Problem of Aggregation in Disaggregate Behavioral Travel Choice Models With Emphasis on Data Requirements

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A preliminary consideration of the process leading to acts of choice is outlined in terms of the underlying dynamic process that molds the consumer's preference functions. This is designed with 3 main objectives in mind: the role of attitudes in influencing behavior, the directional relation between behavior and attitudes, and the identification of various homogeneous groups of travelers based on various prespecified physical and value-associated criteria and designed to ensure a more meaningful aggregation where within-group variance is minimized and between-group variance is maximized. An important feature of attitude-behavior models is that, being based on psychological principles, they are applicable to more than simply transportation problems. They can, therefore, be applied in some form to all aspects of human behavior (though perhaps with varying success) and so provide a basis for more coordination in governmental decision-making. A consideration of data requirements can emphatically contribute to a greater understanding of the causal connection within and between various acts of travel choice and accordingly lead to improvements in the models themselves via improved perspective in the selection of variables.

In recent years the progress of analytical rigor in modeling travel demand at the level of disaggregate behavioral travel choice has far outpaced the consideration of data requirements compatible with the relative level of sophistication of such models. [Tanner (46) gives an excellent discussion of the various interpretations of disaggregate and behavioral.] It is important to indicate the greater predictive ability of disaggregate stochastic behavioral models (henceforth referred to as behavioral models) tested on existing inappropriate and somewhat uncertain data collected in the past before the development of improved predictive models [for example, the Cook County Highway Department's data used by Warner and Lave (37)]. However, there are now new issues and emphases not evident in data requirements specified at previous points in time.

In addition to recognizing the urgent need for improved data sources, we must establish a number of guidelines to identify the nature of data requirements in terms of the real issues in planning for an improved quality of urban life and to meet the specification and estimation requirements of current and future modeling systems. Both the content (i.e., range) and conceptualization (i.e., structure) of mechanisms used to collect new data must be clearly spelled out. Once the objectives are clarified, then the issue of aggregation in its various guises should be operationally clearer.

This paper confines the discussion of aggregation in behavioral travel choice modeling to specific data needs and possible structural mechanisms suitable to the development of models that display a maximum maintenance of relevant behavioral interactions identified and measured at the level at which primary travel choice decision processes occur. Data requirements are broadly interpreted to entail identification and measurement of the physical and nonphysical attributes of an individual or type of individual, his or her environment, and the interaction within the attribute space and between this space and environment space. The individual as the basic decision unit attempts to maximize some objective function (subjectively defined and not necessarily homogeneous across individuals) subject to household and environmental constraints. That is, relative travel preferences and choices are related to the values and perceptions of individuals for the attributes associated with travel. This approach is operationally better than having the family as the decision-making unit, for identification of a utility function for an individual can be regarded as a relatively less onerous task than the identification of a utility function for a family. Immediate additivity problems associated with interpersonal comparisons occur at the level of the family unit.

BASIC HIERARCHICAL STRUCTURE

The emphasis is on the development of a schema that focuses on the understanding of the decision process leading to action by the user of various transport facilities in time and space. A great deal can be learned in the process of identifying data requirements by referring to the microstructural schemes that originated in the early 1920s with Tolman's cognitive maps (48, pp. 279-361) and in the 1930s with Lewin's topological spaces and valences (30, pp. 197-221) and Lazarsfeld's structural scheme to explain consumer behavior (28, pp. 26-38). These structural models are explanatory and predictive in contrast to the reduced-form models typified by contemporary transport planning submodels, which are noncausal associative models. Explanation is the vital link in the process of essentially improving predictability in the light of any system-sensitive adjustments [e.g., the effect of a fare increase on choice of mode (25)]. There is a need not only to identify and measure the relative influence of the determinants of the status quo but also to identify and measure the sensitivity of parameters from a given point in time and over time. Although time series data are necessary and are being collected by a few researchers or organizations (24), the time-dependent interaction effects will only be acknowledged as another area for data-requirement consideration. The discussion will be confined to cross-sectional issues associated with data needs in behavioral travel choice modeling in accordance with the requirement of desirable spatial aggregation criteria.

The Lazarsfeld approach, which was extended by Nicosia (34), emphasized the study of human conduct in natural settings in an attempt to uncover the structure of action (29, pp. 99-155). Assume that the individual's travel considerations can be represented in terms of 8 basic choices, each influenced and constrained by the traveler and his or her environment. That is, each component of travel choice can be divided into variables internal and external to the traveler. The 8 choices are

1. Whether to make a trip,
2. Single or multiple destinations,
3. Connecting and main modes,
4. Connecting and main routes,
5. Timing of trip,
6. Frequency of trip,
7. Employment location, and
8. Residential location.

Choice in this context is derived from preference in a way that gives the greatest weight to preference eventually (with flexible timing), and this requires that preference be sometimes revealed in immediate choice, sometimes distorted or abandoned (32, pp. 139-143).

In addition to the internal-external division, analysis of action can be expressed in terms of the morphological and analytical approaches. The morphological approach involves the form of a decision process obtained when certain types of variables are considered rather than others (34). Initially, a behavior space is postulated to include the set of all variables necessary and sufficient for understanding the act of travel choice. Successive stages in model building can then be described by the travel choice variables being postulated on the basis of previous empirical evidence or causal hypotheses, their functional relations determined, and their relative role in the decision process assessed.

Existing data sources completely disregard the extent of the behavior space. The result is that variables are postulated as relevant without really having any adequate ex ante empirical support other than that these variables have been shown to be correlatively good predictors in other contemporary studies (no mention of explanation, causality, or behavioral space identification). Transferability is almost certainly a risky game when such second-best approaches are adopted.

Lazarsfeld's paradigm of consumer action (Fig. 1) can be used to develop the general framework for identifying the orientation of data requirements and also as a lead into the specification of a number of major homogeneity criteria on which such consumer travel choices might be based. Aggregation of disaggregate homogeneous groups can be a useful way of modifying the criticisms currently associated with initial aggregation models. The measurement of the relevant variables in the behavior space will also be discussed.

Exposure is defined in terms of external variables such as the characteristics of a mode, a route, or a destination; influence is an exposure to which a causal impact has been imputed; dispositions are essentially the consumers' preferences; and motives are dispositions to which a causal impact has been imputed. The relations between these 4 classes of variables can be traced through. At any point in time, the consumer is in a circumstance that may be described in terms of a set of variables representing geographic (e.g., residential and employment location), social (occupational and class constraints), and other elements external to the individual (such as neighborhood and workplace considerations). The role of these elements can be seen as stimuli that may or may not impinge on the traveler. If they do impinge, they may act either as forces setting the individual's responses in motion or as constraints that bound and hence partially direct these responses.

There are a number of environmental variables to which the consumer is exposed, for example, the visual awareness of the existence of a public transport system. The relation between environmental and exposure variables implies a mechanism by which the environmental variables are (or are not) transformed into exposure variables. This mechanism may include those internal and external variables that assist or constrain the individual's exposure to a certain stimulus. For example, residential location may significantly influence the number, type, and destination of trips that the individual will usually be associated with and thus the spectrum of modes and routes to which he or she will usually be exposed. In addition, dispositions and motives might lead the individual to expose himself or herself only to certain information channels and certain messages. The influence variables are a subset of the exposure variables. Nicosia (34, p. 104) indicates that such variables are singled out as a morphologically relevant group because "an exposure variable may or may not have a psychological meaning for the receiving consumer."

For example, advertising might expose an individual to an alternative form of transport (the transit organizations are attempting to sell their products by marketing them along the lines of private organizations), but not alter any of his or her dispositions toward this alternative facility. At this point, the advertisement of this mode is not a component of the individual's decision process. The relation between exposure and influence variables implies a mechanism by which the former are (or are not) transformed into the latter. This mechanism consists of dispositions and motives (cognitive structures). The stimulus influence is now a relevant component of the decision process and hence becomes internalized as part of the individual's psychological reality. This suggests that data contributing to the explanation of the individual's nonphysical value structure are required in any study of travel choices. The explicit nature of this data requirement will become even clearer when we note that this internalized stimulus relation (externally influenced by the environment broadly interpreted) is tied in with the organization of the individual's cognitive processes (6, pp. 285-287) and structure.

Lazarsfeld identified 2 broad groupings of internal variables: dispositions and motives. Disposition variables are passive nondriving from a dynamic point of view, for example, opinions and beliefs. In contrast, motive variables (encompassing attitudes) drive the individual's behavior toward object goals (travel choices) from a dynamic point of view. More explicitly, the distinguishing feature of motives is that they

Figure 1. Lazarsfeld's paradigm of consumer action.

	Described	Causally Assessed
External	Exposure	Influence
Internal	Disposition	Motive

Figure 2. Questionnaire for collecting data on levels of importance and satisfaction of attributes of modes.

(a) This question is concerned with how you, with respect to any particular method of travel, value the various factors you consider important in the selection of a method of travel to work. Some of these factors are written below. If you wish, write in any other factors that might be important to you in items 5, 6 and 7 below. You have 100 points in total. Allocate points to each factor to indicate how important you consider that factor to be.

POINTS YOU WOULD ALLOCATE

1. TIME
2. COST
3. CONVENIENCE
4. COMFORT
5.
6.
7.

TOTAL 100 POINTS

(b) Please indicate how satisfactory your usual method of travel is by crossing (x) the scale below (or by placing a cross in a box) to show the degree of satisfaction to you of each feature listed below. Repeat the procedure to indicate your satisfaction with your best available alternative method of travel to work that you can afford.

USUAL METHOD OF TRAVEL: TIME COST COMFORT CONVENIENCE

ALTERNATIVE METHOD OF TRAVEL: TIME COST COMFORT CONVENIENCE

COMPLETELY SATISFACTORY (place a cross in the box) — 100

VERY SATISFACTORY Mark between 71 and 99 — 75

GENERALLY SATISFACTORY Mark between 51 and 70 — 50

GENERALLY UNSATISFACTORY Mark between 31 and 50

VERY UNSATISFACTORY Mark between 1 and 30 — 25

COMPLETELY UNSATISFACTORY (place a cross in the box) — 0 appear in the decision process as driving forces that direct the individual toward an act of choice. This frame of reference is seen as a sequence, exposure-influence-disposition-motive, indicating an overall pattern of interaction up to the point of contributing to the explanation of the choice process. However, given the many inherent difficulties in operationalizing this schema, we will concentrate on the motivational level of disaggregation, which can be interpreted to encompass attitudes as driving forces. Attitudes, hence, represent a major determinant of the individual's orientation toward the social and physical environment, including himself or herself. An attitude implies that motives are aroused and action is mobilized to approach or avoid a situation. In the travel choice context, it is becoming clear that the basis of selecting maximum-similarity criteria as a means of suitably aggregating disaggregate behavioral travel choice models must include a level of segmentation related to the individual's decision process that can be identified initially by developing attitudinal indexes.

The homogeneity criterion need not be purely physical. Differences in the values of individuals are an important source of transport discrimination (51, pp. 83-90). An individual who prefers to travel in a second-class train compartment and to be classified as working class might own a very expensive car. A high-paid individual may prefer to run an old car and spend more money in entertaining. The same individual might be involved in a dichotomous value situation because of differing experiences. By segmenting the market on the basis of values, purposes, needs, and attitudes relevant to the product being investigated (i.e., travel as represented by a series of choices), misleading information derived from attempts to divide people solely on physical socioeconomic characteristics might be minimized. This procedure is seen as a complementary mechanism to the physical orientation. Since attitudes are related to motives and hence to the exposure and influence variables in the paradigm of action, the environmental variables (broadly defined to include physical trip characteristics and socioeconomic characteristics of the travelers) must also be considered as constraining influences on attitudes and acts of choice. Physical segmentation is only one of a number of maximum-similarity criteria.

Census and existing area transportation study data contain useful information, but they identify neither the crucial issues of the urban transport demand problem nor those groups whose behavior patterns are still fluid nor the needs, values, and attitudes that influence how these various groups of actual and potential travelers react to system changes. Far too often, recommended transport improvements are directed to all members of the community, but are often only of relevance to a partitioned group within that community. We need to seek out the various groups on a psychological continuum and then recommend improvements that best meet those requirements (including unmet needs) rather than those that conform to planner's deficiency-oriented, model-prediction recommendations based on observed behavior that was influenced by past experience with existing systems.

Value segmentation can be usefully represented along a number of continua just as various socioeconomic characteristics are split (e.g., age groups). A threefold division representing how individuals look at the meaning of value in a mode might be

1. Individuals who travel by a mode for cost reasons;
2. Individuals who want to use the best mode available for their money (the emphasis is on values such as reliability, economy in utilization, speed, and comfort); and
3. Individuals interested in personal enhancement (although the value of a car as a status symbol has declined, the personal satisfaction from owning a fine car has not lessened for this segment of the market).

Attitudinal Schema

In recent years, evidence on price inelasticity (11, 36) has reduced the relative influence of division 1 and increased the relative importance of division 2, product value. The reduced influence of cost has tended to marginally reduce the importance of misperception of money cost but at the same time has reoriented identification and measurement to the previously referenced nonquantifiable abstract summarizers such as comfort, convenience, and reliability. The data requirement in accordance with the second division points to the use of techniques capable of accommodating such nonquantifiables. It is most convenient that attitudinal measurement techniques are admirably suited to this task in addition to being suited to the decision process schema on which the foundations of acts of choice are based.

In the majority of contemporary social psychology textbooks, attitude is defined as a concept containing an affective or liking component, a cognitive or belief component, and a conative or action tendency component. The broad acceptance of this multiple component view has been usefully explained by Fishbein (19, p. 4):

> Two people might feel the same amount of affect toward an object but might behave differently with respect to that object and/or might hold different beliefs about what should be done with respect to that object. Clearly then, since the "action" component is different, these people must have different attitudes. Similarly, two people might be equally favourable toward the object, but they might also have different cognitions about the object....Here again they must have different attitudes.

Despite the theoretician's espousal of the multicomponent view of attitudes, most psychological and marketing research seems to consider only the affective component, a single overall liking index expressed in the form of a linear summation of the perceived instrumentality subcomponent of the evaluative belief model. The basic formulation is

$$\sum_i \sum_j (S^i_{1j} - S^i_{2j}) \tag{1}$$

where S^i_{kj} = degree of satisfaction associated with the k th mode with respect to the i th attribute for the j th individual (k = 1, 2).

In addition to summing evaluative beliefs prior to relating them to affect (overall liking), a number of studies (2, 14, 22, 23) have expressed evaluative beliefs in a way that distinctively retains each belief in the individual's perceptual map by relating the separate attributes to behavior (choice of mode) or to overall liking. The latter is empirically identified as a single satisfaction rating, $(S_{1j} - S_{2j})$.

Several recent studies (2, 22, 23, 35, 39, 42) have introduced a relevance weight. The argument is that an individual's attitude toward a mode is determined by his or her evaluations of a set of beliefs expressed in the general form

$$\sum_i \sum_j I^i_j (S^i_{1j} - S^i_{2j}) \tag{2}$$

where I^i_j = index of the relative importance of the i th attribute for the j th individual with respect to a particular set of circumstances (e.g., the choice of commuter mode).

In addition to the role of importances indicated above, the importance, I, weights are introduced because of the artificial measurement of affect on the satisfaction, S, scales (44, pp. 10-12; 23, pp. 137-141). As stated by Stanley (44, p. 11), "The scaled satisfaction from each (attribute) is equal by construction (Fig. 2) but the corresponding utility scale ranges differ." It is argued that deterministically the correct operational measure of affect or utility is a composite I•S index. In terms of utility measurement, the generalized utility function can be given as

$$du^j = \sum_i (\partial u^i_j / \partial A_i)\, dA_i \tag{3}$$

where

du^j = change in utility of the j th individual,

$\partial u_j^i / \partial A_i$ = change in utility of individual j resulting from a small change in attribute i, and

A_i = i th attribute.

Stanley has shown (44, p. 10) that

$$du^j = \sum_i I_j^i (\partial S_j^i / \partial A_i) \, dA_j \tag{4}$$

where

I_j^i = positive constant that may differ for each attribute, and
S_j^i = real-valued function over the i th attribute.

The ∂S_j^i are representations of ∂u_j^i except for scale unit. For example, an individual may be completely satisfied with automobile travel time and automobile comfort yet derive less utility from the latter than the former. To make the S scales consistent with the ∂u_j^i scales, the I weights are introduced. The interpretation of this composite utility function is, for example, the traveler derives more utility from present levels of automobile comfort than from automobile travel time because comfort is more important even though he or she is completely satisfied with both.

In completed studies the deterministic summation of the importance weights has been either constrained to unity (23) or unbounded (22, 35). The importance weight must be constrained to unity to provide a measurement unique up to a positive linear transformation since the strength of the attitudinal index approach lies in the ability to compare relative utilities on attributes for each individual. If it is open ended, then the absolute intensity of each variable can be observed but not the relative attribute value intensity. The perceptual importance weight is a way of ensuring this compatibility.

An alternative procedure is to use probabilistic estimation procedures and interpret the estimates of the attitudinal parameters as statistical proxies of the relative importance of attributes in explaining behavior (39, 40). The standardized partial regression coefficients (beta coefficients) have been interpreted as directly assigned importances. The major criticism of this approach is that the beta weight is a statistical weight, a number associated with a given attribute in such a way that some combination of attributes is observed to account for or "explain" behavior of a group of individuals. As such, it is an ex post standardized raw coefficient that is not related in any necessarily predictable way to the utility function of a particular individual but rather performs as an average indicator of likely response of the "typical" sample observation. This assumes that the attribute weights may be attributed to all travelers within the market. It does not perform the scaling function performed by the I weights on an individual basis. Until a mapping test is undertaken to test for invariance between the single statistical beta weight and the distribution of psychological weights, this general area of modeling remains open to debate. An important issue is the extent to which the inclusion of I weights as scale standardizers in the utility function introduces an element of double counting in the probabilistic function where beta weights are obtained. Limited empirical work is generally inconclusive.

It is concluded that the complete utility index unique for each individual should be obtained prior to statistical estimation both to conform with scaling requirements and to increase the influence of causative rather than necessarily correlative relations. Figure 2 gives an example of the type of empirical question designed to elicit the information required for the deterministic formulation (Eq. 2) and its probabilistic equivalent, i.e.,

$$\text{Choice of mode} = f\left[\sum_i \sum_j I_j^i (S_{1j}^i - S_{2j}^i)\right] \tag{5}$$

Finer divisions into the various components of travel time may also be obtained by the use of the same technique (23, p. 16).

The conative component, $(AT)^i_j$, involving sensitivity testing of individuals' preferences to single and combination changes in attributes influencing acts of choice, is somewhat more difficult to handle, especially when the number of attributes exceeds 3, because the possible combinations of attributes increase by $2^n - 1$. Ackoff (1) selected 3 attributes for automobile users whom he asked to supply information on hypothetical questions as to what conditions must occur in order for them to switch to public transport. He also asked whether combinations of the attributes will make the individual change mode. Multiple answers may exist for 2 reasons:

1. In terms of the individual's utility, a change in A alone or B alone may not be enough to cause a modal switch; and
2. If an individual indicates that a change in B is enough to make him or her switch modes, this implies that AB, BC, and ABC should also be chosen by the individual since all the attributes yield positive utility for the individual.

An interpretation applied to cognition that needs to be separated out for consideration refers to the individual's awareness and knowledge of the existence of the travel circumstances (modes, number of trips, timing) and their associated characteristics. Cognition interpreted as an awareness component of attitudinal measurement is particularly relevant where information and perception are not uniformly distributed among the various relevant determinants of travel choice and among the various groups of individuals. Although behavioral mode choice research has provoked much discussion on the misperception of costs of travel by an alternative mode in contrast to the knowledge of costs of travel on the chosen mode, little evidence is available on the extent of misperception or the degree of awareness of attributes of alternative modes. In general, there is a spectrum of degrees of awareness of attributes that influence travel choice. This must be allowed for somewhere in the planning model. One potentially useful empirical way of identifying the awareness-cognition is shown in Figure 3. This attitudinal component now becomes an additional component in an attitudinal model or index, which might be analytically expressed in a final form as

$$A^i = f \sum_{ij} \left[I^i_j(S^i_{1j} - S^i_{2j}),\ (K^i_{1j} - K^i_{2j}),\ (AT)^i_j \right] \quad (6)$$

where

$I^i_j(S^i_{1j} - S^i_{2j})$ = affective index,
$K^i_{1j} - K^i_{2j}$ = cognitive-awareness index, and
$(AT)^i_j$ = conative index.

In the modal context, A^i could be the choice of mode or a measure of overall attitude. The precise functional form of the model is an issue for further investigation.

Allen (2) cites an example of 9 individuals answering the hypothetical question in the following manner:

	Individual								
Attribute	1	2	3	4	5	6	7	8	9
A	x								
B	x		x	x					
C		x			x				
AB	x		x	x					
AC	x	x	x		x	x	x		
BC	x	x	x	x	x				
ABC	x	x	x	x	x	x	x	x	
None									x

This information can be summarized as follows:

Figure 3. Questionnaire for collecting data on awareness of attributes of travel mode.

How well do you believe you know the time, cost, levels of comfort, convenience of your USUAL method of travel and your best available ALTERNATIVE method of travel for the journey to work?

Answer by crossing (x) on the scale below or placing a cross in a box.

		USUAL METHOD OF TRAVEL				ALTERNATIVE METHOD OF TRAVEL			
		TIME	COST	COMF-ORT	CONVEN-IENCE	TIME	COST	COMF-ORT	CONVEN-IENCE
I know exactly (Place a cross in the box)	100	☐	☐	☐	☐	☐	☐	☐	☐
I know very well Mark between 71 & 80	80								
I know fairly well Mark between 51 & 70	70								
I have some Knowledge Mark between 31 & 50	50								
I have very limited knowledge Mark between 21 & 30	30								
	20								
I do not know at all (Place a cross in the box)	0	☐	☐	☐	☐	☐	☐	☐	☐

Figure 4. Questionnaire for collecting data on usage intention.

Do you believe you would change COMPLETELY to public transport (where the automobile might only be used as a connecting transport to your local station) for traveling to work if the following single changes or combinations of changes occured:

		I believe I definitely would change	I believe I probably would change	I believe I probably would NOT change	I believe I definitely would NOT change
(a)	Public transport was free (TICK ONE)	( )	( )	( )	( )
(b)	Public transport was made more comfortable according to your meaning of comfort given in Q.17 (TICK ONE)	( )	( )	( )	( )
	The time spent travelling to work in the train was reduced by:				
	(c) 5 minutes (TICK ONE)	( )	( )	( )	( )
	(d) 10 minutes (TICK ONE)	( )	( )	( )	( )
	(e) 15 minutes (TICK ONE)	( )	( )	( )	( )
(f)	Free and more comfortable public transport (TICK ONE)	( )	( )	( )	( )
(m)	Free, more comfortable and a 5 minutes reduction in travel by public transport (TICK ONE)	( )	( )	( )	( )
(n)	Free, more comfortable and a 10 minutes reduction in travel by public transport (TICK ONE)	( )	( )	( )	( )
(o)	Free, more comfortable and a 15 minutes reduction in travel by public transport (TICK ONE)	( )	( )	( )	( )

Attribute	Number of Individuals
A	1
B	3
C	2
AB	3
AC	6
BC	5
ABC	8
None	1

Transit ridership will increase by 1 if A is improved, by 3 if B is improved, and by 2 if C is improved. Thus, if improvements could be implemented with equal ease, B would be implemented first. However, if resources exist to make 2 improvements, A and C should be undertaken and not B. An example of a question designed to elicit this information is given in Figure 4, where the 3 attributes, time, cost, and comfort, are assumed for illustrative purposes to be the most significant determinants of modal choice. The "I believe" approach should be tested against revealed preference data to evaluate reliability. Empirical information on the perceptual meaning of the abstract summarizer "comfort" would also be required in order to use the results of an attitudinal study to suggest various policy options (24). This conceptual framework presented is currently being empirically tested in Australia with information gathered from questionnaires shown in Figures 2, 3, and 4.

So far the attitudinal index has been illustrated in the context of modal choice. However, its powerful generalization permits transference to other (interdependent) choice situations. For example, the frequency-of-trips process may be expressed in the following form:

$$\text{Number of trips per unit of time} = f\sum_i\sum_j\sum_k \left[I^i_{jk}(S^i_{ujk} - S^i_{ajk}),\ (K^i_{ujk} - K^i_{ajk}),\ (AT)^i_{jk}\right] \quad (7)$$

where

$\sum_i\sum_j\sum_k I^i_{jk}(S^i_{ujk} - S^i_{ajk})$ = affective index of summation of the relative importance of the i th factor in influencing the number of trips per unit of time for the k th journey purpose, weighted by the level of satisfaction associated with the present situation, u, with respect to that factor for the k th journey purpose in relation to the degree of satisfaction associated with the i th factor when less (or more) weekly trips, a, for the k th purpose are undertaken;

$(K^i_{ujk} - K^i_{ajk})$ = awareness component defined in terms of the relative level of awareness of the influence of the various factors included in the affective index for the k th journey purpose by the j th individual under present and any indicated new circumstances resultant from change; and

$(AT)^i_{jk}$ = conative component defined in terms of the probability of the i th individual adjusting the number of weekly trips for the k th purpose as a result of a change (reaction tendency) in the i th factor or a combination of i factors.

The degree of nonindependence among the 3 indexes must be assessed before the trichotomous model can be adopted.

ATTITUDES AND BEHAVIOR

Although attitudinal indexes can provide the core data for developing choice models, discrepancies are expected between attitude and behavior because individuals do not always act in accordance with what they believe. Behavior is determined not only by attitudes but also by external factors in the immediate environment (e.g., social, geographical, legal, and economic considerations).

The complete range of data requirements should be extracted from each trip producer if the causal criterion is to be met. All requirements are assumed to be internally measured. Three broad categories of measurement are identified: the psychologically defined measures (e.g., attitudinal and perceptual), the physically defined personal user characteristics, and the physically defined nonpersonal characteristics. Family and traveler behavior might be expressed as a function of the interaction between all the individual's inner determinants, such as temperament, attitudes, or character traits and all the environmental factors as perceived by the individual, i.e., action space. [Action space can be defined as the collection of all urban locations about which the individual has information. It is the subjective utility the individual associates with these locations (27).] With complete knowledge of all but one part of the formula, the variable that is not known can be predicted.

Behavior has a complex relation with its various inner determinants because of the influence of environmental factors (which may be differently perceived by different individuals). Thus, it cannot be used as a measure of inner determinants, and we cannot accurately infer attitudes from behavior unless full knowledge of the effects of environmental determinants is assumed. Furthermore, for the same reasons we cannot expect a direct prediction of overt behavior merely from a knowledge of one determinant, such as a score on an attitude scale. Other inner determinants (including conflicting attitudes) may play a part, but above all we need full knowledge of the effects of the perceived environment. An attitude scale may indicate inclinations toward cheating, but respondents will probably act honestly if they think they will be found out. Behavior is a compromise, a resultant of the interaction of multiple forces. We may conclude, therefore, that the failure to predict a particular action does not mean that the attitude scale is invalid. The scale may well have given valid and accurate measures of a given attitude and correctly described the individual's response tendencies. These may, however, have been offset or nullified by other tendencies that have gone unmeasured and by the individual's perception of the environment at that time, which likewise has not been taken into account.

Attitudes to choice are seen as the guiding rather than the motivating force behind activity. What influence do attitudes have on behavior? Among the more important research findings that are relevant from social psychology are those concerned with cognitive dissonance (18). The dissonance principle (17, p. 13) holds that 2 elements of knowledge "are in dissonant relation if, considering those two alone, the obverse of one element would follow from the other."

It is predicted that all choices result in dissonance to the extent that the alternative not chosen contains positive feasures that make it attractive also, and the alternative chosen contains features that might have caused it to be rejected. Hence, after making a choice, people seek evidence to confirm their decisions and so reduce dissonance. This finding suggests that behavior change may cause attitude change rather than the reverse. This situation has clear implications for data requirements. There is no point in setting out to influence attitudes if they do not influence behavior—but do they?

One prediction from dissonance theory is that, in certain circumstances, dissonance may be reduced by the fitting of behavior to attitudes. We become increasingly dissatisfied with our usual mode or the timing of a usual trip or the frequency of shopping trips. Dissonance theory can assist in the recognition of the dual-directional relation between attitudes and behavior, i.e., attitudes $\rightleftarrows$ behavior, in a tug-of-war situation. In situations where attitudes and behavior are dissonant, one or the other may change. Hence, the attitudinal focus must be seriously investigated. Although planners may choose to disregard, at some peril, the utility or attitudinal judgments of individuals, it is at least possible and often desirable for them to aim at the maximization of a welfare function that is based on private utilities or attitudes. The case for this would be considerably strengthened if a complete utility theory of traveler behavior (i.e., not just modal-choice behavior) could be developed.

HOMOGENEITY OR MAXIMUM SIMILARITY RATIONALE

The homogeneity rationale entails the selection of groupings of data in which the measure of central tendency is a sufficiently useful indication of a particular group of observations in accordance with the goals of developing demand models. In essence, minimization of variation within a homogeneous group and maximization of variation between homogeneous groups are the procedural rule. (In Australia, traffic zones are defined in terms of aggregates of census collector districts; i.e., areas in which the distances within the district enable a census collector to manually collect census forms with minimum effort. This suggests, however, that information can still be physically collected along existing lines but reshuffled in accordance with various homogeneity criteria to obtain relevant groupings.) The existing zonal demarcation structured on physical geographical rules has been continually criticized on many grounds, especially the existence of within variances often greater than between variances on many important predictors of choice. We are continually emphasizing a systematic approach enabling the planner to select the strategically most important segmentations and then plan around them (for example, the disadvantaged). However, this group can be defined along a number of continua (e.g., poverty scale, nonavailability of alternative mode, handicapped), each requiring separate homogeneity analysis. Given that market segmentation emphasizes the group as the unit of analysis, then variance among groups and not individuals should be the unit of analysis.

The automatic interaction detector (AID) is one multivariate technique suitable for determining those variables considered and categories within them that combine to produce the greatest discrimination in group means by the dependent variable. Data need not be limited to the handling capacity of models but can be as extensive as necessary in accordance with the requirement to explain and predict travel choice. AID offers an efficient method of data reduction and selection of the characteristics related to travel choice. From a large group of possible explanatory variables, AID selects those most useful for statistically explaining the variation in a given explanand by employing a nonsymmetrical branching process. Analysis of variance techniques subdivide the total number of observations into K mutually exclusive types that, for a given K, explain more of the total sum of squares than any other K types. By this procedure, potentially relevant data required are not excluded on the basis of some intuitive criterion. For travel choice analysis, each of these types may be viewed as defining a relatively homogeneous class of travelers with respect to the taxonomy of travel choices.

Input to the AID analysis is a raw data matrix consisting of every respondent's score on the usage level variable and on several independent predictor variables. At the outset of the analysis, there is only 1 group—the total population. The performance of this group on the dependent variable, e.g., usage level, can be represented by a frequency distribution such as that shown in Figure 5, where the horizontal axis represents values of usage level and the vertical axis represents number of respondents. Typically the total population has a high variance about its mean value. When there is so much variation about the mean, to predict what the usage level of any one individual in the group will be is difficult.

The AID program seeks to subdivide the total population into 2 subgroups having significantly different mean values on the dependent variable and much smaller variances about their means (Fig. 5, distributions B and C). If this can be done, then knowing whether a respondent is a member of one of these subgroups will help in predicting more accurately his or her usage level.

In the subdivision, the difference in usage level is considered between all possible 2-way splits on the predictor variables. The predictor variable that is selected depends on a statistical analysis. The procedure is as follows. Suppose one of the variables is age, having 4 different levels. The program will consider every possible 2-way split of this variable: It will divide the population into people in age brackets 1 and 2 versus those in 3 and 4; 1 versus 2, 3, and 4; and finally 4 versus 1, 2, and 3. For each split, the program calculates the mean value and the variance of usage level for each of the subgroups. It then goes on to calculate the significance level of the split. Thus, it uses the explanatory variable to yield subgroups and then evaluates how different these

Figure 5. Population divided by AID into subgroups.

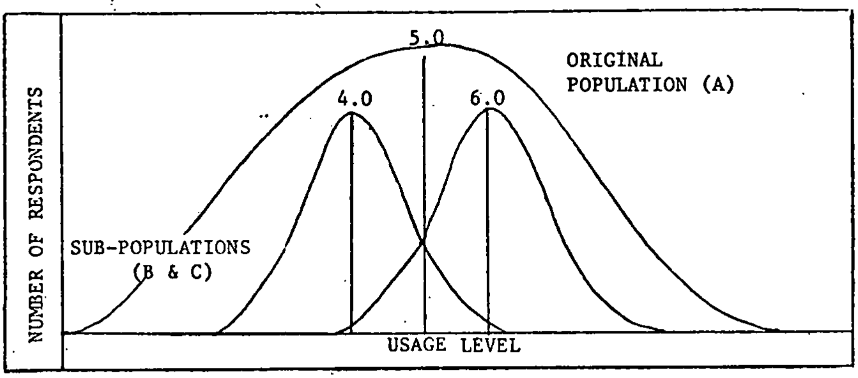
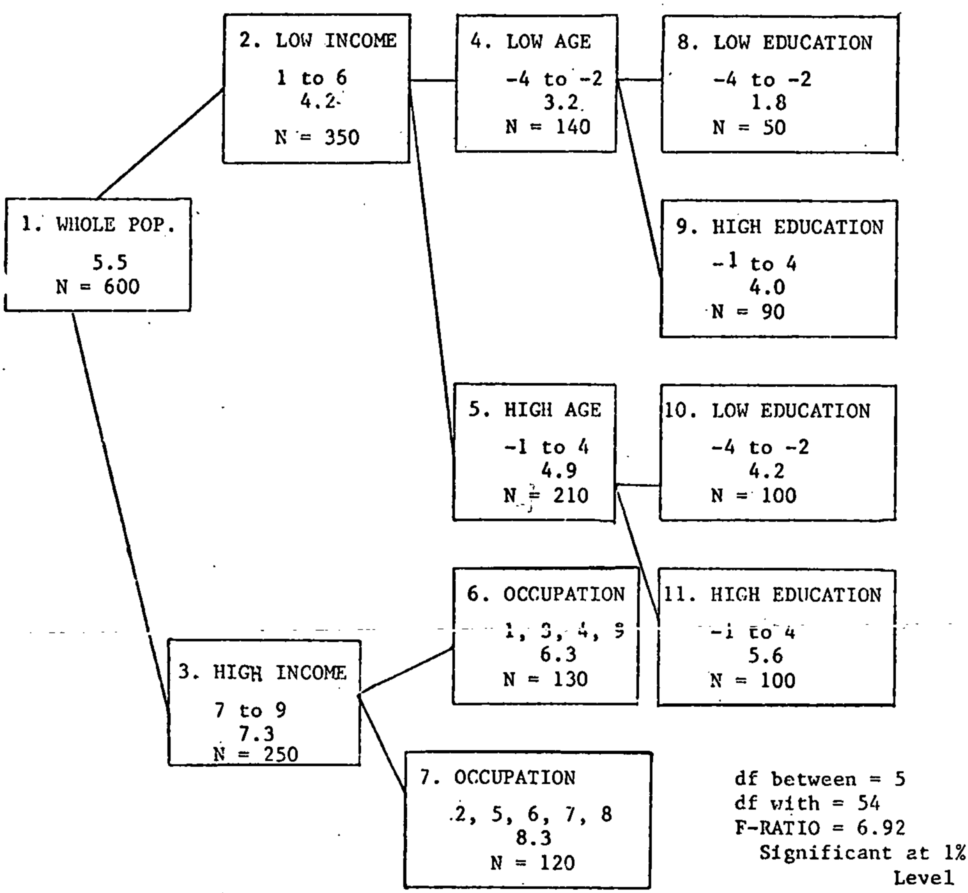


Figure 6. AID tree diagram.



subgroups are with respect to usage level, the dependent variable.

Having done this, the program then considers the next explanatory variable and all its possible 2-way splits. Finally, when all the possible 2-way splits on all the explanatory variables have been considered, the program selects the one explanatory variable and its one 2-way split that yields the best division of the total population. This split is then used to subdivide the original population.

Having thus completed one division of the population, the program treats each subgroup as if it were a base population, and the entire process of searching all the explanatory variables for the most significant split is repeated for each subgroup. Every time a new subdivision of the population is completed, the process repeats itself on the new subgroups until, finally, preset criteria for subdivision are met.

The final result is a tree structure in which every split of the population is shown. The end points of the branches of this tree are the mutually exclusive subgroups or market structures of the total population. These groups all differ significantly in their performance on the dependent variable and are all well defined in terms of the levels of the predictor variables that were used in dividing them from the total population (Fig. 6).

The procedure used by AID has several important consequences. First, because the AID program considers all predictor variables for every split, it allows for detection of interaction effects. Thus, although age might not have proved to supply a significant 2-way split for the original division of the population, it may turn up as an important way to split a subpopulation. Also, the AID analysis, by a process of statistical evaluations, selects only those explanatory variables that are significant to a subdivision of the population. The original data may be on some 30 different variables, but AID may have used only 10 of them to divide up the population into its market structures. Finally, the AID program can operate equally well on classificatory data as on scaled data. It makes no difference if one constructs a split that is long trips versus short trips or a split that actually represents ages 20 to 40 versus ages 40 to 60.

CONCLUSIONS

Appropriate specification of choice in accordance with the processes leading to acts of choice and development of criteria based on maximum-similarity groupings will contribute significantly to the development of disaggregate behavioral models of travel choice capable of aggregation at various levels of regional segmentation devoid of some of the contemporary aggregation problems. Data requirements have been broadly outlined in the context of decision processes. The essential point is that a reasonable proportion of information originally collected in accordance with other data requirements will be more useful in a complementary role with the type of information that will be obtained in accordance with data required to explain and predict travel choices. The formatting of existing transportation study data files in terms of individuals and household records instead of a record of each trip made will enable greater conformity of data with the more relevant behavioral modeling statistical procedures (15, pp. 53-70). In addition, some existing data will become redundant, helping to offset the absolute cost of data acquisition. When consideration is given to the costs and benefits of such improved and relevant data, then the real cost increase might be minimal if not negative.

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