Attitudes of Drivers Toward Alternative Highways and Their Relation to Route Choice

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To determine the factors influencing drivers' choice of alternative routes, a study was conducted in which the attitudes of drivers toward two highways were measured. In addition, traffic characteristics of the routes were measured and the tension generated on each was determined using nine test drivers. The routes employed were 47-mi sections of an expressway-design toll road and parallel rural primary highway. Drivers were sampled entering and exiting on both highways. A summated rating attitude scale was administered to a sample of 3,259 drivers. Also descriptive information was obtained about the driver, his trip, and travel habits. The results indicated that these drivers hold stable attitudes toward the two highways which clearly differentiate between them. It appears that direct measurement of driver attitudes is a better predictor of route choice than descriptive information about the drivers or their driving habits. In addition, the results provide a means of rationalizing the attraction of traffic to an expressway on the basis of drivers seeking to minimize tension in driving. The results suggest that total stress incurred in driving is a more important determinant of route choice than either operating costs or travel time costs. A model of route choice and attraction of traffic is proposed based on tension generation which can be related to travel time data. The results of this research indicate that drivers evaluate alternative highways in a rational, though subjective, fashion. Such evaluation, however, appears quite independent of the usual monetary schemes for rationalizing highway benefits and costs.

•WHEN a driver is provided alternative routes he must make an evaluation of the benefits and costs of each in order to make a choice. If drivers knew nothing about available alternative highways or they did not make an evaluation of them, their choices would be random. Since drivers do not operate in a random manner, it would appear reasonable that they learn the characteristics of the highways and out of this learning develop a basis for evaluation of alternatives. Drivers' choices thus become dependent on the diverse characteristics of the alternatives relative to his trip objectives and it is these which determine stable choice behavior. This behavior is of considerable significance both in determining the use of highway facilities and the benefits drivers derive from them.

Three major factors have been developed to account for the patterns of choice that drivers make among alternative highways: time savings, direct and indirect operating cost savings, and comfort and convenience savings.

BACKGROUND

In general, travel time savings have been the dominant criterion of use of alternative facilities, with the best predictor being the travel time ratio. In both rural (1, 3)

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and urban studies (2, 10) a driver appears to choose routes which provide significant time savings, even though he may have to drive a greater distance. All these studies imply that the driver values time directly and hence scales that variable. From an economic standpoint, a considerable effort has been made to determine the dollar equivalent of this time scale. For passenger car drivers these attempts have not been particularly successful (6).

Relative to operating cost, the relation with choice by passenger car drivers appears to be weak (4). Either drivers do not evaluate operating cost differences or these differences are insignificant. Relative to the total costs of a trip, it may well be that operating cost differences among alternative routes are quite trivial for the passenger car driver.

In addition to these physical measurements, the purely subjective concept of comfort and convenience has been developed. This has generally been described qualitatively as the ease of driving or freedom of movement. Claffey (4) has scaled this factor in terms of the changes in speed imposed on the driver and hence counted the impedances to movement. Michaels (8) has differentiated among highways on the basis of the tension aroused in drivers from traffic and geometric design features. His results indicate that tension reduction is the greatest single saving accruing to a driver choosing an expressway over a parallel non-controlled access highway, and drivers appear to evaluate alternatives subjectively in conformity to the tension induced on each.

Although the research on the whole problem of use of alternatives has described what traffic does, little research has been carried out on drivers preception of alternative routes available to them (2). Further, no attempts have been made to measure on a quantitative scale the evaluations drivers make or their relation to choice of routes. Thus, there is now no reliable way to predict use of facilities except by empirical studies of traffic.

In regard to any benefit analysis of highway facilities it is obvious that drivers evaluate highways on a predominantly subjective basis. No economic determination seems feasible without knowing the scale of value drivers use and its relation, if any, to dollars.

Considering the problem of selection of alternative routes, it seems a reasonable assumption that that choice will be based on what the driver has learned about the alternatives. Either directly or indirectly a driver must develop some stable evaluations; that is, he must have some predisposing views toward the routes or his choices would be random. These predisposing views are, by definition, the attitudes an individual holds toward some object or process. If route choice is rational then a direct measure of a driver's evaluation should be his attitudes toward the alternatives. By determining the intensity of these attitudes toward a pair of highways it should be possible to determine how they relate to the characteristics of the highways and the choices drivers make toward them.

To achieve these objectives, however, it is first necessary to determine whether there is a stable set of attitudes toward highways of different character. Second, it is necessary to determine whether these attitudes depend on the characteristics of the drivers which are relatively permanent, or on the characteristics of a particular trip which would lead to highly variable attitudes. It is in this context that the present study was developed. Its aim was to test the hypothesis that there were significantly different attitudes toward two highways by the drivers on each, and that these attitudes depended on the more enduring characteristics of the routes and the drivers.

Development of the Attitude Scale

The attitude scaling technique employed in this study was the method of summated ratings, which employs a series of direct statements to which the respondent expresses the extent of his agreement. An example of such a statement is "A road with many hills and curves is interesting to drive." The subject then responds in one of five categories ranging from strongly agree to strongly disagree. A score of 0, 1, 2, 3, or 4 is given to his response according to the category chosen with a score of two being neutral. Thus, using a set of such items a total attitude score can be obtained for any subject toward the road under study.

The general procedure for preparing such an attitude battery is described by Edwards (5). In this experiment it was decided to compare attitudes on a toll road and a rural primary, since these are two of the more common choices that a driver has and yet have radically different design characteristics. To develop the final items for the attitude scale, 61 statements were initially prepared. These statements described a variety of characteristics of a rural primary and an expressway both positive and negative. They were presented to a sample of 260 staff members of the Bureau of Public Roads. The instructions that they were given were as follows:

> Place yourself in a hypothetical situation of having the choice of two routes for home to work trips: (1) a limited-access toll road and (2) a parallel free-access primary roadway. The toll on the turnpike is $1.00. The trip is 30 miles on both routes. Assume that the primary route is similar to US 1 between Baltimore and Washington, or between Alexandria and Woodbridge.
>
> The attached questionnaire is designed to elicit attitudes toward these two types of highways. You should respond to each statement in terms of your own personal feelings, checking one of the five categories that range from strongly agree to strongly disagree.

Some basic objective information was obtained about the respondents including age, sex, and the percentage of time they would choose the toll road. Adding the last item allowed an initial check on the validity of the final scale, for it was hypothesized that those responding most positively to expressway items would be most likely to use that facility and vice versa. All items were scored in terms of favorability toward the expressway. The returns were then analyzed according to the standard procedure in which the highest scoring quarter of the sample was compared with the lowest scoring quarter. Well over half the items significantly differentiated the two highways. The final battery was composed of 18 items from the original group of 61 that were found to be the most discriminating between the high and low groups.

A further analysis was done on this pretest group. The attitude scores were correlated with the respondents percentage of choice of the toll road. The two distributions were dichotomized and a phi coefficient computed. The correlation coefficient was + 0.52 between attitudes scores and choice of routes. Thus, it was reasonable to conclude that in this hypothetical situation, there was a stable set of attitudes toward the two types of highways which was significantly related to the choice of routes that the respondents would make.

In addition to the final attitude battery, a questionnaire was included to obtain some basic descriptive information about the respondents' trips so that the attributes of the drivers and their trips could be related to their attitudes. These items were to provide a means for testing the stability of the attitudes and fell in three basic categories: (a) characteristics of the driver and his vehicle which included age, sex, and age of car; (b) characteristics of the trip which included purpose, number of car occupants, and the driving time already completed and that still left to be done; and (c) descriptive information on the driver's estimate of the frequency with which he made this kind of trip and the frequency with which he used the alternative route.

The item on driving time was included because there were no statements in the attitude battery relating to travel time alone. In the sample used to develop the scale, time did not discriminate between the high and low scoring groups. By treating travel time as an independent variable it was possible to relate subjective estimates of driving time to the respondent's attitudes toward the routes. It is obvious that if travel time were a dominant criterion of choice, then there should be a correlation between a driver's attitude toward the route and the duration of trip that he was undertaking. Using this approach an independent test could be made of a driver's choice of routes and of travel time.

Selection of Test Location

In considering a pair of roads of sharply different characteristics between which a driver might choose, the ideal would be a pair which had a common beginning and a

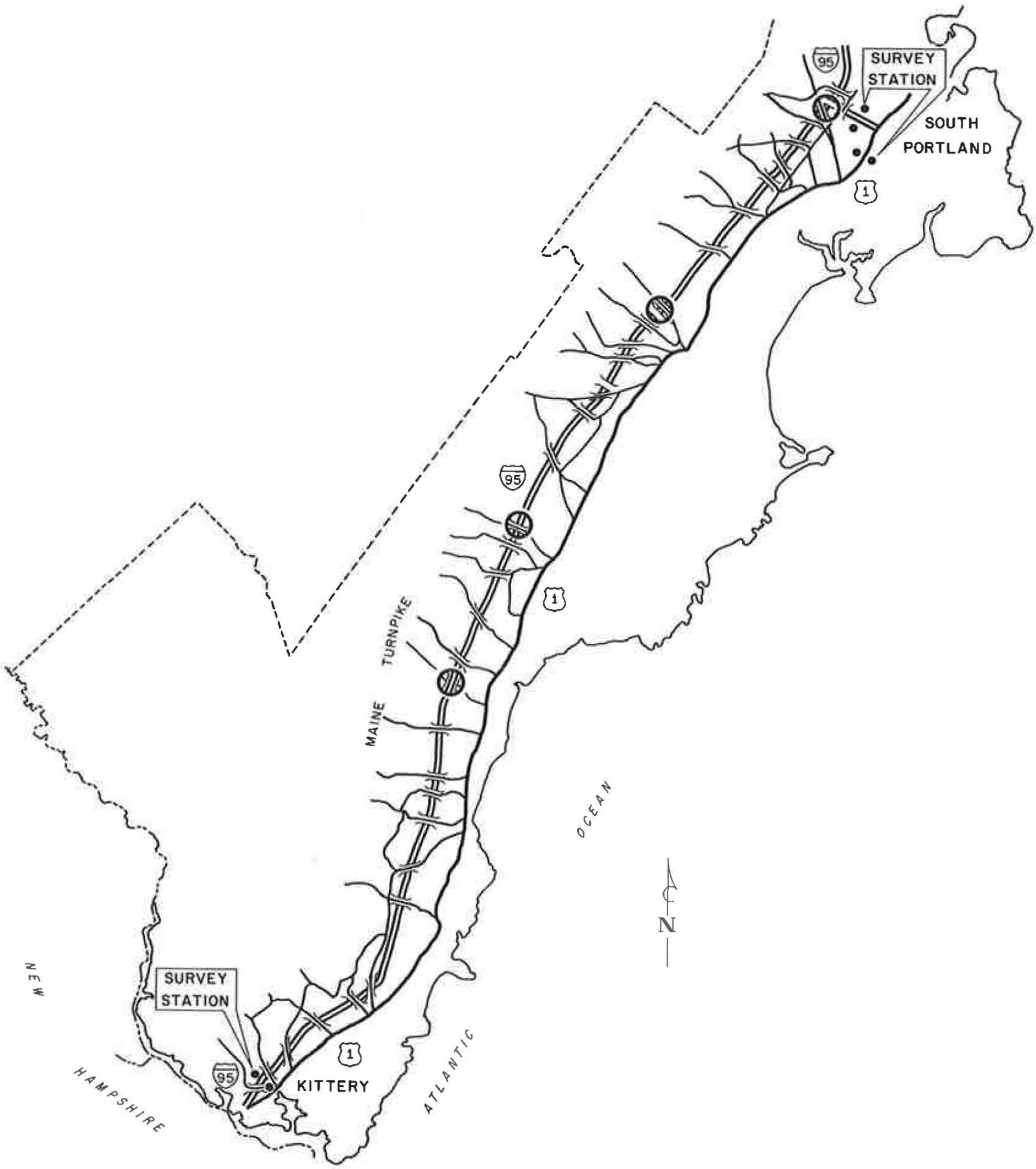

Figure 1. Study routes.

common terminus. In addition, the pair should be long enough to permit a meaningful choice for the drivers. A pair of highways meeting these requirements is the Maine Turnpike between Kittery and South Portland and the parallel rural primary, US 1 which has been studied extensively over the past decade (1, 3). The sections are both approximately 45 miles long. At the Kittery end, the choice of either route is a simple one for the driver for the connection is a Y. At the South Portland end, US 1 and the turnpike join again (Fig. 1).

The characteristics of both routes are quite typical of a modern toll road on the one hand and a rural primary on the other. The turnpike is a four-lane divided highway with interchanges spaced 5 to 15 miles apart and generally built to Interstate design standards. US 1 varies from two to four lanes passing through several small towns as well as undeveloped countryside. There is no control of access and the route has a variety of traffic control devices.

PROCEDURE

A survey team of nine men was used. The sampling schedule was set to run during daylight hours between 8:00 a.m. and 5:00 p.m., with sampling being done at both ends of each highway. For the first 4 hours vehicles were stopped as they entered the test sections. For the next 4 hours vehicles were stopped as they left the test sections. In this fashion samples of drivers were obtained from north and south ends of both routes with drivers never being stopped twice on the same trip. By counterbalancing the order, an approximately equal sample of drivers entering and exiting at both ends of the two highways was obtained.

To obtain the most stable attitudes toward the routes under study, only Maine or New Hampshire drivers were sampled. No fixed procedure was established for stopping a particular vehicle. The complexities of traffic and the limitation of only two interviewers at each station precluded any formal sampling procedure. However, by extending the sampling period over 30 days it was felt that most such biases would be eliminated.

When a driver was stopped, a common set of instructions was given:

> Good morning. We are doing research on why drivers pick particular roads for their trips and would like to enlist your assistance. We have a questionnaire that we would like you to complete which will take about five minutes of your time. If you can spare that time, we would appreciate it.

If the driver agreed, the attitude form was handed to him and the instructions for filling it out were read with him. When the interviewer and the driver were satisfied as to what was to be done, the interviewer withdrew and the driver completed the attitude questionnaire. When finished he handed the form back to the interviewer who then asked the objective questions marking the verbal replies on a coding sheet. The two parts of the form had a common number so that both parts of the survey could be subsequently combined.

Speed and Volume Measurements

In addition to the attitude survey, traffic measures were taken on the two routes. Rather complete volume counts were made daily for both the turnpike and US 1. The latter had volume counters at three locations so that hourly traffic counts were available. On the turnpike, volume was sampled at four separate locations during several different time periods. In addition, daily samples of traffic speed were made on both routes using a radar speed meter. Thus, a fairly complete record of the traffic characteristics on both test sections over the period of the study was obtained.

Tension Measurements

The Galvanic Skin Reflex (GSR) was employed to obtain tension measurements on both the turnpike and US 1. Over the one month study each one of the interviewers was used as a test subject and drove both routes twice in both directions. The procedure outlined in previous reports (7, 8) was employed.

RESULTS

Attitude Survey

During the four weeks of surveying on both routes a total sample of 3, 259 different drivers was obtained. No significant differences were found between drivers sampled at the two ends of the test routes. Further, there were no differences between drivers sampled on entering the test sections and those leaving them. Therefore, these data

TABLE 1

ATTITUDES OF DRIVERS TOWARD MAIN TURNPIKE AND US 1

Driver	Turnpike			US 1		
	N	Mean	St. Dev.	N	Mean	St. Dev.
Male	1,138	41.33	9.40	1,039	32.09	9.56
Female	482	38.52	9.54	600	30.20	8.65
Total	1,620			1,639		

TABLE 2

SEX DISTRIBUTION OF DRIVERS

Driver	Turnpike		US 1		Total	
	N	Percent	N	Percent	N	Percent
Male	1,138	70.4	1,039	63.4	2,177	0.667
Female	482	29.6	600	36.6	1,082	0.333
Total	1,620	100.0	1,639	100.0	3,259	0.100

TABLE 3

DISTRIBUTION OF VEHICLES OF DIFFERENT AGE

Vehicle Age	Total Proportion	Turnpike		US 1	
		Male	Female	Male	Female
<1 yr	0.186	0.225	0.221	0.167	0.132
1 to 3 yr	0.393	0.459	0.396	0.342	0.359
4 to 6 yr	0.262	0.201	0.271	0.285	0.328
>6 yr	0.157	0.114	0.111	0.213	0.180

were pooled. Approximately the same number of observations were taken on both routes (Table 1). This, of course, does not represent the distribution of traffic but only the method of sampling on the two highways.

Fourteen percent of the drivers stopped refused to participate in the survey. The percentage was the same on both routes. In addition, approximately 6 percent of the drivers stopped had been interviewed before. As might have been expected the percentage of repeats from first week to the last week increased on US 1 from 1.9 percent at the end of the first week to 5.7 percent in the third week. On the turnpike, it increased from 0.8 percent to 10.3 percent in the third week.

The attitude questionnaires were scored with the turnpike used as a reference for assigning a quantitative score to the responses. Thus, all statements about US 1 that reflected a positive attitude toward that highway were given a 0 score for the category of strongly agree and a score of 4 for the response of strongly disagree. For those

TABLE 4

ANALYSIS OF VARIANCE OF ATTITUDES ON BASIS OF DRIVER AND VEHICLE AGE

Source	Sum of Square	d.f.	Mean Square	F	P(F)
(a) Turnpike Male Drivers					
Driver age	656.53	3	215.51	2.468	<0.05
Vehicle age	996.48	2	498.24	5.706	<0.01
Driver x vehicle	243.35	6	40.56	-	N.S.
Within	99,454.14	1,139	87.32	-	-
Total	101,341.50	1,150	-	-	-
(b) Turnpike Female Drivers					
Driver age	464.30	3	154.80	1.543	N.S.
Vehicle age	263.10	2	131.55	1.312	N.S.
Age x vehicle	418.42	6	69.74	-	N.S.
Within	48,342.20	482	100.30	-	-
Total	49,488.02	493	-	-	-
(c) US 1 Male Drivers					
Driver age	2,532	3	844.0	9.58	<0.01
Vehicle age	629	2	313.5	3.56	<0.05
Age x vehicle	1,390	6	231.7	2.62	<0.05
Within	86,299	980	88.1	-	-
Total	90,850	991	-	-	-
(d) US 1 Female Drivers					
Driver age	1,148	3	382.7	5.50	<0.01
Vehicle age	755	2	377.5	5.42	<0.01
Age x vehicle	722	6	120.3	1.73	N.S.
Within	42,605	604	69.5	-	-
Total	45,230	615	-	-	-

items which were unfavorable statements about US 1, strong agreement was scored as 4 and strong disagreement as 0. Statements about the turnpike were rated in the obvious fashion. Thus, the total score of a respondent was interpreted to reflect his attitude toward the turnpike. The scores on each of the items along with the descriptive information obtained from the interview were placed on punch cards and all of the basic analyses of the attitude sample was done on the computer.

Table 1 summarizes the attitudes of drivers on each route, classified by sex. The higher the score the more positive are the drivers' feelings toward the turnpike. A score of 36 would indicate a neutral attitude toward the turnpike. There were significant differences between the two highways. Drivers on US 1 held a negative attitude toward the turnpike, while turnpike users held a positive attitude toward that facility. The differences between the sexes were also significant. The male turnpike driver was significantly more positive toward the turnpike than the female driver. The US 1 male driver, although still holding a negative attitude toward the turnpike,

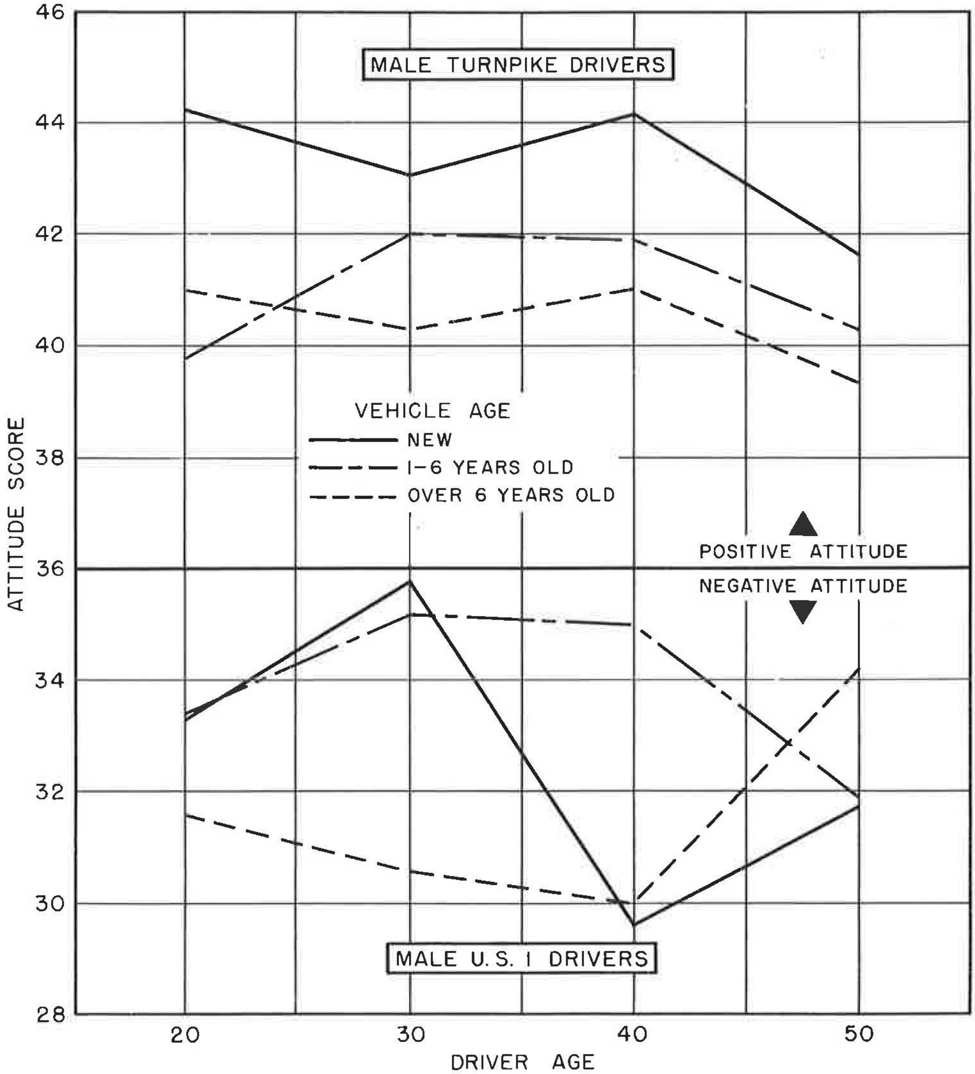

Figure 2. Attitude of male drivers toward turnpike as a function of driver and vehicle age and travel route.

was less negative toward the turnpike than the female driver on US 1. Finally, the attitudes of male and female drivers on both routes were significantly different from neutral. Thus, it is reasonable to conclude that the attitude scale did differentiate between the users of the two highways.

The sex distribution of the drivers on the two routes was analyzed (Table 2). Two-thirds of the total sample were male. More significant, however, is the difference in the proportion of male or female drivers between the two routes. There were significantly more women drivers traveling US 1 than the turnpike. Comparison of this sex distribution with attitudes toward the turnpike from Table 1 indicates a significantly less positive attitude toward the turnpike than for the males. It may be reasonably concluded that there was a correlation between the attitudes that the two sexes held toward the highways and the actual choices they made between them.

The third category under the driver and vehicle characteristics concerns that of vehicle age. Table 3 gives the percentages of vehicles on each route by age and by the sex of the driver. Women drivers in this sample drove older vehicles than the men;

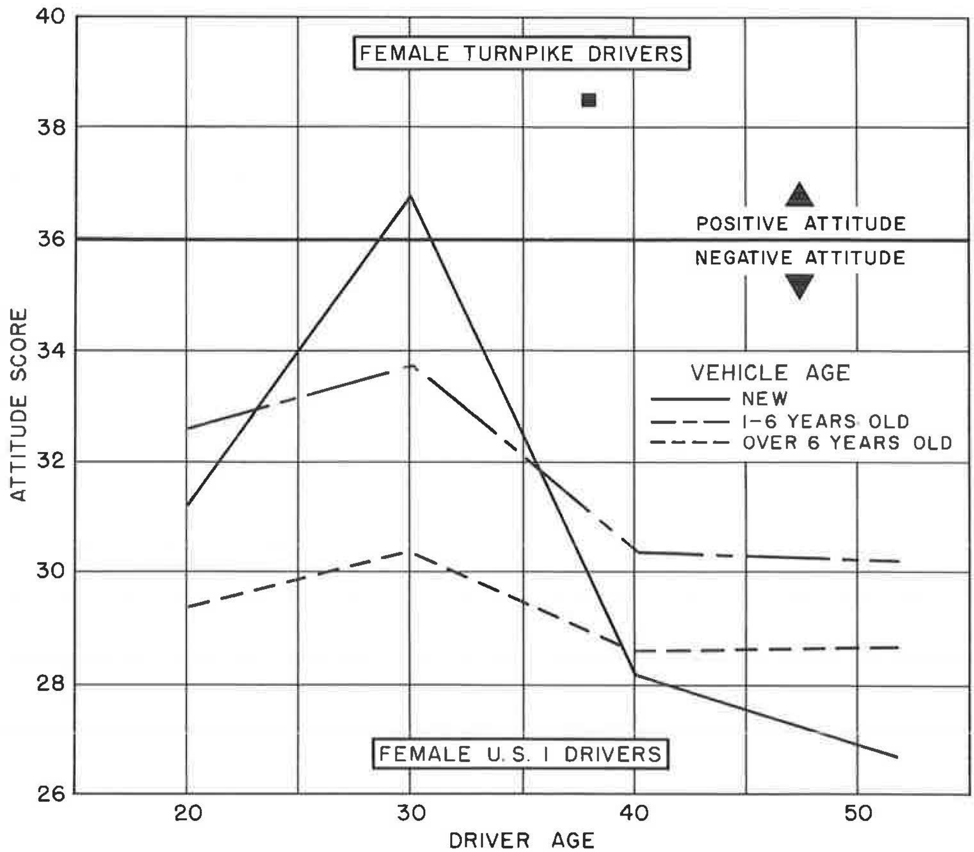

Figure 3. Attitude of female drivers toward turnpike as a function of driver and vehicle age and travel route.

and more significantly, the percentage of older vehicles found on the turnpike was significantly less than that found on US 1.

Drivers in the sample on both routes were compared for age differences. In relation to attitudes toward the two highways, rather clearcut differences exist. An analysis of variance was done for both driver age and vehicle age, the attitude scores being the dependent variable (Table 4). Both driver age and vehicle age are statistically significant for every case but the female turnpike drivers.

The mean attitude scores as a function of age are shown for all conditions (Figs. 2 and 3); vehicle age is the parameter in these curves. For the male drivers, attitudes toward the turnpike became less positive with increasing age. In addition, there is a clear effect of vehicle age on the attitudes toward the turnpike. Thus, the newer the automobile the more positive was the attitude toward the turnpike. In general, the same results follow for the females on US 1; there was a definite ordering of attitudes by vehicle age and by driver age. There appears to be a peak in attitudes toward the turnpike in the age range of 25 to 35, after which driver attitudes become more negative toward the turnpike. There were no significant differences for the female turnpike driver as shown by the single point (Fig. 3). It is reasonable to conclude from these analyses that attitudes toward the alternative highways depended significantly on the stable characteristics of drivers and their vehicles. These results further indicate that drivers' attitudes toward alternative routes were quite stable, evolving partially out of the enduring characteristics of the driver and his vehicle.

TABLE 5

DISTRIBUTION OF DRIVING TIMES

Driving Time Left (min)	Driving Time Completed (min)											
	< 15		15 to 30		31 to 60		61 to 120		>121		Total	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
(a) Drivers on Turnpike												
< 15	55	4	16	8	35	13	31	10	36	12	173	47
15 to 30	12	2	40	23	43	21	44	28	64	23	203	97
31 to 60	45	22	32	15	27	12	33	20	38	22	175	91
61 to 120	35	11	32	24	34	8	59	35	72	32	232	110
>121	68	23	66	25	42	13	85	35	173	64	434	160
Total	215	62	186	95	181	67	252	128	383	153	1,217	505
(b) Drivers on US 1												
< 15	190	136	91	94	41	12	25	7	14	8	361	227
15 to 30	146	96	146	92	51	34	27	20	16	16	386	266
31 to 60	29	17	31	20	12	9	17	7	10	4	99	57
61 to 120	16	4	14	13	11	5	16	8	26	1	83	31
>121	29	7	19	6	14	6	20	3	48	16	130	38
Total	410	260	301	195	129	66	105	53	114	45	1,059	619

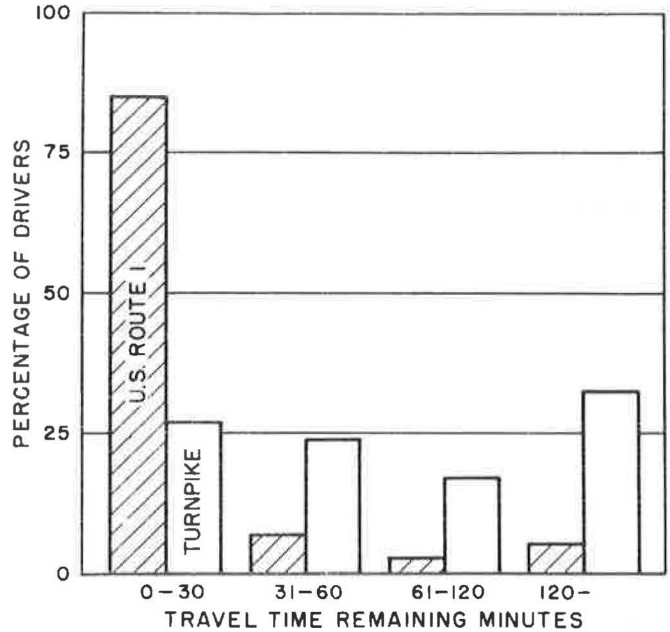

Figure 4. Percentage distribution of trip time remaining for drivers who have been driving less than 30 min.

TABLE 6

MEAN ATTITUDE SCORES FOR MALE DRIVERS HAVING APPROXIMATELY COMMON ORIGINS AND DESTINATIONS

Age	Turnpike	US 1
< 24	—	35.27
25 to 34	42.47	34.22
35 to 44	43.32	33.72
>45	41.73	29.90

Attitudes and Trip Characteristics

The second class of relations with driver attitudes concerns the characteristics of the specific trip during which a driver was sampled. The objective of these analyses was to determine whether attitudes toward the two highways were markedly modified by the purpose of the trip, the number of occupants in the vehicle, and the travel time associated with the trip. Analysis of the data showed that no significant relations existed between either the trip purpose or the number of occupants in the vehicle and the drivers' attitudes toward the turnpike. Similarly, the relation between subjective estimates of trip duration was unrelated to drivers' attitudes toward the turnpike. Thus, the results of this analysis on the characteristics of the specific trip indicate that a driver's attitudes toward the highways among which he could choose were quite independent of the specific trip. This would indicate that the choice among alternatives was made on a basis of stable and pre-existing attitudes toward the different types of highways.

The results relevant to travel time should not be interpreted to mean that there were no differences in the distribution of trip durations on the two highways. Table 5 gives the frequency distributions for the sample. These time values are subjective estimates of the time already spent driving as well as estimates of the amount of time required to complete the trip. The longer the trip, the more likely was it to be done on the turnpike. Thus, approximately 32 percent of all the drivers sampled on the turnpike had been traveling for less than ½ hr and 54 percent had more than 1 hr left to drive. On US 1, 70 percent of the drivers had been driving for less than ½ hr and only 25 percent of the drivers had more than ½ hr more to drive. Figure 4 shows the percentage distribution of remaining trip time for those drivers who had just started their trips. Only 15 percent of all the US 1 drivers expected to be driving for longer than 30 min whereas 71 percent of the drivers just beginning their trips on the turnpike expected to drive more than 30 min. Thus, the longer trip drivers tended to gravitate toward the turnpike.

A clearer picture of the effects of trip time and attitudes results from examining only those travelers on both routes who had approximately common origins and destinations. If only those turnpike drivers who had been traveling less than 30 min and had between 15 min and 1 hr left to travel, are compared with US 1 drivers who also had been traveling less than 30 min but who had between ½ and 2 hr yet to drive, it is obvious that US 1 drivers who made this choice were sacrificing time. The attitudes toward the turnpike for male drivers of different ages were compared (Table 6). For turnpike drivers there were no significant differences among the ages, whereas on US 1 there was a significant decrease in attitudes toward the turnpike as the age of the driver increased. In all cases, however, the US 1 driver held significantly negative attitudes toward the turnpike. Thus, it is reasonable to conclude that for trips having common origin and destination the drivers' choice between the two routes was highly related to their attitudes toward the alternative. In the case of such drivers on US 1, this meant that they chose the rural primary over the expressway even though in so doing it caused a 30 percent increase in travel time.

The sample was also analyzed in relation to the frequency with which drivers make trips between South Portland and Kittery. The trip frequency was defined in three categories: less than 1 trip per year, 1 to 12 trips per year, or more than 1 trip a month. Table 7 gives the percentage of the total sample on each route for each sex and the trip frequency. For the turnpike sample, the majority made the trip more often than once a month. On US 1, however, drivers who made these trips between once a year and once a month predominated. A chi-square test was used to test the differences between the turnpike and US 1 drivers, and the differences between the distributions were significant. When trip frequency increases beyond one trip a month, there is a decrease in the proportion found on US 1, together with an increase in the proportion found on the turnpike. This may indicate that the turnpike exerted an attraction for drivers as the frequency with which they traveled between Kittery and South Portland increased.

The attitudes of drivers toward the two routes were also analyzed as a function of frequency with which they made the trips between South Portland and Kittery (Table 8). Because of the significant differences among driver ages, the data were also separated by that variable. Table 8 indicates that the influence of age is the same as was discussed previously. There is also a consistent and significant increase in the average attitude score toward the turnpike as a function of trip frequency for both male and female drivers sampled on the turnpike. Furthermore, US 1 drivers, although holding negative attitudes toward the turnpike, showed a trend in attitudes approaching neutrality toward the turnpike as trip frequency increased. Thus, there was a general shift toward more positive attitudes toward the turnpike as trip frequency increased. This result offers further evidence that drivers' attitudes toward the two highways developed out of their driving experiences on each of the routes, and from this learning, there was a shift in attitudes toward favoring the expressway-type facility.

The final general analysis concerned the extent of use of the alternative routes by drivers. Each driver sampled was asked what percentage of time he used the other route for his trips (Fig. 5). There were no differences between male and female drivers and all the data were combined. The drivers sampled on the turnpike rarely used US 1: only 12 percent used US 1 for more than half their trips. On the other hand drivers sampled on US 1 frequently used the turnpike: 42 percent for more than 50 percent of their trips. Again, this appears to indicate an attraction of drivers toward the turnpike.

The attitude scale employed in this study was composed of two classes of statements: one was their reference to either the turnpike or US 1; the other was favorable or unfavorable statements. Hence, the items in the attitude scale can be classified in a 2 × 2

TABLE 7

RELATIVE FREQUENCY OF TRIPS OF DRIVERS SAMPLED

Frequency (per yr)	Male		Female	
	Turnpike	US 1	Turnpike	US 1
< 1	0.047	0.073	0.124	0.136
1 to 11	0.441	0.534	0.426	0.473
>12	0.511	0.394	0.451	0.390

matrix. In addition, the total attitude score was arbitrarily scored relative to the turnpike. A negative statement about US 1 with which a respondent agreed was interpreted as favorable toward the turnpike. Conversely, a statement which made positive reference to US 1 and was agreed to by the respondent was interpreted as negative toward the turnpike.

An item analysis of the attitude scale was made to determine the effects of these different kinds of statements. A sample

TABLE 8

AVERAGE ATTITUDE TOWARD TWO HIGHWAYS AS A FUNCTION OF FREQUENCY OF TRIPS BETWEEN SOUTH PORTLAND AND KITTERY

Route	Frequency (per yr)	Driver Age (yr): < 24		25 to 34		35 to 44		>45	
		Male	Female	Male	Female	Male	Female	Male	Female
Turnpike	< 1	-	-	40.07	39.00	41.18	-	36.93	-
	1 to 11	38.92	38.02	40.25	36.87	41.31	38.00	39.13	39.25
	>12	43.21	33.78	43.23	40.33	42.93	41.10	41.77	38.24
US 1	< 1	32.65	28.48	34.54	30.32	32.08	26.33	29.98	27.19
	1 to 11	32.96	31.15	33.05	32.29	31.34	29.63	30.00	28.47
	>12	31.32	31.54	34.97	32.79	33.68	29.12	30.72	30.36

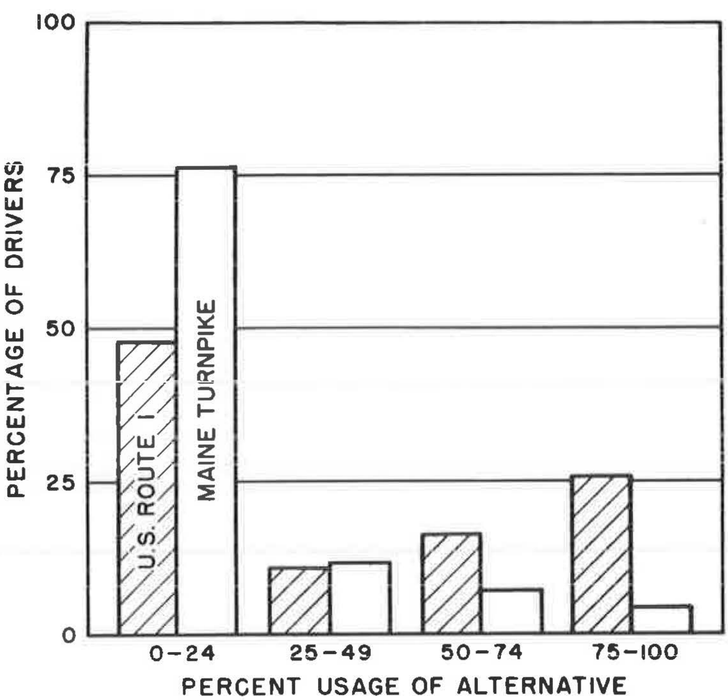

Figure 5. Frequency of use of alternative routes by drivers sampled on Maine Turnpike and US 1.

TABLE 9

AVERAGE ITEM SCORE FOR MALE DRIVERS USING THE TURNPIKE EITHER RARELY OR FREQUENTLY

Use of Turnpike (%)	Favorable		Unfavorable	
	Turnpike Drivers	US 1 Drivers	Turnpike Drivers	US 1 Drivers
(a) Turnpike Statements				
< 24	2.45	2.14	1.71	2.58
>75	2.54	2.44	1.70	1.70
(b) US 1 Statements				
< 25	2.09	2.60	2.46	1.61
>75	2.00	2.20	2.42	2.13

of the respondents was randomly selected on the basis of the percentage of the time they used the alternate. Each item was classified according to whether it referred to the turnpike or US 1 and to whether it was a favorable or unfavorable statement. The score value was determined by the extent of agreement with the item itself by the respondent. Thus, a score value greater than two indicates agreement with the item regardless of whether it is favorable or unfavorable. Conversely, a score value less than two indicates disagreement with the statement.

Regardless of the route on which they were sampled and the percentage of trips in which the turnpike was used, drivers responded positively to favorable statements about the turnpike (Table 9). In response to unfavorable turnpike statements, drivers sampled on the turnpike, regardless of their frequency of use, disagreed with the statements and were thus providing a positive response toward the turnpike. Drivers on US 1, however, strongly agreed with the negative turnpike statements if they were infrequent users of the turnpike, but strongly disagreed if they were frequent users. Thus, there was a significant shift in response to the negative statements by US 1 drivers as a function of the frequency with which they used the turnpike.

Conversely (Table 9), drivers sampled on the turnpike were essentially neutral in their responses to favorable statements about US 1, regardless of whether they were frequent or infrequent users of the turnpike. Drivers sampled on US 1 responded positively to favorable items but less so if they used the turnpike most of the time. On unfavorable US 1 statements there was consistent agreement among drivers sampled on the turnpike which was independent of the frequency with which the turnpike was used. The US 1 driver, however, showed a definite shift from disagreement with unfavorable statements if he was an infrequent user of the turnpike to a positive response if he was a frequent user of the turnpike.

The significant aspect is that drivers sampled on the turnpike made consistent responses to statements about both routes whether they were frequent or infrequent users of the turnpike. For the driver sampled on US 1, however, there were significant shifts in response to both classes of statements depending on whether they were frequent or infrequent users of the turnpike, but the major shift occurred in response to the unfavorable-type statements. These are the ones that appeared to be the most discriminating items in the scale.

These results indicate that drivers who have been sampled on the turnpike show a significant stability in their responses regardless of frequency of turnpike use. The driver sampled on the turnpike consistently agreed with positive statements about the turnpike while disagreeing with unfavorable statements. He also showed significant agreement with statements about the unfavorable characteristics of US 1. Drivers sampled on US 1, however, showed an adaptability to change in their response which was a function of experience with the turnpike. It seems reasonable to conclude that it was the negative characteristics experienced on US 1 relative to the turnpike that caused drivers to shift to the turnpike and that minimized the probability of turnpike drivers shifting back to US 1.

Speed, Volume and Travel Time Results

On the turnpike, speed and volume were determined on a sampling basis. Speed and volume measurements were made at 10-mi intervals both northbound and southbound. A radar speed meter was mounted in the rear of a station wagon which was parked on the shoulder. The speed meter was aimed at the approaching traffic at an angle of about 10 deg. This angle was greater than recommended for the most accurate speed measurements with the result that there is some error in these measurements.

Normally, a sample of 100 vehicles was counted. In addition, the time required for those 100 vehicles to pass the counting station was also determined. Thus, it was possible not only to determine the speed distribution but also to estimate the hourly volume passing that point. The same procedure was followed on US 1.

The cumulative speed distributions for the turnpike are shown in Figure 6. Data was kept separate for the two directions in morning and afternoon sampling periods. The mean speed of these samples is approximately 61.9 mph with a standard deviation of 9.1 mph. The speed distribution is slightly negatively skewed. These values should be viewed cautiously for as has been shown by Shumate and Crowther (9) there is nonhomogeneity among spot-speed samples.

For US 1, the cumulative speed distributions are shown in Figure 7. The mean of this sample is 43.7 mph with a standard derivation of 10.3 mph. The distribution is

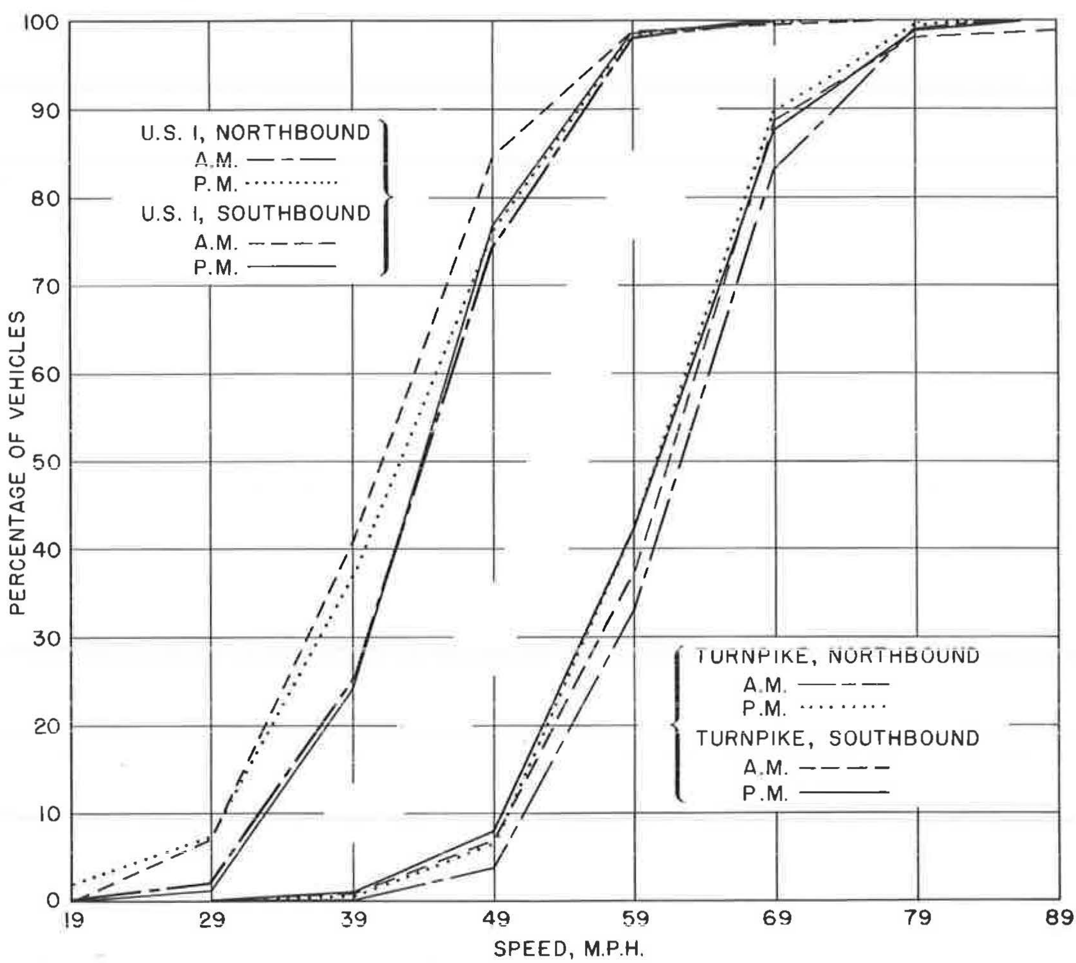

Figure 6. Cumulative distribution of vehicle speeds on Maine Turnpike.

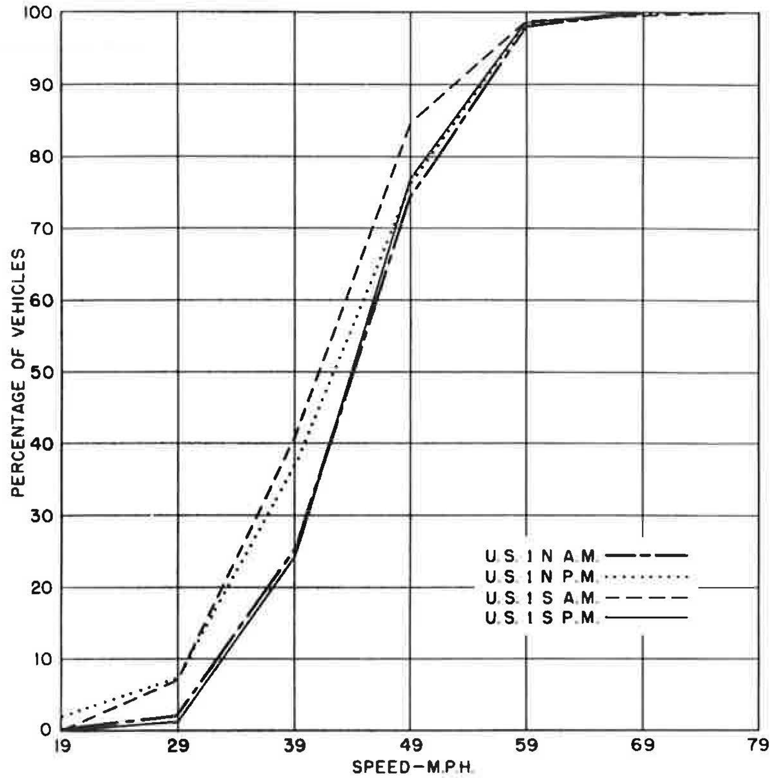

Figure 7. Cumulative distribution of vehicle speeds on US 1.

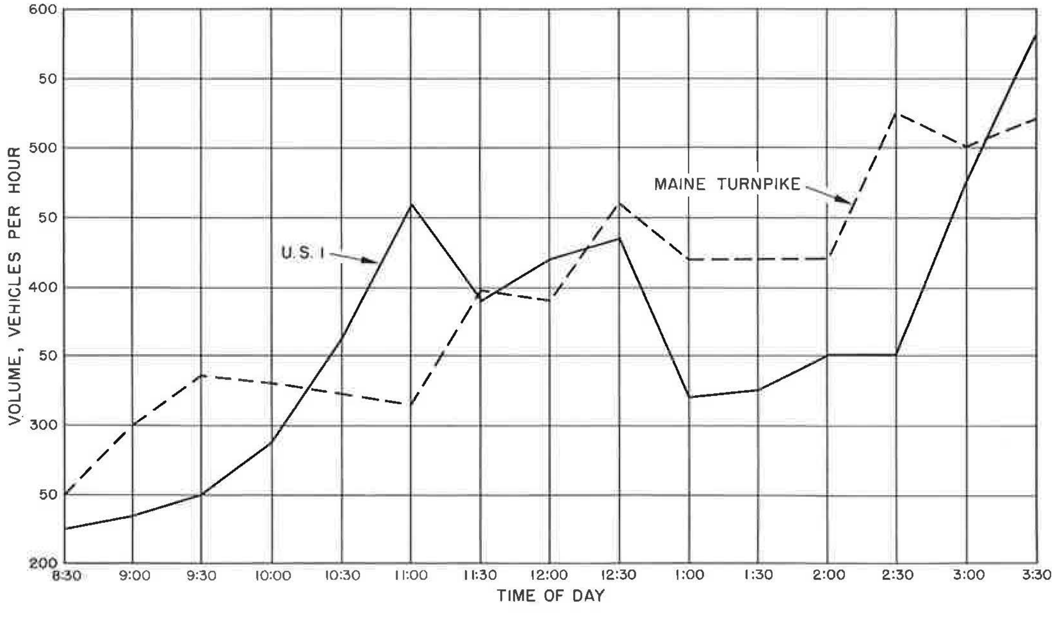

Figure 8. Calculated average hourly volumes on Maine Turnpike and US 1.

TABLE 10

TRAVEL TIMES BETWEEN SOUTH PORTLAND AND KITTERY

Highway	Mean (min)	St. Dev.	95% Conf. Interval
Turnpike	41.1	3.61	±1.25
US 1	63.9	4.31	±1.51

also negatively skewed but not as much as the turnpike. The variability of speeds from sample to sample, as well as in location to location, was far greater on US 1 than on the turnpike. Therefore, the reliability of these summary statistics is in question.

Volumes were calculated for both the turnpike and US 1 on the basis of the same samples of the speed distribution. The average calculated hourly volumes between 8:00 a.m. and 4:00 p.m. are shown for both routes (Fig. 8). The volume on US 1 was not uniform over the entire 47-mi study length, being consistently higher at the more populous northern end. In addition, three counting stations were set up on US 1: one at each end of the study section and a permanent counting station about the middle of the test section. The calculated hourly volumes were approximately the same as those from the counting stations. Finally, the volumes on the two routes were quite comparable, generally paralleling each other in their variations throughout the day.

Travel time data were obtained from the trips made by the 9 test drivers used for the GSR study. In these runs, the drivers were instructed to float with the two highways a total of 4 times. Thus, there were 36 observations of travel time on each route. The summary statistics are given in Table 10 where the standard deviations indicate that on both routes there was a coefficient of variation of 7 percent in travel time. This implies a variation for travel speed of approximately 17 percent on US 1 and 14 percent on the turnpike. Actually, the mean travel time on US 1 agrees quite closely with the travel time predicted from the mean speed of traffic on US 1. On the turnpike, however, the average speed of the test drivers was nearly $7\frac{1}{2}$ mph faster than traffic sampled on the turnpike, indicating that the mean travel time on the turnpike for normal traffic may be up to $4\frac{1}{2}$ min more than given in Table 10. Finally, the maximum range in time savings by selecting the turnpike was calculated on the basis of confidence intervals, and it was found that traveling between South Portland and Kittery a driver would obtain a maximum travel time savings of 35 ± 4 percent by driving the turnpike.

TABLE 11

INTERFERENCES CAUSING GSR IN TEST DRIVERS

No.	Interference
1	Other vehicles traveling in same direction
2	Vehicles merging into driver's path
3	Vehicles turning out of driver's path
4	Traffic control devices
5	Pedestrians on or near driver's path
6	Grades
7	Curves
8	Shoulder objects
9	Opposing vehicles

Tension Measurements

The data for the nine test subjects were analyzed by determining the peak magnitude of GSR for observed interferences (Table 11) which caused the driver to change his speed or position on the roadway. Interference No. 4 (traffic control devices) appears on the turnpike as well as on US 1, because highway maintenance operations were continually performed on the turnpike during this period. Normally advisory speed signs were placed on the highway to protect the maintenance crew and these were included in the definition of traffic control devices.

The magnitude of galvanic skin response per minute which is the defined measure of driver tension was statistically analyzed using the analysis of variance (Table 12). There were significant differences between the routes and subjects but not between directions. These results are similar to

TABLE 12

ANALYSIS OF VARIANCE OF GSR DATA

Source	Sum of Square	d.f.	Mean Square	F	P(F)
Routes	308.65	1	308.65	305.59	<0.01
Subjects	421.11	8	52.64	52.12	<0.01
Direction	0.89	1	0.89	0.89	N.S.
Routes and subjects	62.60	8	7.83	7.75	<0.01
Routes and directions	28.59	1	28.59	28.31	<0.01
Subjects and directions	34.87	8	4.36	4.32	<0.01
Remainder	44.38	44	1.01	—	—
Total	901.14	71	12.69	—	—

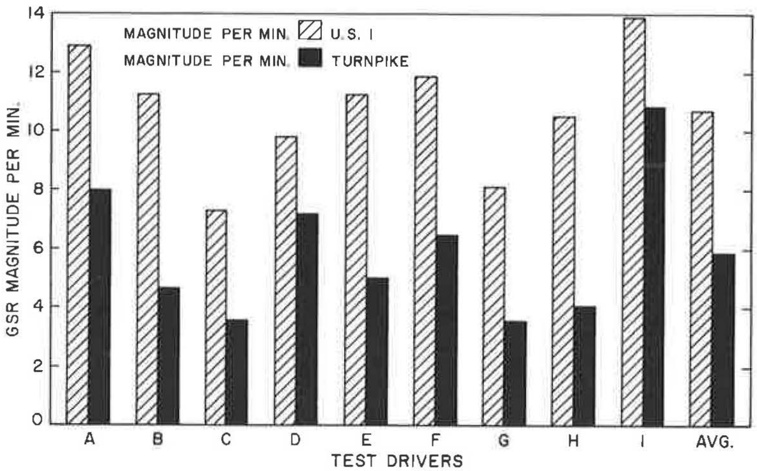

Figure 9. Mean tension generated on Maine Turnpike and US 1.

those reported previously (8). The comparison of tension between the two routes is shown for each subject in Figure 9. The average tension varied considerably between subjects, but in every case US 1 generated significantly more tension than the turnpike. The range of reduction of tension among this group of turnpike subjects was from 22 to 61 percent. The overall average saving of tension by taking the turnpike was 46 percent.

Each route was divided into four $10\frac{1}{2}$-mi sections. The tension data were analyzed to determine whether or not there were differences in tension generation between the sections of the test routes. As expected, there were no significant variations from segment to segment on the turnpike. On US 1 there were also no significant differences between the sections. This finding was unexpected because the highway and traffic from section to section had rather different characteristics. There was also considerable variation in land use adjacent to the highway. One reason for the lack of difference among these sections was because the predominant interference in generating GSR arose directly from other vehicles in the driver's path. Furthermore, when driving through the more complex environments, all drivers reduced their speed and in the process, reduced the probability of unexpected interferences. These compensatory changes may have eliminated any differences between the sections.

INTERPRETATION OF FINDINGS

One of the main objectives of this study was to determine whether there were stable attitudes held by drivers which correlated with their choices between two alternative highways. The results clearly indicate that there were. The attitudes of the users of the one highway differ significantly from the attitudes of the users of the other. Furthermore, the users of the controlled-access highway hold significantly positive attitudes toward that highway, whereas users of the rural primary hold significantly negative attitudes toward the turnpike. On the basis of the results, the likelihood of any sample of drivers holding a positive attitude toward the turnpike actually driving the primary is very small. Furthermore, in the alternative choice situation studied here, an attitude scale appears to be strongly related to choice, much more so than any descriptive information about the characteristics of the drivers or their trips.

This study clearly indicates that drivers do evaluate their experiences on different highways. This organization develops from a variety of elements in the highways they travel. Whether consciously or unconsciously, drivers weigh the various features of highways and combine subjective experiences into an overall evaluation. This evaluation is reflected in attitudes which predispose drivers toward the choice of one highway over another. In fact, these attitudes overwhelm all the specific short-term aspects of a particular trip and dictate which route will be taken.

A third aspect of this study concerns the problem of attraction of traffic to an expressway. In several of the analyses it was quite evident that there was shift in attitudes in favor of the turnpike. The most clear-cut case is the one where the individual items on the scale were analyzed by the route sampled. The significant finding was that the more drivers experience the two highways the more the primary suffers by comparison. The learning experience apparently makes drivers increasingly aware of the negative characteristics of the primary, and hence become more dissatisfied with it. The direct experiences obtained in driving the primary-type highway appear to force drivers onto the turnpike. Thus, the overall problem of the attraction of traffic to an expressway may be considered as arising out of the direct experiences that drivers have in driving it and any alternatives. Because the expressway is perceived by drivers as having fewer negative effects relative to an alternative primary there is a slow shift to the expressway which appears to be motivated by a desire to escape the characteristics of the older design highway.

Three major factors are inherent in this kind of situation which may motivate a shift in favor of an expressway.

1. One factor is the reduction in travel time obtained by choosing the expressway; however, the results of this study show no significant shifts in attitudes as a function of driving time. Drivers feel the same way about both routes whether they are traveling for $1/4$ hr or more than 2 hr even though, as a proportion of the total trip, savings in time gained from taking the expressway decrease for long trips.
2. The original validation study found that an item concerning the time savings to be obtained from an expressway was non-discriminating; that is, regardless of whether people had positive or negative attitudes toward a turnpike, they all agreed that a time saving was to be obtained on the expressway. Thus, although all drivers knew there was a time saving, it had no influence on their attitudes. Since drivers know this to start with, time savings cannot be the basic cause of the shift in attitudes favoring the expressway. Some more subtle aspect of driving must be the source and it appears most sensitive to the negative characteristics of the primary.
3. The third factor is the direct costs of travel to the user, but it does not appear reasonable, since the shift is in the wrong direction. That is, if cost of travel were a significant determinant of choice, one would find a shift of attitudes away from the turnpike especially as trip frequency increased. However, the results clearly indicate that as the frequency of trips increase there is an increasingly positive attitude toward the turnpike and an even greater likelihood that a driver will choose that highway.

In addition, two items which bear directly on economic evaluation by the driver were added to the scale. These two items were actually the same except that one dealt with direct out-of-pocket cost, whereas the other dealt with cost per vehicle-mile. The two statements read, "I would always travel the turnpike between South Portland and Kittery if the cost were no more than" and the alternatives provided, in one case, increased from \$0.25 to \$4.00, doubling over each of the five categories or, in the other case, from \$0.005 per mile to \$0.08 per mile. It was found, as might be expected, that the cost per mile item was nondiscriminating. Very few drivers have any idea of what the cost per mile is. Estimates on both routes were randomly distributed, with a small proportion of drivers omitting the item.

More surprising was the finding that actual out-of-pocket cost was also nondiscriminating. The reliability on the turnpike was a little higher, possibly because the drivers had just received a toll ticket. Furthermore, drivers sampled on both highways consistently reported to the interviewers that the cost of the turnpike was irrelevant to their choice. This finding may simply mean that most drivers in this sample were quite indifferent to the expense of traveling the turnpike at current cost levels.

Neither time savings nor direct costs appear dominant in determining the attraction of traffic to the turnpike. What appears to be required is something drivers must learn by direct experience and which relates primarily to the negative characteristics of the rural primary-type highway. This leads to the consideration of the stresses arising in driving on the two routes. From the results of the GSR phase of this study, the tension aroused in the test drivers on the expressway is approximately one-half that generated on the primary. This tension is caused by interferences which have purely negative effects. It seems reasonable that shifts in traffic to an expressway-type facility is actually a forcing of drivers away from the primary in order to avoid its stress inducing characteristics. Stated more generally, drivers make choices among routes in order to minimize total stress to which they are subjected in driving. Thus, for the passenger car driver, the basis for scaling the benefits to be obtained from an expressway are neither economic nor time saving but rather stress saving.

The objective of minimizing the stress level in driving may explain two characteristics of the distribution of trips found in this study: (a) the more frequent a trip the more likely were these drivers to take the turnpike, and (b) the longer the duration of a trip the more likely was it to be made on the turnpike.

It is obvious that the total stress experienced on either route is a function of the particular properties of the route and the duration of the trip. That is, the total tension incurred is the integration of the unit stress over the duration of the trip. These tension inducing interferences occur randomly in time with the mean value being greater on the primary highway than on the expressway. Since the variance in rate of occurrence of tension inducing interferences is high, the differences between the stress experienced on two highways in any short time interval will be unpredictable. It will take frequent repetitions or an increased sampling interval, i.e., longer trips, for the driver to detect the difference between the alternatives reliably. By doing either, the likelihood will increase that drivers will detect the differences and thereby modify their choice behavior. The travel time distribution and trip frequency data found in this study conform to this hypothesis.

In simplest terms, the tension generated on any trip is some function of total travel time and the frequency and intensity of stressing interferences. Using a relative measure of tension then, a dimensionless constant is obtained. The relative stress obtained on any trip of a given highway may be defined:

$$S = \frac{T_n}{T_R} (t) \qquad (1)$$

where

T_n = magnitude of GSR per minute on highway n;
T_R = magnitude of GSR per minute on reference highway; and
t = trip duration.

Thus, using tension generated on a freeway as a reference, a numerical value of relative stress can be calculated if the type of highway traveled and trip duration are known.

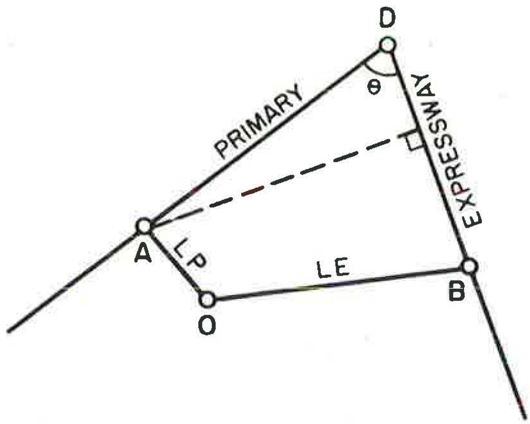

Figure 10. Geometry of diversion situation.

In this and previous studies (7, 8), it was shown that tension generated relative to the controlled-access highway was approximately 1.8 for a primary-type highway and 3.3 for an urban arterial. For a low-volume rural secondary highway, the ratio is probably intermediate, or about 2.5. Similarly, the relative stress for any set of routes may also be computed by summing the stress for the components and the minimum stress route determined.

Concerning the problem of diversion to an expressway this model suggests that drivers will divert to an expressway if the total stress experienced in reaching the expressway and from the expressway to the destination does not exceed that of the trip from origin to the alternative highway and on the alternative to the destination.

A general situation is shown in Figure 10. Assume there is an expressway E and a primary P having a common terminus. Also assume that the origin of a trip is located in the space bounded by the two routes so that there is a direct connection to either by link L. According to the proposed hypothesis a driver will divert to the expressway to reach his destination if the total tension generated on the link L_E and the expressway E is equal to or less than the tension generated on the link L_P and the primary P. If the special case is taken where the origin lies on the primary and L is a perpendicular connection to E (Fig. 10) then an inequality is obtained. The minimum separation between the primary and expressway for which 50 percent diversion will occur is defined

$$K_L \sin \theta + K_E \cos \theta \leq K_P \tag{2}$$

The constants are the relative stress developed on each of the links. The solution of Eq. 2 is simply derived. Solving in terms of the cos θ, a quadratic equation is obtained whose real root is

$$\cos \theta = \frac{\dfrac{T_P}{T_E \cdot V_P \cdot V_E} + \dfrac{T_L}{T_E \cdot V_L}\sqrt{\left(\dfrac{T_L}{T_E \cdot V_L}\right)^2 + \left(\dfrac{1}{V_E}\right)^2 - \left(\dfrac{T_P}{T_E \cdot V_P}\right)^2}}{\left(\dfrac{T_L}{T_E \cdot V_L}\right)^2 + \left(\dfrac{1}{V_E}\right)^2} \tag{3}$$

where

$\frac{T_P}{T_E}$ = ratio of stress developed on a primary-type highway to that developed on an expressway;

$\frac{T_L}{T_E}$ = ratio of stress developed on the link between primary and expressway; and

V = mean speed on appropriate highway, in mph.

It is further possible to define the travel distance ratio and the travel time ratio for this case.

$$\frac{d_L + d_E}{d_P} = \sin \theta + \cos \theta \tag{4}$$

TABLE 13

THEORETICAL SOLUTION OF EXPECTED DIVERSION FROM A PRIMARY HIGHWAY TO AN EXPRESSWAY

Link Type	Separation Between Primary and Expressway (radians)	Trip Distance Ratio	Travel Time Ratio
Primary	0.99	1.39	1.24
Secondary	0.34	1.28	1.12
Arterial	0.13	1.12	1.02

where

d_L = distance on link;

d_E = distance on expressway; and

d_P = distance on primary

and

$$\frac{t_L + t_E}{t_P} = \frac{V_P}{V_L} \sin\theta + \frac{V_P}{V_E} \cos\theta \qquad (5)$$

where

t = travel times on each link; and
V = mean travel speed on each link, in mph.

Using the values for relative stress for three different types of highways and the travel speeds, Eqs. 3, 4, and 5 may be solved with the results given in Table 13. The mean travel time ratio decreases consistently as the stress inducing characteristics of the link increase.

Two other aspects may be considered using this model. One is the variance in tension. In this analysis the relative stress is treated as a constant, although it is, of course, a mean value. On the basis of the data in this study the variance of that ratio was 0.42. Using this value and Eqs. 3 and 5, it is possible to calculate the percent of drivers diverting to an expressway (Fig. 11).

The other aspect concerns the volumes that the highways are carrying. As has been shown previously (8), the mean tension on an expressway increases linearly up to about 1,400 vehicles per lane per hour. Beyond that volume tension increases very rapidly. On urban arterials (7), volume appears to have relatively little overall effect on tension generation. For primary-type highways, however, no data are available on the effect of increasing volume. If it is assumed that the effect of volume on the primary type is similar to that on arterials, diversion to an expressway will vary solely with volume on that type of highway. The effect of increasing expressway volume on the travel time ratio for 50 percent diversion is shown for the three types of links in Figure 12, where the travel time ratio for 50 percent diversion decreases until, with volumes exceeding 1,000 vehicles per lane per hour on the expressway, an actual time savings must occur before half the traffic diverts.

The diversion curves developed from this special case do not conform to those developed from origin and destination studies in this corridor (1). The model predicts much more attraction than actually found, partly due to the assumptions about the connection between primary and expressway. The choice points are not very direct for drivers within the Maine Turnpike-US 1 corridor. Furthermore, a significant propor-

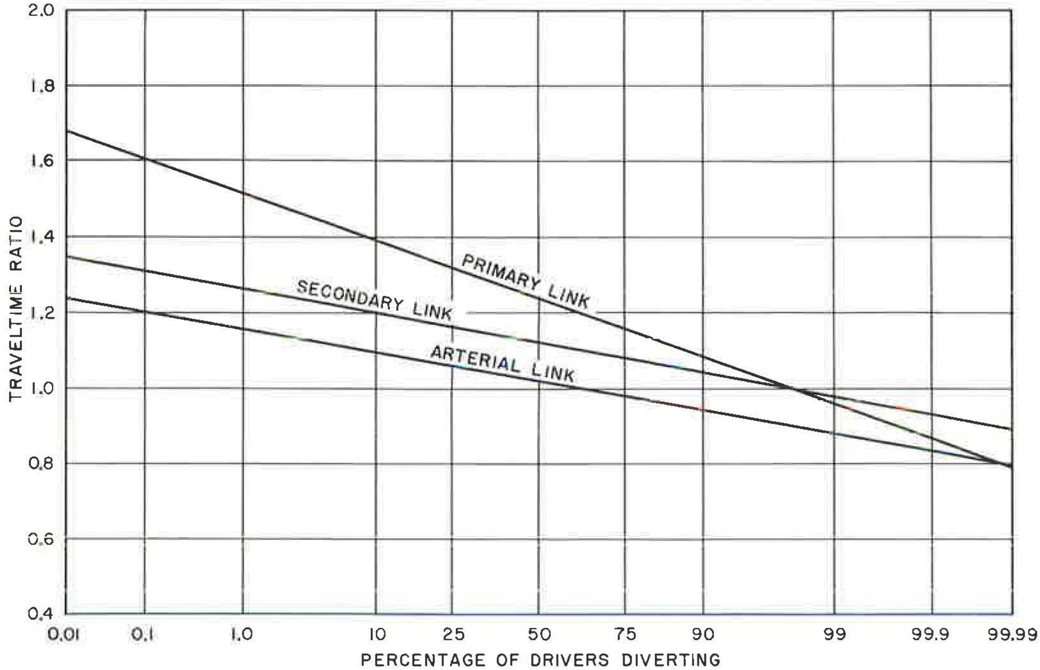

Figure 11. Theoretical diversion distributions for different connections from primary to expressway.

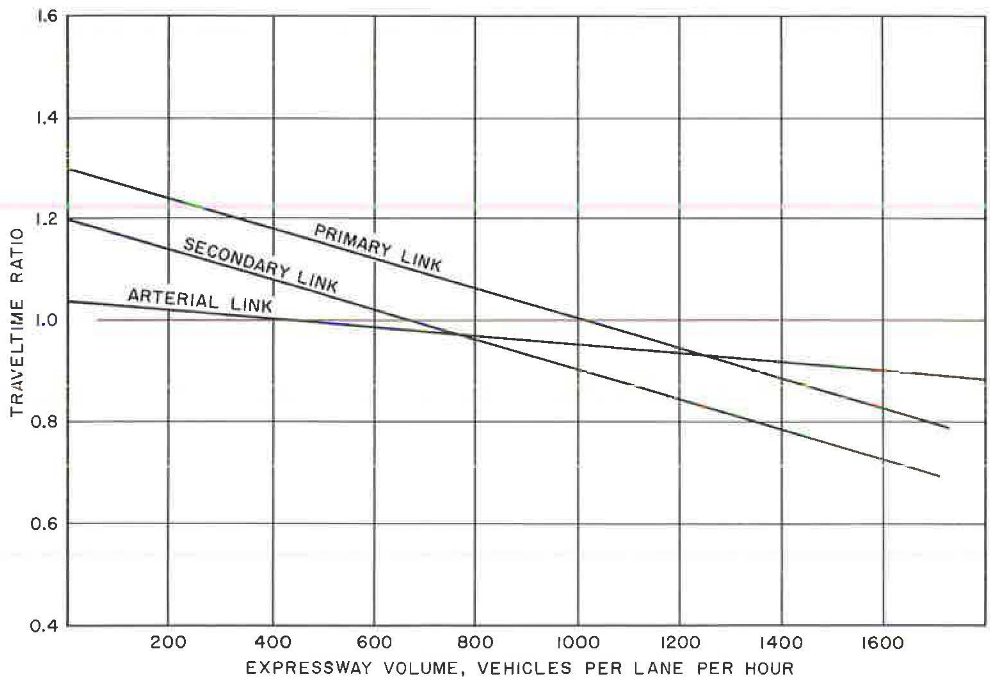

Figure 12. Expected travel time ratio for 50 percent diversion as function of expressway volume.

tion of trips are quite short. For this class of traffic, essentially trapped on US 1, diversion to the turnpike would gain the driver no detectable stress reduction and hence little diversion would be expected.

However, for corridor trips more than ten miles and north-south oriented, considerably more diversion should occur than appears in the general diversion curves. In this respect, Carpenter (3) examined through trips between Wells and Saco and found that 30 percent of the trips diverted to the turnpike. This occurred even though the travel time ratio was approximately 1.22. However, on the basis of the link characteristics, the tension ratio for the alternatives may be calculated and is approximately 1.09. This yields expected diversion of approximately 35 percent of these trips.

It seems reasonable to conclude from this analysis that whenever the alternatives available are equally stress inducing, drivers will always choose the route that takes the least time. Nor is it surprising that most drivers when questioned about choice of route commonly use travel time as a response. Not only is total stress directly related to travel time, but also many of the alternatives available offer no significant stress reduction. Furthermore, such trips are often so short that stress differences are hardly detectable. It is evident from this study, however, that drivers will actually tolerate a time loss as well as a distance loss if the total stress to which they may be subjected is perceptibly reduced.

On the basis of this model, measures that reduce stress should lead to both increases in trip lengths and trip frequency. Since driving is a stressful and energy consuming task, each driver has a tolerance or limit beyond which the subjective cost of driving becomes excessive. The satisfactions to be gained by a trip are less than the energy required to achieve it. If trips are predominantly goal-oriented, the stress imposed on a driver becomes the equivalent of a cost whose value is determined in part by the desirability of the goal. Conversely, reduction of this subjective cost by the addition of improved highways not only makes any given trip easier, but also lower priority goals become attainable, and thus new travel is generated.

It would seem that the value of these subjective costs of driving are determinable experimentally. One way is by subjective scaling of simulated trips which is a variation of game theory techniques. The other is subjective evaluation of actual trips made under defined conditions. However, a significant problem would remain—the measurement of the value a driver places on the goal which motivates a trip. It is this goal desirability, as satisfied through highway transport, which is the measure of the subjective benefits of that system. Apparently, there do exist methods for quantifying the subjective costs of travel but not for subjective benefits. However, it is becoming increasingly clear that even though passenger car drivers make rational evaluations of transportation, their benefit-cost ratio appears to have little in common with the economic criteria normally used in highway transport.

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