tries. Humanities Press, Atlantic Highlands, NJ, 1972.
4. J. P. Robinson. How Americans Use Time. Praeger Special Studies Program, New York, 1977.
5. Y. Zahavi. Equilibrium Between Travel Demand System Supply and Urban Structure. In Transport Decisions in an Age of Uncertainty (J. Visser, ed.), Proc., 3rd World Conference on Transport Research (Rotterdam, the Netherlands, April 26-28, 1977), Martinus Nijhoff, Boston, 1977.
6. N. P. Hummon, R. Baker, and L. Zmotel. An Analysis of Time Budgets of U.S. Households: Transportation Energy Conservation Implications. Institute for Research on Interactions of Technology and Society, Univ. of Pittsburgh, Sept. 1979.
7. Survey Research Center. Time Use and Economic and Social Accounts, 1975-1976. Institute for Social Research, Univ. of Michigan, Ann Arbor, 1976.

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Theory of Destination Choice-Set Formation Under Informational Constraint

Robert Meyer

A theoretical framework for the behavioral analysis of destination-choice set formation is proposed that consists of a set of postulates that purport to explain how individuals' previous experiences with respect to destinations influence patterns of search behavior in the formation of choice sets. The theory yields predictions concerning (a) how destination choices are made by individuals who have limited information concerning the set of alternative destinations and (b) the likely nature of choice sets within differing sets of alternatives. Models describing the behavior of groups deduced from this theory are described.

Disaggregate behavioral models of destination choices are based on a rather simple and well-known behavioral postulate: When an individual makes a choice from among a set of destinations, there initially exists a subset of alternatives that are actively considered. The individual then assigns a utility value to each of these alternatives and chooses that destination for which utility is the highest. Current choice models represent an extension of this postulate to the study of group or repeated choice behavior; in this case, the utility function of a representative consumer is used to assign utility values to destinations under study. Assumptions made about the distribution of utilities within the population are then employed to yield expressions for the frequency or probability with which individuals in the population will choose each destination (1).

A major obstacle to the direct application of this approach in the study of destination choice, however, is that current models tend to be insensitive to one major aspect of the above behavioral postulate—the initial identification of sets of relevant or actively considered alternatives (2, 3). In other words, while we have developed analytic tools to model the behavior of individuals faced with a set of alternatives, we have few tools for identifying what those alternatives are.

From a modeling standpoint, the problem is as follows: It is quite likely that in a given study area many individuals consider different sets of alternatives when making destination choices. Without a means for assessing these sets a priori, the researcher is forced either to make the simplifying assumption that all individuals actively consider all destinations or to advance hypotheses about what the choice sets are likely to be for various segments of the population (3, 4). It is quite possible, of course, that such assumptions or hypotheses may prove untenable in practice. This would particularly be the case, for example, when the behavior of a group of individuals who vary greatly in their knowledge of potential destinations (owing to varying lengths of residency) is to be modeled or when some alternatives exist that completely dominate others in terms of their qualities (5-7). Because of this, model parameters that describe the relationship between predicted utilities and observed choices may be influenced as much by variations in choice sets among individuals (which are not fully accounted for in the model) as by variations in preferences (which are accounted for). Because changes in the nature of destinations may affect both choice sets and preferences to differing degrees, this potential confusion is likely to cause model parameters to be intransferable over time and space. In other words, forecasts of behavior may be prone to error (6, 8).

Although considerable discussion has been devoted to the choice-set problem, its solution has so far eluded researchers in the field (3, 8). One impediment seems to be simply that we have little theory related to choice-set formation to guide the work. For example, a number of authors have suggested that choice sets are largely determined by how individuals learn about spatial opportunities within time and space budgetary constraints (5, 6, 9, 10). Theories of spatial learning that might be used to predict choice sets, however, have not been forthcoming.

It is my purpose to suggest such a theory of learning. In particular, the theory is one that purports to explain how individuals make destination choices over time, given increasing levels of information with respect to the set of opportunities. The theory postulates that information gained over time as a result of feedback from choices is used to update beliefs about the structure of the available opportunity set. These beliefs determine the composition of a choice set; that is, they are the set

of alternatives with a nonzero probability of being chosen. The theory is then used to suggest aggregate models describing the probability that a given destination will be in an individual's choice set at a given time.

It should be emphasized that the present theory is essentially aspatial: It is a psychological theory of the way in which individuals form choice sets, given a pattern of destinations. In the models deduced from this theory, the effect of individual variations in patterns of locations—such as using both work and home as origins for trips—is represented as a random disturbance about an "average locational convenience" term. How changes in either the relative locations of destinations or the tendency to make multipurpose trips affect the probabilities of choice-set membership, however, is not explicitly examined.

BEHAVIORAL THEORY

Overview

Here we review a behavioral theory of how individuals form choice sets during the course of learning about sets of destinations. A more thorough discussion of both the theory and related empirical work is available elsewhere (11).

The theory views the individual's destination-choice behavior as it arises over time as follows: A decision maker is sampling sequentially from a set of destinations, each characterized by a bundle of attributes. The number of destinations within this set may or may not be known a priori by the decision maker. Within each bundle of attributes is a set of place-specific attributes (such as the destination's quality) and a perceived level of locational convenience or disutility in traveling to the destination. The decision maker may or may not have a priori knowledge of either the place-specific attributes or the locational convenience but nevertheless is assumed to hold a hypothesis with respect to their values for all destinations.

On each occasion the decision maker may choose either (a) a new or unfamiliar destination (hence gaining information about its attributes) or (b) a familiar destination, that is, a destination that was chosen previously. The theory assumes that this decision is made by assigning an overall utility value to each available destination, including those that are mainly unfamiliar. All those destinations whose utility is within some critical deviation of the "best" available alternative have a nonzero probability of being chosen. On each choice occasion, all such destinations define the individual's choice set. If an unfamiliar destination is in the choice set and is chosen, feedback may be used to redefine the choice set for the next choice occasion. The choice set is thought to stabilize when it contains no unfamiliar members (that is, when updating is less likely to occur).

The modeling problem therefore reduces to the following:

1. How can we characterize utility assignments made to largely unfamiliar alternatives?
2. How are these assignments updated as the result of direct feedback from choice?
3. How can we formalize the definition of choice sets, given the first two questions?

Approaches to these problems will be discussed.

Formal Statement of the Theory

Let V_{it} represent the overall value or utility that the decision maker associates with destination i on choice occasion t. It is assumed that there exists a function $f(D_{it}, \mu_{i1t}, \ldots, \mu_{int})$ such that

$$V_{it} = f(D_{it}, \mu_{i1t}, \ldots, \mu_{int}) \quad (1)$$

The term D_{it} represents the part-worth utility of the average locational convenience associated with destination i. For example, D_{it} might correspond to a weighted average of the travel times associated with destination i over all origins, such as work and home. In addition, μ_{ijt} is the part-worth utility of the jth place-specific (aspatial) attribute of i (such as quality or appearance). We follow Anderson and others by postulating that part-worth utilities c_{it} and μ_{ijt} may be decomposed as follows (12):

$$\mu_{ijt} = W_{ijt} S_{ijt} \quad (2)$$

where

$$W_{ijt} > 0 \forall j \qquad \sum_{j=1}^{n} W_j = 1$$

W_{ijt} is the relative weight or importance associated with the jth attribute of i, and S_{ijt} is the subjective value of j of i. The constraint that all weights are nonnegative and sum to 1 is imposed to ensure that all U_{it} share a common bounded interval scale (such as "certain to choose," "certain not to choose").

In this discussion we will make the simplifying assumption that W_{ij} is time invariant; that is, the importance of a factor in forming evaluations does not change as a result of information gathered about the set of available destinations. A more general discussion of this model in which weight updating is recognized has been provided elsewhere (11).

It is postulated that the subjective value of attribute j [including locational convenience (D_{it})] of destination i on any choice occasion t (S_{ijt}) is given by the equation

$$S_{ijt} = A_{ijt}/(1 + aV_{ijt}) \quad a > 0 \quad (3)$$

where A_{ijt} is defined as the average value of attribute j of destination i on t, V_{ijt} is the perceived dispersion about A_{ijt}, and a is an empirical parameter reflecting the decision maker's attitude toward risk. Formal definitions of these terms follow.

Definition of Average Value

The average value of attribute j of destination i on t (A_{ijt}) is defined as

$$A_{ijt} = \sum_{k=1}^{P_i} W_{(1)k} X_{ijk} + W_{(1)0} AL_{jt}$$

$$\sum_{k=0}^{P} W_{(1)k} = 1 \qquad W_{(1)k} > 0 \forall k \quad (4)$$

P_i is the number of information bits associated with alternative q on attribute j, X_{ijk} is the value of the kth bit of information about i on j, and $W_{(1)k}$ is a weight reflecting the perceived reliability of the kth information source. AL_{jt} is termed the decision maker's adaptation level on attribute j on choice occasion t and is defined as follows:

$$AL_{jt} = \sum_{q=1}^{N} \sum_{k=1}^{P_q} W_{(2)ak} X_{ajk}$$

$$\sum_{q=1}^{N} \sum_{k=1}^{P_N} W_{(2)qk} = 1 \qquad W_{(2)qk} > 0 \forall q,k \tag{5}$$

where N is the total number of destinations previously inspected within the class of destinations of which i is a member.

In words, Equation 4 states that the average value associated with an attribute of an alternative on some choice occasion is a weighted average of (a) the information bits available that directly pertain to j of i and (b) the individual's adaptation level on that attribute. The adaptation level is defined to be a weighted average of the decision maker's previous experiences with respect to other destinations on attribute j. Equation 4 implies that, if a destination is unfamiliar on attribute j, its average value is the decision maker's adaptation level on that attribute.

Definition of Perceived Dispersion

The perceived dispersion associated with attribute j of destination i on choice occasion t (S_{ijt}) is given as

$$S_{ijt} = \sum_{k=1}^{P_i} W_{(3)k} (X_{ijk} - AL_{jt})^2 + W_{(3)0} T_{jt}$$

$$\sum_{k=1}^{P_i} W_{(3)k} = 1 \qquad W_{(3)k} > 0 \forall k \tag{6}$$

where

$$T_{jt} = \sum_{q=1}^{N} \sum_{k=1}^{P_q} W_{(4)qk} (X_{qjk} - AL_{jt})^2$$

$$\sum_{q=1}^{N} \sum_{k=1}^{P_q} W_{(4)qk} = 1 \qquad W_{(4)qk} > 0 \forall q,k \tag{7}$$

T_{jt} is termed the perceived total dispersion on attribute j on choice occasion t. All other terms are defined as above.

Perceived dispersion may be thought of as a measure of the decision maker's uncertainty with respect to what the value of an attribute of an alternative will be on a given choice occasion. Much like average value, it is defined to be a weighted average of (a) the observed variance in the values of the information bits associated with an attribute of an alternative and (b) the total amount of variability that exists in an attribute both within and among other destinations of the same type. Equation 7 implies that, if a destination is unfamiliar on an attribute, the perceived dispersion is the perceived total dispersion on that attribute.

Choice-Set Formation

We start by making the assumption that individuals hold strong a priori beliefs with respect to the locational convenience associated with all destinations, both familiar and unfamiliar. In other words, we assume that, while individuals may not always know about a destination's place-specific attributes (such as its quality), individuals always have some idea about the psychological cost (perhaps travel time) associated with inspecting it. In other words, the average value of locational convenience for an alternative is never solely given by the individual's adaptation level on locational convenience.

The way in which choice sets are thought to be formed over time during the course of learning about sets of destinations might best be described by first considering an individual faced with a totally unfamiliar set of destinations. The above assumption implies that in this case destinations would differ only in terms of the locational conveniences or distances associated with each. As noted previously, the average values and perceived dispersions associated with each destination's place-specific attributes are their adapted values, given by Equations 5 and 7, respectively.

The individual's hypothesized decision rule is as follows: There exists some critical threshold utility V* (the activity threshold) such that the probability that some destination i will be chosen on the first choice occasion (P_{i1}) is

$$P_{i1} = \begin{cases} 0 & \text{if } V_{i1} < V^* \\ P(V_{i1}) & \text{otherwise} \end{cases} \tag{8}$$

where V_{i1} is the overall utility associated with destination i (Equation 1).

If one can assume that search is initiated on the first choice occasion, behavior on the second choice occasion can be expressed as follows: Let V_{i2} represent the overall utility associated with the destination chosen on the first choice occasion (as measured on the second occasion) and $V_{max\,2}$ the overall utility associated with the most preferred unfamiliar destination (that is, the unfamiliar destination with the highest locational convenience). Define a comparison statistic C_{ij2} as follows:

$$C_{i\,max\,2} = (V_{i2} - V_{max\,2}) PCOV(i,max) \tag{9}$$

where PCOV(i, max) is the perceived covariance or similarity between i and the most preferred unfamiliar destination (max) over their place-specific attributes. It is postulated that in this and all comparisons involving an unfamiliar alternative the perceived covariance is the average covariance among all pairs of familiar or previously inspected destinations. The probability that the unfamiliar destination (max) will be chosen on the next (second) choice occasion (that is, the probability that search will continue) is given by

$$P_{max\,2} = \begin{cases} 0 & \text{if } V_{max\,2} < V^* \\ 0 & \text{if } C_{i\,max} > C^* \\ P(V_{max\,2}) & \text{otherwise} \end{cases} \tag{10}$$

where C* is a critical threshold value.

It is postulated that the behavior of successive choice occasions may be modeled as if the above binary comparisons were made between all pairs of familiar destinations as well as the most preferred unfamiliar destination. In general, therefore, the probability that some destination i will be chosen among n such destinations on choice occasion t is given by

$$P_{it} = \begin{cases} 0 & \text{if } V_{it} < V^* \\ 0 & \text{if } C_{1it} > C^* \\ 0 & \text{if } C_{2it} > C^* \\ \vdots & \\ 0 & \text{if } C_{nit} > C^* \\ P(V_{it}) & \text{otherwise} \end{cases} \tag{11}$$

Specification of $P(V_{it})$ is not straightforward, however, because the only relevant V_{jt} values that enter this ex-

pression are those for which the probability of choice is nonzero. That is, probability is estimated only with respect to other destinations in the choice set. Approaches to specifying $P(V_{it})$ in various contexts will be explored next.

MODELS OF GROUP BEHAVIOR

Overview

The purpose of this section is to discuss some of the aggregate modeling implications of the theory just described. Specifically, models of aggregate choice behavior are derived from the assumption that individuals behave in accordance with the hypotheses advanced in the two previous sections.

When viewed in the aggregate, the probability that some destination i will be chosen by a representative individual on choice occasion t may be broken down into two components: (a) the probability that an initial choice is made on t (that is, a choice made during the course of searching to obtain information about i) and (b) the probability that a repeat choice is made on t (that is, a choice made with full knowledge of i's characteristics or attributes).

Formally, this probability may be decomposed as follows:

P (i will be chosen on choice occasion t) = P (i is familiar on choice occasion t) × P (i will be chosen given that it is not familiar and is in the choice set) + P (i is familiar on choice occasion t) × P (i will be in the choice set given that it is familiar) × P (i will be chosen given that it is familiar) × P (i will be chosen given that it is familiar and is in the choice set).

The basic idea behind this decomposition is that the utilities associated with destinations are largely dependent on whether or not the destinations are familiar to decision makers at the time that choices are observed. Specifically, if a destination is unfamiliar to all individuals in a study area, the appropriate average value associated with that destination is a representative individual's adaptation level on all its place-specific attributes. As more and more individuals become familiar with the destination, the appropriate average value becomes increasingly a direct function of the destination's place-specific, objectively measured attributes. Hence, the term P [i (is, is not) familiar...] serves to weight the appropriate utility value associated with the destination at the time that choices are made. The term P (i is in the choice set...) is the nonzero probability that the destination will be chosen, be it familiar or unfamiliar. In the language of the theory described above, it is the probability that there exists no criterion statistic with respect to that alternative that is above the critical threshold. In the aggregate this term may again be thought of as a weight; the higher the likelihood that an alternative is not in the choice set, the lower the relevant representative utility.

It should be noted that the separation of the probability of choice-set membership from the probability of choice has pragmatic meaning only when one is attempting to model choice behavior across differing sets of alternatives. Specifically, if one is strictly concerned with describing choice behavior within a unique choice context (such as in a specific area at a specific time), the two probability expressions can be confounded; that is, a single set of model coefficients can simultaneously capture both variations in individuals' preferences for alternatives and the frequency with which alternatives appear in individuals' choice sets. On the other hand, if one seeks to forecast behavior—that is, to use a model derived in one context to predict behavior in another (in which the set of alternatives differs)—the confounded model parameters would clearly be of little value. In this case it would be desirable to develop separate expressions for choice-set membership probability and choice probability given choice-set membership.

Of the three general terms in the calculation above, we currently have an analytic expression only for the last term, the probability that a destination will be chosen given that it is in the choice set. Such an expression, for example, might be given by a traditional multinomial logit model (1). How one might specify the other two terms—the probability that a destination is familiar and is in the choice set—is not immediately clear. In the following sections, expressions for these two probabilities are deduced from the theory presented earlier. These expressions are then integrated into a model of independent, full information choice to yield an illustrative general model of choice behavior.

Probability That Destination Is Familiar on Choice Occasion t

The probability that a destination i will be familiar (that is, an initial inspection of i made) by choice occasion t is given by first finding the probability that i is not among the n destinations inspected by that time. Initially, one represents the behavior of a representative individual on the first choice occasion, that is, when individuals are unfamiliar with the set of destinations except for hypotheses about their locations. Assuming that there exists a distribution of activity thresholds (V^*) and adaptation levels within the population, one may deduce from Equation 8 that the probability that some destination i will not be selected on the first choice occasion is given by

$$P(\text{not } i)_1 = P(V_{i1} < V^*) + P(V_{i1} \geq V^*)[1 - P(V_{i1})] \quad (12)$$

Because any one individual's activity threshold (V^*) will be difficult (if not impossible) to actually measure, it is unlikely that Equation 12 can be estimated in practice. Hence, a simplifying assumption is made:

$$P(V_{it} < V^*) = 0 \quad (13)$$

In brief, it is assumed that search is undertaken and that its characteristics are governed solely by interalternative comparisons. This assumption implies that the probability that an alternative i will not be selected on the first choice occasion is purely a function of locational convenience. Let this value be θ_i.

The probability that a destination will not be chosen at least once by the second choice occasion is the probability that i was not chosen on the first choice occasion (θ_i) and that either search stopped after the first occasion (that is, $C_{i12} > C^*$) or search did not stop after the first occasion but i still was not chosen after the second occasion. Formally, the probability that i will not be inspected after two choice occasions may be written as

$$P(\text{not } i)_2 = \theta_i P(C_{i12} > C^*) + P(C_{i12} \leq C^*)\theta_i \quad (14)$$

Let $C_{\max ij}$ represent the maximum comparison statistic observed for alternative i at choice occasion j [that is, the comparison statistic of i with respect to the most preferred familiar destination available (labeled max) after j choice occasions]. The probability that i will still not have been inspected after t choice occasions is thus given by

$$P(\text{not } i)_t = \theta_i \prod_{j=1}^{t} P(C_{\max ij} > C^*) + P(C_{\max ij} \leq C^*) \quad (15)$$

Recalling the definition of the comparison statistic (Equation 9), Equation 15 may be rewritten as follows:

$$P(\text{not } i)_t = \theta_i \prod_{j=1}^{t} P\{V_{\max j} > [C^*/PCOV(\max,i)_j] + V_{ij}\}$$
$$+ \theta_i P\{V_{\max j} \leq [C^*/PCOV(\max,i)_j] + V_{ij}\} \quad (16)$$

where $V_{\max j}$ is the overall utility associated with the most preferred familiar destination available on choice occasion j. Because i is an unfamiliar destination, the terms on the right-hand side of the inequalities in Equation 16 are constant for all values of $V_{\max j}$. That is, if a destination i is unfamiliar, $PCOV(U_{\max} U_i)_j$ is the average covariance among all pairs of familiar destinations.

To specify Equation 16, distributional assumptions are necessary for $V_{\max j}$ and θ_i. If overall utilities V_{kj} are distributed in the population as an exponential-type density function (for example, a normal), the maximum in a sample of size j ($V_{\max j}$) has a type 1 extreme value distribution (13). That is,

$$P(V_{\max j} < V) = \exp\{-\exp[-(V - a_j)]\} \quad (17)$$

If the underlying distribution of V_{kj} can be approximated by a distribution unbounded to the right and left (for example, a normal or Weibull), the parameter a_j in Equation 17 will increase linearly with the log of the sample size (j) (13).

Let θ_i be characterized by an exponential density in which

$$\theta_i = \exp[-(D_i + b)] \quad (18)$$

and let

$$V'_{ij} = [C^*/PCOV(\max,i)_j] + V_{ij} \quad (19)$$

Then by substituting Equations 17, 18, and 19 into 16, one obtains the following result for the probability that destination i will not be inspected after t choice occasions:

$$P(\text{not } i)_t = d(-D_i - b) \prod_{j=1}^{t} \left\{\left[1 - e^{-e^{-(V'_{ij}-a_j)}}\right] + e^{-D_i-b-e^{-(V'_{ij}-a_j)}}\right\} \quad (20)$$

Clearly, Equation 20 is an expression that would be difficult to estimate in practice. Two additional assumptions, however, enable the specification of a much simpler form. These assumptions are that (a) over the ranges of t being examined, a_j is fixed and (b) over the ranges of t being examined, V'_{ij} is fixed. That is, one assumes that for the representative individual there is no change in the adaptation level over time (it is equal to the mean overall utility within the set of available destinations). In reality this would be the case if the distribution of adaptation levels within a population is symmetric about the actual mean utility for available destinations for all choice occasions (j). Under these assumptions, taking logs of both sides of Equation 20 yields

$$\ln[P(\text{not } i)_t] = -D_i - b + t\left\{\ln\left[1 - e^{-e^{-(V'_i-a)}} + e^{-D_i-b-e^{-(V'_i-a)}}\right]\right\} \quad (21)$$

Two points concerning Equation 21 are worth noting. First, because all V'_i vary only in terms of perceived distance (all are unfamiliar alternatives), P (not i)$_t$ is essentially a function only of choice occasions (t) and locational convenience (D_i). Second, the limit of P (not i)$_t$ as either D_i or t approaches infinity is zero. These are useful features for computational approximations to Equation 21.

The probability that destination i would have been inspected at least once after t choice occasions is thus given by

$$P(i \text{ by } t) = 1 - P(\text{not } i)_t \quad (22)$$

where P (not i)$_t$ is given by either Equation 20 or Equation 21.

Probability That Destination Will Be in Choice Set on Choice Occasion t

This section concerns the derivation of an expression for the probability that a destination will be in the choice set on a given choice occasion t, that is, that a destination will have a nonzero probability of being chosen. As will be demonstrated, the solution to this problem is straightforward when there are two potential destinations. However, it appears excessively complex in the general or n-destinations case. In light of this result, approximations to the solution are proposed.

The model of individual behavior outlined in the last major section posits that individuals exclude from consideration all destinations thought to be decidedly inferior or highly similar to more preferred destinations. Judgments related to whether some destination i is considered (that is, has a nonzero probability of being chosen) are hypothesized to be a function of (a) the relative magnitude of the overall utility of i vis-à-vis other destinations and (b) the similarity between i and other destinations. Specifically, it is posited that, in a comparison between two destinations (i and j), j will not be excluded from consideration by an individual if the statistic

$$C_{ijt} = (V_{it} - V_{jt})PCOV(i,j)_t \quad (23)$$

is less than some critical threshold value (C*). As before, V_{it} and V_{jt} represent overall utilities, and PCOV (i, t)$_t$ represents the perceived covariance between i and j.

When group behavior is being modeled, it is of interest to derive an expression for the probability that a destination will be considered by assuming that individuals employ the elimination strategy outlined above for all pairs of potential alternatives. A straightforward solution to the problem, at least for the two-destination case, may be obtained by assuming that overall utilities (V_{it}) vary randomly within the population, whereas critical thresholds (C*) are fixed.

Let the overall utilities associated with two destinations (i and j) be represented by the sum of fixed and random components associated with each. Specifically, V_{it} and V_{jt} are defined as follows:

$$V_{it} = V''_{it} + r_{it} \quad (24)$$

$$V_{jt} = V''_{jt} + r_{jt} \quad (25)$$

where V''_{it} and V''_{jt} are fixed (nonstochastic) components of utility and r_{it} and r_{jt} are random components. The components r_{it} and r_{jt} reflect the distribution of tastes and preferences within the population on choice occasion t. From Equation 23, the probability that destination j will be considered on choice occasion t is given by

$$P(j \text{ is considered})_t = P[(V_{it} - V_{jt})PCOV(i,j)_t < C^*] \quad (26)$$

Through substitution of Equations 24 and 25, Equation 26 may be rewritten as

$$P(j \text{ is considered})_t = P\{[V''_{it} + r_{it} - (V''_{jt} + r_{jt})]\,PCOV(i,j)_t < C^*\}$$
$$= P\{r_{it} - r_{jt} < V''_{jt} - V''_{it} + [C^*/PCOV(i,j)_t]\} \quad (27)$$

If it is assumed that r_{jt} and r_{it} have independent type 1 extreme value (Gumbel) distributions, Equation 27 may be

$$P(j \text{ is included}) = 1/\left(1 + \exp\{[-C^*/PCOV(i,j)_t] + V''_{it} - V''_{jt}\}\right) \quad (28)$$

The derivation of Equation 28 is directly analogous to that of the binomial logit model (1).

It is clear that Equation 28 will be difficult to generalize beyond the two-destination case. To develop a workable general formulation for the probability that a destination will be considered, it therefore appears necessary to make some simplifying assumptions. In particular, workable forms for the general (n-destination) case of Equation 28 result if one can make either of the following assumptions:

1. Covariances (similarities) among all pairs of destinations are equal or
2. Covariances are unequal but the differences $V_{it} - V_{jt}$ are minimal; that is, exclusion decisions are based solely on similarity considerations.

Under assumption 1, the probability that a destination j will be considered on a choice occasion t given n potential destinations is given as follows: Let $V''_{max\,t}$ represent the maximum overall mean utility among n destinations. The probability that a destination j will be considered under assumption 1 is given by

$$P(j \text{ is considered}) = 1/[1 + \exp(-C^* + V''_{jt} - V''_{jt} - V''_{max\,t})] \quad (29)$$

Equation 29 follows directly from Equation 28.

The derived expression under assumption 2 is analogous. Specifically, let $PCOV(j,k)_{max\,t}$ represent the maximum covariance observed among all (j, k) pairs of destinations and let V''_k represent the overall utility associated with the most similar destination. The probability that a destination j will be considered in this case is given by

$$P(j \text{ is considered}) = 1/\left(1 + \exp\{[-C^*/PCOV(j,k)_{max\,t}] + V''_{jt} - V''_{kt}\}\right) \quad (30)$$

The logic behind both of these models is simply that, if the maximum criterion statistic (C_{ij}) evaluated for all pairs of destinations with respect to j is below the critical threshold (C^*), j will be in the choice set. If one assumes equal covariances (Equation 29), this maximum statistic is that with respect to the alternative with the highest overall utility ($V_{max\,t}$). If one assumes minimal differences, this maximum statistic is that with respect to the destination with which j holds the greatest similarity [$PCOV(j,k)_{max\,t}$].

Choice Probabilities

Given expressions for the probabilities that a destination is familiar on some choice occasion t and will be in the choice set, it is possible to derive expressions for the probability that a destination will be chosen on that particular occasion. The analysis starts by advancing an expression for the probability that some destination i will be chosen among n familiar, considered alternatives. A starting point might be to represent this probability by a multinomial logit model (1). Specifically,

$$P(i/1, \ldots, i, \ldots n) = e^{V_i} \Big/ \sum_{j=1}^{n} e^{C_j} \quad (31)$$

We seek to derive a more general form of Equation 31 by relaxing the assumption that all n alternatives are familiar and are in the choice set.

The approach to modeling proposed here consists of redefining the utility arguments (e^{V_j}) contained in Equation 31. In particular, utility arguments are redefined in terms of a weighted average of the utilities associated with each destination derived under the assumption that it is either familiar or unfamiliar to an individual on a particular choice occasion. As was suggested earlier, the weights in this definition correspond to two probability estimates:

1. That a destination is familiar on a particular choice occasion and
2. That a destination is in the choice set on that choice occasion.

Formally, each term e^{V_j} in Equation 31 is redefined as follows:

$$e^{V_j} = F_{jt} S_{jt}\, e^{V'_{jt}} + (1 - F_{jt}) S_{jt}\, e^{V'''_{jt}} \quad (32)$$

where F_{jt} is the probability that j is familiar on choice occasion t, S_{jt} is the probability that j will be in the choice set on choice occasion t, V''_{jt} is the overall utility associated with destination j under the assumption that it is familiar (an average within the population), and V'''_{jt} is the overall utility associated with destination j under the assumption that it is not familiar (an average within the population). F_{jt} is given by Equation 22, and both V''_{jt} and V'''_{jt} are given by substituting Equations 2, 4, and 6 in Equation 1. As noted previously, at the moment there is no general expression for the probability of consideration (S_{jt}). Hence, S_{jt} must be approximated, with such approximations being given by Equations 29 and 30.

Clearly, models of group choice behavior derived by substituting Equation 32 in Equation 31 would be rather complex. For example, under the assumption of equal covariances (Equation 29), the probability that some destination i will be selected among n alternatives is given by

$$P(i/1, \ldots, i, \ldots n)_t = \left[\frac{F_{it}\exp(V''_{it})}{1 + \exp(-C^* + V''_{it} - V_{max\,t})} + \frac{(1 - F_{it})\exp(V'''_{it})}{1 + \exp(-C^* + V'''_{it} - V_{max\,t})}\right] \div \sum_{j=1}^{n}\left[\frac{F_{jt}\exp(V''_{jt})}{1 + \exp(-C^* + V''_{jt} - V_{max\,t})} + \frac{(1 - F_{jt})\exp(V'''_{it})}{1 + \exp(-C^* + V'''_{jt} - V_{max\,t})}\right] \quad (33)$$

where $V_{max\,t}$ is the maximum average overall utility observed among n destinations.

Of course, greater simplicity is achieved if one can assume that all potential destinations are familiar to individuals or that all destinations are in the choice set or both. For example, under the assumption that all destinations are familiar [that is, $(F_{jt} - 1)$] and by using Equation 29 for the probability of choice-set membership, the probability that some destination i will be chosen among n alternatives on choice occasion t is given by

$$P(i/1, \ldots, i, \ldots, n)_t = \frac{\exp(V''_{it})}{1 + \exp(-C^* + V^*_{it} - V_{max\,t})} \div \sum_{j=1}^{n} \left[\frac{\exp(V''_{jt})}{1 + \exp(-C^* + V''_{jt} - V_{max\,t})} \right] \quad (34)$$

It should be noted that if $V_{max\,t}$ is constant across choice sets, Equation 34 can be reduced to a simple multinomial logit model (Equation 21). Specifically, in this case $V_{max\,t}$ and C* would serve simply as scaling constants; hence, their presence in the model would not affect choice probabilities. It would be important to retain the choice-set probability term (including $V_{max\,t}$) only if one wished to use a single acontextual utility function (which yields the V''_{jt} values) to predict choice behavior across differing sets of alternatives.

In the derived models, the term $(1 - F_{it})$ may be thought of as the probability that an observed choice is one made as a consequence of search or learning. The extent to which such choices would pervade aggregate data is a function of the rate at which alternatives under study are consumed. For example, if individuals make infrequent choices, there are continual changes in the set of available destinations (such as stores opening and closing), and there is a continual inflow and outflow of decision makers; then one would expect aggregate choice data to be heavily influenced—if not dominated—by search-related choices (F_{it} would be nearly zero). On the other hand, for those activities associated with frequent destination choices (for example, grocery shopping), search-related choices should represent only a small proportion of the total number of choices observed (F_{it} would be nearly 1).

DISCUSSION OF RESULTS

From a pragmatic point of view, the misspecification of choice sets in disaggregate destination-choice models manifests itself most seriously in terms of contributing to parameter intransferability. In particular, current models assume that the population of individuals under study (or segments thereof)

1. Have full knowledge of all alternatives potentially available to them (or at least have an equal probability of knowing about all alternatives),
2. Are unaffected by habit or uncertainty, and
3. Do not systematically alter preferences or levels of knowledge over time.

Because it is likely that violations of these assumptions permeate revealed-preference data, the parameters of choice models are highly confounded by a number of such unexplained exogenous variables. Hence, the frequent finding that parameters are intransferable should not come as a surprise (8).

This paper is advanced as an exploratory step toward overcoming some of the problems of intransferability. In particular, a theory has been proposed to describe the way in which individuals process information about sets of destinations over time in the formation of choice sets. This theory was then used to deduce possible forms of aggregate models that recognize and predict variations in the probability that a given alternative will be in a given individual's choice set across varying spatial choice contexts.

In communities characterized by a large number of recent migrants, for example, the model predicts that individuals would be relatively insensitive to variations in the place-specific attributes of destinations. Choice behavior within such a community would be largely influenced by the relative distances to destinations and each individual's adaptation levels. The longer that aggregates of individuals reside in an area, the greater is the likelihood that choice behavior is directly in response to the qualitative attributes of destinations. In a traditional multiattribute destination-choice model, this would manifest itself in terms of shifts in the saliency of predictor variables.

It is not proposed, of course, that the posited theory of choice-set formation represents a complete solution to the problems of choice-set specification and intransferability. The theory, for example, does not address how changes in relative location (such as destination agglomerations) are likely to influence the likelihood that an individual will both know about and consider a given destination. Clearly, this is an important element that must be included in future formulations. Although the results described are somewhat limited, it is hoped that they will prove useful as a framework for guiding future work that incorporates such elements.

REFERENCES

1. T. A. Domencich and D. F. McFadden. Urban Travel Demand: A Behavioral Analysis. North-Holland, Amsterdam, 1975.
2. J. A. Ansah. Destination Choice-Set Definition in Travel Behaviour Modeling. Transportation Research, Vol. 11, 1977, pp. 127-140.
3. D. A. Hensher. Behavioural Demand Modelling: Some Recent Issues and Possible New Directions. In Particular Choice-Set Generation, Endogenous Attributes, Decomposition of Utility Functions, and Congestion Modelling. Presented at Regional Transport Research Workshop on Methods and Concepts in Transportation Modelling, Melbourne, Australia, 1979.
4. F. S. Koppelman. Prediction with Disaggregate Models: The Aggregation Issue. TRB, Transportation Research Record 527, 1974, pp. 73-80.
5. J. Anderson. Space-Time Budgets and Activity Studies in Urban Geography and Planning. Environment and Planning, Vol. 3, 1971, pp. 353-368.
6. G. H. Pirie. Thoughts on Revealed Preferences and Spatial Behavior. Environment and Planning A, Vol. 8, 1976, pp. 947-955.
7. R. Keeney and H. Raiffa. Decisions with Multiple Objectives: Preferences and Value Trade-Offs. Wiley, New York, 1976.
8. J. J. Louviere. On the Interregional and Intercultural Transferability of Disaggregate Choice Models: Some Selected Comments. Institute of Urban and Regional Research, Univ. of Iowa, Iowa City, Tech. Rept. 111, 1979.
9. K. P. Burnett and S. Hanson. Rationale for an Alternative Mathematical Approach to Movement as Complex Human Behavior. TRB, Transportation Research Record 723, 1979, pp. 11-24.
10. G. H. Pirie. Measuring Accessibility: A Review and Proposal. Environment and Planning A, Vol. 11, 1979, pp. 299-312.
11. R. J. Meyer. Consumer Information Search and Choice Behavior: Two Models and Empirical Tests. School of Business Administration, Univ. of Iowa, Iowa City, Working Paper, 1979.
12. N. H. Anderson. Functional Measurement and Psychophysical Judgment. Psychological Review, Vol. 77, 1970, pp. 153-170.
13. E. J. Gumbel. Statistical Theory of Extreme Values and Some Practical Applications. National Bureau of Standards, Washington, DC, Applied Mathematics Series 33, 1954.

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