Abridgment

Applicability of Guidance and Navigation Systems

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ABSTRACT

Vehicle location, guidance, and navigation systems of varying degrees of complexity are receiving increasing attention in an attempt to reduce adverse energy consumption safety, and environmental effects of excess travel as a result of navigational failures. The various systems advocated or proposed apply to different types of travel as described by trip length, trip purpose, driver demographic characteristics, and other factors. The National Personal Transportation Study data base was analyzed to determine the distribution of a number of pertinent variables. These data are presented and examples are provided of how the results of this analysis can be used to determine the applicability of specific system configurations.

Driver information systems may apply to all or only some of the drivers exposed to the information sources. Most regulatory signing falls into the first category; directional signing is a good example of the second type. Information system design must include consideration of constraints imposed by characteristics of the specific user population. Economic analyses of potential improvements in these systems must also include consideration of the number of drivers and the number and characteristics of vehicle trips to which they apply. This paper contains applications of these concepts to one particular class of information systems--systems that deal with one or more aspects of route planning, navigation, and route guidance. One function of these systems is to minimize excess travel (i.e., the difference between actual highway travel and the amount that would occur if each motor vehicle trip used an optimum route). Excess travel results from the interaction of deficiencies in route selection criteria and in route planning and following.

A number of previous research efforts, both in the United States and abroad (1-3) have attempted to quantify excess travel. Excess travel was found to be a significant component of total travel with one study finding this proportion to exceed 40 percent. A synthesis of all studies of this type made in England led to the conclusions that between 2 and 4 percent of all travel represented waste that might be eliminated, and that for certain trip purpose-trip length combinations, this proportion of waste increased to 20 percent (4,5).

REMEDIAL MEASURES

Remedial measures that have been conceived, advocated, designed, or tried cover a great range of techniques, devices, or systems that include

1. Improved trip planning and map reading skills;
2. Improved availability, accuracy, and legibility of highway maps;
3. Computer-assisted trip planning;
4. Improvements in the highway information system;
5. Improved radio broadcast traffic condition advisory; and
6. Improvements in vehicle location and navigation systems.

To make an economic assessment of the measures, it is necessary to determine not only the effectiveness of the individual remedial measure to abate the excess travel problem, but also the specific characteristics of the trips for which such measures are applicable. The applicability of a given type of remedial measure and the benefits to be derived therefrom are functions of both trip and driver characteristics. In this context, the term applicability addresses whether a system can be used as well as whether it will be used.

Trip characteristics of interest include length and purpose. With increased trip length, there will be a consequent increase in the probability of entering relatively unfamiliar territory, in the number of alternate routes available, and in the number of decision points. Consequently, the probability of error is likely to increase. Applicability of a given remedial measure can thus be expected only if trips exceed some minimum length.

Trip purpose interacts with trip length and also serves as a rough indication of route familiarity. Furthermore, trip purpose is also correlated with trip urgency, that is, with the driver's desire to optimize his route and with the economic effects of departures from such an optimum.

All potential remedial measures affect the perceptual and cognitive demands placed on the driver. Different information sources must be detected, recognized, and sampled, and the information so obtained must be processed. The process of information acquisition and utilization must be time-shared with the preeminent perceptual and cognitive demands of operating a vehicle in a traffic stream. In some cases (e.g., consulting a detailed, small-scale map) such time-sharing is impossible if safe vehicle operating conditions are to be maintained. The presence of another person in the vehicle, who can act as a navigator, would eliminate this problem.

TRIP AND DRIVER CHARACTERISTICS

A complete assessment of the applicability of cost-effectiveness of remedial measures for navigational waste thus requires data on the distribution of trip and driver characteristics. These data were obtained from the National Personal Transportation Study (NPTS) (6).

Previous analysis of the problem has shown that the applicability of various navigation and guidance

TABLE 1 Mileage by Trip Purpose *(6)*

	Minimum Trip Length								
	1 Mi			5 Mi			9 Mi		
Trip Purpose	Male	Female	Total	Male	Female	Total	Male	Female	Total
A Earning a living[a]	30.5	9.5	40.0	32.4	9.5	41.9	33.9	9.0	42.8
B Family and personal business	7.2	6.0	13.2	7.0	5.3	12.3	6.8	4.8	11.6
C Civic, educational, or religious	1.6	1.2	2.8	1.5	1.1	2.6	1.4	1.0	2.4
D Social and recreational	10.0	4.1	14.1	10.2	4.1	14.3	10.7	4.1	14.8
E Return home[a]	14.9	8.3	23.2	15.0	7.5	22.5	15.3	7.1	22.3
F Other[a]	3.9	2.8	6.7	3.8	2.5	6.3	3.8	2.2	6.0
Total	68.0	32.0	100.0	69.9	30.1	100.0	71.8	28.2	100.0

[a]The basic NPTS Trip Purpose Classification includes all trips whose destination is "home" into aggregate class "other" (including work-to-home trips).

TABLE 2 Driver Median Age *(6,7)*

Trip Purpose	Day			Night			All		
	Male	Female	All	Male	Female	All	Male	Female	All
A	39	32	37	38	35	37	39	33	37
B	40	37	38	35	35	35	38	37	37
C	28	30	30	39	34	36	30	30	30
D	34	34	34	28	28	28	34	32	33
E	40	36	37	34	33	34	36	35	36
F	35	33	33	31	32	32	33	33	33
Total	38	34	37	35	33	34	37	34	36
U.S. Population, 16 and older							37	40	38

techniques is a function of trip length and purpose while the usability of these techniques depends on such driver characteristics as age, sex, and education, and on the presence of a navigator.

Trip length by trip purpose is shown in Table 1. A tabular presentation of the role played by longer trips follows.

Minimum Trip Length (mi)	Vehicle Miles Traveled	Trips
5	.87	.45
9	.72	.26
14	.57	.15
24	.38	.06

No data are available concerning driving experience; however, this variable is highly correlated with age. Table 2 shows the median driver age for each trip purpose and for day and night conditions. Table 3 shows that proportionately less driving is done at each tail of the distribution of driver age.

The educational level of drivers is higher than that of the population as a whole as can be seen by comparing proportions of drivers who have completed 12 or more years of school such as high school graduates (6).

Population Group	Percent of Individuals Who Have Completed 12 or More Years of School (%)
Total U.S. population	64.9
Drivers, all trips	80.8
Drivers, trips over 4 mi	81.2
Drivers, trips over 8 mi	81.5

The disparity is actually greater than shown because an appreciable proportion of young drivers have not yet completed their education.

TABLE 3 Driver Median Age—Tails of the Distribution *(6,7)*

	Male		Female		All	
Age	U.S. Population (%)	Miles Driven	U.S. Population (%)	Miles Driven	U.S. Population (%)	Miles Driven
21 and younger	16.3	10.4	14.9	13.9	15.8	11.6
65 and older	12.5	10.3	16.6	4.1	14.7	8.3

Tables 4 and 5 give a summary of navigator status by trip purpose and length. It can be seen that the availability of a potential navigator is highly dependent on trip purpose and that this proportion increases for longer trips. It is also worth noting that for all trip purposes, the availability of a potential navigator is considerably smaller for female drivers than for male drivers.

DISCUSSION

These data can be used to determine the potential applicability, as previously defined, of different configurations of remedial measures for the problem of navigational waste. These determinations involve the following steps:

1. Estimate the prerequisites, in terms of driver age, sex, education, and other demographic attributes for the usability of a proposed remedial measure.
2. Estimate the proportion of all trips, stratified by trip length and trip purpose, for which the remedial measure would be applicable.
3. Estimate whether these factors would be affected by the presence of a potential navigator.

TABLE 4 Percent of Total Mileage by Navigator Status and Trip Purpose—All Trips *(6)*

Navigator Status	Driver Sex	Trip Classification A	B	C	D	E	F	All	5 Mi	9 Mi
1. Alone	Male	96.1	55.7	76.8	48.0	58.4	51.5	74.7	74.1	72.9
	Female	94.1	60.5	74.5	57.2	61.4	47.0	70.6	70.3	69.4
	Overall avg	95.6	57.8	75.9	50.7	59.5	49.4	73.4	73.0	71.9
2. Child only	Male	0.4	4.0	2.1	3.1	2.7	5.6	1.9	1.8	1.7
	Female	4.1	23.3	13.3	21.9	21.9	34.3	17.1	16.6	16.1
	Overall avg	1.3	12.5	6.9	8.7	9.6	18.9	6.8	6.2	5.8
3. 1 + 2	Male	96.5	59.7	79.0	51.1	61.1	57.1	76.6	75.9	74.6
	Female	98.2	83.9	87.7	79.1	83.4	81.3	87.7	86.8	85.5
	Overall avg	96.9	70.3	82.8	59.4	69.1	68.3	80.2	79.2	77.7
4. Navigator available	Male	3.5	40.3	21.0	48.9	38.9	42.9	23.4	24.1	25.4
	Female	1.8	16.2	12.3	20.8	16.6	18.7	12.2	13.2	14.5
	Overall avg	3.1	29.7	17.2	40.5	30.9	31.7	19.8	20.8	22.3

TABLE 5 Percent of Total Mileage by Navigator Status and Trip Length *(6)*

Navigator Status	Minimum Trip Length (mi) 0	5	11	15	21	31	41	51
Male	23.4	24.5	26.4	27.8	32.7	40.1	45.7	50.4
Female	12.2	13.0	15.4	16.3	19.8	26.5	29.4	32.0

4. Compute the proportion of all U.S. highway travel characterized by these combinations of driver and trip characteristics.

5. Estimate the proportion of navigational waste within each of these classes that is likely to be eliminated by application of the proposed remedial measure. These estimates are based on empirical data on the distribution by type and consequence of navigational errors and on data concerning route familiarity within trip classes.

6. Compute the amount of navigational waste that will be eliminated by application of the proposed remedial measure.

The results of a number of hypothetical examples of this process follow with an outline of assumptions.

1. Highway Information System--Improvements in the highway information system such as elimination of ambiguous or confusing messages, location information, and advance warning of decision points will affect navigational waste that results from route-following difficulties. Assumptions include (a) No work trips, (b) Applicability ranges from 50 to 90 percent as function of trip length, and (c) No pertinent driver characteristics.

2. Highway Maps--Improvements in highway maps including clarity, inclusiveness, legibility, availability, and correspondence to ground truth will affect navigational waste resulting from both trip planning and route-following deficiencies. Such improvements may affect navigational waste as a result of trip planning deficiencies. Assumptions include (a) Applicability ranges from 25 to 90 percent as function of trip length, and (b) Usability ranges from 10 to 90 percent as joint function of education and sex.

3. Navigation Systems--Computer-controlled, real time navigation and guidance systems will, theoretically, alleviate the need for trip planning and eliminate the possibility of route-following errors. It can be estimated that real time navigation systems will, 5 years after implementation, lead to a reduction of 17 percent in navigational waste. This proportion will increase rapidly as the number of adequately equipped vehicles increases. Assumptions include (a) Entire arterial system would be instrumented; (b) System would be installed in 50 percent of all new vehicles--there would be no after-installation; (c) Equipped vehicles would accrue 120 percent of average mileage; and (d) Computer routings would be accepted and followed in 85 percent of all cases.

REFERENCES

1. D.A. Gordon and H.C. Wood. How Drivers Locate Unfamiliar Addresses--An Experiment in Route Following. Public Roads, Vol. 36, No. 2, 1970.
2. V.E. Outram and E. Thompson. Driver Route Choice. Proc., PTRC Summer Annual Meeting, University of Warwick, Coventry, England, 1977.
3. F. Tagliacozzo and F. Pirzio. Assignment Models and Urban Path Selection: Results of a Survey of the Behavior of Road Users. Transportation Research, Vol. 7, No. 3, Sept. 1973.
4. D.J. Jeffery. The Potential Benefits of Route Guidance. L.R. 997. U.K. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1981.
5. S.E. Lunn. Route Choice by Drivers. S.R. 374. U.K. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1978.
6. R.H. Asin. 1977 National Personal Transportation Study--Users Guide for the Public Use Tapes. Federal Highway Administration, U.S. Department of Transportation, April 1980.
7. Bureau of the Census, Statistical Abstracts of the United States: 1978, (99th Edition), U.S. Department of Commerce, 1978, p. 29.

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