VALUE OF TIME SAVED BY TRIP PURPOSE

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Values of travel-time savings are estimated for personal business trips, social-recreational trips, vacation trips, school trips, and work trips by applying the model previously used by the authors to obtain estimates for commuter work trips. Several route and motorist characteristic variables were studied to determine those that have an effect on the valuation of travel-time savings by motorists. Time saved and income were found to be the most important variables. The benefits of travel-time savings are also shown to differ significantly according to trip purpose. The data base consisted of more than 4,100 usable responses collected in 9 different states from motorists who had a choice between a toll route and a free route. The paper includes tables for estimating the dollar values of travel-time savings as a function of both the motorist's income level and the amount of time saved for each of the 5 trip purposes. In addition, a figure shows the percentage of toll route users as a function of the time-saved and income variables.

•ESTIMATES of the value of travel-time savings as a function of the amount of time saved, income level, and trip purpose are presented in this paper. Such values are required for economic analyses of transportation systems. They convert travel-time savings into equivalent dollar values, which can then be compared with construction costs, maintenance costs, and other real or equivalent cost factors.

The estimated values are the product of a series of studies that were begun in 1962 for the Bureau of Public Roads. The first study developed the conceptual models for a value of travel time saved (1). Small-scale survey work and limited modeling led to a full-scale empirical attempt to estimate a value of time for commuters. This work resulted, in 1968, in an estimate of $2.82 per person per hour as the value of time saved for commuters (2, 3).

However, even as this estimate was made, it was highly qualified. Past work done by Stanford Research Institute (SRI), both theoretical and empirical, indicated that a single constant value of time, even for a single trip purpose, was only a first approximation to a more general variable value. Estimation techniques have subsequently been developed that indicate the value of time saved to be dependent on both the motorist's income level and the amount of time saved. This work was previously reported elsewhere (4).

A second thrust of the study, the principal focus of this paper, was to estimate the value of time saved for trip purposes other than work. Values of time have been estimated for personal business trips, social-recreational trips, vacation trips, and school trips. In addition, the value of time saved for work trips has been revised by use of an enlarged data base.

The purpose of this study, then, has been to determine those route and motorist characteristic variables that have an effect on the valuation of travel-time savings by motorists and to estimate quantitatively the effects of those variables for several trip purposes. Consistent with past findings, the most important route characteristic variable is time saved, and the most important motorist characteristic variable is income.

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Therefore, the value of travel time saved depends on both the motorist's income and the amount of time saved. The benefits of travel time savings also differ significantly according to trip purpose. The results by trip purpose support the hypothesized S-shaped benefits curve presented in an earlier report, especially for small time savings (1, 2, 4). Tables for estimating these dollar values of travel time savings as a function of both income and time saved are given in this paper.

The effects of many other variables on the benefits of time saved were studied. Their inclusion in the benefit estimates was not indicated. For example, the effect of an hour-of-day variable appears to be reflected already in the amount-of-time-saved variable, i.e., travel times on alternative routes vary during different hours of the day. The effect of geographic region, i.e., north versus south or urban versus rural, appears to be accounted for by variations reflected in income level so that the estimated benefits can be used nationwide. It was not possible to analyze the effect of other variables, such as type of highway, because of data limitations.

ROUTE-CHOICE MODEL

On the basis of both theoretical and empirical considerations, SRI chose to define the value of savings in travel time in terms of the motorist's perception of costs and time savings. In essence, the perceived costs and other route characteristics are the variables in the route-choice model in the motorist's head. The use of variables not perceived by the motorist has been viewed as a specification error in a route-choice model. This point is emphasized because SRI's premises have led to a different treatment of the measurement of time saved and of changes in motor vehicle operating costs from that used in most other studies (2).

The mathematical model was built by using microeconomic theory. The value of time saved was conceptualized in terms of a motorist's indifference curve for a choice between 2 alternative routes. In microeconomic terminology, the value of time is the slope of the motorist's indifference curve for differential trip costs and trip times; i.e., it is the rate at which the motorist is willing to trade more money for less travel time.

In the real-life situations in which motorists face different route choices, the money and time-saved trade-off cannot be directly observed. It must be inferred from the relationships that emerge when the route choices are estimated on the basis of data on alternative trip costs, time saved, and other route characteristics and on the characteristics of the motorists themselves. The coefficients of the route and the motorist variables in the route-choice estimator specify the relative importance of each variable to the motorist's choice. Therefore, they can be used to calculate the trade-off between cost and time saved.

The mathematical formulation of the route-choice model treated each driver as a separate data point with a binary choice between 2 routes. Monetary considerations in the choice of route were stressed by having 1 route always be a toll road and the other always be a free road.

The analysis estimated the route choice by use of a logit function (2):

$$p(x) = \frac{e^{f(x)}}{1 + e^{f(x)}}$$

where

p(x) = probability of the free road being taken,
f(x) = function of the characteristics of the route and the motorist, and
e = base of the natural logarithms.

The f(x) was restricted to a linear function of the characteristics of the route and the motorist:

$$f(x) = a_0 + a_1x_2 + \ldots + a_nx_n$$

where the a_i's are coefficients to be estimated; and the x_i's are characteristics of the motorist (such as income or sex) or of the route (such as travel time, toll cost, or number of speed-change units).

The p(x) can be interpreted in 2 ways: as a probability estimate of the individual motorist's choice or as the percentage split of a group of motorists all having the same characteristics (the same values) of the independent variables.

When the parameters of the route-choice model have been estimated, the value of travel time saved can easily be estimated from the function f(x). The motorist is assumed to be indifferent to the choice of alternative routes when p(x) equals 0.5. For p(x) = 0.5, f(x) = 0, or

$$0 = a_0 + a_1x_1 + a_2x_2 + \ldots + a_nx_n$$

This equation can be solved for the sum of monetary charges that the motorist will pay. These charges will then be a function of his characteristics and the characteristics of the alternative routes. The resulting function, called the benefits function, gives the differential amount the motorist will knowingly pay to take the better route. In route-choice situations, it has been demonstrated that motorists neither perceive accurately nor make choices based on the differences in motor vehicle operating costs between alternative routes. Therefore, the only monetary variable in the route-choice equation is the toll charge. If we let x_1 be the toll variable, the amount the motorist is willing to pay is

$$\text{Benefits function} = x_1 = \frac{-a_0}{a_1} - \frac{a_2}{a_1}x_2 - \ldots - \frac{a_n}{a_1}x_n$$

The value of time saved is the derivative of the benefits function with respect to the amount of travel time saved. This derivative is the trading ratio between toll and time saved at a point on the average motorist's indifference curve.

The benefits function finally used in estimating the value of time took 2 general forms:

$$\text{Benefits function} = a_0' + a_1'\,\Delta t + a_2'\,I\Delta t$$

and

$$\text{Benefits function} = a_0'' + a_2''\,I\Delta t$$

where I is the family income of the driver and Δt is the travel-time difference between alternative routes. This formulation made the value of time saved a function of income level. Estimates were made on data stratified on amount of time saved to establish the dependence of the value of time saved on amount of time saved. The coefficients estimated for each trip purpose are in Appendix B[1]. Appendix C provides estimates from route-choice models incorporating a variety of other route and motorist characteristic variables.

DATA COLLECTION

Personal business, social-recreational, and vacation travel were selected as the most important new trip purposes on which to collect data. Data on school trips and additional data on work trips were also collected.

[1] The original manuscript of this paper included Appendix B, Analyses, Appendix C, Effects of Route and Motorist Characteristic Variables, and Appendix D, Derivations of Average Total Benefits Function. The three appendixes are available in Xerox form at cost of reproduction and handling from the Highway Research Board. When ordering, refer to XS-37, Highway Research Record 369.

SRI investigated the possible advantages of using modal-choice decisions in addition to route-choice decisions to estimate the value of time saved. This option was very attractive because better information on intermodal values of time saved is badly needed. However, it appeared that the quality of the available experimental situations, except for rail rapid transit or railroad, was low. In particular, except for New Orleans, which has special express bus lanes on major streets, it did not appear that nonrail alternatives to the automobile would offer the prerequisite time advantage for a cost and time-saved trade-off analysis.

Therefore, it was decided not to use observations on modal choice and, thus, avoid a sizable number of practical and theoretical questions that had not previously been dealt with. Lisco (5) has been using techniques similar to those used by SRI to study the rail versus automobile alternative.

Sites were selected where motorists on other than work trips would be faced with a choice between a faster toll road and a slower free road. Site locations were found in Florida, Texas, Oklahoma, Maine, New Jersey, Pennsylvania, Virginia, Kentucky, Kansas, and Illinois.

Information was collected by using prepaid mail-back questionnaires designed to require a minimum amount of effort on the respondent's part. The use of such a questionnaire requires English literacy of the driver or a passenger, and this could be a source of bias in the data. However, because the data are stratified by income in the analysis, any bias that might exist is probably limited to those in income level 1, i.e., less than $4,000 per year. Any effect on the overall analysis should be minimal.

Table 1 gives the distribution of motorist and route characteristics by trip purpose. A high proportion of the usable data were for work trips, despite choice of off-peak hours and weekends for most of the survey work. This result was not unexpected, however.

Because the quality of the data obtained compared very favorably with the characteristic of the high-cost personal interview and independent measurement of route characteristics used previously, it was possible to use this low unit cost of data collection confidently to increase the size of the usable data sample by an order of magnitude and explore trip alternatives not previously possible.

BENEFITS OF TIME SAVED

The benefits of time saved are given in Table 2 for work trips, in Table 3 for social-recreational trips, in Table 4 for personal business trips, in Table 5 for vacation trips, and in Table 6 for school trips.

The income variable is the family income of the driver. For social-recreational, personal business, and vacation trips where those in the car are usually members of the same family, the best estimates of benefits were obtained on a per-vehicle basis. For work and school trips, the benefits were estimated on a per-person basis, i.e., per vehicle-passenger. School trips were estimated almost entirely for college students.

The tables give the total value of the specific amount of time saved rather than the value per hour. These dollar figures for specific amounts of time are called the benefits of time saved, whereas dollars-per-hour figures are called the values of time saved. For example, the benefits of a 15-min time saving during work trips to motorists earning $8,000 to $10,000 per year are valued at 57.0 cents (Table 2); i.e., the average amount motorists would be willing to pay for a 15-min time saving is 57.0 cents. (Note that this amount is not the hourly value of time saved nor the value of the 15th minute by itself but rather the sum of the values of each of the 15 individual minutes.)

The value of time saved is a nonlinear function of the amount of time saved, so benefits are not a linear function of the amount of time saved. Hence, the benefits of an amount of time saved cannot be obtained by simply multiplying the amount of the time saving by a constant value of time saved (e.g., the $2.82 per person per hour previously estimated for commuters).

TABLE 1

NUMBER OF USABLE RESPONSES OR DATA POINT STRATIFICATION BY TRIP PURPOSE

	Toll Route Data					Free Route Data				
	Work	School	Vacation	Personal Business	Social-Recreational	Work	School	Vacation	Personal Business	Social-Recreational
Toll cost (cents)										
0-10	47	3	3	14	8	25	2	0	18	20
11-20	152	3	7	33	31	36	3	3	25	18
21-30	172	5	24	48	89	94	12	8	71	100
31-40	184	8	10	47	42	104	7	4	37	42
41-50	174	5	9	41	43	71	17	16	31	39
51-60	71	12	21	38	32	37	18	2	33	29
61-70	125	8	13	39	43	41	2	2	20	12
71-80	60	3	3	21	25	20	11	4	19	26
81-90	30	5	5	13	13	16	6	5	8	11
91-100	42	2	15	18	34	18	2	21	6	21
101-150	197	8	44	63	105	54	5	35	39	54
151-200	41	2	21	21	39	8	2	5	10	12
201-250	29	0	21	22	21	4	3	9	7	10
Over 250	48	5	44	35	29	4	0	10	7	6
Time saved (min)										
0-5	80	0	3	19	17	132	13	3	47	53
6-10	310	20	17	73	74	192	38	13	122	101
11-15	314	14	19	85	121	96	27	25	77	105
16-20	219	7	25	59	65	44	8	21	29	56
21-25	44	5	5	17	25	9	2	6	7	11
26-30	213	10	50	77	121	40	1	29	25	45
31-35	17	0	3	5	4	2	0	3	5	1
36-40	25	0	6	12	16	5	1	2	4	4
41-45	43	1	15	27	21	5	0	4	5	10
46-50	5	1	3	3	5	0	0	0	1	1
51-55	1	1	1	4	0	0	0	0	0	0
56-60	65	5	48	45	46	4	0	18	7	11
61-90	14	2	17	13	12	1	0	1	1	1
91-120	19	2	15	9	20	2	0	2	1	1
Over 120	3	1	13	5	7	0	0	0	0	0
Trip frequency										
Daily	583	24	2	27	15	293	58	1	18	15
Once a week or more	343	24	22	109	101	111	21	20	86	115
Once a month or more	192	3	18	97	114	59	5	15	73	81
Occasionally	203	14	144	186	270	52	5	68	122	155
First time	51	4	54	34	54	17	1	23	32	34
Time of day										
7:00-7:59	157	2	0	6	0	23	1	1	3	1
8:00-8:59	197	26	15	36	17	97	33	3	31	23
9:00-9:59	86	7	24	42	55	43	3	4	24	24
10:00-10:59	174	6	26	77	63	95	11	23	52	65
11:00-11:59	17	1	9	10	23	16	7	0	8	2
12:00-12:59	65	4	17	23	29	27	2	3	26	36
1:00-1:59	145	1	25	58	65	68	3	27	56	69
2:00-2:59	151	9	34	60	51	27	15	15	29	34
3:30-3:59	129	3	20	37	38	49	4	5	38	41
4:00-4:59	163	4	16	40	59	51	9	24	34	52
5:00-5:00	15	3	14	11	31	4	0	8	5	15
6:00-6:59	11	1	20	10	40	6	0	8	8	23
7:00-7:59	47	2	14	32	70	25	2	2	15	11
8:00 and later	15	0	6	11	13	1	0	4	2	4
Day of week										
Monday	185	6	12	54	22	49	7	2	23	14
Tuesday	192	4	10	52	23	55	7	3	22	12
Wednesday	343	17	8	39	31	101	10	2	29	18
Thursday	190	9	13	40	14	121	39	6	44	25
Friday	205	13	49	80	109	125	20	34	83	74
Saturday	225	14	92	133	193	68	6	55	107	157
Sunday	32	6	56	55	162	13	1	25	23	100

TABLE 1 (Concluded)

	Toll Route Data					Free Route Data				
	Work	School	Vacation	Personal Business	Social-Recreational	Work	School	Vacation	Personal Business	Social-Recreational
Route reason										
Less congestion	97	0	9	35	35	18	0	13	15	17
Shorter time	542	23	89	153	185	0	0	0	0	0
Safety	38	4	12	20	21	4	0	6	8	2
No toll	0	0	0	0	0	298	68	42	158	190
Lower gas and oil costs	3	1	0	1	1	2	0	0	1	3
Scenery	3	0	3	1	7	19	2	17	17	29
Convenience	121	6	32	43	51	119	4	19	72	80
Availability of disabled vehicle service	0	0	1	1	1	7	0	2	8	3
Combinations of all these reasons	568	35	94	199	253	65	74	90	279	324
Number of adults										
1	1,147	45	40	223	158	449	66	21	164	127
2	182	17	155	190	305	63	18	81	134	203
3	27	3	28	28	44	14	3	14	22	41
4	8	0	14	7	31	4	1	8	10	23
5	3	4	3	4	10	1	1	2	0	5
6	3	0	0	1	5	0	0	1	1	1
7	2	0	0	0	1	1	1	0	0	0
Automobile year										
1950 or earlier	1	0	0	0	0	1	0	0	1	1
1951-55	2	1	0	3	2	1	2	1	2	1
1956-60	24	1	2	8	14	5	7	0	10	17
1961-65	232	21	67	101	146	141	24	48	113	126
1966-70	1,113	46	171	341	392	384	57	83	205	255
Income level (per year)										
Under $4,000	15	9	10	18	30	11	15	5	29	46
$4,000-5,999	37	2	16	36	36	23	9	9	43	41
$6,000-7,999	92	8	19	48	60	64	14	12	52	65
$8,000-9,999	156	8	29	42	61	84	19	27	38	49
$10,000-11,999	198	7	36	62	87	87	8	15	45	67
$12,000-14,999	299	11	50	70	81	113	10	15	60	54
$15,000-19,999	244	10	32	72	83	76	7	12	27	43
$20,000 or more	331	14	48	105	116	74	8	32	37	35
Driver's age										
Under 19	7	9	2	5	7	5	6	4	7	16
19-25	116	20	29	63	101	65	50	18	68	93
26-65	1,232	40	202	359	417	457	34	101	238	267
Over 65	17	0	7	26	29	5	0	4	18	24
Driver's sex										
Male	1,216	48	210	339	412	468	70	117	230	284
Female	156	21	30	114	142	64	20	10	101	116
Total	1,372	69	240	453	554	532	90	127	331	400

For an example of this nonlinearity in the value of time, consider again the work-trip data given in Table 2. It is estimated that a motorist earning $8,000 to $10,000 per year would be willing to pay 1.9 cents for a 5-min saving, 27.6 cents for a 10-min saving, and 73.2 cents for a 20-min saving. Note that the value of the 20-min saving is not twice that of the 10-min saving, nor is the value of the 5-min saving half that of the 10-min saving.

The tables have been developed subject to 2 limitations—an upper limit on the amount of time saved and, within this limit, a further limitation on the maximum amount of benefits per person or per vehicle. Both of these limitations result from constraints in the range of variables in the data sample and are not theoretically required. The upper limit on time saved is 40 min on work trips, 30 min on personal business and vacation trips, and 20 min on social-recreational and school trips. Within this time restriction, the maximum benefit that should be considered for any single person or

TABLE 2

BENEFITS OF TIME SAVINGS IN DOLLARS PER PERSON FOR WORK TRIPS

Time Saving (min)	Income Level of Motorist							
	1	2	3	4	5	6	7	8
1	0.001	0.002	0.003	0.004	0.006	0.008	0.011	0.015
2	0.002	0.004	0.005	0.008	0.011	0.016	0.022	0.031
3	0.004	0.005	0.008	0.012	0.017	0.024	0.033	0.046
4	0.005	0.007	0.011	0.015	0.022	0.032	0.045	0.061
5	0.006	0.009	0.013	0.019	0.028	0.040	0.056	0.077
6	0.009	0.014	0.022	0.034	0.051	0.075	0.108	0.149
7	0.013	0.022	0.036	0.057	0.089	0.132	0.186	0.249
8	0.018	0.033	0.056	0.093	0.144	0.210	0.285	0.365
9	0.026	0.048	0.086	0.142	0.216	0.302	0.393	0.487
10	0.036	0.070	0.126	0.205	0.299	0.401	0.505	0.610
11	0.050	0.099	0.177	0.276	0.387	0.502	0.618	0.732
12	0.068	0.136	0.236	0.354	0.478	0.604	0.729	0.854
13	0.091	0.180	0.300	0.434	0.570	0.706	0.841	0.975
14	0.119	0.230	0.368	0.514	0.661	0.807	0.952	1.096
15	0.135	0.261	0.412	0.570	0.727	0.883	1.033	1.191
16	0.139	0.273	0.433	0.602	0.768	0.934	1.094	1.261
17	0.144	0.285	0.454	0.633	0.810	0.986	1.155	1.330
18	0.148	0.297	0.476	0.666	0.853	1.038	1.216	1.400
19	0.153	0.309	0.498	0.699	0.896	1.091	1.277	1.470
20	0.158	0.322	0.521	0.732	0.939	1.143	1.338	1.539
21	0.162	0.335	0.544	0.765	0.982	1.195	1.399	1.608
22	0.167	0.348	0.567	0.799	1.025	1.247	1.460	1.678
23	0.172	0.361	0.591	0.833	1.069	1.299	1.521	1.747
24	0.177	0.375	0.615	0.867	1.112	1.352	1.581	1.816
25	0.182	0.389	0.639	0.901	1.156	1.404	1.642	1.885
26	0.187	0.403	0.664	0.935	1.199	1.456	1.702	1.954
27	0.192	0.417	0.688	0.970	1.243	1.508	1.763	2.023
28	0.198	0.431	0.713	1.004	1.286	1.560	1.823	2.091
29	0.203	0.446	0.738	1.039	1.329	1.612	1.884	2.160
30	0.208	0.460	0.763	1.074	1.373	1.664	1.944	2.229
31	0.214	0.475	0.789	1.108	1.416	1.715	2.004	2.298
32	0.219	0.491	0.814	1.143	1.459	1.767	2.064	2.366
33	0.225	0.506	0.839	1.178	1.503	1.819	2.124	2.435
34	0.230	0.521	0.865	1.212	1.546	1.870	2.184	2.504
35	0.236	0.537	0.891	1.247	1.589	1.922	2.244	2.572
36	0.242	0.552	0.916	1.282	1.632	1.974	2.305	2.641
37	0.247	0.568	0.942	1.316	1.675	2.025	2.365	2.709
38	0.253	0.584	0.968	1.351	1.719	2.077	2.425	2.778
39	0.259	0.600	0.994	1.386	1.762	2.128	2.485	2.847
40	0.265	0.616	1.020	1.420	1.805	2.180	2.545	2.915

Annual income level: 1 = less than $4,000; 2 = $4,000-5,999; 3 = $6,000-7,999; 4 = $8,000-9,999; 5 = $10,000-11,999; 6 = $12,000-14,999; 7 = $15,000-19,999; and 8 = more than $20,000.

vehicle is $1 for work trips and $2 for all other trips. Larger dollar amounts are given in the tables ($1 and more than $1, Table 2; $2 and more than $2, Tables 3-5), but the use of these data should be avoided if possible because they are an extrapolation outside the data base.

Limitations placed on the use of the tables and the choice of the specific estimators used to construct them were to a large extent based on the authors' best subjective judgment, given the data available. In most instances, however, either the choices were quite obvious or the results were relatively insensitive to the particular choice.

The dollar amounts in the benefit tables are the total benefits as perceived by the motorist for the faster route. Other benefits calculated by highway engineers such as changes in operating, maintenance, and accident costs are in general not perceived by the nonbusiness motorist. It is recommended that the different types of benefits not be added together in making benefit-cost calculations but rather be shown separately to the highway decision-maker.

TABLE 3

BENEFITS OF TIME SAVINGS IN DOLLARS PER VEHICLE FOR SOCIAL-RECREATIONAL TRIPS

Time Saving (min)	Income Level of Motorist							
	1	2	3	4	5	6	7	8
1	0.000	0.000	0.000	0.001	0.001	0.003	0.005	0.010
2	0.000	0.000	0.001	0.001	0.002	0.005	0.010	0.020
3	0.000	0.000	0.001	0.002	0.004	0.008	0.015	0.030
4	0.000	0.001	0.001	0.002	0.005	0.010	0.020	0.040
5	0.000	0.001	0.001	0.003	0.006	0.013	0.026	0.050
6	0.000	0.001	0.002	0.005	0.013	0.029	0.065	0.132
7	0.000	0.001	0.003	0.009	0.026	0.065	0.146	0.278
8	0.001	0.002	0.005	0.017	0.050	0.132	0.278	0.467
9	0.001	0.002	0.008	0.029	0.094	0.236	0.442	0.669
10	0.001	0.003	0.013	0.050	0.162	0.369	0.618	0.872
11	0.001	0.004	0.019	0.083	0.256	0.517	0.796	1.074
12	0.001	0.005	0.029	0.132	0.369	0.669	0.973	1.274
13	0.001	0.007	0.044	0.197	0.492	0.822	1.149	1.475
14	0.001	0.009	0.065	0.278	0.618	0.973	1.324	1.674
15	0.002	0.014	0.086	0.343	0.719	1.098	1.469	1.839
16	0.003	0.021	0.108	0.392	0.795	1.197	1.585	1.971
17	0.004	0.028	0.131	0.443	0.874	1.296	1.701	2.102
18	0.005	0.035	0.157	0.496	0.954	1.396	1.816	2.233
19	0.006	0.044	0.184	0.552	1.035	1.495	1.932	2.364
20	0.007	0.052	0.213	0.611	1.117	1.595	2.047	2.495

TABLE 4

BENEFITS OF TIME SAVINGS IN DOLLARS PER VEHICLE FOR PERSONAL BUSINESS TRIPS

Time Saving (min)	Income Level of Motorist							
	1	2	3	4	5	6	7	8
1	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003
2	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.007
3	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.010
4	0.000	0.000	0.000	0.000	0.001	0.002	0.005	0.014
5	0.000	0.000	0.000	0.000	0.001	0.002	0.006	0.017
6	0.000	0.000	0.000	0.001	0.002	0.007	0.026	0.084
7	0.000	0.000	0.000	0.001	0.006	0.026	0.100	0.272
8	0.000	0.000	0.001	0.003	0.017	0.084	0.272	0.543
9	0.000	0.000	0.001	0.007	0.048	0.213	0.508	0.827
10	0.000	0.000	0.002	0.017	0.118	0.403	0.756	1.108
11	0.000	0.000	0.004	0.039	0.241	0.614	1.003	1.388
12	0.000	0.001	0.007	0.084	0.403	0.827	1.248	1.667
13	0.000	0.001	0.014	0.161	0.579	1.038	1.492	1.946
14	0.000	0.001	0.026	0.272	0.756	1.248	1.737	2.225
15	0.001	0.005	0.058	0.402	0.950	1.478	2.004	2.480
16	0.002	0.012	0.109	0.552	1.160	1.728	2.293	2.811
17	0.002	0.020	0.175	0.713	1.370	1.977	2.583	3.141
18	0.003	0.032	0.258	0.879	1.579	2.225	2.872	3.472
19	0.003	0.046	0.353	1.047	1.787	2.473	3.161	3.802
20	0.004	0.065	0.463	1.215	1.994	2.721	3.450	4.132
21	0.005	0.089	0.580	1.383	2.201	2.969	3.739	4.463
22	0.007	0.119	0.702	1.550	2.408	3.217	4.028	4.793
23	0.008	0.155	0.827	1.716	2.614	3.465	4.318	5.124
24	0.009	0.198	0.952	1.882	2.821	3.712	4.607	5.454
25	0.011	0.249	1.079	2.048	3.027	3.960	4.896	5.784
26	0.013	0.306	1.205	2.214	3.234	4.208	5.185	6.115
27	0.016	0.370	1.330	2.379	3.440	4.456	5.474	6.445
28	0.018	0.439	1.456	2.544	3.647	4.704	5.763	6.776
29	0.022	0.513	1.581	2.710	3.854	4.951	6.052	7.106
30	0.025	0.590	1.706	2.875	4.060	5.199	6.341	7.437

TABLE 5

BENEFITS OF TIME SAVINGS IN DOLLARS PER VEHICLE FOR VACATION TRIPS

Time Saving (min)	Income Level of Motorist							
	1	2	3	4	5	6	7	8
1	0.044	0.050	0.057	0.064	0.073	0.082	0.091	0.102
2	0.087	0.100	0.113	0.129	0.145	0.163	0.183	0.203
3	0.131	0.149	0.170	0.193	0.218	0.245	0.274	0.305
4	0.174	0.199	0.227	0.257	0.291	0.327	0.365	0.407
5	0.218	0.249	0.284	0.322	0.363	0.408	0.457	0.509
6	0.224	0.262	0.306	0.355	0.408	0.467	0.530	0.598
7	0.230	0.276	0.330	0.390	0.457	0.530	0.609	0.694
8	0.236	0.291	0.355	0.427	0.509	0.598	0.694	0.796
9	0.242	0.306	0.381	0.467	0.563	0.669	0.783	0.903
10	0.249	0.322	0.408	0.509	0.621	0.744	0.875	1.013
11	0.256	0.338	0.437	0.552	0.681	0.822	0.971	1.126
12	0.262	0.355	0.467	0.598	0.744	0.903	1.069	1.241
13	0.269	0.372	0.498	0.645	0.809	0.985	1.169	1.357
14	0.276	0.390	0.530	0.694	0.875	1.069	1.270	1.474
15	0.283	0.408	0.562	0.741	0.940	1.152	1.370	1.590
16	0.290	0.425	0.593	0.788	1.004	1.233	1.468	1.705
17	0.297	0.443	0.624	0.835	1.069	1.315	1.568	1.821
18	0.305	0.461	0.656	0.884	1.135	1.399	1.669	1.938
19	0.312	0.480	0.689	0.934	1.202	1.484	1.770	2.055
20	0.320	0.499	0.723	0.985	1.271	1.569	1.872	2.172
21	0.327	0.518	0.758	1.036	1.340	1.656	1.974	2.290
22	0.335	0.538	0.793	1.089	1.410	1.742	2.076	2.407
23	0.343	0.558	0.829	1.143	1.481	1.830	2.179	2.524
24	0.350	0.579	0.866	1.197	1.552	1.917	2.282	2.641
25	0.358	0.599	0.903	1.252	1.624	2.005	2.384	2.758
26	0.367	0.621	0.941	1.307	1.696	2.093	2.487	2.875
27	0.375	0.642	0.979	1.363	1.769	2.181	2.589	2.992
28	0.383	0.644	1.018	1.419	1.842	2.269	2.692	3.109
29	0.392	0.687	1.058	1.576	1.915	2.357	2.794	3.225
30	0.400	0.709	1.089	1.533	1.988	2.445	2.897	3.341

TABLE 6

BENEFITS OF TIME SAVINGS IN DOLLARS PER PERSON FOR SCHOOL TRIPS

Time Saving (min)	Income Level of Motorist							
	1	2	3	4	5	6	7	8
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
3	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002
4	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.003
5	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004
6	0.000	0.000	0.000	0.000	0.001	0.002	0.005	0.011
7	0.000	0.000	0.000	0.001	0.002	0.005	0.013	0.032
8	0.000	0.000	0.000	0.001	0.004	0.011	0.032	0.083
9	0.000	0.000	0.001	0.002	0.007	0.025	0.075	0.179
10	0.000	0.000	0.001	0.004	0.014	0.053	0.151	0.309
11	0.000	0.000	0.001	0.006	0.028	0.013	0.258	0.452
12	0.000	0.000	0.002	0.011	0.053	0.179	0.380	0.597
13	0.000	0.000	0.003	0.019	0.093	0.275	0.507	0.741
14	0.000	0.001	0.005	0.032	0.151	0.380	0.633	0.884
15	0.000	0.001	0.007	0.053	0.225	0.489	0.759	1.027
16	0.000	0.001	0.011	0.083	0.309	0.597	0.884	1.169
17	0.000	0.002	0.017	0.126	0.398	0.705	1.009	1.312
18	0.000	0.002	0.025	0.179	0.489	0.813	1.134	1.454
19	0.000	0.003	0.036	0.241	0.579	0.920	1.258	1.596
20	0.000	0.004	0.053	0.309	0.669	1.027	1.383	1.739

As an added aid to the highway economist, graphs and equations have been prepared that indicate the percentage of toll route users as a function of the amount of time saved and the toll costs (Appendix).

A CHALLENGE

The analyst who attempts to use these tables will find a whole new set of requirements for data on highway improvements as a result, primarily, of the finding that the value of time is a function of the amount of time saved. The total amount of time saved by a motorist on his trip is therefore crucial. The average value of 1 min of time saved is dependent on whether this minute is the only time saved, part of a total of 10 min saved, or part of a total of 20 min saved. As an example, at income level 4 (Table 2), 1 min will be valued at 0.4 cents if it is the only minute saved, at an average of 2.05 cents (20.5/10 = 2.05) if it is part of a 10-min saving, or at an average of 3.66 cents (73.2/20 = 3.66) if it is part of a 20-min saving.

The highway economist now requires more information than just the amount of time saved by a single highway improvement and the volume of motorists who will use it. He needs cross-tabulated information on all the improvements (actual and planned), on motorists' different trips and their trip lengths, and on their income levels.

Consequently, the use of these tables imposes data requirements far greater than those met by data currently collected for highway economy studies. Yet even the present requirements, such as estimates for the volume of motorists who will use a single improvement, are sometimes difficult to meet accurately. The result is certain to present the highway economist with a challenge.

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APPENDIX

TOLL-ROUTE PATRONAGE ESTIMATES

The percentage of toll-route users P can be determined from

$$P = [1 + \exp(F)]^{-1}$$

where F is the estimated discriminant function for the trip purpose of interest. The discriminant functions to be used in this equation are given in Table 7 for each trip purpose. (Although these estimated functions have been modified for fitting the benefits functions more closely to the data, the constant terms have not been adjusted to eliminate the discontinuity encountered at the point of time savings where the 2 piecewise functions meet.)

Figure 1 shows the percentage of toll-route users as a function of both time saved and toll cost for work trips. Note that demand is inelastic for the higher income levels and larger time savings. Smaller time savings and lower income levels yield more elastic demand curves. Similar curves and results can be obtained for the other trip purposes.

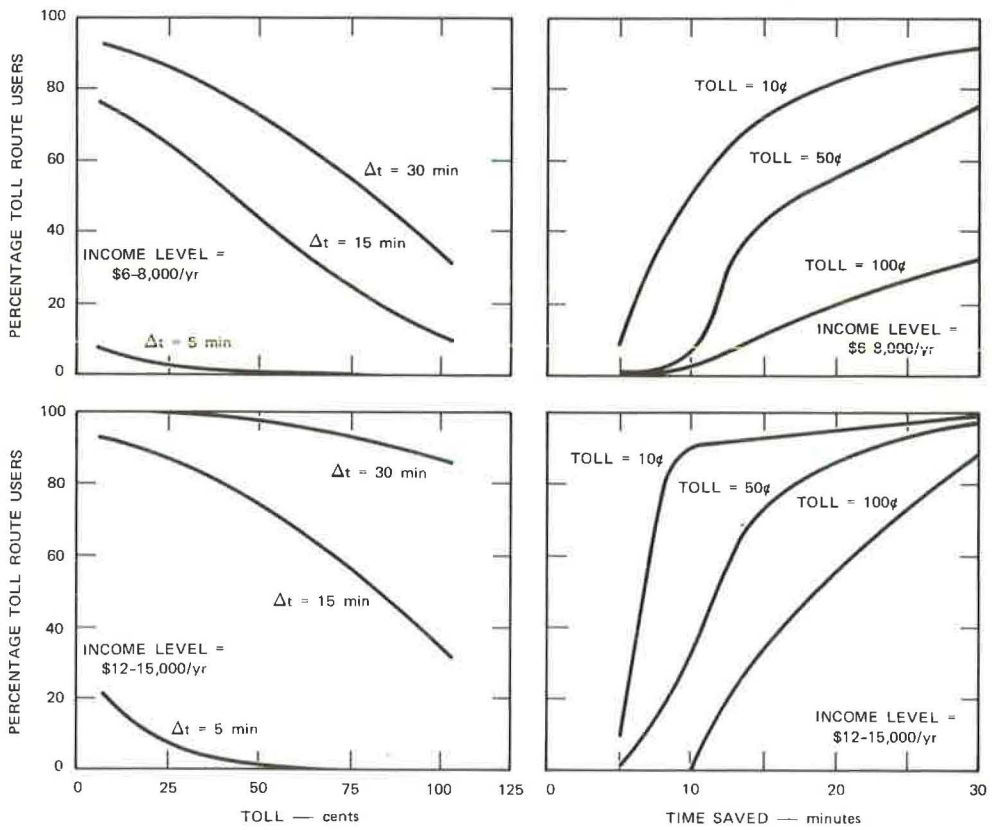

Figure 1. Toll-route patronage for work trips

TABLE 7

ESTIMATED DISCRIMINANT FUNCTIONS BY TRIP PURPOSE

Trip Purpose	Discriminant Function F	Time Interval (min)
Work	$+4.49 - 0.290\Delta t - 0.778\, I\Delta t + 0.0757\, C$	5-15
	$-0.171 + 0.0014\Delta t - 0.0290\, I\Delta t + 0.0337\, C$	5-30
Personal business	$+8.50 - 0.158\, I\Delta t + 0.0627\, C$	5-15
	$+3.16 - 0.0975\, I\Delta t + 0.03660\, C$	5-30
Social-recreational	$+6.66 - 0.148\, I\Delta t + 0.0594\, C$	5-15
	$+2.08 - 0.0457\, I\Delta t + 0.0281\, C$	5-20
School	$+13.1 - 0.188\, I\Delta t + 0.0813\, C$	5-20
Vacation	$+0.275 - 0.0332\, I\Delta t + 0.231\, C$	5-30

DISCUSSION

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It is clear that some of the contributions of this paper are likely to have noticeable effects in the field of transportation economics. In terms of modeling transportation demand, for instance, the use of perceived data alone to generate time values, the construct of time benefits as distinct from time values, and the derivation of different time benefits by trip purposes will each have important implications. For this reason, it is appropriate to raise a number of questions concerning the applicability of the reported results.

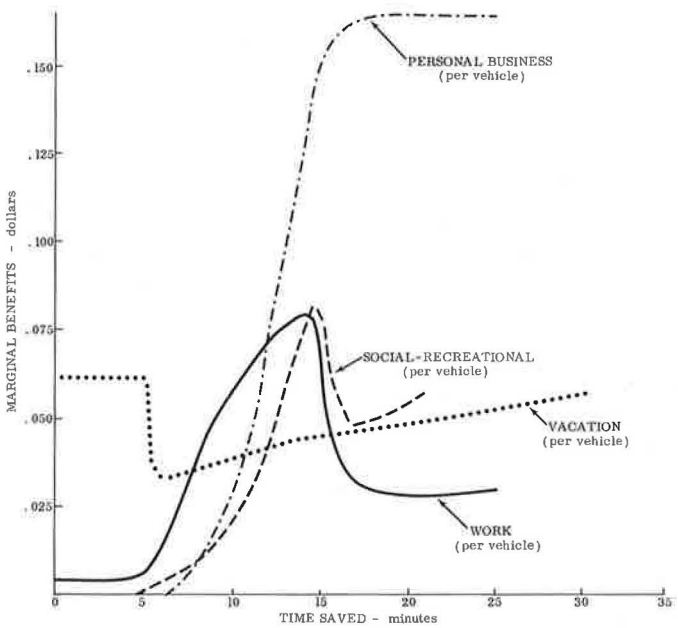

Figure 2. Marginal benefits of time saved, by purpose and amount of time saved, for annual income level of $8,000-9,999.

One question refers to an apparently unrealistic use of perceived data. Let us assume, as did the authors, that a behavioral microeconomic approach to route choice requires the use of perceived rather than measured data. But then to assume a continuous, minute-by-minute perception of time saved is not realistic because such a brief time interval reaches the limit of human discrimination. By plotting the marginal benefits of time saved by income class ($\Delta b/\Delta t$, $Y = Y_0$) as given in Tables 2, 3, 4 and 5, one can compare the results in a diagrammatic form (Fig. 2). It should be noted that Figure 2 shows only those values within the original constraints of 20, 30, and 40 min of time saved for social-recreational, personal business and vacation, and work trips respectively. The same holds for the maximum benefit restriction of $1 for work trips and $2 for all other trips. Also, school trips were not included, as the authors themselves place a wide confidence limit on the derived values.

It is immediately apparent that the time-saved continuum, or x-axis, can be divided into 3 zones. In the first zone, ranging from 0 to 5 min saved, marginal time benefits for each purpose are constant, although of different magnitudes. The same is generally true for time savings of more than 16 min. Only in the second zone, which ranges from 5 to 16 min, do marginal benefits change as a function of the amount of time saved. A question that naturally presents itself is whether this segregation of the time continuum stems from empirical observations in the field or from mathematical requirements of the models used in the derivation of time benefits. Moreover, no behavioral or economic explanation is offered for the different shapes and magnitudes of the marginal benefits, even in the interval of 5 to 16 min saved.

To conclude, it is suggested that a general application of the reported results should await further clarifications on the points raised in the preceding.

AUTHORS' CLOSURE

The discussion has raised some technical questions about the research. It is clear that other questions could also be raised and that future research will improve on the results presented in this paper. However, the crucial question for the highway economist is, should the present results be used in making economic analyses? Reichman's answer appears to be that they should not be used without further clarification of some technical points.

However, if these results are not used, then the "old results" (also developed by SRI for the Federal Highway Administration) are all that are available (2). As Reichman knows, it was the deficiencies in these old results that lead to the present study and the results reported here. The deficiencies of the previous work included the limitation of trip purpose to commuters, a linearization of the value of time saved that was not supported by the data, a value of time not directly a function of income level, and a much smaller and more geographically limited data base. These deficiencies were overcome in the new study. There is no question in our minds that, subject to the limitations set forth in the paper, the new results represent the most accurate inputs to highway economy studies currently available.

The figures that Reichman plotted appear to be consistent with the S-shaped benefits function that is supported by both theory and empirical evidence (2, 3, 4). In general, piecewise linear estimates were made on 2 intervals—5 to 15 min and greater than 15 min. Continuity requirements were used to estimate the value of time saved in the 0-to-5-min interval. The precise estimates for each trip purpose are available in Appendix B. The development of the techniques is given in a previous publication (4).

A second point concerns the use of motorist-reported time savings. The issue of reported versus measured versus perceived data (which, it should be noted, are not the same as reported data) has concerned us throughout our series of studies (2). It is a complicated question involving matters of accuracy of each sample point, sample size, and geographic coverage within the constraints of limited financial resources. Our analyses of previous data samples involving both measured and reported data on the

same trips indicated that reported data were at least as valid as measured data (4). It is incorrect of Reichman to state that an unrealistic continuous minute-by-minute perception of time saved was made. Neither we nor the mathematical techniques employed make such an assumption.

We hope that the paper will raise many methodological and empirical questions in the field of transportation economics. However, because practice cannot wait until all research questions are answered, we recommend that the reported results be put to use now by practitioners.