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ANALYSIS OF USER PREFERENCES FOR SYSTEM CHARACTERISTICS TO CAUSE A MODAL SHIFT

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This study is an investigation of the use of subjective preferences to complement behavioral observations as a means of determining the propensity, or tendency, of an individual automobile driver to shift to a new mode. A so-called propensity model of the discrimination-classification type is formulated from individual preferences for the performance characteristics required to encourage a shift to a multimodal park-and-ride type of transportation system or, conversely, a change in downtown parking cost to effect a shift to bus transit. The propensity model indicates that a substantial shift could be brought about by relatively small decreases in overall travel time, provided that walk times in parking terminals are about 2 min or less and transit line-haul frequency is $4\frac{1}{2}$ min or less. Parking charges were found to be an effective instrument to create a shift to bus transit. The validity of the preference-based model is tested by analyzing the degree to which stated preferences are independent of existing service levels. The test shows that respondent preferences for travel time and parking costs were not radically different from those existing but that walk times and transit frequency for a new mode must be radically different. It is concluded that subjective preferences are useful to study travel mode diversion but that better subjective surveys and means of controlling and monitoring changes in modal split with changes in policy-related variables are needed.

•THE trend in modal-choice analysis is toward the use of behavioral models that treat modal choice as a function of the performance characteristics of a transportation system. Behavior models structured in policy terms allow us to study and plan a socially desirable modal split by using simulation methods. This approach, if it is to be successful when applied to modal-split planning, requires that behavioral data be available for all combinations and ranges of transit service and that the model be structured in terms of those instrument variables that have maximum user sensitivity. Because existing transit usage may be constrained by the lack of some of the attributes deemed desirable by potential new users, behavioral data by themselves may lessen the predictive ability of the model if a new mode, consisting of radically different performance levels, is introduced. One way of overcoming this limitation is to model a user's subjective evaluation of the attributes of any mode to find the relative importance of the attributes introduced in a new mode. Inferences can then be made from the subjective attitudes about future usage on the new mode, if implemented. If the variables used in the evaluation are instrumental ones, modal-split planning can be carried out by changing the value of the variables in the model to simulate policy options for the community.

The present study explores the feasibility of a modal-split planning model based on the stated preferences of automobile commuters for those system attributes that would encourage a modal shift. Specifically, the objectives of the study are to discuss a method, based on the use of subjective preferences, that might be useful to study the diversion of commuters to a multimodal park-and-ride system and to find the relative importance of each of the attributes of the system in causing a modal shift.

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RECENT ADVANCES IN MODAL-CHOICE RESEARCH

Two major recent advances in modal-choice research have been the abstract mode concept, in which a mode is defined by its performance attributes and the relative utility of these attributes for the individual trip-maker, and the use of attitudinal and opinion surveys to derive subjective measurement of modal attributes.

The abstract mode concept is based on Lancaster's thesis that it is the intrinsic properties of a good that give satisfaction, not the good per se (1). Quandt and Baumol (2) applied this thesis to modal choice and conceptualized a transportation mode as a bundle of attributes characterized by its performance dimensions (such as travel time, travel cost, and frequency of service). Several models that use abstract mode attributes and the utilitarian concept that an individual seeks to maximize his satisfactions (or minimize his dissatisfactions) have been formulated. Ackoff's diversion model (3) is based on the idea that an individual will switch from his usual mode to the best alternative when changes in the perceived differences between the attributes of the usual mode and the alternative reach a certain point. Quarmby (4) conceived of travel dimensions which give rise to disutility of travel. He was able to study a planned shift by simulating new variable values, thereby making the alternative assume a lower disutility than the usual mode. Pratt (5) and McGillivray (6) provide similar analyses.

Several studies have used subjective measurements of modal performance characteristics in modal-choice research. Ackoff (3) scaled travel-time and travel-cost attributes to determine at what point a respondent would switch modes. Wachs (7) studied the subjective evaluation of a transportation system by using an opinion survey. Nash and Hill (8) used factor analysis to determine the most important subjective attributes of an ideal transportation system. Golob (9) studied the relative satisfaction of the users with the first and second choices of mode; Sommers (10) studied relative satisfaction and the acceptability of a hypothetical mode.

OUTLINE OF A SHIFT PROPENSITY MODEL

The present study uses stated preferences to model the propensity of an individual to shift to a new mode. The model is called a propensity model because prediction of behavior from stated preferences for modal attributes is only possible if those who say they will shift (provided their preferences are met) actually do so if the system is changed. Given the state of the art, the most we can assert is that any individual will have some tendency to act in accordance with his stated preferences. The concept assumes that there is some level of service of the new mode at which rational automobile drivers will shift because the perceived disutility becomes equal to or drops below that of driving. Consequently, the individual whose stated preference pattern is met by the new combination of attributes will have some propensity to shift modes.

It is assumed that each user chooses the mode that he perceives to have the least disutility of all modes available to him. Also, it is assumed that a user's perception of a mode is in terms of its intrinsic characteristics, or attributes, and not of its institutionalized nature (e.g., bus, rail rapid, or automobile). If we further assume that the total disutility of a mode is linear and is an additive function of its attributes as perceived by any user k, we can state, after Golob (9), that the decision to take a particular mode is because

$$U_k^1 < U_k^2$$

where

U_k^1 = total disutility of accepted mode (i.e., mode 1), and
U_k^2 = total disutility of rejected mode (i.e., mode 2).

But each mode is an abstraction of some combination of modal attributes so that

$$\sum_{i=1}^{p} U_{i,k}^1 < \sum_{i=1}^{p} U_{i,k}^2 \qquad (1)$$

where

$U^j_{i,k}$ = disutility of attribute i for mode j as perceived by user k, and
p = total number of attributes considered in the choice decision.

Each disutility term $U^j_{i,k}$ can be conceived to consist of two components: a parameter that is a variable measure of the attribute and a parameter that weighs that attribute in relation to all other attributes considered with respect to the relative value placed on the attribute in the modal-choice decision. Therefore, the disutility of any attribute is the product of a weighting coefficient and the number of units of the attribute experienced, or

$$U^j_{i,k} = V_i X^j_{i,k} \tag{2}$$

where

V_i = value user k places on attribute i, and
$X^j_{i,k}$ = measure of attribute i of mode j as perceived by user k.

Consequently, mode 1 is accepted and mode 2 is rejected when

$$\sum_{i=1}^{p} V_i X^1_{i,k} < \sum_{i=1}^{p} V_i X^2_{i,k}$$

or when

$$\sum_{i=1}^{p} V_i (X^1_{i,k} - X^2_{i,k}) < 0 \tag{3}$$

Several aspects of this function are noteworthy. First, the function is described in terms of relative disutilities of two alternatives (i.e., a binary choice problem). The function has been derived here by using differences between attributes of the two modes, but the form of the inequality remains the same if ratios are used (i.e., the right-hand side would be < 1 for ratios, rather than < 0). Second, the function applies only to a single individual. Individual utilities are not comparable. That is, the function describes the relative disutilities of each attribute for the modal-choice decision, but the strength of acceptance of a mode by an individual cannot be compared with the strength of another individual's acceptance. Because of this, individual disutilities are not additive. However, if the vectors **X** are treated as random vectors, a probability distribution can be determined that will be a statistical description of the aggregation of individual k, where k = 1, N. Third, note that disutility is described in terms of perceived differences between modal attributes. Utility (disutility) is purely subjective and depends on subjective values for the variables of the disutility function. One disadvantage of this approach is the possible interdependence between the subjective measure given through interview of the system attributes and the psychological value attached to that attribute. That is, if an individual places great value on travel time, he may overestimate his actual travel time to work (i.e., by objective measurements). There may also be some intercorrelation between the existing level of service and the subjective evaluation of ideal levels of service preferred. These problems are discussed later.

The shift propensity scheme may be outlined in terms of indifference curve analysis using stated preferences as follows.

Consider I_k, I_k, the indifference curve for individual k, which is the locus of all combinations of two system attributes (e.g., overall travel time and overall travel cost) as shown in Figure 1. The curve describes an individual's preferences within the context of his budget constraints and the modes available to him. U^1_k is the point at which the time-cost combination gives him least dissatisfaction and therefore represents the disutility of the characteristics of mode used (if we assume the modal attributes are continuous). On the other hand, U^2_k represents the characteristics of the mode rejected and is always to the right of I_k, I_k because the disutility of this combination is greater than that of the mode used. However, the characteristics of U_k^2 can be changed in such a way that individual k will be indifferent to whether he continues to use the existing mode or shifts to the alternative. This point is shown at U_k^3, which in this example results from decreasing the cost of the alternative.

The relative attribute values X of U_k^3 to U_k^1 define a relative disutility function for the individual and describe his propensity to shift modes. These relative values can then be plotted in two-dimensional space (using time and cost attributes), which represents the location of that individual vis-à-vis all other individuals. Assume that U_k^1 represents (for these two attributes) the cluster of disutility measures for a sample of individuals who drive to work and that U_k^3 represents the cluster of propensity measures for these same individuals if they were to become new mode riders, as shown in Figure 2. If there is sufficient differentiation between the clusters, we may say that (for these attributes) there exists a different combination of attributes for automobile drivers than for this same group if they were to become new mode riders.

The distance between cluster means and the overlap of observations can be used to estimate whether automobile drivers are different from the new mode group in relation to the variables considered. Multiple discriminant analysis (11) can be used to test whether the differences found are statistically significant and to classify new observations by modal group. A discriminant function is the linear function of the set of variables characterizing the individuals in the sample that best discriminates between the clusters of observations representing the two groups. This function is such that it maximizes the ratio of the variance between the groups to the common variance within each group and consequently maximizes the "distance" between the means of the groups. In the general case, a discriminant function can be found for each group and takes the following form:

$$z = V_1X_1 + V_2X_2 + V_3X_3 \dots + V_nX_n$$

in which

- X = variable measure,
- V = parameters that represent individual subjective weighting of the relative importance of each variable associated with it, and
- z = discriminant score, or value of discriminant function for the individual under consideration.

The vector of parameter values V of the discriminant function is analogous to the disutility weighting V for the individual from Eq. 3 and suggests the connection between disutility functions and discriminant functions. The analysis therefore gives a boundary condition that separates the modal groups on the basis of their average disutility, as measured by the parameter values and variables of the discriminant function.

When a group discriminant function is valued, it can be used to predict the propensity to shift modes. That is, the z value of any individual can be found and his group identified. Because the z value is a function of systems attributes and individual value orientations (which here are assumed to be stable, i.e., as parameters), any change in the system attributes will change the z value. If any individual's z value changes enough, it will transfer him from the region of mode 1 to the region of mode 3. At some extreme change in system attributes, all z values change sufficiently such that all members of the region of mode 1 are transferred to the region of mode 3. For any given policy change, the probability of an individual remaining an automobile driver or shifting to a new mode can be determined. Conversely, the probability of an individual shifting to a new mode can be stated as follows:

$$P(X) = e^z/(1 + e^z) \tag{4}$$

in which z is the discriminant function value (or discriminant score) for each individual as an automobile driver and in his potential group as a new mode user. The discriminant rule will assign him to the new mode if his z value is closer to the mean of the new mode group than to the mean of the automobile group; otherwise, the rule will leave him a member of the automobile group.

The method presumes some restrictive preconditions. Assumptions are (a) that every individual is aware of the potential alternatives, (b) that his preferences are rational in terms of the utility postulate of maximizing satisfactions, (c) that his behavior and stated preferences are coincident, and (d), which is related to c, that his perception of a preferred system is independent of the existing level of service.

Assumptions a and b present no particular problem because they are intrinsic assumptions of any analysis using utility theory. Assumption c is important to the practical application of the model as a device for making transportation decisions and therefore deserves some discussion. The congruence of stated preferences and behavior is tied to the relation between an individual's value system, as manifested in specific attitudes, and his behavioral response. Early behaviorists, who believed in the mechanistic behaviorist system of stimulus-response and resulting habit patterns, felt that attitudes were redundant in explaining social phenomena. Later, however, it was recognized by social behaviorists that the concept of attitude was needed to give reality to the idea of the mechanistic model of man. This concept was first introduced into the behavioristic system as a predisposition to respond and later in terms of the subjective meaning the attitude had for the individual (12). The current consensus is that attitudes and behavior are interrelated although the relation may go from a very weak connection to a very strong one. In the present case, it is postulated that individuals can articulate their evaluation of the transportation systems' attributes in terms of preferences and that, if these attributes are included in a new arrangement, there will be a tendency to react accordingly.

Assumption d presupposes that individual travelers can perceive a transportation system independently of the existing level of service. The validity of this assumption is examined later.

SHIFT PROPENSITY OF A SAMPLE OF COMMUTERS

The model was empirically tested by studying a sample of commuters in one radial travel corridor in Vancouver, Canada. The corridor tested served the "north shore" communities in metropolitan Vancouver and consisted of traffic crossing a high suspension bridge to the central business district (CBD). The catchment area consists of three municipalities with a combined population of about 107,000. It is separated from the CBD of Vancouver by Burrard Inlet and connected to it by the Lion's Gate Bridge. The data set was a sample of automobile drivers who crossed the bridge between 7 a.m. and 9 a.m. on a weekday in March 1967. The original survey was a "handout-mailback" modified origin-destination study conducted by a transportation consultant for the British Columbia Highway Department. At the time of the survey, the bridge carried about 6,500 automobiles in the 2 hours as well as 52 buses with about 2,500 passengers.

The present investigation used the data to study the potential impact on modal shift of (a) a hypothetical park-and-ride system and (b) changes in the use of existing bus transit if parking costs in the CBD were increased.

The performance dimensions used to estimate modal shift were those that defined the relative values of a preferred level of service in the hypothetical system and the actual level of service by car. The explanatory variables were those that defined the preferred level of service if a shift was to occur and those that defined the actual level of service experienced at the time of the trip. On the original questionnaires, each automobile driver was asked to indicate on a categorized scale the minimum quality of service desired for him to use a park-and-ride system and the maximum charge he would accept for parking before he would use bus transit. The preferred situation is measured by his stated preferences, which is used as the explanatory variable for the individual as a hypothetical transit rider. The actual measure is the explanatory variable for the individual as an automobile driver. The performance variables used in the model are the relative value of these characteristics. A description of these variables is as follows:

1. Relative overall travel time: The preferred relative door-to-door journey time by a park-and-ride system in 5-min increments as compared with that by automobile

Figure 1. Disutility of combinations of time and cost of two modes.

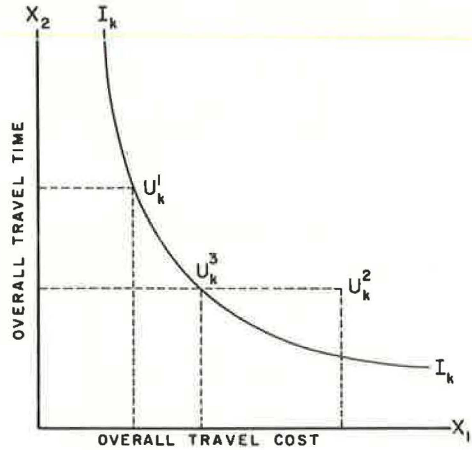

Figure 2. Disutility values illustrating two hypothetical modes.

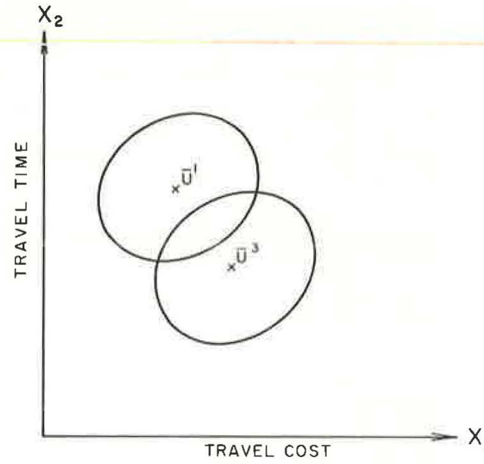

Table 1. Means and standard deviations for automobile and shift groups.

	Automobile Group		Shift Group		Average	
Variable	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
X_1	30.849	8.381	25.806	8.799	28.328	8.971
X_2	0.549	0.420	0.533	0.328	0.541	0.377
X_3	0.669	1.554	2.022	0.953	1.345	1.455
X_4	17.409	4.870	4.503	2.192	10.956	7.478
X_5	0.549	0.420	1.011	0.532	0.780	0.532

Note: X_1 = relative overall travel time, X_2 = relative out-of-pocket expenses, X_3 = relative residential travel time, X_4 = relative frequency of service, and X_5 = relative parking charge.

Table 2. Modal shift propensity for automobile and shift groups.

Variable	F-Ratio	F_p
X_1	80.09	<0.001
X_2	0.47	NS
X_3	256.03	<0.001
X_4	2,715.61	<0.001
X_5	215.20	0.001

Note: The variables are identified in Table 1.

Table 3. Correlation matrices for automobile and shift groups on system variables.

For Automobile Group	X_1	X_2	X_3	X_4	For Shift Group
X_1	1.00	0.12	0.11	0.15	X_1
X_2	0.09	1.00	0.12	0.15	X_2
X_3	-0.01	0.05	1.00	0.17	X_3
X_4	0.32	-0.05	-0.05	1.00	X_4

Note: The variables are identified in Table 1.

Table 4. Canonical tests of independence of preferred attributes with actual ones.

	Variable								
Variable	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
X_1	1.00								
X_2	-0.09	1.00							
X_3	-0.01	0.05	1.00						
X_4	0.32	-0.05	-0.05	1.00					
X_5	0.65	0.10	-0.08	0.27	1.00				
X_6	0.04	0.19	-0.06	0.04	0.12	1.00			
X_7	-0.02	-0.02	0.10	-0.07	0.11	0.12	1.00		
X_8	0.03	0.03	0.07	-0.00	0.15	0.15	0.17	1.00	
X_9	0.09	0.60	0.02	0.01	0.13	0.17	-0.08	-0.00	1.00

Table 5. Significance of canonical roots.

Root	Canonical Correlation (R_c)	χ^2	Discriminant Function Value	χ^2_p
1	0.678	493.5	20	0.001
2	0.595	202.0	12	0.001
3	0.155	11.7	6	0.05

was indicated by the respondent. This value was then converted to preferred absolute travel time and compared to the actual travel time by automobile. This process was carried out so that both differences and ratios could be used as relative disutility measures.

2. Relative out-of-pocket expenses: This variable is the maximum two-way combined bus fare and parking charge that the respondent would insist on before shifting as compared with the actual parking charge levied.

3. Relative residential travel time: This value is the walking duration from the parking location to the transit vehicle preferred in a park-and-ride system as compared with the actual walking distance from residence to automobile at the trip origin.

4. Relative frequency of service: This parameter is the preferred frequency of transit vehicles leaving the park-and-ride terminal in minutes as compared with the actual frequency of bus service in the zone of origin of the automobile driver.

5. Relative parking charge: This measure is the parking rate at which the respondent said he would switch to bus service if the parking rates were substantially increased in downtown Vancouver as compared with actual parking charge experienced at the time of the journey.

If the preferred service was provided, each driver willing to shift modes could, under the preferred conditions, be considered a user of the multimodal system. The automobile-driving population actually tested and the hypothetical users of the new system then define two groups in two regions of the test space. These would (in the statistical sense) be matched pairs with each member of each pair (i.e., group) being located at two points on an indifference surface, for example, at points U_k^1 and U_k^3 in Figure 1 for the case of two attributes. The problem is to find the discriminant function that maximally separates the two groups and the attributes that contribute to the separation. The significant discriminant function variates indicate the policy changes that would encourage drivers to change modes. The probable number of persons that would be classified as a park-and-ride system user or a bus transit user at any level of change in the system can be determined.

Because some people would shift only under the most extreme conditions, which may not have been covered in the questionnaire, a follow-up question was asked to determine if the respondent would definitely shift if the quality of service he specified was actually provided. Those who answered no to this question were eliminated from the sample, leaving a total of 465 respondents who said they would in fact shift if the service they desired was provided. Discriminant analysis was then used to determine (a) if actual individual behavior patterns of the original anchor group (i.e., actual automobile drivers) were significantly different from the preference patterns of the shift group (i.e., hypothetical park-and-ride or bus transit users' patterns based on the combination of attributes that they said would cause them to shift) and (b) what attributes serve to define the separation between automobile drivers that shift to a new mode and those that remain automobile drivers.

Two series of tests were carried out. The hypothesis of discrimination, using five instrument variables, was tested by using the program DISCRIM as documented in Cooley and Lohnes (13) and modified by the author for tape reading options. A second series of runs was made to test the effects of deleting some of the variables by a stepwise discriminant program using University of California, Los Angeles, program BMD07M (14). Posterior classification checks were also made by using the latter program.

The central tendencies of the observations of the two groups, as given in Table 1, give a general indication of the preference pattern of the automobile driving population with regard to shifting travel modes. If the distribution of both groups is assumed to be normal, the data in the table describe those measures needed to bring about a shift of one-half the automobile group. The other half would be those who required changes which locate them below the mean. This shift would occur with a decrease in mean travel time of about 5 min. Total out-of-pocket expenses would have to decrease, but not substantially. The overall walking time from the parking lot of a park-and-ride station to the bus compared with the existing time at the residential end of the journey would have to be about 2 min. This implies that drivers would tolerate this amount of walking at the residential end of the trip if other desirable characteristics are provided. One characteristic that shows up very dramatically is a large increase in the frequency of public transit vehicles needed within the park-and-ride system compared with the existing frequency of buses. The average driver who is a potential shift patron would require about 4.5 min of headway between buses as compared with the more than 17 min he has at present.

The parking charge needed, by itself, to effect the 50 percent shift to bus transit would increase from an average of about $0.55 to about $1.00 per day.

Some caution is necessary in the interpretation of these data. First, the large standard deviations for the out-of-pocket cost factor results from a few extreme observations of those who pay a very high parking cost at present and those who demand a very low total expense for the shift condition. Many respondents indicated that they desired a system with no out-of-pocket expenses. Second, the spread between the existing frequency and the one preferred may be biased because of the way they were measured. The existing frequency is a rush-period average for the zone of origin for each driver and may not represent the combination of extremely high or extremely low existing frequencies with extremely low or extremely high preferred frequencies on an individual basis. If precise frequencies were used for the hour of departure, the spread in means would decrease, and the effect of this factor would be expected to moderate somewhat.

The univariate F-ratios given in Table 2 give the relative importance of each variable when considered alone. F-probability tests show that all variables, except changes in parking expenses, are significant. For the park-and-ride system, the frequency of buses leaving the terminal shows the greatest contribution to the separation of modal groups. Walking distance from parking location to terminal loading point and overall travel time are also important variables when taken by themselves. The effect of parking charge increases on the shift to the bus mode is also shown to be significant. A statistic, Mahalanobis D^2, gives the standardized measure of the "distance" between the modal groups and is the difference in mean values on the discriminant function. D^2 for the separation of car mode and park-and-ride mode is 147.45 and between the automobile mode and the bus mode is 0.213. The more familiar R^2, which shows the effectiveness of discrimination by the ratio of variance due to regression of the differences between groups to total variance (or proportion of variance accounted for in the discrimination), can be calculated from D^2. The R^2 for park-and-ride propensity is 0.762 and that for bus transit is 0.175. Both R^2's are significant at the 0.001 level. However, the relatively small amount of variance extracted by parking charge changes on bus transit (17.5 percent) indicates that other variables would also be operative (and may be more important than parking costs) if they were included.

The relative contribution of each of the variables can be estimated by using a scaled vector of weights on the discriminant function. These are variable weightings, or coefficients, that are scaled by dividing through by the standard deviation of the variable in question. The vector of weights for each of the instrument variables tested is as follows:

Variable	Scaled Vector
X_1	-17.85
X_2	0.43
X_3	-11.48
X_4	108.13
X_5	14.61

These values show that bus frequency dominates the preferred attributes in a park-and-ride system. This reflects the differences found between the frequency preferred for each and that averaged by zone and then averaged over the rush period. The travel-time dimension, isolated by the analysis, distinguishes between existing and preferred services with frequency and residential travel time contributing substantially to the desire for a shorter duration trip. This test shows a relative insensitivity to the combined fare and parking cost variable.

The preceding analysis considers the contribution of each variable to the separation of the modal groups when taken as a system of variables. However, one of the variables tested is not significant (combined out-of-pocket expenses), and some intercorrelation exists between overall travel time and bus frequency as given in Table 3. Also, it is convenient for classification purposes to go to the general case and produce discriminant functions for each group. A stepwise discriminant analysis was therefore carried out in which variables were entered into the function according to three criteria: highest F-ratio value, highest multiple correlation, and greatest decrease in ratio of within-group to total variances. This program values the group functions for each individual and determines the posterior probability of each individual belonging to each group. The individual is assigned to the group for which he has the greatest posterior probability, that is, the largest P(X) value as calculated by using Eq. 4.

The discriminant functions as determined by the stepwise procedure of the anchor group for the park-and-ride system and the bus transit system respectively are as follows:

$$z_{a_{pr}} = -10.761 + 0.401X_2 + 1.221X_4$$

$$z_{a_{bt}} = -0.657 + 2.390X_5$$

Those for the shift group are respectively

$$z_{s_{pr}} = -1.940 + 1.216X_2 + 0.316X_4$$

$$z_{s_{bt}} = -2.222 + 4.397X_5$$

If we use an acceptance-rejection criterion of $F_p \leq 0.05$, out-of-pocket expenses and overall travel time drop out of the function, and the discriminant scores are calculated on the basis of residential travel time and frequency. This increases the F-ratio from F = 744.90 to F = 1,484.74 for the park-and-ride scheme. The R^2 of 0.760 for this scheme indicates good discrimination on only these two variables. The posterior classification by means of the discriminant functions results in less than 1 percent misclassification. Using only parking charge as a variable in the model produces only moderately successful results with almost 33 percent misses. This may be partially due to a relatively crude breakdown in the parking charge categories used in the survey, which were $10 per month intervals, with 60.5 percent of all responses in two categories, $0 to $10 and $10 to $20 per month, and 30.5 percent with free parking.

VALIDITY OF PREFERENCE MODEL

The modal shift described here is based on an analysis of what people say they would do when given a hypothetical situation. To improve study validity, we analyzed only those respondents who stated a second time that they would shift if their preferences were met. A question, however, still remains as to whether the respondents would in fact shift if their desires were met. Some attempt was made to further understand the preference structure of the sample to estimate the validity of stated preferences as a tool to analyze modal shift.

It was reasoned that, if an individual's preferences were independent of the level of existing service, it was likely that he perceived the hypothetical service attributes independently of his currently available service levels, and therefore propensity to shift was higher than if preferences were constrained by actual service conditions. Consequently, a correlation test of the independence of preferences from existing service levels was carried out by using canonical analysis. Canonical correlation analysis (15) is a statistical technique used to analyze the relations between two sets of variates when the sets are in some sense maximally correlated. As such, it is a generalized extension of multiple linear regression analysis but with multiple dependent as well as multiple independent variables making up the two sets of variables. In the case at hand, the technique helps us to understand how the set of perceived existing service attributes is related to the preferred set of attributes.

Table 4 gives the correlation coefficients for the four variables that represent existing attributes and the five variables that represent preferred attributes. (Preferred parking charge X_9 is compared with actual parking charge X_2 to account for the extra variable in the second set.) Some correlation exists between preferred travel time X_5 and actual travel time X_1 and between parking charge X_2 and preferred parking charge X_9.

The canonical correlation between the sets is significant (Table 5). Two roots with $R_c = 0.68$ and $R_c = 0.60$ are both significant at $p < 0.001$. The inference is that the two sets of variates can be combined in such a way as to produce correlation between what an individual prefers in the way of transportation service and the existing alternatives available.

The coefficients of the two sets for the first canonical variate are $X_1 = 0.881$, $X_2 = 0.280$, $X_3 = -0.135$, $X_4 = 0.121$, $X_5 = 0.952$, $X_6 = 0.025$, $X_7 = -0.138$, $X_8 = -0.089$, and $X_9 = 0.229$. These indicate that the factor contributing most to the intercorrelation is the relation between actual travel time and that which is preferred. The second canonical variate has the following coefficients: $X_1 = -0.355$, $X_2 = 0.967$, $X_3 = 0.038$, $X_4 = 0.008$, $X_5 = -0.381$, $X_6 = 0.140$, $X_7 = 0.087$, $X_8 = 0.052$, and $X_9 = 0.951$. This canonical variate brings out the remaining intercorrelations: that between actual parking cost and that preferred. The results indicate that, as far as travel time and parking cost factors are concerned, automobile drivers do not think that radical changes would be part of the hypothetical system. However, indications are that other attributes such as transit fares, residential travel time, and service frequency can be changed in a way very much different from that which is currently experienced.

SUMMARY OF FINDINGS

The results of the analysis support the concern of transportation planners with travel time. If a park-and-ride system could be developed that would reduce the overall travel time by about 5 min in a 30-min average trip, such a system would have a significant effect on the number of persons who would shift to the system. However, it is evident that the decrease in system overall travel time must come about by low levels of walk and wait time in the systems. Transit frequency within the overall system was shown to be the most important factor in a consideration of this type of system. But the frequencies demanded for a substantial shift are not unrealistic, with a frequency of 4.5 min achieving substantial success. Given a sufficient capacity and an efficiently designed feeder system (roads, parking, and feeder buses) such a system appears feasible.

Although residential walk times need to be minimized, the tests show that drivers will tolerate some walking in the system at the origin end of the trip. The mean walking distances preferred for a shift of just over 2 min is well within the usual walking distances most motorists face in other circumstances. For large cities, this may be up to 5 min at the destination end and somewhat less than 10 min at the origin end although little is known about this aspect of a motorist's walking tolerance. It is highly likely that if these were put together, however, the total of 15 min would discourage a modal shift (although in Vancouver almost 32 percent of those going to the CBD by automobile walk 10 or more min at the trip destination). Because substantial numbers of automobile drivers walk more than 5 min at trip destination and because park-and-ride as well as bus transit passengers would in general be deposited closer to destination, it seems likely that a 2-min walking distance at the parking-transit interface would cause no problem in encouraging the use of the system.

The insensitivity of out-of-pocket costs in the manner of combined bus fare and parking cost is difficult to interpret. Most studies have shown that transit fare decreases have little effect on diverting automobile drivers. On the other hand, parking cost is usually found to be a sensitive factor. One explanation is that the respondent perceives this combined expense as an over-the-road cost (which is usually not a strong incentive to shift) as he would vehicle operating cost or transit fare. It seems highly likely from the evidence available that vehicle operating costs are perceived differently than are parking costs in the "decision calculus" of automobile users. Transit usage is not directly related to transit fares because of the large number of transit captives who have no choice but to pay the fare and because automobile drivers put costs low on their list of priorities when considering transit. The psychological perception of a package cost, including fringe parking charge and transit fare, may be different from either a vehicle operating cost or a parking fee at the destination of a single automobile mode journey, and therefore automobile drivers are insensitive to a combined fare, particularly if the fare is collected at the line-haul terminal. On the other hand, a more rigorous breakdown of this cost in the survey stage may show different results.

As expected, parking charges levied in the CBD may have substantial effects on changing the modal split in favor of bus transit. Whether the charge is levied as a fee increase or as a tax would not affect the results because the important aspect of the factor is that it is not a hidden cost, such as vehicle operating costs. This appears to be a fruitful area in which to pursue ways of rationalizing modal balance.

CONCLUSIONS AND IMPLICATIONS

The use of stated preferences may be an effective means of determining the propensity of automobile drivers to shift to a radical new transportation system. Use of this technique on a somewhat conventional multimodal park-and-ride system gives expected results. Use of subjective preferences for a completely radical system depends on the link between preference patterns and subsequent behavior patterns. There appears to be two ways of allowing for this: (a) improvement of the survey instrument (e.g., the questionnaire) so as to be able to make inferences about preference-behavior linkages and (b) field-testing by structuring the model so that its inputs reflect incremental or largely noncapital changes to the system.

Some validation of the survey used here was undertaken, which provided inferential conclusions about whether respondents could perceive radical changes in the system and could differentiate between existing service and new levels of service. This was used to conclude that citizens viewed dramatic changes in extra-vehicular time to be necessary to encourage diversion to the park-and-ride system. This close link between the value given here to excess time and what we know to be the case with similar analyses of work-trip behavior patterns indicates that, in the case of travel time, stated preferences and behavior may be congruent. This study considered only selected variables (those available in the original study), and it is necessary to examine a much broader set of service variables (such as comfort for example) before definite conclusions can be made. The main emphasis on research in this area is to develop a much better survey instrument than the traditional origin-destination survey, one that allows, as a minimum, tests for reliability and validity of results.

The advantage of structuring a model in terms of the inputs investigated here (such as parking charges, bus frequencies, and walking times) is the possibility of including these in policies that can be implemented with relatively little capital investment. The methodology can be used to study and monitor the effects of these adjustments on the system. If the effects are not in the direction of preset community objectives, the model can be adjusted and new tests made. The factors found here to be subjectively important are in effect the antecedents of a control mechanism that is both goal-oriented and incremental, incorporating both system planning and decision-making in the long-term context and flexible control of the system to meet short-term objectives. However, such a scheme depends on an integrated concept of streets, parking, and transit and an institutional framework that is able to coordinate the planning of street elements, parking supply (both fringe and downtown lots), transit facilities, and fare and parking charge structures. If the institutional framework can be effected, the propensity model appears to be a useful tool to study modal diversion.

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