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AN ATTITUDINAL TRAVEL DEMAND MODEL FOR NON-WORK TRIPS OF HOMOGENEOUSLY CONSTRAINED SEGMENTS OF A POPULATION

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Abstract—Market segmentation techniques are used to capture effects of opportunity and availability constraints on urban residents' choice of mode for trips for major grocery shopping and for visiting friends and acquaintances. Attitudinal multinomial logit choice models are estimated for each market segment. Explanatory variables are individual's beliefs about attributes of four modal alternatives: bus, car, taxi and walking. Factor analysis is employed to identify latent dimensions of perception of the modal alternatives and to eliminate problems of multicollinearity in model estimation.

INTRODUCTION

A fundamental assumption of any cross-sectional analysis of choice behavior is the homogeneity of the sample with respect to the structure of the decision process. Previous cross-sectional analyses in transportation demand modeling either have inherently assumed such homogeneity existed or have attempted to control for inhomogeneity in the choice mechanism by removing so-called "captives" from the sample before model estimation. In a recent attitudinal study of modal choice for the work and shop trips Recker and Golob (1976a,b) present evidence to support the hypothesis that significant inhomogeneity in both indivuals' perception of modal alternatives and also in actual choice behavior exists, in general, and is principally attributable to variations in supply-side constraints faced by these individuals.

In this study, use of market segmentation techniques to account for non-compensatory supply-side constraints on travel choice is extended to include destination opportunities as well as accessibility to modes as dimensions in the choice-constraint space. The choice situation considered is that of individuals' choice of mode of transport for two non-work trips; (1) major grocery shopping, and (2) visiting friends and acquaintances. The models developed are probabilistic, of the strict utility genre incorporating the travelers' beliefs regarding a set of descriptive attributes of modal alternatives (car, bus, taxi and walking) as explanatory variables.

The data used in this study were collected through an attitudinal home interview survey administered in the city of Buffalo, New York, in the Spring of 1974. The city of Buffalo is part of an SMSA of 1.35 million persons that extends over two counties and has a population of approximately 462,000 persons.

The sample selection for the survey was based on a random sampling of five separate areas of the city chosen on the basis of mean car ownership, mean income and level of bus use. The survey was administered to 397 respondents including 105 who were classified in households that had no car.

Information on attitudes toward existing transportation alternatives was collected in the form of a seven-point Likert scale of survey respondents' agreement with statements regarding a set of descriptive attributes of automobile, bus, taxi and walk modes of travel. The scale ranged from -3 to $+3$ ratings (-3 for strong agreement with the statement and $+3$ for strong disagreement with the statement). The actual questions used in this study are reproduced in the Appendix.

To facilitate interpretation of results of analyses, statements with negative descriptors were rewritten as positive counterparts and the signs of corresponding responses were reversed. The statement "Buses are unsafe", for example, was changed to "Buses are safe" and a disagreement with the original attribute was converted to an agreement with the new question. A dictionary of the attributes and abbreviations of terms used in the models also appears in the Appendix.

CHOICE CONSTRAINT SEGMENTATION

Choice constraint segmentation was performed along two major facets of the supply-side: (1) individual's accessibility to alternative modes, and (2) relative number of destination opportunities attainable by the individual within prescribed time limits by the various alternative modes of travel. Since by survey design all respondents lived within 5 min walking distance to a bus stop (and those few who indicated they had difficulty walking were removed from the sample) variance in individuals' accessibility to alternative modes was limited to accessibility to the automobile. Two dimensions were used to measure individuals' accessibility to an automobile: (1) household automobile ownership, and (2) possession of a valid driver's license. To capture the destination opportunity characteristics of the supply-side the number of destinations (appropriate to each activity considered) attainable by each of the modal alternatives within specified time limits from the individual's residence was determined. In the calculations, travel-times by automobile and by taxi

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were assumed equal (waiting time for taxi assumed to be preplanned), travel times by bus included walking time, waiting time as well as actual riding time, and the number of destinations used for the grocery shopping trip and for visiting friends and acquaintances were the number of grocery stores and the population count, respectively. For each of the two activities considered, a two-dimensional measure of destination opportunities was constructed for each individual as (1) the ratio of the number of appropriate destinations attainable by bus to the number attainable by automobile, and (2) the ratio of the number of appropriate destinations attainable by walking to the number by automobile. In determining these ratios a time limit of 30 min was assumed since very few individuals in the sample traveled more than that time for any activity measured and a large proportion indicated 30 min as an upper limit to the time they were willing to spend in travel for the two activities. Furthermore, measures constructed using other time limits were highly correlated with that chosen.

The mode accessibility and destination opportunity measures were used to segment the sample into homogeneous groups relative to supply-side conditions measured in terms of the four dimensions:

(1) number of automobiles owned by the household

(2) possession of a valid driver's license

(3) relative number of destinations attainable by bus from home within 30 min

(4) relative number of destinations attainable by walking from home within 30 min.

The variables were standardized to zero mean and unit variance to eliminate clustering bias due to scale differences. This standardization also enables interpretation of the resulting cluster centers in terms of deviations from the means, allowing meaningful interpretation for market segmentation.

The ISODATA clustering algorithm (Ball and Hall, 1967) was used to identify subgroups of the sample population which are relatively homogeneous with respect to the supply-side constraint measures. With the algorithm groups or segments are constructed such that the average response pattern calculated from the patterns within a group is reasonably typical of that group. Any response pattern in a group more closely corresponds to the average response in its own group than the average response pattern of any other group. The number of clusters was determined by an iterative search process employing as a criterion a pseudo F-ratio of the total between-group variance divided by its degrees of freedom to the pooled within-group variance divided by its degrees of freedom.

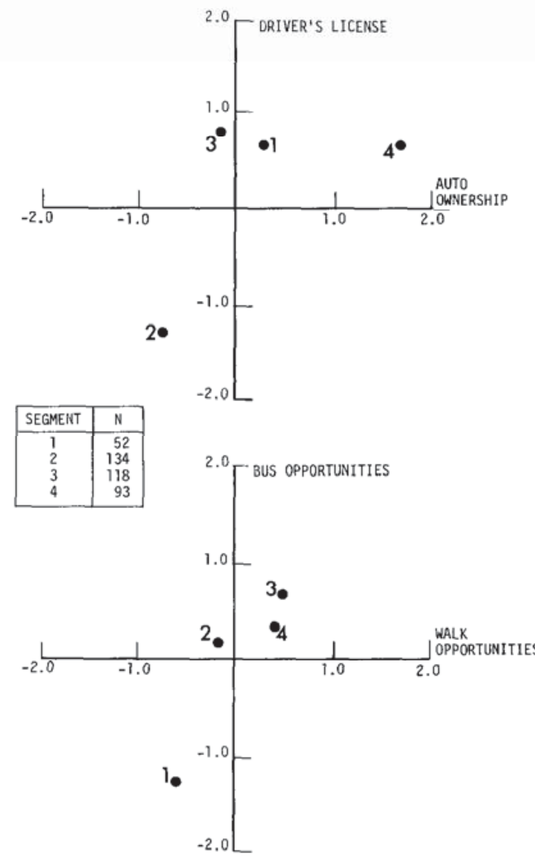

Fig. 1. Cluster centers associated with major grocery shopping trip.

RESULTS OF THE CLUSTER ANALYSIS—MAJOR GROCERY SHOPPING

For the case in which destinations were associated with a major grocery shopping trip the 397 respondents were found to be best segmented into four clusters. The stability of the resulting clusters was confirmed by performing sensitivity analyses with respect to cluster centers. The positions of the four group centroids in the four-dimensional mode accessibility/destination opportunity standardized space were used to interpret the segments (Fig. 1). Segment 1, labeled the "Mobile/Low Non-Auto Opportunities" group, is composed of individuals who possess a driver's license and are in households with slightly greater than the mean (total sample) number of automobiles. Individuals in this group are located in areas in which relatively few grocery stores can be reached within 30 min either by bus or by walking. Segment 2, labeled the "Carless/Mean Non-Auto Opportunities" group, has the lowest auto ownership and is composed of individuals without driver's licenses. Individuals in this group have about the sample mean number of grocery shopping destinations attainable by non-auto modes within 30 min. Individuals in group 3, labeled the "Mobile/High Non-Auto Opportunities" group are similar to those in segment 1 with respect to their accessibility to the auto. However, unlike segment 1, this segment is in a highly favorable position with respect to accessibility to grocery stores by non-auto modes. Individuals in segment 4 are differentiated from their counterparts in segment 3 by their high level of household automobile ownership and are labeled the "Highly Mobile/High Non-Auto Opportunities" group.

RESULTS OF THE CLUSTER ANALYSIS-VISITING FRIENDS AND ACQUAINTANCES

For the cluster analysis associated with trips to visit friends and acquaintances the destination opportunities used were the total population that could be reached in a 30 min period by walking and by bus, normalized to the corresponding number associated with travel by automobile. As was the case for major grocery shopping, the respondents were found to be best segmented into four groups, the centroids of which are shown in Fig. 2. Segment 1, labeled the "Mobile/High Walk Opportunities" group, is composed of individuals with accessibility to auto approximately equal to the sample mean, located in densely populated areas that are poorly serviced by bus. Segment 2, labeled the "Carless/Mean Non-Auto Opportunities" group, is almost identical to its counterpart for the grocery shopping trip. Individuals in segments 3 and 4, labeled the Mobile/High Non-Auto Opportunities" and "Highly Mobile/Low Non-Auto Opportunities" groups, respectively, have high auto accessibility but are differentiated by the relative number of destinations attainable by non-auto modes.

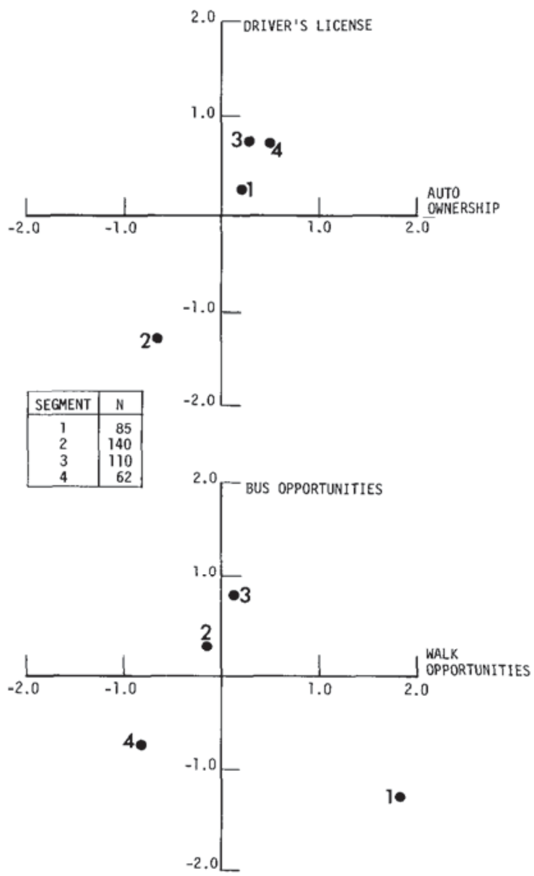

Fig. 2. Cluster centers associated with visiting friends and acquaintances.

INDIVIDUALS' PERCEPTIONS OF MODAL ALTERNATIVES

To remove problems of multi-collinearity in the explanatory variable sets and to identify latent dimensions of the attribute spaces associated with individuals' perceptions of the attributes of modal alternatives, factor analysis of the perception space is employed for each of the groups identified through the cluster analyses that had sufficient membership to yield reliable statistical results. Separate factor analyses of the perceptions of the "Mobile/Low Non-Auto Opportunities" and "Highly Mobile/High Non-Auto Opportunities" groups associated with the grocery shopping trip and of the "Mobile/High Walk Opportunities" and "Highly Mobile/Low Non-Auto Opportunities" groups associated with trips for visits were not attempted due to sample size restrictions. The specific intent of the factor analysis is the identification of selected attributes as relatively uncorrelated measures representative of the latent dimensions of the choice alternatives. Use of such methods to identify selected attributes as representative of the latent factors of mode choice (Hartgen and Tanner, 1971; Constantino, Golob and Stopher, 1974, Recker and Golob, 1976a, 1976b) aids not only in developing a better understanding of decision making behavior, but also can lead to a simpler model parameter specification.

Correlation matrices for the ratings of the attributes of each of the mode choice alternatives by individuals in the four groups with sufficient membership (i.e. the "Carless/Mean Non-Auto Opportunities" and "Mobile/High Non-Auto Opportunities" groups associated both with the grocery shopping trip and with trips for visiting friends and acquaintances) were factored using principal components analysis (Harman, 1967) and a varimax orthogonal rotation (Kaiser, 1958) performed on each factor set to facilitate interpretation. Attributes included in the factor analyses were determined by an iterative process in which attributes having low correlations (factor loadings) with respect to the factors retained were deleted from the correlation matrices and adjusted matrices refactored until only significant attributes remain in single factors (Recker and Stevens, 1976). Attributes included in the final factors are termed "factorable" attributes and those deleted "non-factorable" attributes.

The number of factors retained for each modal alternative was determined by a comparison of the set of eigenvalues obtained from analysis of the correlation matrices with those obtained from random data matrices of the same order and also by consideration of the "Kaiser rule" in which eigenvalues > 1.0 are retained (Horn, 1965).

Expectedly, both because of high common membership in the "Carless/Mean Non-Auto Opportunities" groups and in the "Mobile/High Non-Auto Opportunities" groups† and also because individuals faced with similar supply-side conditions can be expected to exhibit similar modal perception spaces (see e.g. Recker and Golob, 1976b), the separate factor analyses identified factor spaces that were virtually identical for groups corresponding to similar supply-side conditions for shopping trips and for trips to visit.

Principal components analyses of the ratings of the attributes of the modal alternatives for the "Carless/Mean Non-Auto Opportunities" groups, hereafter simply called

†Seventy eight percent of individuals classified as being either in the "Carless/Mean Non-Auto Opportunities" group for grocery shopping or in the "Carless/Mean Non-Auto Opportunities" group for visits to friends and acquaintances were in both. The corresponding commonality measure for the "Mobile/High Non-Auto Opportunities" groups was 63%.

the "Carless" groups, resulted in selection of three factors to represent bus, two factors to represent car, three factors to represent walking and two factors to represent taxi. The factors retained for the groups for each of the modal alternatives are shown in Table 1. The "factor description" column gives a subjective label for each factor and is an attempt to define and interpret the corresponding factor in a concise manner. The "dominant attributes in factor" column lists those attributes with loadings for each factor which are significantly different from zero.

Table 1. "Carless" groups modal perception factors

MODE	FACTOR DESCRIPTION	DOMINANT ATTRIBUTES IN FACTOR
BUS	SERVICE	RELIABILITY PUNCTUALITY FLEXIBILITY PARCEL CONVENIENCE ROUTE FAMILIARITY
	COMFORT	COMFORT PRIVACY SAFETY
	SOCIAL STATUS	CLASS OF RIDERS STATUS
CAR	FLEXIBILITY & SOCIAL STATUS	FLEXIBILITY PRIVACY ADDED OPPORTUNITIES STATUS
	COST & SAFETY	COST SAFETY
WALK	CONVENIENCE	TIME WEATHER PARCEL CONVENIENCE STATUS
	PERSONAL SAFETY	NIGHT SAFETY DAY SAFETY GETTING LOST
	EFFORT	EFFORT GETTING LOST CROSSINGS ADEQUATE SIDEWALKS
TAXI	SERVICE	COURTESY WAITING TIME DRIVING CAPABILITY
	COST	COST HONESTY

As shown in Table 1, members of the "Carless" groups perceive the bus to be described along three dimensions: service, comfort and social status. Unlike bus, the compositions of the perception factors obtained for car attributes are not easily explained. The first factor, labeled "flexibility and social status", includes elements of privacy and status together with the increased flexibility in destination choice offered by car. The second factor, labeled "cost and safety", pairs intuitively dissimilar attributes "cost and safety", while a third aspect, "enjoyment", is a non-factorable descriptor (Table 2). Walk perception factors are aligned along convenience, personal safety and effort dimensions. For taxi, "service" and "cost" dimensions are supplemented by perception of "safety", a non-factorable attribute.

Table 2. "Carless" groups non-factorable variables

MODE	NON-FACTORABLE ATTRIBUTES
BUS	COST NIGHT SAFETY DAY SAFETY CONVENIENCE GROCERY PRACTICALITY TRANSFERS
CAR	ENJOYMENT
WALK	--------------------
TAXI	SAFETY

Factor spaces, and non-factorable attributes associated with the "Mobile" groups' perceptions (hereafter, referred to as the "Mobile") of modal alternatives are shown in Table 3 and Table 4, respectively. As with their counterparts in the "Carless" groups, members of these groups perceive bus to be described along three dimensions. For the latter groups, however, the service dimension has been expanded to include "cost" and "vehicle transfer". In addition, the comfort dimension associated with the former groups has been more sharply defined by the "Mobile" groups with the inclusion of aspects of personal safety while waiting for the bus as a "personal security" dimension. The third dimension of perception of bus is associated with the practicality of bus for carrying articles. The inclusion of the attribute "status" in this factor may be explained by the inescapable conclusion that individuals who must resort to using the bus for such shopping cannot afford taxi and simply do not own a car.

The "flexibility and social status" factor identified for the "Carless" groups has split into two factors, "flexibility and status" and "personal automomy", for the "Mobile" groups reflecting, perhaps, their greater familiarity with

Table 3. "Mobile" groups modal perception factors

MODE	FACTOR DESCRIPTION	DOMINANT ATTRIBUTES IN FACTOR
BUS	SERVICE	RELIABILITY PUNCTUALITY FLEXIBILITY COST CONVENIENCE ROUTE FAMILIARITY TRANSFERS
	PERSONAL SECURITY	COMFORT PRIVACY NIGHT SAFETY DAY SAFETY SAFETY
	PRACTICALITY	STATUS PARCEL CONVENIENCE GROCERY PRACTICALITY
CAR	FLEXIBILITY & STATUS	FLEXIBILITY STATUS ENJOYMENT
	PERSONAL AUTONOMY	PRIVACY ADDED OPPORTUNITIES
	COST & SAFETY	COST SAFETY
WALK	CONVENIENCE	WEATHER PARCEL CONVENIENCE
	PERSONAL SAFETY	NIGHT SAFETY DAY SAFETY
	EFFORT	EFFORT TIME GETTING LOST
	SYSTEM SUITABILITY	CROSSINGS ADEQUATE SIDEWALKS
TAXI	SERVICE	COURTESY WAITING TIME DRIVING CAPABILITY
	COST	COST HONESTY SAFETY

Table 4. "Mobile" groups non-factorable variables

MODE	NON-FACTORABLE VARIABLES
BUS	CLASS OF RIDERS
CAR	--------
WALK	STATUS
TAXI	--------

aspects of the car. The remaining dimension, "cost and safety", is identical for both groups.

The most significant differences in modal perceptions between the groups occurs for the walk mode. Not only do individuals in the "Mobile" groups perceive walking as having one more dimension than do their counterparts in the "Carless" groups but also composition of the three factors identified as representing convenience, personal safety and effort dimensions for the previous groups has been significantly changed for the "Mobile" groups. The additional dimension associated with the present groups involves ambiant conditions for walking and is labeled "system suitability".

Factor perception spaces associated with taxi are virtually identical for all groups.

CHOICE MODEL

Individual's choice of a modal alternative for trips of specific purpose is assumed to be described by the multinomial logit form:

$$P_i^p(k: A_i) = \exp(V_i^{kp}) / \sum_{l \in A_i} \exp(V_i^{lp}) \qquad (1)$$

in which $P_i^p(K: A_i)$ = the probability that individual i will choose modal alternative k from a set of available alternatives A_i for trip with purpose p, and where; V_i^{kp} = the deterministic component of the utility of modal alternative k to individual i for trips with purpose p, measured in terms of the individual's expressed attitudes toward that alternative.

A detailed derivation of this type of strict-utility model, called the multinomial logic model, is provided by McFadden (1973); discussions of the rationale for the properties of such models are provided by Ben-Akiva (1973) and McFadden (1968, 1973) and arguments for distributional properties of the random components of utility leading to the multinomial form are advanced by Gumbel (1954).

In the formulation of eqn (1) it has been assumed that the deterministic component of utility can be specified solely in terms of individual i's attitudes toward alternative k. Situational variables, such as times and costs, and demographic characteristics are not explicitly included in the utility specification. Rather, it is purported that such influences are implicitly contained in the individual's attitutes toward aspects of the various alternatives. Such an approach is consistent with a goal of providing an understanding of urban travel developed from a behavioral framework rather than from strictly correlative relationships.

Consistent with social psychology theories of attitude and behavior (e.g. Fishbein, 1963) and with extensive market research applications in consumer buying behavior and information processing (e.g. Howard and Sheth, 1969), a utility form which is linear and additive in terms of attitudes toward the attributes of the alternatives is employed, e.g. it is assumed that

$$V_i^{kp} = \sum_{j \in S^{kp}} a_j^{kp} X_{ij}^k \qquad (2)$$

where a_j^{kp} = utility weight reflecting the importance of the jth attribute in contributing to the overall utility to individual i of modal alternative k for trips with purpose p. X_{ij}^k = manifest belief of individual i that alternative k possesses attribute j. S^{kp} = set of attributes associated with modal alternative k that are significantly determinant to choice for trips with purpose p; $S^{kp} = S_{NF}^{kp} + S_F^{kp}$, and S_F^{kp} = set of "factorable" attributes associated with modal alternative k that are significantly determinant to choice for trips with purpose p, S_{NF}^{kp} = set of "non-factorable" attributes associated with modal alternative k that are significantly determinant to choice for trips with purpose p.

The utility weights a_i^{kp} are assumed to be both mode and purpose specific and also invariant across individuals. This latter assumption underlies the use of cross-sectional analysis to estimate utility parameters. The mode-specific nature of the weights is dictated by the interpretation of explanatory variables as representing latent dimensions of perceptions of the modes; dimensions which, as determined by the factor analyses, are not coincident.

While factor scores more properly take up the contribution of attributes in the factorable set S_F^{kp}, specification of a choice model in terms of latent factors as explanatory variables leads to major problems in interpretation of results and prediction of consequences. As a result, in the specification of the choice model only a single selected attribute from each of the factors is used as representative of the corresponding factor. As intercorrelations among attributes with high loadings on each of the factors approach unity in absolute magnitude this approximation becomes exact; a detailed derivation of the error involved for intercorrelations which are not unity in absolute magnitude is contained in Recker and Golob (1976a). The choice criteria for selecting representative attributes must be related to specific planning objectives. From each factor significantly determinant to choice that component with high loading which is policy-sensitive in the particular application would be selected.

APPLICATION

The utility weights of the modal choice model specified by eqn (2) were estimated for the "Carless" groups and for the "Mobile" groups using maximum likelihood techniques for two non-work activities: (1) major grocery shopping, and (2) visiting friends and acquaintances. Modal alternatives consisted of: (1) bus, (2) car, (3) walk, and (4) taxi. Choice was determined as the mode most frequently used for the associated activity.

Only attributes with estimated coefficients which are significantly different from zero at the 95% confidence level were included in the model estimations. This significance test was performed by comparing the ratio of the coefficient values to their estimated standard errors, which are asymptotically distributed as t-statistics in a linear model (Theil, 1971), to a critical value of approximately 1.65. This represents a one-tailed test of the null hypothesis for each variable. All attributes with coefficients insignificantly different from zero at this confidence level were not included in the final estimations.

In addition, only a single representative variable, chosen on the basis of the t-statistic, from any given factor was allowed in the model estimation. The resulting explanatory variables were thereby almost completely mutually uncorrelated.

Because of the lack of goodness-of-fit measures with well-defined statistical properties (such as the linear regression coefficient of determination, R^2) for such probabilistic choice models (see Burns, Golob, Nicolaidis, 1975), emphasis was placed on coefficient significance tests and on predictive performance criteria for evaluating the models. One such indicator is the ratio of choices predicted correctly by the models, determined as the ratio of the number of times the predicted probability of the chosen alternative is greater than that of a non-chosen alternative to the total number of choices. This ratio was also categorized by alternative chosen to better identify strengths and weaknesses of the models. In addition, a measure known as "pseudo R^2" (or ρ^2) and apparently attributable to McFadden (1968) was used to evaluate the models. This measure,

$$\rho^2 = 1 - \log [L(\theta)/L(0)] \tag{3}$$

where $L(\theta)$ = likelihood function value for the vector of estimated coefficients θ, and $L(0)$ = likelihood function value with all coefficients set equal to zero, is a nonlinear analogy of the multiple correlation coefficient and, while not having well-defined distributional properties so that significance levels can be defined, can provide comparative goodness-of-fit information for models of approximately equal sample sizes and number of explanatory variables.

To assess sensitivities of the choice probabilities to changes in the explanatory variables aggregate elasticities were calculated as:

$$E_j^{klp} = \frac{\sum_{i=1}^{N} [P_i^p(k:A) E_{ij}^{klp}]}{\sum_{i=1}^{N} P_i^p(k:A)}$$

where E_k^{klp} = aggregate elasticity of the probability of choosing alternative k for trips with purpose p with respect to uniform changes in the perceived evaluation of alternative l on attribute j for all $i = 1, \ldots, N$ individuals; E_{ij}^{klp} = elasticity of the probability that alternative k is chosen by individual i for trip with purpose p with respect to the rating by individual i of alternative l on attribute j.

$$= X_{ij}^l \sum_{q \in A_i} P_i^p(q:A_i) \left(\frac{\partial V_i^{kp}}{\partial X_{ij}^l} - \frac{\partial V_i^{qp}}{\partial X_{ij}^l} \right).$$

A detailed derivation of this elasticity measure is contained in Recker and Golob (1976a) and employs principles developed by Warner (1962) and Ben-Akiva (1973).

1. *Results—"carless" group*

Maximum likelihood estimates of the modal choice model given by eqn (1) were obtained for the major grocery shopping trip and for trips to visit friends and acquaintances for the "Carless" group. Displayed in Table 5 for the major grocery shopping trip are: the a_i^{kp} coefficients for variables described in eqn (2), the factors

Table 5. Logit modal choice model—major grocery shopping "Carless" group

VARIABLE	FACTOR	COEFFICIENT	t	ELASTICITY	CROSS-ELASTICITY
WALK-EFFORT	EFFORT	0.515	4.82	0.496	-0.719
CAR-FLEXIBILITY	FLEXIBILITY & SOCIAL STATUS	0.247	3.32	0.379	-0.357
BUS-STATUS	SOCIAL STATUS	0.409	2.44	0.739	-0.164
CONSTANT	-----	-1.38	-3.21	---	---

$\rho^2 = 0.301$

PERCENT OF CHOICES PREDICTED CORRECTLY	= 80.3 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN CAR WAS THE CHOSEN MODE (41.5% OF TOTAL CASES)	= 83.1 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN BUS WAS THE CHOSEN MODE (3.2% OF TOTAL CASES)	= 33.3 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN TAXI WAS THE CHOSEN MODE (4.9% OF TOTAL CASES)	= 14.3 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN WALK WAS THE CHOSEN MODE (50.4% OF TOTAL CASES)	= 87.4 %

represented by these variables, the t values associated with the estimations and the aggregate elasticities and cross elasticities of choice probability with respect to the variables. Also shown in Table 5 are goodness-of-fit measures: ρ^2 and model prediction ratios.

The results of this model estimation indicate that individuals classified within the "Carless" group base their modal choice decisions associated with grocery shopping primarily on three factors: effort involved in walking, the destination flexibility and social status associated with the automobile and the social status identified with using the bus. No variables in factors other than those mentioned could be found with estimated coefficients that were significantly different from zero and, hence, were not included in the estimation. No taxi attribute could be found with a significant estimated coefficient; instead, a constant was assigned to this mode and was found to be significantly different from zero indicating, for this group, that factors other than those described by the evoked set of attributes may be influencing choice relative to the taxi.

Choice of mode for this case is seen to be relatively inelastic with respect to the explanatory variable subset. Only the status dimension of bus approaches an elastic variable. Model goodness-of-fit indices shown in Table 5 are judged to be good for such probabilistic choice models. About 80% of the choices are predicted correctly through utility comparisons using the estimated parameters, and only for infrequently chosen modes is the explanatory power of the model questionable.

Shown in Table 6 are results of the model estimation for this group for trips to visit friends and acquaintances. While some loss in explanatory power of the model (compared to that associated with major grocery shopping trips) is evidenced by the ρ^2 value, prediction ratios for this model remain high.

Choice of mode for visiting friends and acquaintances is seen to be more complex than the corresponding choice for major grocery shopping trips for individuals in the "Carless" group. Whereas choice is determined by only three factors in the latter case, five factors are determinant to choice of mode for visits. Aspects of walking account for two of the factors with the addition of a "convenience" dimension to the "effort" factor which

Table 6. Logit modal choice model—visits to friends and acquaintances "Carless" group

VARIABLE	FACTOR	COEFFICIENT	t	ELASTICITY	CROSS-ELASTICITY
CAR-PRIVACY	FLEXIBILITY & SOCIAL STATUS	0.277	3.16	0.461	-0.268
WALK-TIME	CONVENIENCE	0.295	3.15	0.392	-0.431
TAXI-COST	COST	0.464	2.45	0.777	-0.217
WALK-ADEQUATE SIDEWALKS	EFFORT	0.216	2.14	0.237	-0.267
BUS-PUNCTUALITY	SERVICE	0.210	1.61	0.328	-0.078

$\rho^2 = 0.188$

PERCENT OF CHOICES PREDICTED CORRECTLY	= 74.6 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN CAR WAS THE CHOSEN MODE (29.6% OF TOTAL CASES)	= 74.6 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN BUS WAS THE CHOSEN MODE (15.4% OF TOTAL CASES)	= 35.1 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN TAXI WAS THE CHOSEN MODE (2.1% OF TOTAL CASES)	= 20.0 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN WALK WAS THE CHOSEN MODE (52.9% OF TOTAL CASES)	= 88.2 %

was also found to be a significant determinant of choice for major grocery shopping. The flexibility and social status associated with car continued as an important consideration in modal choice and cost of taxi emerged as the single attribute contributing to its low use by this group (Taxi was used most frequently by only 2% of individuals in this group). The social status aspect of bus, which was found to be an important consideration for major shopping trips, has been replaced by its service characteristics in the model for visits. It may be argued that, while carrying grocery bags on a bus may lead to the rather inescapable conclusion (and resultant social stigma) by others that the individual does not have access to a car, such inferences are less likely if the purpose of the rider's bus trip is not evident. With the security of anonymity of economic class the individuals' consideration switches to aspects of service rendered.

As with major grocery shopping, modal choice for visiting friends and acquaintances for the "Carless" group is relatively inelastic with respect to the subset of explanatory variables. However, significant increases in probability of choosing taxi for this group of "Carless" individuals may be realized with decreases in fare.

2. *Results—"mobile" group*

Shown in Tables 7 and 8 are results of maximum likelihood estimates of modal choice models for major grocery shopping and for visits to friends and acquaintances for the "Mobile" group.

Modal choice of individuals in this group for the major grocery shopping trip is described by a larger subset of variables (Table 7) than that associated with their counterparts in the "Carless" group. The importance of flexibility and status associated with car to individuals in the latter group is maintained by individuals in this group. However, the aspect accounting for the greatest amount of explanatory power in this model is personal autonomy derived from the automobile—an aspect which is not a determinant to choice among individuals in the "Carless" group. The high cross-elasticity associated with this dimension indicates substantial diversions from the automobile can be expected with perceived decreases in privacy associated with this mode.

Table 7. Logit modal choice model—major grocery shopping "Mobile" group

VARIABLE	FACTOR	COEFFICIENT	t	ELASTICITY	CROSS-ELASTICITY
CAR-PRIVACY	PERSONAL AUTONOMY	0.569	5.15	0.238	-1.356
CAR-FLEXIBILITY	FLEXIBILITY & STATUS	0.325	2.64	0.146	-0.792
BUS-GROCERY PRACTICALITY	PRACTICALITY	0.640	2.10	1.202	-0.113
BUS-RELIABILITY	SERVICE	0.764	1.94	1.371	-0.232
WALK-TIME	EFFORT	0.169	1.70	0.480	-0.082
TAXI-COST	COST	0.345	1.66	0.583	-0.175

$\rho^2 = 0.587$

PERCENT OF CHOICES PREDICTED CORRECTLY	= 92.2 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN CAR WAS THE CHOSEN MODE (82.9% OF TOTAL CASES)	= 99.5 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN BUS WAS THE CHOSEN MODE (1.2% OF TOTAL CASES)	= 66.7 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN TAXI WAS THE CHOSEN MODE (0.0% OF TOTAL CASES)	= 0.0 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN WALK WAS THE CHOSEN MODE (15.9% OF TOTAL CASES)	= 56.4 %

Table 8. Logit modal choice model visits to friends and acquaintances

VARIABLE	FACTOR	COEFFICIENT	t	ELASTICITY	CROSS-ELASTICITY
CAR-PRIVACY	PERSONAL AUTONOMY	0.710	7.73	0.407	-1.612
BUS-NIGHT SAFETY	PERSONAL SECURITY	0.407	2.08	0.607	-0.084
TAXI-COST	COST	0.318	1.69	0.627	-0.081
WALK-TIME	EFFORT	0.187	1.28	0.293	-0.072

$\rho^2 = 0.436$

PERCENT OF CHOICES PREDICTED CORRECTLY	= 86.6 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN CAR WAS THE CHOSEN MODE (78.0% OF TOTAL CASES)	= 97.3 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN BUS WAS THE CHOSEN MODE (5.9% OF TOTAL CASES)	= 28.6 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN TAXI WAS THE CHOSEN MODE (2.5% OF TOTAL CASES)	= 16.7 %
PERCENT OF CHOICES PREDICTED CORRECTLY WHEN WALK WAS THE CHOSEN MODE (13.6% OF TOTAL CASES)	= 56.3 %

Unlike their counterparts in the "Carless" group, individuals in this group are less concerned with social status aspects of bus and, conversely, are more concerned with service and practicality characteristics of bus in their choice of mode for grocery shopping. In fact, elasticities corresponding to these two latter attributes indicate significant increases in the choice probabilities of bus can be expected with positive changes in these individuals' perceptions of such characteristics. It must be emphasized, however, that such potential increases are applied to a base choice probability that is, in general, extremely low for individuals in this group. The de-emphasis of considerations of status in modal choice of individuals in this group may be reflective of their low level of use of bus for grocery shopping or for any other purpose. Members of the "Carless" group, on the other hand, may be more keenly aware of the realities of bus travel.

As with individuals in the previous group, persons in this group view effort involved with walking as a significant determinant of modal choice for shopping.

Model estimation results for the "Mobile" group for visits to friends and acquantances, shown in Table 8, are more contrasted with results corresponding to the "Carless" group (Table 6) by differences in underlying perceptions of the two groups than by composition of the respective explanatory variable subsets in the models. While the "privacy" attribute of car is included as significant in both models it is interpreted as representing a dimension describing the car's flexibility and social status to individuals in the "Carless" group and as representing the more sharply-defined dimension "personal autonomy" (which is composed of attributes that are a subset of those contained in the former factor) to individuals in the "Mobile" group. Similarly, the attribute Walk-time, included in both models, is interpreted as representing an aspect of "effort" to individuals in the "Mobile" group while the same variable is interpreted by persons in the "Carless" group as representing a "convenience" dimension which is orthogonal to the "effort" dimension and also a significant determinant of modal choice for the "Carless".

CONCLUSIONS

Summary comparisons of factor and variable determinants to modal choice for the two activities considered for each of the groups are provided by Tables 9 and 10 in which aspects of the modal alternatives which are significant in the choice process are indicated by an "X". Significant differences in modal choice decision processes not only between "Carless" and "Mobile" individuals but also between activities for the same group are apparent. Among "Carless" individuals choice of mode for major grocery shopping is centered about considerations of social status and effort while for visiting friends and acquaintances these considerations are supplemented by aspects of cost and service. The decision process of "Mobile" individuals for grocery shopping is complex, involving aspects of service, status, effort, autonomy and cost. For social trips their decision process is simpler, focusing on elements of personal security, effort and cost.

Table 9. Factor and variable inclusions in models "Carless" group

	MODAL ASPECT	ACTIVITY	
		MAJOR GROCERY SHOPPING	VISITING FRIENDS & ACQUAINTANCES
FACTORS	BUS-SERVICE		X
	BUS-COMFORT		
	BUS-SOCIAL STATUS	X	
	CAR-FLEXIBILITY & SOCIAL STATUS	X	X
	CAR-COST & SAFETY		
	WALK-CONVENIENCE		X
	WALK-PERSONAL SAFETY		
	WALK-EFFORT	X	X
	TAXI-SERVICE		
	TAXI-COST		X
NON-FACTORABLE ATTRIBUTES	BUS-COST		
	BUS-NIGHT SAFETY		
	BUS-DAY SAFETY		
	BUS-CONVENIENCE		
	BUS-GROCERY PRACTICALITY		
	BUS-TRANSFERS		
	CAR-ENJOYMENT		
	TAXI-SAFETY		

Table 10. Factor and variable inclusions in models "Mobile" group

	MODAL ASPECT	ACTIVITY	
		MAJOR GROCERY SHOPPING	VISITING FRIENDS & ACQUAINTANCES
FACTORS	BUS-SERVICE	X	
	BUS-PERSONAL SECURITY		X
	BUS-PRACTICALITY	X	
	CAR-FLEXIBILITY & STATUS	X	
	CAR-PERSONAL AUTONOMY	X	X
	CAR-COST AND SAFETY		
	WALK-CONVENIENCE		
	WALK-PERSONAL SAFETY		
	WALK-EFFORT	X	X
	WALK-SYSTEM SUITABILITY		
	TAXI-SERVICE		
	TAXI-COST	X	X
NON-FACTORABLE ATTRIBUTES	BUS-CLASS OF RIDERS		
	WALK-STATUS		

Market segmentation techniques have been shown to be an effective procedure for including non-compensatory supply-side constraints in modal choice modeling processes. Differences in structure of perception of modal choice alternatives were found to be related to differences in supply-side conditions faced individuals. Whereas these differences in perception appear to be mostly subtle, differences in choice behavior among groups of individuals faced with various supply-side constraints can be significant. Important aspects of the modal choice process may be completely ignored by model estimations using a sample that is heterogeneous with respect to supply-side conditions. It is concluded that reliance on models based on such sample estimates can result in misleading, and often erroneous, conclusions regarding modal choice behavior.

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APPENDIX

Attitudinal questionnaire

On this scale, −3 means that you *agree* very strongly, +3 means that you *disagree* very strongly. The numbers in between represent feelings of agreement or disagreement in between. Using this scale, tell me how strongly you agree or disagree with the following statements about walking:

	Attribute	Abbreviation†
a	It is safe to walk at night	Night Safety
‡b	It is unsafe to walk during the day	Day Safety
c	For most places I want to go, walking does not require too much effort	Effort
‡d	It usually takes too long to walk where I want to go	Time
e	When walking, I don't get lost easily	Getting Lost
‡f	Poor weather greatly hinders walking	Weather
g	There are no dangerous crossings in my neighborhood	Crossings
‡h	Walking is inconvenient if you have things to carry	Parcel Convenience
‡i	Most people who walk probably can't afford a car or taxi	Status
j	Sidewalks are adequate	Adequate sidewalks

†Abbreviations were not included in questionnaire.
‡Attributes with negative descriptors that were changed to positive descriptors and scale values reversed.

Using the same scale, tell me how strongly you agree or disagree with these statements about buses:

	Attribute	Abbreviation
a	You can always rely on buses	Reliability
†b	Buses are seldom on time	Punctuality
c	Buses go where I usually want to go	Flexibility
†d	Lower class people tend to ride buses	Class of Riders
e	A lot of doctors ride buses	Status
†f	Buses are uncomfortable	Comfort
†g	The large number of unfamiliar people on buses makes me uneasy	Privacy
h	Bus fares are not too high	Cost
i	It is safe to wait at Bus Stops at night	Night Safety
†j	It is unsafe to wait at Bus Stops during the day	Day Safety
†k	Buses are unsafe	Safety
†l	Buses are very inconvenient	Convenience
†m	It is too difficult to carry packages on buses	Parcel Convenience
n	Buses are very practical to use for grocery shopping	Grocery Practicality
†o	It is difficult to determine bus routes and schedules	Route Familiarity
p	Most places I go do not require transfers	Transfers

†Attributes with negative descriptors that were changed to positive descriptors and scale values reversed.

Again, using this scale, tell me how strongly you agree or disagree with the following about cars:

	Attribute	Abbreviation
a	With a car I could go just about anyplace I would like	Flexibility
†b	A car is generally more expensive than other ways of travelling	Cost
c	I enjoy the privacy of a car	Privacy
d	I could go more places if I had a car	Added Opportunities
†e	A car is unsafe	Safety
f	Most people who can afford to have a car do have one	Status
†g	Driving is not enjoyable	Enjoyment

†Attributes with negative descriptors that were changed to positive descriptors and scale values reversed.

Using the scale again, tell me how strongly you agree or disagree with these statements about taxis:

Attribute	Abbreviation
†a Taxi fares are too high	Cost
b Taxi drivers are generally courteous	Courteousy
†c Taxi drivers probably don't take the shortest route	Honesty
d It does not take long to arrange for a taxi to pick me up	Waiting Time
e Taxi drivers are generally good drivers	Driving Capability
†f Taxis are unsafe	Safety

†Attributes with negative descriptors that were changed to positive descriptors and scale values reversed.