Perception of the Availability of Transportation Alternatives for Various Trip Purposes

Timothy J. Tardiff, University of California, Davis

Mode choice models require five decisions concerning model structure. These are the selection of (a) a statistical technique, (b) the method of comparing the characteristics of competing modes, (c) the method of representing socioeconomic variables, (d) objective or subjective measures of times and costs, and (e) objective or subjective criteria for separating those who choose among modes from those who are captive to a mode. The purpose of this paper is to examine the implications of the subjective approach to separating choosers from captives. To do this, various models that distinguish choosers from captives are developed. The data were obtained from a stratified probability sample of 223 households from the Santa Monica-west Los Angeles, California, area. Variables distinguishing choosers from captives for the work trip and the most frequent nonwork trip as well as personal and locational descriptors of the individual and information on the characteristics of the competing modes were available. Logit analysis was used to test the alternative models, and the conclusion reached was that models containing specific information about the characteristics of the competing modes were superior to models containing only locational and personal information on individuals. The implications of this finding in terms of predicting modal split, understanding transportation behavior, and transportation policy are noted.

Recent disaggregate models of mode choice have been based on common concepts. They key hypothesis governing most of these models is that people trade off time saving for increased costs, or vice versa, if necessary when they select a mode of travel for a particular trip (5, 7, 12, 14, 15). Because this choice is assumed to be made among a finite set of alternatives, appropriate statistical techniques for choice problems have been devised and used.

Several research approaches have been used in specific studies. This paper considers these approaches by answering five basic questions that distinguish existing mode choice models. The answer to the fifth question is considered in detail and is the key part of this paper. The other four questions are useful background for the key question.

RESEARCH QUESTIONS IN MODE CHOICE MODELING

Five questions dealing with alternative data analysis decisions are the basis of the formulation of a specific mode choice model. The first three of these have received extensive attention in the literature and are discussed briefly here. The fourth question is closely related to the main focus of the paper, the fifth question. These two issues form the background for the empirical work.

Questions 1 Through 3: The Structure of Choice Models

The first research question concerns the statistical technique used to calibrate the choice model. Although binary probit and discriminant analyses were used in early applications, the majority of recent studies have used binary and multinomial logit analysis.

The answer to question 2 results in a particular functional form for the comparison of the times and costs of competing modes. Although functional forms such as ratios and logarithms of ratios of competing times or costs have been used, a simple difference function has been used most extensively and has been shown empirically to yield results at least as good as the other two forms in binary situations (5, 12, 17). The difference function also appears to be the most appropriate for multinomial logit models.

The third question deals with the way in which variables describing individuals are represented in the model. The most common approach has been to add these variables as additional linear terms. This approach is consistent with the hypothesis that the trade-off mechanism involving time and cost is the same for all individuals. Two alternative approaches allow different trade-off functions for people with different characteristics. The first of these is to express the coefficient of the time or cost variable as a function of an individual descriptor, usually income (5, 10, 11). The alternative approach is to stratify the sample on the basis of the individual descriptors and calibrate a separate model for each stratum (3, 17). In this way, the coefficients of time and cost are allowed to vary for different individuals, which results in possibly different trade-off mechanisms.

Question 4: How to Measure the Characteristics of Competing Modes

The question on how characteristics of competing modes are measured has been addressed mainly with respect to time and cost. The two basic approaches are to measure time and cost objectively, i.e., through either some network model or replications of the actual trip, or subjectively, i.e., as reported by the trip makers. The issue of which approach is superior has not been resolved. Those advocating objective measures claim that this procedure is more appropriate for prediction purposes and for calculating real benefits in time savings from transportation improvements (1, 8); those advocating subjective measures claim that such procedures better represent the actual choice process and are better for calculating the value of time (4, 16). Determining systematic relationships between subjective and objective measures would be helpful in assessing the relative merits of the two approaches and in making the subjective models appropriate for prediction purposes. However, one recent study (13) indicated that the relationships between subjective and objective measures might not be straightforward.

Question 5: How to Separate Those Making a Choice Between Modes From Those Captive to a Mode

In most mode choice studies, the sample of those assumed to be making a choice has been smaller than the total sample of trip makers. In some situations, the reduction in sample size was considerable. The need to separate choosers from captives is based on the theoretical argument that only people actually making a choice should be included in a model representing a choice process. Further, some empirical studies (5, 9) have indicated that the separation of choosers from captives makes a difference in terms of the goodness of fit of the model.

In much the same way as in question 4, the two basic approaches to separating choosers from captives are to use either objective or subjective criteria. The objective approach, which has been used in most studies, is simply to specify as choosers those individuals meeting certain criteria, e.g., not needing the car for work, within a certain distance of a bus line, or car owners. The subjective approach is to define as choosers those people who perceive the existence of an alternative mode for the trip in question regardless of their objective characteristics.

Although the issue of objective versus subjective separation of choosers and captives has not been dealt with explicitly in the literature, the arguments justifying the alternative positions are analogous to those used in the time and cost issue. That is, the use of objective criteria facilitates the use of models for prediction because the choosers can be selected by using population distribution projections on the criteria. On the other hand, using those people who actually think they are choosing is more appropriate in terms of explaining behavior.

As in the case of the measurement of time and cost, the use of subjective selection of choosers and captives requires a procedure for relating this perception to objectively measured criteria if the models are to be used for practical predictive purposes. Lave (5) recognized this need and suggested that the techniques appropriate for mode choice modeling were appropriate for developing a model to distinguish those who perceive a choice from those who feel they are captive to a particular mode. Essentially, such a model views the decision of whether to be a chooser as a function of several independent variables.

Besides the question of developing a procedure for predictive purposes, the question of the perception of transportation alternatives has theoretical implications. It can be argued that the decision of whether to place oneself in a position in which alternatives are perceived is a more fundamental issue than the mode choice question because a person must perceive the existence of a choice before he or she will make one. In this sense, the decision of whether a choice of modes exists becomes one of the longer range transportation decisions such as automobile ownership (2, 6) or household location decisions.

This paper examines the issue of the perception of transportation alternatives by modeling the decision of whether one has a choice of modes. The issue of whether the subjective criterion is superior to objective criteria in separating choosers from captives is not directly addressed. Rather, the development of the model is useful in addressing some of the practical and theoretical issues implicit in the decision to use the subjective criterion.

Therefore, the models are primarily exploratory in nature. They illustrate the degree to which subjective choosers and captives can be distinguished by certain types of independent variables. In this way, it should be possible to determine whether this subjective categorization is systematically related to personal characteristics, location, and transportation-related variables or whether the perception is essentially random. A related question is whether the subjective criterion can be used for predictive purposes. Although the models developed in this study are not explicitly designed for predictive purposes, the quality and structure of such models should indicate the potential of similar models in this regard.

DEVELOPMENT OF THE MODEL

Data from a study of transportation attitudes and behavior (18) conducted in November-December 1973 were used in this study. A stratified probability sample of 223 households in the Santa Monica-west Los Angeles, California, area was selected. The size of the sample was based on the fact that, in a study using a random sample of this size, the probability of the mean response being within 6½ percent of the true mean for the entire population is 95 percent.

Alternative Model Structures

The variable indicating whether an individual perceives a choice of modes, the dependent variable in the models, is defined for both the work trip and the most frequent nonwork trip made by the respondent in the month preceding the interview. Because the only modes available to the people in the sample area are private automobile and bus, the dependent variable is defined to distinguish those who perceive the existence of a choice of modes from those who feel they are captive to a particular mode. This definition eliminates from the sample all respondents who either did not make the trip in question or used neither the car nor the bus. In addition, the heavy automobile orientation of the suburban Los Angeles sample area led to an extremely small number of people who perceived themselves as captive to the bus (three for the work trip and six for the most frequent nonwork trip). When these cases were eliminated, a dependent variable was left that distinguishes automobile captives from those who perceive the existence of a choice between the

bus and the automobile. Finally, cases with missing data on the independent variables were eliminated, resulting in 104 cases for the work trip and 173 cases for the nonwork trip.

The dependent variable essentially divides the people making vehicle trips and having access to an automobile into those who consider the bus as a possible alternative to the automobile (or vice versa) and those who feel the automobile is the only viable mode. These two groups cover the great majority of individuals making vehicle trips in the sample area. However, the conclusions of this study may not be applicable in an area where there are a substantial number of bus captives.

The independent variables were structured into sets that yield models consistent with alternative hypotheses about the nature of the decision of whether to perceive the existence of alternative modes. The first set, which is consistent with the hypotheses that the perception of alternatives is a longer range decision than the choice of modes, uses variables that are independent of the characteristics of the available modes. In particular, variables that describe the individual and his location are included. These are the respondent's age (AGE) and sex (SEX), the ratio of automobiles in the respondent's household to licensed drivers (C/DL)—the best indicator of socioeconomic status (best in the sense of yielding the best fitting model), the perceived distance of the trip (TDIS) in kilometers, and the distance of the respondent's home to the closest bus line (BDIS) in blocks. SEX is given on a scale of 1 for males and 2 for females. Income (INC) given for the work trip, the respondent's occupation (OCC) given for the most frequent nonwork trip, and AGE are measured on seven-point scales. The scale values for each of these variables are given in Table 1.

The second and third sets of independent variables are both designed so that specific features of the modes used in making the trip can be included. In this way, the assumption that the perception of a choice situation is independent of and made prior to the actual choice of modes is relaxed. Therefore, acceptance of one of these models instead of the model using the first set of independent variables might suggest a simultaneous structure rather than a recursive structure for the perception and choice decisions. Although theoretically a simultaneous perception of choice and mode choice model could be developed, data limitations preclude the calibration of such a model here. However, rejection of the models involving the first set of independent variables would indicate that a simultaneous model might be worthy of future exploration with an appropriate data source. In practical terms, models developed from the second and third sets would be more difficult to apply because of the additional information on the specific trips in question.

The second and third sets of independent variables substitute information about the actual trip for some of the locational descriptors. Aside from AGE, SEX, C/DL, and TDIS, the second set uses travel time (TIME) in minutes on the actual mode used. The third set uses the three former variables and the actual cost of the trip (COST) in cents and excludes TDIS. Neither set 2 nor set 3 uses BDIS. Both TIME and COST are subjectively measured.

The fourth set yields further information about the extent to which specific data about the competing modes are related to the perception of whether a choice of modes exists. Because the models based on set 4 are designed as an extension of the hypothesis underlying the models using sets 2 or 3, set 4 includes variables from set 2 or set 3, whichever has the better statistical fit, and a variable measuring the overall comparative satisfaction of the two competing modes (CSAT). The attitudinal variable is the weighted sum of the differences in perceived satisfaction with the bus and automobile modes with respect to cost, convenience, reliability, comfort, safety, travel time, privacy, and reduction of smog. The weights in each case are the importance scores. Both importance and satisfaction scores are measured on five-point scales. In the former case, 1 equals very unimportant and 5 equals very important. In the latter case, 1 equals very unsatisfactory and 5 equals very satisfactory.

In summary, the empirical tests are the development of alternative binary logit models of the decision of whether a choice between modes is perceived. Symbolically, the models are of the following form:

$$P(\text{chooser}) = \exp L(X)/[1 + \exp L(X)] \qquad (1)$$

where L(X) is a linear function of the variables of one of the alternative sets of independent variables.

Results

The alternative models for the work trip and most frequent nonwork trip are given in Table 2. The four logit equations corresponding to the four alternative sets of independent variables are given.

The conclusion apparent from the tests of the alternative models for the work trip is that none of the models that do not include the attitudinal variable explains the data very satisfactorily. In addition, of the three models tested, the one that includes perceived trip time for the chosen mode and the trip distance appears to be the best. For this model, the trip distance variable was statistically significant in a negative direction, and the time variable was close to being significant at the 0.05 level in a positive direction. Among the other independent variables, the direction of the relationships was such that the choosers tend to be (a) those who have fewer travel resources (cars and income), (b) women, and (c) younger people.

The directions of the relationships involving the trip distance variable and the travel time variable are interesting. Those who make longer work trips are less likely to perceive the existence of a choice situation, but, for a given trip distance, those who spend more time in travel are more likely to be choosers. In other words, although the automobile tends to be perceived as the only available mode for longer trips, as the time required for those trips increases, the likelihood of transit being a viable alternative also increases.

The final test involving the work trip was the addition of the attitudinal variable measuring the comparative satisfaction of the competing modes to the variables in the second set, which yielded a model superior to that of the third set in the previous test.

The addition of the attitudinal variable considerably improved the model. This variable was easily the most important. As expected, the variable was such that, as an individual perceived the bus as relatively more satisfactory, he was more likely to be a chooser. The addition generally leaves the relative importance of the remaining variables similar to that of the corresponding model that does not include the attitudinal variable.

The results of the tests of alternative models for the work trip indicate that information about the modes available for the trip, i.e., travel time and perception of the attributes of the competing modes, yields a better model than locational and personal descriptors of individuals. That is, the perception of the availability of a choice of modes is related to the quality of the available modes. A practical implication is that successful prediction of the choosers for a mode choice model using the subjective criterion to separate choosers from captives would

require some fairly specific information about the available modes.

The results of the tests of the alternative models explaining the difference between choosers and captives for the most frequent nonwork trip were in many ways similar to those for the work trip. Again, the second set of independent variables yielded the best fitting model of those not including the attitudinal variable. Also, the structures of the nonwork trip models were similar to those of the corresponding work trip models. Specifically, forthe model using TDIS and TIME, the relationships involving these variables were both strongly significant and in the same direction as in the case of the work trip model.

There were a number of important differences between the work trip models and the corresponding nonworktrip models, however. First, all of the nonwork trip models that did not contain the attitudinal variable were statistically stronger than the corresponding work trip models. Second, although women were more likely to be choosers in the work trip models, for all nonwork trip models men were more likely to be choosers (statistically significant). Perhaps this finding reflects household priorities on automobile availability for particular trips. The final difference was that the attitudinal variable was of much less importance for the nonwork trip model. The nonwork trip model containing this variable was actually statistically weaker than the corresponding work trip model. Further, when the nonwork trip model using this variable was compared to the model using the second set of independent variables, the amount of improvement was small.

The major conclusion for the case of the most frequent nonwork trip is, not surprisingly, similar to the earlier conclusion for the work trip models. Although the information on the perception of modal attributes proved to be of less importance, specific information on the available modes, especially the travel time, resulted in an improvement in model performance.

Table 1. Scale values of age and socioeconomic variables.

Scale Value	AGE (years)	INC ($)	OCC
1	18 to 24	Under 4000	Higher executives of larger concerns, proprietors, major professionals
2	25 to 34	4000 to 7999	Business managers, proprietors of medium-sized businesses, lesser professionals
3	35 to 44	8000 to 11 999	Administrative personnel, owners of small businesses, minor professionals
4	45 to 54	12 000 to 14 999	Clerical and sales workers, technicians, owners of smaller businesses
5	55 to 64	15 000 to 24 999	Skilled manual workers
6	65 to 74	25 000 to 49 999	Machine operators and semi-skilled manual workers
7	75 and older	50 000 and more	Unskilled manual workers

CONCLUSION

This paper explores the implications of one of the decisions necessary to the development of specific mode choice models: the question of the criteria for separating choosers from captives. The issue of how those who perceive the existence of a choice of mode for a trip are distinguished from those who feel they are captive to a mode is examined.

The key conclusion from the empirical tests is that models containing information on the modes perform better than models containing only locational or personal descriptions of the individuals. From this conclusion various implications concerning prediction, travel behavior, and transportation policy emerge.

Before these implications are discussed, however, it is useful to mention several alternative approaches that might be tried in future studies of this nature. Such approaches might lead to somewhat different conclusions and implications from those of this study.

The subjective information on trip making (trip distance, travel time, cost) could be replaced by the corresponding objectively measured variables. Such an approach might make some difference in model structure and would also facilitate the use of the models for practical purposes. The nature of the independent variables used in the models could also be altered. Specifically, more information on the conceivably available alternatives could be used in place of information on only the chosen alternative. (The latter strategy was chosen here because only those who perceive the existence of a given alternative reported on its characteristics.) Information on all of the alternative modes could be used

Table 2. Models to distinguish choosers from captives for both work trip and most frequent nonwork trip.

		Equation 1		Equation 2		Equation 3		Equation 4	
Trip	Variable	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Work	Constant	0.51	1.20	-0.038	1.20	-0.11	1.16	0.050	1.29
	AGE	-0.027	0.15	-0.11	0.16	-0.024	0.15	-0.036	0.18
	SEX	0.47	0.44	0.41	0.45	0.56	0.43	0.75	0.50
	C/DL	-0.29	0.66	-0.31	0.67	-0.18	0.66	-0.38	0.76
	INC	-0.14	0.15	-0.063	0.16	-0.14	0.15	-0.017	0.17
	TDIS	-0.058[a]	0.028	-0.12[a]	0.047			-0.11[a]	0.047
	BDIS	-0.068	0.18						
	TIME			0.047	0.026	-0.0036	0.016	0.056[a]	0.028
	COST					-0.0025	0.0040		
	CSAT							0.032[b]	0.0094
	ρ^2	0.06		0.09		0.03		0.20	
Nonwork	Constant	0.89	0.89	-0.23	0.97	0.11	0.96	0.10	1.02
	AGE	-0.033	0.11	-0.046	0.11	-0.058	0.11	-0.049	0.11
	SEX	-1.11[b]	0.39	-1.11[b]	0.42	-1.07[b]	0.41	-1.09[b]	0.42
	C/DL	-0.75	0.47	-0.44	0.52	-0.46	0.50	-0.42	0.51
	OCC	0.25[a]	0.10	0.23[a]	0.11	0.21	0.11	0.21	0.11
	TDIS	-0.016	0.019	-0.12[b]	0.039			-0.12[b]	0.040
	BDIS	-0.12	0.16						
	TIME			0.073[b]	0.022	0.056[b]	0.017	0.070[b]	0.023
	COST					-0.016[a]	0.0061		
	CSAT							0.0062	0.0062
	ρ^2	0.07		0.143		0.139		0.15	

Note: For work trip models, N = 104 (46 choosers and 58 captives). For nonwork trip model, N = 173 (53 choosers and 120 captives).

[a]Logit coefficient significant at $p < 0.05$. [b]Logit coefficient significant at $p < 0.01$.

to form generalized prices or other accessibility measures in the binary case or could be disaggregated in the case of a multinomial model that distinguishes among various types of choosers and captives.

In terms of predicting which people will be choosers or captives and, ultimately, modal split, the results do not imply whether using the subjective criterion of separating choosers from captives is more satisfactory than using objective criteria. This issue was not addressed directly. However, given the fact that specific information about the modes in question appears to be desirable in the models examined here, using objective criteria may be simpler and more straightforward for practical purposes. This depends on the accuracy of the objective criteria in specifying that those who are assumed to be modal captives actually use that mode and on the accuracy of the corresponding choice model. The suggestion also is more applicable to the case of the work trip because of the greater importance of the attitudinal variable and the rather poor fit of the models not including this variable.

The important feature of the results in terms of explaining travel behavior is the apparent dependence of the perception of the availability of transportation alternatives on specific features of the trip-making experience. This dependence suggests that the decision to be a chooser or a captive might be a short-range rather than long-range transportation decision. It also leaves open the possibility that mode choice and the perception of the availability of alternatives occur simultaneously. In any event, the fact that whether a person is a chooser depends on his trip-making behavior is of theoretical, and possibly practical, importance.

Finally, the results are of possible importance to transportation policy makers. If one assumes that an alternative must be perceived to be available before it is used or even if one assumes that a transportation mode is valuable to citizens because of its option demand when it is perceived to be available for a given trip, as many economists might, knowledge of the factors that affect the perception of the availability of particular modes might be useful. In this regard, the positive relationship between being a chooser and travel time, as well as the positive relationship between the variables measuring the comparative satisfaction of the bus and car modes, is of primary interest. In terms of a policy maker who is interested in increasing the number of people who at least consider using some form of public transportation, a strategy of making the automobile relatively slower and of improving the attributes of the transit system relative to those of the automobile would appear to be effective.

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REFERENCES

1. M. Ben-Akiva. Alternative Travel Behavior Structures: Structure of Passenger Travel Demand Models. TRB, Transportation Research Record 526, 1974, pp. 59-64.
2. L. D. Burns, T. F. Golob, and G. C. Nicolaidis. Theory of Urban-Household Automobile-Ownership Decisions. TRB, Transportation Research Record 569, 1976.
3. D. P. Costantino, R. Dobson, and E. T. Canty. An Investigation of Modal Choice for Dual Mode Transit, People Mover, and Personal Rapid Transit Systems. TRB, Special Rept. 170, in preparation.
4. J. Guttman. Avoiding Specification Errors in Estimating the Value of Time. Transportation, Vol. 4, No. 1, March 1975, pp. 19-42.
5. C. A. Lave. Modal Choice in Urban Transportation: A Behavioral Approach. Department of Economics, Stanford Univ., PhD dissertation, 1968.
6. S. R. Lerman and M. Ben-Akiva. Disaggregate Behavioral Model of Automobile Ownership. TRB, Transportation Research Record 569, 1976.
7. T. E. Lisco. The Value of Commuters' Travel Time: A Study in Urban Transportation. Department of Economics, Univ. of Chicago, PhD dissertation, 1967.
8. T. E. Lisco. Common Economics of Travel Time Value. TRB, Special Rept. 149, 1974, pp. 103-115.
9. C. H. Lovelock. Consumer Oriented Approaches to Marketing Urban Transit. Urban Mass Transportation Administration, University Research and Training Grant CA-11-0008, Research Rept. 3, 1973.
10. D. McFadden. The Measurement of Urban Travel Demand. Journal of Public Economics, Vol. 3, No. 4, Nov. 1974, pp. 303-328.
11. D. McFadden and F. Reid. Aggregate Travel Demand Forecasting From Disaggregated Behavioral Models. TRB, Transportation Research Record 534, 1975, pp. 24-37.
12. D. A. Quarmby. Choice of Travel Mode for the Journey to Work: Some Findings. Journal of Transport Economics and Policy, Vol. 1, No. 3, 1967, pp. 1-42.
13. S. Reichman. Subjective Time Savings in Interurban Travel: An Empirical Study. HRB, Highway Research Record 446, 1973, pp. 21-27.
14. S. Reichman and P. R. Stopher. Disaggregate Stochastic Models of Travel-Mode Choice. HRB, Highway Research Record 369, 1971, pp. 91-103.
15. P. R. Stopher. Factors Affecting Choice of Mode of Transport. University College, London, PhD dissertation, 1967.
16. P. R. Stopher. Discussion of paper, Alternative Travel Behavior Structures. TRB, Transportation Research Record 526, 1974, pp. 56-57.
17. P. R. Stopher and J. O. Lavender. Disaggregate Behavioral Travel Demand Models: Empirical Tests of Three Hypotheses. Transportation Research Forum, Vol. 13, 1972, pp. 321-335.
18. T. J. Tardiff. The Effects of Socioeconomic Status on Transportation Attitudes and Behavior. School of Social Sciences, Univ. of California, Irvine, PhD dissertation, 1974.