PRELIMINARY ANALYSIS OF DISAGGREGATE MODELING IN ROUTE DIVERSION

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A study of route diversion in the Baltimore-Washington corridor is presented. A disaggregate model of individual route choice is used. The study investigates diversion from US-1 to I-95 through a license plate sampling technique employed before and after I-95 was opened to traffic. Regression and logit techniques analogous to those in modal-split research were employed to study individual diversion behavior. The research allowed tentative conclusions to be drawn about the use of this kind of study design.

A PROBLEM of continuing relevance to the transportation planner is the set of stimuli that affect choices travelers make and the implications of those choices in terms of facility usage and quality of service.

Choices made by travelers are typically studied in the modal-split and assignment portions of the urban transportation planning modeling process. Classically, they have been studied in the aggregate (2, 3). Recently, however, efforts have been made to study modal choice at the disaggregate or individual level. Virtually all of this work has focused on the issue of mode choice and subsets of travelers in different socioeconomic groups (4). Little attention has been paid to stimuli that affect route choice of an individual automobile traveler and the resulting highway traffic assignment.

The objective of this paper is to report on a pilot study of the motivation for automobile route selection between 2 parallel routes in Maryland. The opening of a new highway during the study period provided an opportunity to develop before-and-after data relating to 2 parallel routes. The specific objectives of the research were

1. To assess the degree of applicability of certain behavioral, disaggregate modal-choice analysis techniques to the study of route choice;
2. To assess data and field study requirements as a learning process to determine future study designs of this type; and
3. To further the use of disaggregate models in all phases of the urban transportation planning process.

SITE SELECTION

Figure 1 shows the region in which the study area is located. Prior to July 1971, I-95 had not been completed between the outer belts of Baltimore and Washington (I-695 and I-495 respectively). Of the remaining 3 routes shown, US-1 was considered functionally to be the primary traffic arterial between Baltimore and Washington. Study timing was such that it was possible to gather information on volumes and use prior to the July 1971 opening of I-95 and then, after a sufficient stabilization period, to study the diversion of traffic to I-95. US-1 is a 4-lane undivided highway that has congestion and relatively high accident rates. I-95 has 4 lanes in each direction, wide grass medians, a high type of shoulders, and excellent design.

STUDY DESIGN AND DATA COLLECTION

Because of severe budget limitations on data collection, a study procedure was developed that would accomplish 2 objectives of data collection for later modeling efforts:

Figure 1. Location of study area.

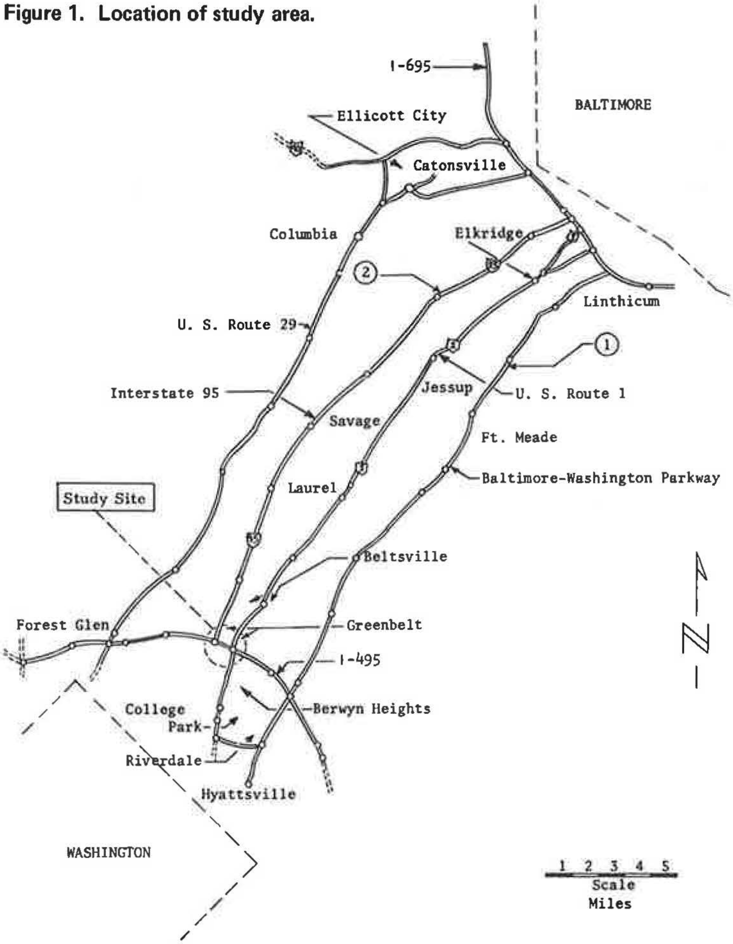


Table 1. Traffic on US-1 before and after opening of I-95.

Day	July 1971	June 1971
Sunday	9,158	11,560
Monday	15,628	19,152
Tuesday	16,940	19,456
Wednesday	16,019	19,672
Thursday	16,305	20,021
Friday	16,908	18,832
Saturday	12,961	15,496
Total	103,919	124,189

Table 2. Analysis of independent and dependent variables.

Grouping	P	R	R^2
1 min	$0.442 + 0.0397(X_1)$	0.76	0.58
	$0.430 + 0.684(X_7)$	0.55	0.30
2 min	$0.451 + 0.0389(X_1)$	0.79	0.63
	$0.439 + 0.665(X_7)$	0.57	0.33
5 min	$0.455 + 0.0370(X_1)$	0.86	0.74
	$0.438 + 0.672(X_7)$	0.67	0.45

1. Allow an inexpensive investigation of the volume changes of commuting traffic in the I-95—US-1 corridor, and

2. Allow further investigation of a subset of diverting and nondiverting commuter travelers with respect to a broad set of stimuli for route choices.

Before I-95 opened, license plates of northbound and southbound vehicles on US-1 were randomly recorded for 1 week in June 1971 during the morning and evening peak hours. Traffic volumes were also recorded on US-1 for 1 week shortly after I-95 opened. Between June and July, volumes dropped 18 percent (Table 1). Finally, license plates were recorded on both I-95 and US-1 in January 1972. Computerized comparison of plates yielded gross information on diversion.

This field procedure yielded an approximate 10 percent sample of peak-hour volumes. Sample sizes as 1-week totals of peak-hour vehicles in both directions are as follows:

Time	US-1	I-95
Before I-95 opened	3,550	—
After I-95 opened	3,224	4,665

Detailed questionnaires were sent to approximately 10 percent of the US-1 and I-95 sample for the after portion of the study. Accordingly, 585 questionnaires were sent to drivers of vehicles whose plates had been tracked through both the before and after portions of the study. The primary objective of the questionnaire was to investigate parallels between route selection and disaggregate mode-choice modeling wherein the driver makes a choice in response to an individual socioeconomic preference and to system characteristics and trip purposes. The questionnaire obtained information on origin-destination, travel time, travel cost, trip purpose, income, family size, number of drivers at origin, sex, and age. This set of data formed the basis for further quantitative analysis of the diversion problem.

ANALYSIS OF DATA AND MODEL DEVELOPMENT

Data from the questionnaires were used to help in understanding the decisions to use US-1 or I-95. The input variables for further quantitative analysis were defined as follows:

X_1 = travel time difference between US-1 and I-95;
X_2 = cost difference between using US-1 and I-95, valued at \$3/hour (7);
X_3 = number of passenger vehicles owned at origin;
X_4 = persons residing at origin;
X_5 = number of persons of driving age at origin;
X_6 = annual income of household; and
X_7 = weighted travel cost, developed by factoring travel time difference with respect to household income.

This latter set of factors used were those developed from previous research on value of time by Thomas and Thompson (5).

Simple bivariate regressions were performed on each of the above independent variables against the dependent variable P, probability of diverting to I-95. This dependent variable was developed by the quotient (number of diversions in class i)/(total population of class i), where class i is a 1-, 2-, or 5-minute increment of travel time difference between the 2 routes over the range of travel time differences developed from the questionnaire response. Results are given in Table 2 and shown in Figures 2 and 3.

Travel time was a consistently fair to good estimator. Travel cost was not shown because, as defined, it is a linear transform of travel time. Weighted or perceived cost by income level was shown as being a potential indicator of diversion. However, reasonably poor-quality estimating capabilities exist for this variable from the equations shown, except at the 5-minute grouping level.

Figure 2. Probability of diverting to I-95 versus travel time difference.

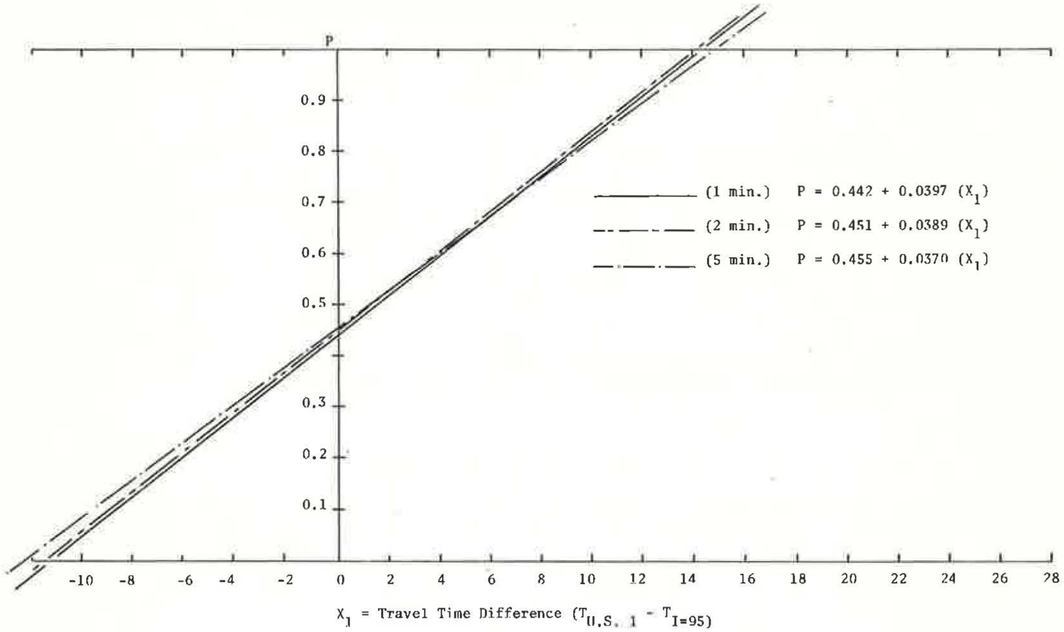
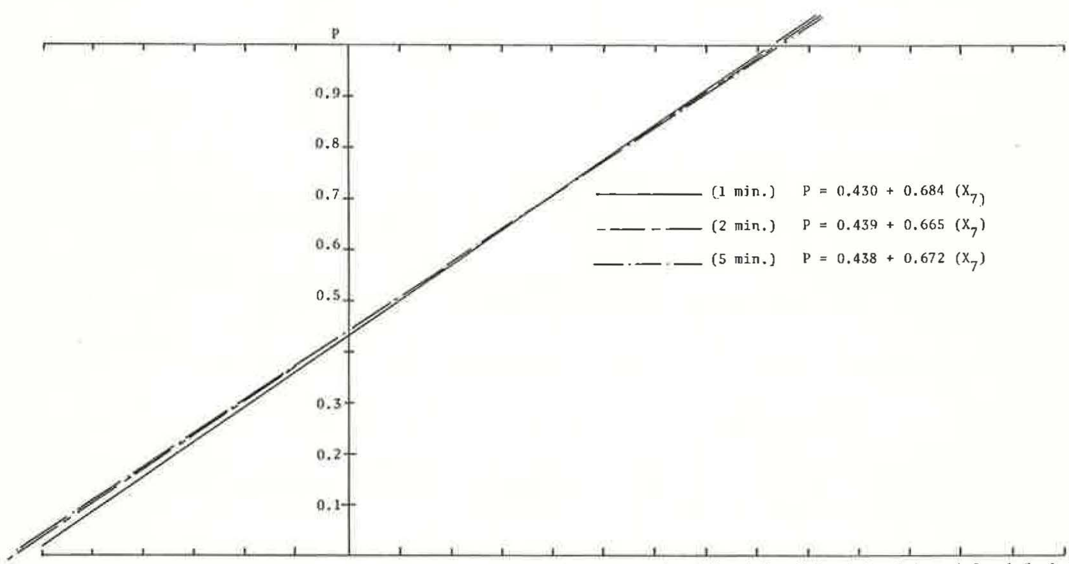


Figure 3. Probability of diverting to I-95 versus cost difference weighted by income.



RELATION TO LOGIT ANALYSIS

The above bivariate equations were used in the logit format of

$$P' = \frac{eP}{1 + e^P}$$

where P' is as defined in the bivariate regressions. The rationale of logit development is to exhibit a more rational stimulus-response conception of probability of diversion and to develop asymptotic limits on diversion at or near P = 0 and P = 1 (4). Three of these plots are shown in Figures 4, 5, and 6. In each case the smoothing or asymptotic effect has not been completely captured within the range of stimuli shown. The implication is that, for this particular study corridor, total assurance of diversion or nondiversion exists only in ranges of greater than 20 to 25 minutes of time lost or saved by use of a respective route, as shown in Figures 4 and 5. Figure 6 implies that high relative weighting of travel time by income is necessary to induce diversion.

MULTIVARIATE ANALYSIS

The variable input set included travel time difference, travel cost factored by income, number of vehicles at origin, number of persons of driving age, and number of persons readily at the origin. A step-wise regression yielded the following information with the final variables in the equation: $P = 0.43 + 0.05X_1 - 0.39X_7 - 0.01X_3 - 0.02X_5$. The following is a summary of explained variation.

Step Number	Variable	R	R^2
1	X_1	0.8610	0.7412
2	X_7	0.8810	0.7762
3	X_4	0.8859	0.7847
4	X_3	0.8870	0.7868
5	X_5	0.8870	0.7868

Seventy-seven percent of the explained variance results from travel time difference and travel cost difference weighted by income. However, even when these 2 or primary indicators are used, only 0.03 is added to the R^2 because of the inclusion of weighted cost difference. The correlation matrix shows an extremely high partial correlation between X_1 and X_7. As developed here, one must conclude that weighted cost difference is autocorrelated with time difference in the analysis. To pursue a logit curve with the above input was considered irrelevant. Further comment will be made on speculative issues of concern about this section in the conclusions.

CONCLUSIONS AND ISSUES FOR FURTHER STUDY

This study was a highly speculative, pilot investigation of route choices of automobile travelers. Its value is more in the enlightened direction provided for further research than in the specific end products obtained. Several items are apparent.

1. More sophisticated questionnaire design is necessary to provide responses that are meaningful for potential use in scaling and weighting socioeconomic preferences related to route choice.
2. More comprehensive field study and counting are necessary in a comprehensive study. The license plate matching survey technique is efficient, but should be employed for a large sample (perhaps 100 percent) of the peak hours during selected weeks before and after diversion. A sampling procedure for off-peak volumes should be designed through classical sampling approaches to yield, along with the peak-hour information, a diversion profile over all time periods throughout the study weeks. Seasonal variation, if important, should be considered.

Figure 4. Probability of diverting to I-95 versus travel time difference (1-min grouping).

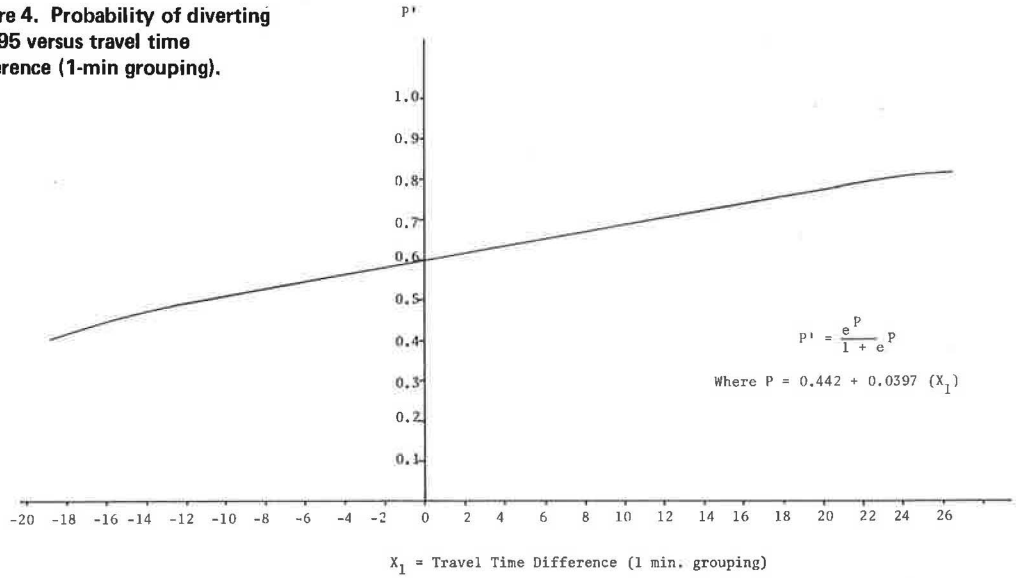


Figure 5. Probability of diverting to I-95 versus travel time difference (5-min grouping).

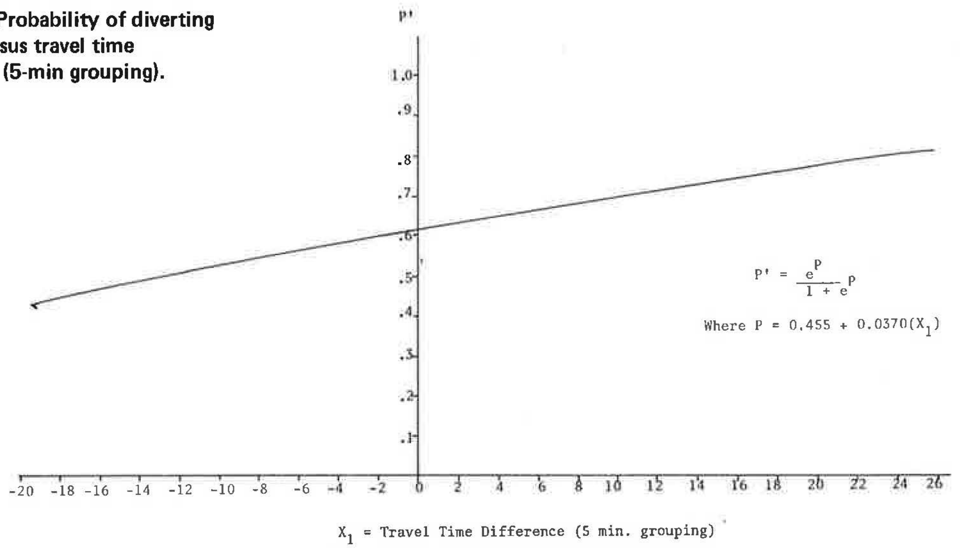
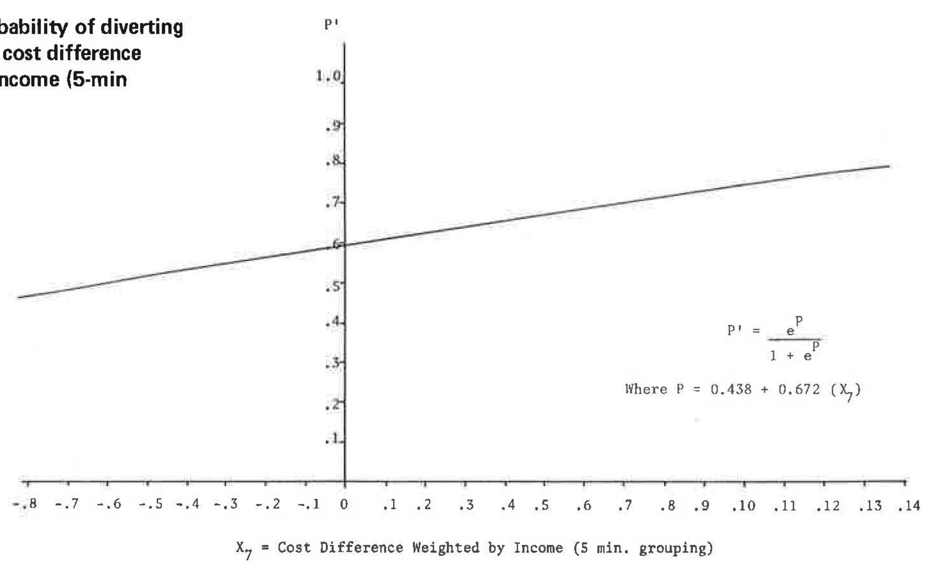


Figure 6. Probability of diverting to I-95 versus cost difference weighted by income (5-min grouping).



3. With respect to actual results obtained here, the most valid indicator is travel time difference as determined from the bivariate analysis and smoothed in a logit format. Although this would appear intuitively obvious, to more adequately investigate the socioeconomic aspects of the driving population is relevant. Although the multivariate analysis of X_1 and X_7, time difference and cost weighted by income, was rejected based on presumed autocorrelation, the authors speculate that perceived economic and social status of the driver may heavily influence his or her route choice and travel patterns generally. A more sophisticated questionnaire might develop the use of quantitative information relating to X_7, which is more indicative of the entire travel choice phenomenon than X_1, and yield X_7 or some other type of status-oriented weighting variable as a surrogate for many stimuli, one being travel time.

4. The above point and the thrust of a study design such as this one are particularly relevant at this time because of energy shortages and extreme travel price alterations. These result in intensive stimuli for individuals to alter route choices and travel patterns and to reexamine these as entities centrally related to their life-style and perceptions of its quality. Travel is considered a derived demand, and excellent opportunity exists to use disaggregate analysis to study the sensitivity of this demand to life-style characteristics and the effect of exogenous forces on automobile travel behavior. To the extent disaggregate analysis yields adequate information on these items, it is a potentially viable modeling component in urban transportation planning in addition to its current use in pure modal-split analysis.

REFERENCES

1. Berkson, J Application of the Logistic Function to Bio-Assay. Journal of American Association, 1944.
2. Guide for Forecasting Traffic on the Interstate System for the 1972 Cost Estimate. Federal Highway Administration, 1971.
3. Martin, B. V., Memmott, F. W., and Bone, A. J. Principles and Techniques of Predicting Future Demand for Urban Area Transportation. M.I.T. Press, Cambridge, 1961.
4. Stopher, P. K. Transportation Analysis Methods. McMaster Univ., Ontario, 1971.
5. Thomas, T. C., and Thompson, G. I. Value of Time Saved by Trip Purpose. Highway Research Record 369, 1971, pp. 104-117.
6. Warner, S. L. Stochastic Choice of Mode in Urban Travel: A Study in Binary Choice. Northwestern Univ. Press, Evanston, Ill., 1962.
7. Winfrey, R. Economic Analysis for Highways. International Textbook Co., Scranton, Penn., 1969.