.0	13.0	1.38	-5.0	7.7	5.2	1.48
11	467	193	41.3	12.0	13.0	0.92	1.0	6.2	4.9	1.27
12	108	100	92.6	12.2	16.4	0.74	4.2	6.2	5.9	1.05
13	176	43	24.4	14.0	21.0	0.67	a/	a/	a/	a/
14	57	55	96.5	9.8	17.2	0.57	7.4	5.4	6.9	0.78
15	89	84	94.4	10.0	17.0	0.59	7.0	5.5	6.8	0.81
16	700	151	21.6	12.7	10.7	1.19	-2.0	4.9	4.3	1.14
17	177	18	10.2	14.7	11.7	1.26	-3.0	6.9	4.7	1.47
18	322	169	52.5	12.6	12.9	0.98	0.3	6.4	5.4	1.19
19	72	60	83.3	14.6	18.6	0.78	4.0	8.4	8.2	1.02
20	291	196	67.4	17.7	20.2	0.88	2.5	10.2	9.4	1.09
21	60	37	61.7	27.3	29.8	0.92	2.5	16.3	15.5	1.05
Origin at Memorial Bridge										
1	242	82	33.9	6.8	6.9	0.99	0.1	3.2	3.2	1.00
2	382	22	5.8	10.8	7.4	1.46	-3.4	4.8	3.5	1.37
3	184	84	45.7	7.5	8.3	0.90	0.8	3.7	3.7	1.00
4	200	15	7.5	11.5	9.2	1.25	-2.3	5.4	4.5	1.20
5	192	123	64.1	8.5	11.1	0.77	2.6	4.0	4.6	0.87
6	198	156	78.8	7.8	11.3	0.69	3.5	4.3	4.6	0.93
7	322	321	99.7	7.0	13.9	0.50	6.9	4.3	5.3	0.81
8	346	284	82.1	10.0	12.3	0.81	2.3	5.2	5.5	0.95
9	188	62	33.0	12.7	12.1	1.05	-0.6	5.6	5.5	1.02
10	560	65	11.6	18.5	15.2	1.22	-3.3	8.1	6.9	1.17
11	65	44	67.7	12.5	15.3	0.82	2.8	6.6	6.2	1.06
12	153	105	68.6	13.0	16.5	0.79	3.5	6.6	7.2	0.92
b/13	27	36	---	---	--	--	--	--	--	--
14	28	28	100.0	10.3	17.6	0.59	7.3	5.7	7.2	0.79
15	27	27	100.0	10.5	17.4	0.60	6.9	5.8	7.1	0.82
16	406	60	14.8	13.2	11.1	1.19	-2.1	5.3	4.5	1.18
17	101	5	5.0	15.2	12.1	1.26	-3.1	7.1	4.9	1.45
18	377	169	44.8	13.1	13.3	0.98	0.2	7.2	5.9	1.22
19	43	30	69.8	15.0	15.9	0.94	0.9	9.2	7.3	1.26
20	281	199	70.8	18.1	20.6	0.88	2.5	11.1	9.9	1.12
21	54	49	90.7	27.8	30.3	0.92	2.5	17.1	16.0	1.07

TABLE 1 (Continued)

Origin at Key Bridge

1	184	66	35.9	9.3	8.4	1.11	-0.9	4.2	3.9	1.08
2	198	8	4.0	13.3	9.9	1.34	-3.4	5.7	4.4	1.30
3	105	23	21.9	10.0	9.8	1.02	-0.2	4.6	4.5	1.02
4	49	10	20.4	14.0	10.8	1.30	-3.2	6.3	5.2	1.21
b/ 5	60	137	--	--	--	--	--	--	--	--
6	86	73	84.9	10.3	12.8	0.80	2.5	5.2	5.7	0.91
b/ 7	141	157	--	--	--	--	--	--	--	--
b/ 8	2	32	--	--	--	--	--	--	--	--
9	113	57	50.4	15.2	14.7	1.03	-0.5	6.5	6.4	1.02
10	290	46	15.9	21.0	17.8	1.18	-3.2	8.9	7.7	1.16
11	65	30	46.2	15.0	16.8	0.89	1.8	7.5	7.0	1.07
12	28	18	64.3	15.5	19.0	0.82	3.5	7.5	7.7	0.97
b/13	0	11	--	--	--	--	--	--	--	--
14	20	20	100.0	12.8	18.7	0.68	5.9	6.7	7.3	0.92
15	24	22	91.7	13.0	18.5	0.70	5.5	6.8	7.2	0.94
16	115	17	14.8	15.7	12.2	1.29	-3.5	6.1	4.6	1.33
17	119	0	0.0	17.7	11.0	1.61	-6.7	8.0	5.8	1.38
18	23	11	47.8	15.6	15.8	0.99	0.2	8.0	6.7	1.19
19	7	4	57.1	17.6	19.2	0.92	1.6	10.0	7.3	1.37
c/20	--	--	--	--	--	--	--	--	--	--
c/21	--	--	--	--	--	--	--	--	--	--

Origin at Pentagon

1	140	55	39.3	4.0	3.8	1.05	-0.2	1.8	1.5	1.20
2	141	19	13.5	7.8	6.2	1.26	-1.6	3.4	2.4	1.42
3	64	56	87.5	4.8	5.8	0.83	1.0	2.3	2.1	1.10
4	29	6	20.7	8.5	7.4	1.15	-1.1	4.1	2.8	1.46
5	234	57	24.4	6.3	7.3	0.86	a/	a/	a/	a/
b/ 6	58	98	--	--	--	--	--	--	--	--
b/ 7	220	424	--	--	--	--	--	--	--	--
8	398	241	60.6	7.9	9.2	0.86	1.3	3.9	3.8	1.03
9	75	40	53.3	10.5	9.8	1.07	-0.7	4.3	4.0	1.08
10	232	66	28.4	15.1	13.6	1.11	-1.5	6.8	4.8	1.42
b/11	0	59	--	--	--	--	--	--	--	--
12	65	46	70.8	11.1	14.3	0.78	3.2	5.3	5.5	0.96
13	30	21	70.0	12.3	17.0	0.72	4.7	5.4	6.9	0.78
14	59	59	100.0	7.8	16.4	0.48	8.6	4.5	6.0	0.75
15	50	50	100.0	8.0	16.2	0.49	8.2	4.6	5.9	0.78
16	148	69	46.6	9.3	10.0	0.93	0.7	4.0	3.2	1.25
17	154	15	9.7	14.0	11.3	1.24	-2.7	5.7	3.7	1.54
18	284	169	59.5	10.9	12.1	0.90	1.2	5.7	4.5	1.27
19	23	19	82.6	12.9	17.7	0.73	4.8	7.6	7.2	1.06
20	139	113	81.3	16.0	19.3	0.83	3.3	9.3	8.5	1.09
21	17	15	88.2	24.9	29.5	0.84	4.6	15.4	14.6	1.05

TABLE 1 (Continued)

Origin at Navy Annex Building

1	65	54	83.1	3.7	4.9	0.76	1.2	1.7	2.1	0.81
2	123	8	6.5	6.9	4.5	1.53	-2.4	2.9	1.5	1.93
b/ 3	17	28	--	--	--	--	--	--	--	--
4	24	8	33.3	8.3	8.0	1.04	-0.3	3.7	3.6	1.03
5	67	41	61.2	6.1	8.3	0.73	2.2	2.5	3.8	0.66
6	74	65	87.8	5.3	8.0	0.66	2.7	2.6	3.2	0.81
7	143	140	97.9	5.0	11.0	0.45	6.0	2.6	3.1	0.84
8	67	53	79.1	7.6	10.7	0.71	3.1	3.5	4.0	0.88
9	49	39	79.6	10.2	11.7	0.87	1.5	3.8	4.7	0.81
b/10	0	50	--	--	--	--	--	--	--	--
b/11	0	15	--	--	--	--	--	--	--	--
b/12	0	5	--	--	--	--	--	--	--	--
b/13	0	6	--	--	--	--	--	--	--	--
14	7	6	85.7	8.0	13.0	0.62	5.0	4.2	4.9	0.86
15	11	11	100.0	8.2	12.8	0.64	4.6	4.3	4.8	0.90
16	112	13	11.6	8.9	7.5	1.19	-1.4	3.6	2.3	1.57
17	65	0	0.0	13.5	8.3	1.63	-5.2	5.2	2.7	1.93
18	72	14	19.4	10.5	9.6	1.09	-0.9	5.4	3.5	1.54
19	2	2	100.0	12.5	15.2	0.82	2.7	7.2	6.4	1.13
20	28	15	53.6	15.6	16.8	0.93	1.2	8.9	7.7	1.16
21	5	2	40.0	25.3	26.4	0.96	1.1	15.0	13.8	1.09

a/- Not included for analysis because percentage of traffic using freeway, when related to travel time ratio, falls far out of general range of other data.
b/- Not used in analysis because of inadequate samples and uncertainties in adjustment of 1948-50 travel.
c/- Insufficient data available to make an estimate of the total zone-to-zone movement.

TABLE 2

Total Number of Trips Studied

	Number of trips	Percentage of total
On freeway	8,152	39.0
On alternate routes	11,604	55.5
Subtotal	19,756	94.5
Not used	1,158	5.5
Total	20,914	100.0

FREEWAY-USE RELATION TO TRAVEL TIME

Figure 4 shows the percentage of passenger-car traffic using the freeway for various travel-time ratios. The travel-time ratio in each case was derived by dividing the amount of time required to make the trip via the freeway by that required via the most favorable alternate route. Each symbol represents the group of trips beginning at one of the 5 points of origin and ending in one of the 21 zones of destination. For example, the small circle near the middle of the chart in the upper right quadrant (1.07 time ratio and 53-percent freeway usage) represents the group of trips beginning at the Pentagon and ending in Zone 9. Table 1 shows the total number of trips in this movement to be 75, of which 40 used the Shirley Highway. The dot to the left and slightly below the circle, but also in the upper right quadrant, represents a movement of 113 trips beginning on the Washington side of the Potomac River, crossing Key Bridge, and, as it happens, also ending in Zone 9; 57 of these trips used the Shirley Highway.

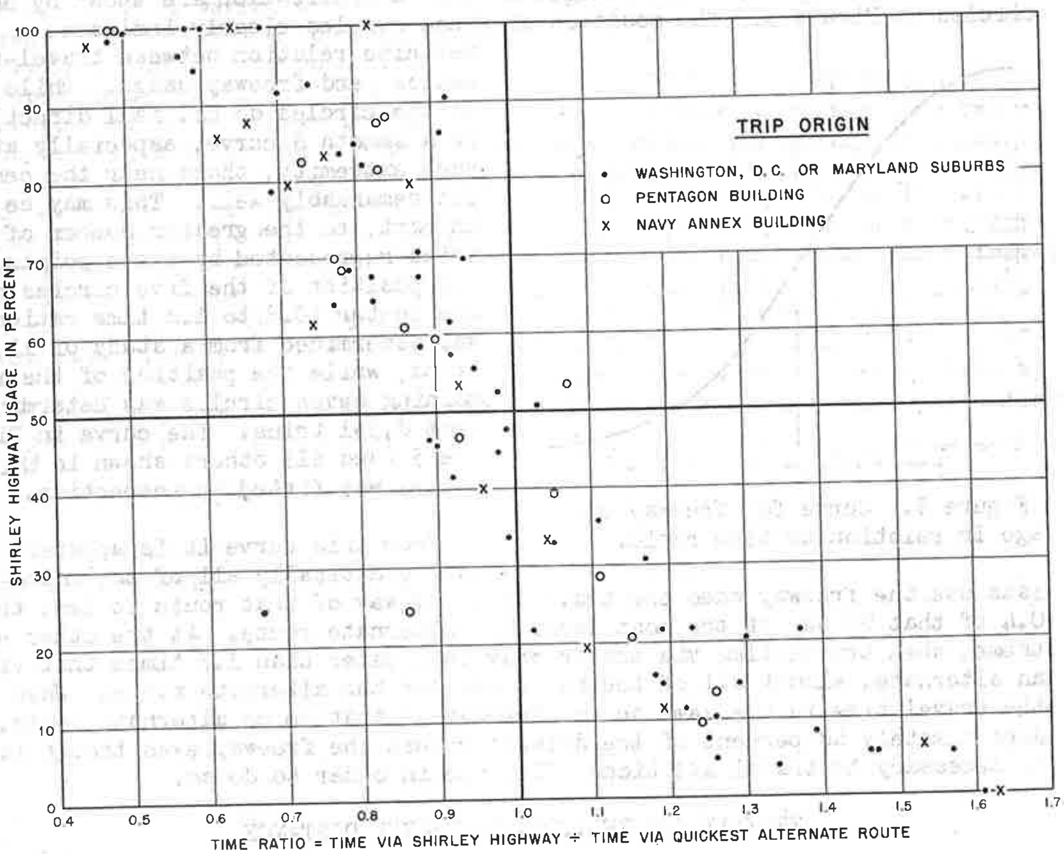

Figure 4. Freeway usage in relation to time ratio.

In total, the 56 dots on the chart represent 16,970 trips originating on the Washington side of the Potomac River, the 18 small circles represent 2,282 trips originating at the Pentagon, and the 16 crosses represent 914 trips originating at the Navy Annex Building. Included are two groups totaling 410 trips that were not used in subsequent analyses because they fall so far out of the general range of the other points. The symbols for these groups are in the 20 to 30 percent usage of the chart, to the left of 0.9 time ratio.

Although, as expected, there is some scatter in the points, they seem to fall within a reasonably close band all the way across the chart. The general pattern suggests the probability of a relation that may be expressed in terms of an S curve. No attempt was made to fit a curve to the points on this chart, however, because they represent different values insofar as the number of trips is concerned.

To arrive at a weighted mean and also to reduce the number of points the data were summarized by combining those movements which have the same travel-time ratio within increments of one tenth (for example, 0.96 to 1.05) and computing the percentage of the total trips of these combined movements that used the freeway. The results of this summarization are shown by small circles in Figure 5. The position of these circles clearly indicates a definite relation between travel-time ratios and freeway usage. While all of the circles do not fall directly on a smooth S curve, especially at each extremity, those near the center fit remarkably well. This may be due, in part, to the greater number of trips represented by those points. The position of the five circles near the center (0.8 to 1.2 time ratios) was determined from a study of 11,205 trips, while the position of the remaining seven circles was determined from 8,551 trips. The curve in Figure 5 (and all others shown in this article) was fitted by inspection.

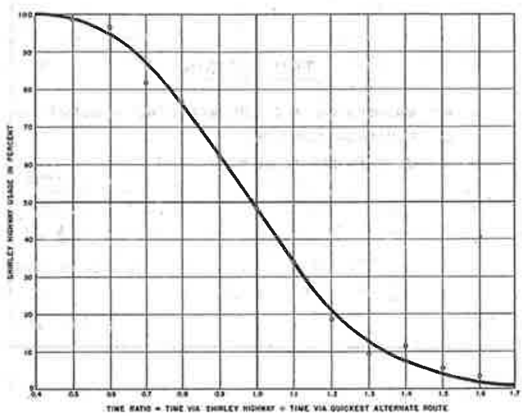

Figure 5. Curve for freeway usage in relation to time ratio.

From this curve it is apparent that practically all of the motorists use the freeway when the travel time by way of that route is less than 0.4 of that by way of the most favorable alternate route. At the other extreme, when travel time via the freeway is greater than 1.7 times that via an alternate, almost all of the motorists use the alternate route. When the travel time is the same on the freeway as that on an alternate route, approximately 48 percent of the drivers choose the freeway even though it is necessary to travel additional distance in order to do so.

FREEWAY USE RELATION TO TRAVEL DISTANCE

Figure 6 shows the percentage of passenger-car traffic using the freeway for various travel-distance ratios. The same general procedure was used in developing this chart as was used for the one shown in Figure 5. In this case, however, the scatter of the points is much greater, especially near the middle of the chart between 1.0 and 1.4 distance ratios. Even though weighted means for groups of points with so much variation have little significance, the data were summarized by one-tenth-distance ratios (shown by the small circles), and a curve fitted to these circles. Note that the shape of this curve, unlike that of the time-ratio S curve, is concave throughout.

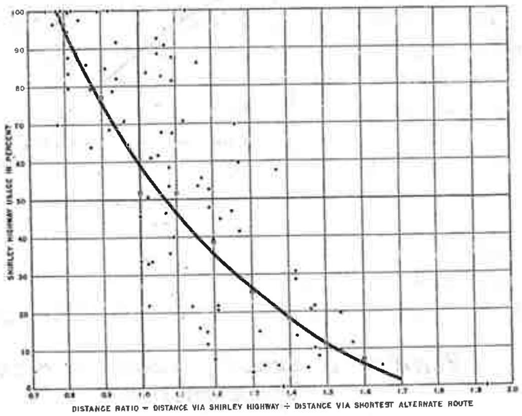

Figure 6. Freeway usage in relation to distance ratio.

It is evident from the data represented on this chart that practically all of the motorists use the freeway when the distance ratio is less than 0.8 and very few use it when the ratio is greater than 1.7. The usage when the distance ratios are between 1.0 and 1.1 varies from 22 to 92 percent. The exact reason for such a wide variation is unknown, although from a supplementary analysis it appears to be directly related to the quality of the traffic service provided by the alternate routes. The 22 movements comprising these trips were separated into two groups: (1) a choice of the freeway or an alternate providing reasonably good traffic service, and (2) a choice between the freeway or a relatively poor alternate. Of the first group, only 37.1 percent chose the freeway, while 66.6 percent of the second group chose that route. Furthermore, all except two of the eight movements included with the first group could travel via alternate routes in the same or less time than via the freeway, while all except one of the fourteen movements included with the second group could save time by using the freeway. Thus it is apparent that motorists making trips that are approximately equal in distance by the freeway and by an alternate route choose the former in greater proportions when travel time can be saved by doing so.

FREEWAY-USE RELATION TO TIME AND DISTANCE COMBINED

Since both the travel-time ratio and the distance ratio appear to bear some relation to the use of the freeway, it was decided to investigate a combination of the two. With this in mind, the distance ratio was divided by the time ratio for each group of trips, in effect giving a speed ratio, and the result plotted according to the percentage of passenger-car traffic using the freeway in each case. No correlation was found with this procedure. A second attempt was made to combine the two ratios, in which the time ratio and the distance ratio for each group of trips were multiplied and the product plotted according to the percentage of passenger-car traffic using the freeway in each case. Figure 7 shows the results of this combination after the detailed data were summarized by increments of one tenth.

The tendency is more toward a straight line than the S curve found in connection with the time ratio (Fig. 5). This is to be expected because, as a matter of mathematics, the product of the time and distance ratios tends to drop the relative position of the product curve below that of the

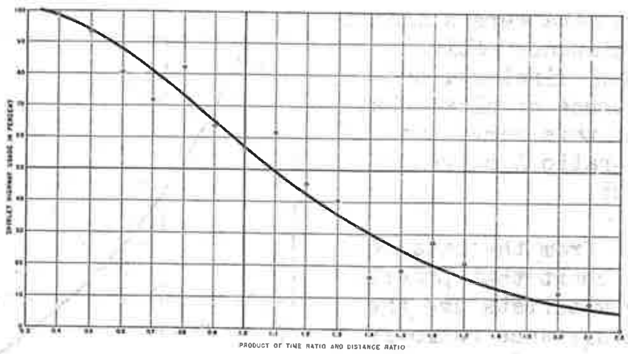

Figure 7. Freeway usage in relation to product of time and distance ratios.

time-ratio curve for each group of trips having a time ratio and a distance ratio both less than 1.0. Conversely, the tendency is to raise the relative position where either or both ratios are greater than 1.0.

While a relation between the freeway usage and the travel time-distance ratio product seems to exist, the correlation is not as good as that found with the time ratio alone. The relation shown in Figure 7 is of general interest, but it appears to be less practicable and would provide less accurate results than the time-ratio curve if used as a basis for making traffic assignments.

FREEWAY-USE RELATION TO TIME DIFFERENTIAL

Figure 8 shows the percentage of passenger-car traffic using the freeway based on the actual number of minutes motorists saved or lost by using that route as compared with an alternate. Here, as in the case of the travel-time ratio, the points fall within a reasonably close band which unmistakably suggests an S-curve relation.

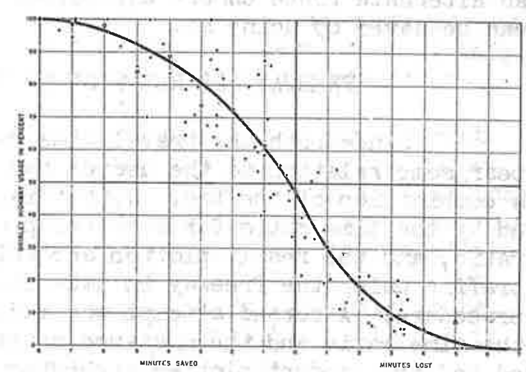

Figure 8. Freeway usage in relation to time differential.

The curve shown was drawn to fit the weighted means computed for each minute saved and each minute lost. As on previous charts, the weighted means are indicated by small circles. The resulting curve shows that where motorists can save 8 min. or more by using the freeway, they all choose that route. At the other extreme, a few motorists use the freeway even though they lost 4 or 5 min. by doing so. When travel time via the freeway is the same as that via an alternate route, the curve shows that approximately 48 percent of the motorists choose the freeway. This agrees properly with the percentage use shown by the time-ratio curve when the travel times are equal.

An interesting feature of this relation is its tendency to group zone-to-zone movements according to length. The longer trips tend to fall near the extremities of the curve while the shorter trips are grouped nearer the middle. This is readily understandable, because it would be impossible to save or lose several minutes by using the freeway instead of an alternate route in making short trips of only 5 or 10 min. total duration. On the other hand, in making trips of 20 or 30 min. duration, a time differential of several minutes would not be at all unlikely.

It is this tendency of trips to fall into groups according to length that results in somewhat better correlation between freeway usage and time differential than between freeway usage and time ratio. The reason for this difference is brought out in Figure 9.

FREEWAY USE IN RELATION TO TRIP LENGTH

Figure 9 shows the percentage of passenger-car traffic using the freeway, based on travel-time ratios, for three increments of travel distance: 4.0 mi. and less, 4.1 to 6.4 mi., and 6.5 mi. and greater. The distance by way of the freeway was used in grouping the trips into the three increments of length. The length in each case is the over-all distance between one of the five points of origin and one of the zones of destination. On this basis, the shortest trip included is 1.7 mi. while the longest is 17.1 mi.

It is evident from the position of the three curves in Figure 9 that, when the time ratio is less than 1.07, a greater percentage of the longer trips than of the shorter trips are on the freeway. When the time ratio is greater than 1.07, however, the position of the curves is reversed and a larger percentage of the shorter trips are on the freeway. For example, when the travel-time ratio is 0.7, these curves show that 89 percent of the longer trips are on the freeway and only 82 percent of the shorter ones. When the time ratio is 1.4, only 3 percent of the longer trips are on the freeway but there are 15 percent of the shorter ones.

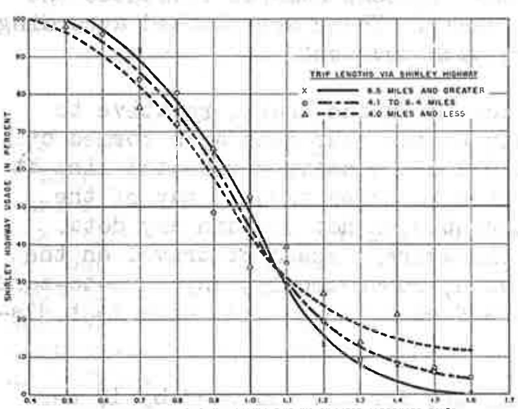

Figure 9. Effect of trip length on freeway usage.

The explanation for this relation appears to be directly connected with the actual amount of time motorists can save, or will lose, in making trips of various lengths by one route as compared with that of another. This point can best be explained by an example. Assume a long trip to require 20 min. by way of the freeway and a short one 5 min. If the time ratio is 0.7, motorists making the longer trip save 8.6 min. by using the freeway while those making the shorter trip save only 2.1 min. The actual amounts of time saved in the case of the longer trip is four times as great as that for the shorter trip. When the time ratio is 1.4 however, motorists lose 5.7 min. in making the longer trip by way of the freeway, but only 1.4 min. for the shorter one. In this case the loss in time is about four times as great for the longer trip.

Thus it seems that motorists attach significance to the actual amount of time saved or lost in traveling from one point to another in urban areas (especially when the amount is substantial) as well as to the relative travel time by way of one route compared with that of another. It is quite possible, in the case of the shorter trips, that the increment of time saved or lost is so small that it is not only insignificant but probably unknown to motorists. This might further explain the reason for the relative position of the curves in Figure 9.

If the travel-time ratio were the only criterion, the point at which the curves in Figure 9 cross each other would occur at a ratio of 1.0 instead of 1.07. The position of the curves show that, when the travel-time ratio is 1.0, the freeway is slightly more attractive to motorists making long trips than it is to those making short trips. The difference is so small in this case, however, that it could not be considered significant insofar as traffic assignment is concerned.

FREEWAY-USE IN RELATION TO TIME AND DISTANCE RATIOS

The percentage use of the freeway in relation to travel-time ratios and to travel-distance ratios has been shown on charts, separately, in Figures 5 and 6. In Figure 10 these two ratios and the percentage use of the freeway are shown on the same chart in order that the general relation of the three variables can be visualized and explored. Each dot on the chart represents a zone-to-zone movement and the adjacent numeral indicates the percentage of that movement using the freeway. These are plotted according to the time and distance ratios for each such movement.

The four statements shown in brackets on the chart, relative to saving or losing time and distance, apply to the four quadrants formed by the heavy vertical line at time ratio 1.0 and the heavy horizontal line at distance ratio 1.0. These statements refer to trips made by way of the freeway. Note that the lower right quadrant does not contain any dots. This is proper because, in this study, the average speed of travel on the freeway exceeds that on any alternate route; consequently, any zone-to-zone movement that would have lost time on the freeway would also have lost distance.

It is of interest that, in total, the freeway was used by 17 percent of the zone-to-zone movements plotted in the upper right quadrant, by 60 percent of those plotted in the upper left quadrant, and by 90 percent of those plotted in the lower left quadrant. Interpreting these percentages further, of the motorists whose trips were studied that would have lost both time and distance by using the freeway, 17 percent chose to do so, as did 60 percent of those who would have saved time but lost distance. On the other hand, of the motorists that could have saved both time and distance by using the freeway, 10 percent did not do so. This, again, seems to indicate the presence of factors other than time and distance that influence motorists in their choice of route.

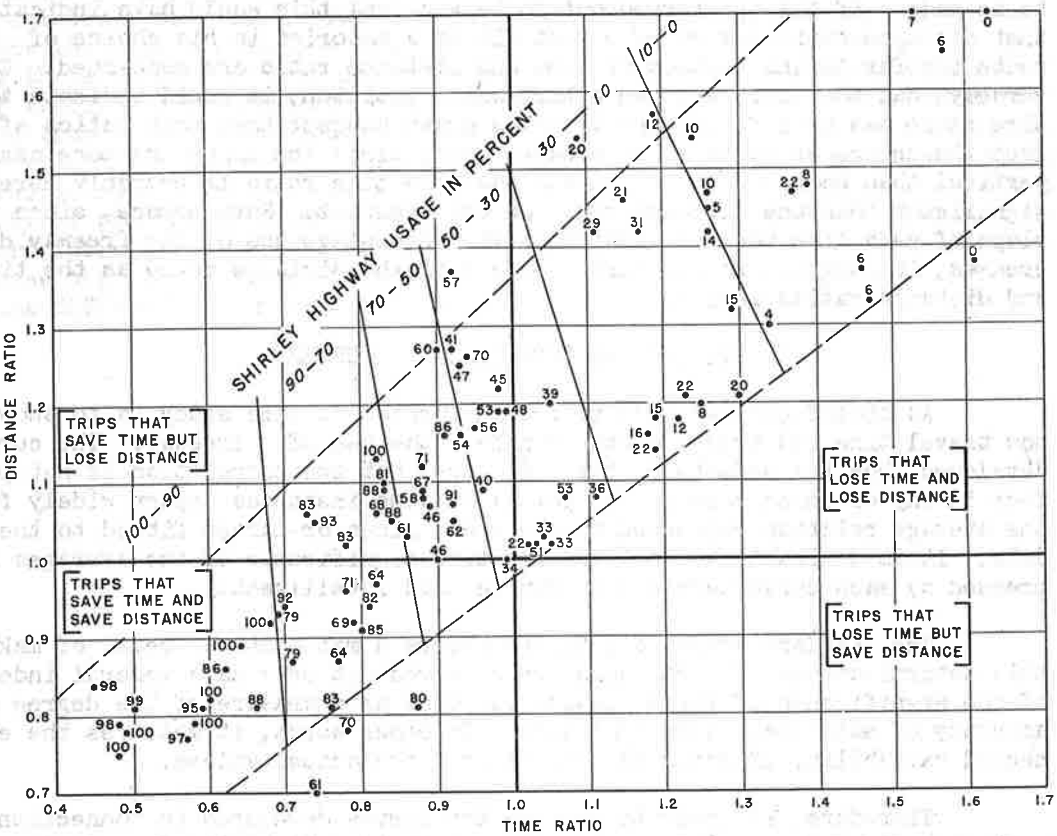

Figure 10. Freeway usage in relation to time and distance ratios.

The two dashed lines extending from the lower left to the upper right of the chart indicate the general range of time and distance ratios within which usage of the freeway occurs. The five solid lines sloping upward slightly to the left subdivide the area between the dashed lines into six segments. Each segment represents roughly a certain percentage range for use of the freeway as designated by the line of numerals extending diagonally across the chart above the upper dashed line, most of the percentages within a segment falling within the range indicated. It will be noted that the percentage of use gradually decreases from 100 percent at the lower left corner to zero at the upper right corner.

While it would have been desirable to have had more points from which to determine the slope of these five "contour" lines, the general direction of the third and fifth line from the left can be determined with reasonable accuracy from the points shown. To determine the slope of the three remaining lines, the third and fifth were extended to an intersection at a point above the chart and the remaining three lines projected back from that point of intersection as radii of a circle. This method seemed to conform with the data as nearly as any other logical one.

The slope of the resulting lines permits some interesting conjectures to be made. If all had turned out to be vertical this would have indicated that distance ratio has no effect at all on a motorist in his choice of route insofar as the factors of time and distance ratio are concerned. Conversely, had the lines assumed a horizontal position, it would indicate that time ratio has no effect. The lines as drawn suggest that both ratios affect the choice of route to some extent but, since the lines are more nearly vertical than horizontal, it follows that the time ratio is probably more significant than the distance ratio in this respect. Furthermore, since the slope of each line becomes greater as the percentage use of the freeway decreases, it suggests an increasing effect of the distance ratio as the time and distance ratios increase.

STATISTICAL COMPARISON OF CURVES

As stated earlier, the principal purpose of this study is to show how travel time and travel distance affect the use of a freeway. The curves developed show the effects of these factors, but the correlation is not perfect in any of these cases. The points in some instances depart widely from the average relation expressed by the trend lines or curves fitted to the data. It is desirable to know the relative significance of the averages expressed by each curve before they can be used intelligently.

The standard error of estimate offers a mathematical means of making this determination. The standard error serves not only as a general index of the significance of these curves, but also as a measure of the degree of accuracy of estimates based upon them. In other words, it measures the expected variability of estimated values from the actual values.

Therefore, in order to compare the curves developed in connection with time and distance ratios and appraise their reliability for use in traffic assignment work, the standard error was computed for each curve. The results of these computations, which is the percentage variation that would not be exceeded more often than about one third of the time, are summarized in Table 3.

TABLE 3

Standard error of estimate

Description of curve	Figure No.	Standard error
		percent
Time ratio	5	8.66
Distance ratio	6	17.54
Product of time and distance ratios	7	11.14
Time differential	8	8.50

Of the four curves, the one based on time differential has the least standard error, while the one based on distance ratio has the greatest. It will be noted that the curve based on time ratio has a standard error only slightly greater than that of the time differential curve. This clearly indicates that the curves based on time differential and time ratio are approximately of equal reliability and that time differential and time ratio show the best correlation with the percentage use of the freeway. Either of these curves, if used for purposes of assigning zone-to-zone movements of traffic to the freeway, would provide results within 8 or 9 percent of the true values in at least two thirds of the cases. This is satisfactorily within the accuracy of the basic data collected in origin-and-destination traffic studies conducted on the usual sampling basis. Moreover, the necessity of projecting traffic estimates into the future, with the attendant uncertainties, can readily introduce differences of greater magnitude than those that would result from the assignment of traffic on the basis of the time differential or travel-time curves.