Alternative Behavioral Approaches to Value-of-Time Models With Implications for Nontraders

Shalom Reichman, Department of Geography,
Hebrew University, Jerusalem

In the choice mechanism leading to the decision to travel, several categories of nontraders of time-cost attributes can be identified and probably make up most of the traveling population. Alternative conceptual approaches to the choice mechanism are reviewed, and their relative merits are discussed in terms of their implications for nontraders. Utility theory, the prevalent approach, is based on the premise that the value of time is a significant choice variable in the trading behavior of the trip-maker. For this, 3 behavioral assumptions are required: utilities can be added so as to obtain generalized costs, attributes can be compared between alternative modes, and alternatives can be clearly separated rather than lumped together. The theory of decision-making, and particularly the modified lexicographic approach or elimination-by-aspects model, possibly provides simpler and more realistic sets of behavioral assumptions: the grouping of attributes by the degree of their being shared by alternatives and the search mechanism that considers first vital and subsequently compensatory attributes. Absolute levels of costs and times can be considered as vital attributes, and costs or time savings as compensatory attributes. Also, following the logic of the elimination-by-aspects model, the present policy of developing additional transit modes is more likely to hurt existing transit modes than to decrease the level of car-owner, nontrader traffic.

The decision to travel includes, in theory, a component of choice, if only in terms of the costs and time attributes of the various transportation modes. In practice, a large number of trips are decided without specific consideration of these system characteristics or attributes. Nontraders are usually identified as travelers whose revealed preferences do not include a trade-off between travel time and travel cost. Three main categories of nontraders may be defined on the basis of the role of time and cost attributes in the trip-making decision.

1. Nontraders who do not face real choices between costs and time. These are usually referred to as travelers facing a predominant choice (1). In such a situation, the probability of choosing mode k over mode 1, when both time and costs characteristics are in favor of mode k, is 1.0, and that of choosing mode 1 is 0. In many of these deterministic choice situations travelers are also characterized as belonging to mode-captive choice decisions.
2. Travelers who face a predominant situation similar to that indicated above but who, instead of choosing mode k, select the inferior mode 1. In this case we have to assume that, irrespective of time and costs, other attributes are more important. For the sake of simplicity, these could be labeled comfort-oriented travelers.
3. Nontraders whose choice situations are confined no longer to mode characteristics but more generally to all other components of travel demand or to individual preferences. One example is a situation where generalized costs of the trip for both mode k and mode 1, though unequal, exceed a certain threshold, so that no trip is generated in the first place. In the case of such latent travelers, no trade is being observed between the various system characteristics.

Evidence from existing mode-choice and value-of-time surveys reveals that choice situations in which the travelers could be classified as nontraders according to the definitions of categories 1 and 2 probably constitute the majority of choice situations facing travelers, especially in urban areas.

To begin with, in many suburban areas with poor transit services, travelers are virtually car-captive since cars are the dominant alternative. Another example may be drawn from travel mode studies in Israel (2), where it was found that heads of households with private cars in the large cities use their cars for 95 percent of their trips. It is suggested that a significant proportion of these trips are made by the inferior mode inasmuch as alternative transit services with reasonable levels of service are available.

Finally, the detailed travel mode studies that resulted in the derivation of travel time values were performed on relatively restricted and selective samples. These samples range from 4,100 usable responses in a 9-state survey in the United States (3) to about 200 "pure" binary choices in Skokie, a U.S. suburb (4). Typically, a recent study in the Netherlands indicated that, out of 2,616 work trips in Rotterdam, only in 482 trips did travelers face a real-world choice and could, therefore, be included in the travel time evaluation model. In the reduced subsample of people facing a real choice, 75 percent used the private car (5). It appears that the number of events, or trips, where mode choice is deterministic by far exceeds that with time-cost trade-offs.

UTILITY THEORY, VALUE OF TIME, AND NONTRADERS

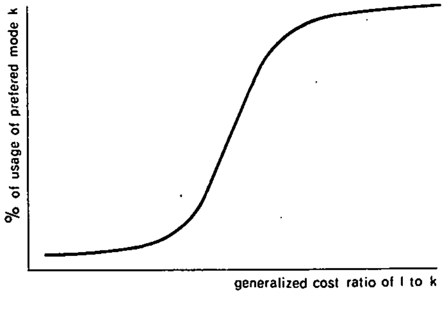
A number of recent studies have focused on the relation between utility theory, or consumer behavior theory, and the trading behavior of individuals to derive travel time values (6, 7). The most detailed review of the theoretical approach is presented in the Charles River study (7) and need not be repeated here. However, it is appropriate to raise the question to what extent are the theoretical constructs applicable to the behavior of nontraders. In particular, the problem arises as to whether values of travel time derived from choice situations can be used to predict changes in the traveling behavior of nontraders.

To simplify the discussion, let us suppose to begin with that only categories 1 and 2 are being investigated so that all observed events may indeed be combined in a single distribution based only on time and cost combinations (Fig. 1). Three important behavioral assumptions are required to project values of travel time derived from pure choice situations to cover the entire range of the distribution of mode usage: the additivity of the utility function, the evaluation of generic attributes rather than mode-specific attributes, and the separability between alternatives.

The additivity of utilities is an issue common to most economic studies based on consumer behavior. What is assumed is that the utility or disutility of a given attribute can be added to those of other attributes. In fact, the concepts of generalized costs or inclusive price found in the mode-choice literature are explicitly derived on the basis of the additivity of attribute utilities, especially costs and times. The validity of this assumption can be said to have been tested in the careful analyses of small samples of travelers. The analyses indicated that trade-offs between attributes apparently account for the revealed preference of one mode or route over the other. However, for mode-captive travelers in a dominant choice situation, the assumption of additivity cannot be tested in detail.

The assumption of the existence of generic rather than mode-specific attributes is equally essential for the derivation of values of travel time. What it assumes, in effect, is that attributes such as time and costs can be compared between modes rather than within a given

Figure 1. Hypothetical distribution of mode usage by system characteristics.



mode. It can be argued that there exist choice situations, such as a route-choice situation, where values of travel time can be determined within a given mode. Furthermore, since there are no substantial differences between the values derived from route choice and those derived from mode choice, it may be reasonable to infer that generic rather than mode-specific attributes are indeed being evaluated by the traveler.

In the case of this assumption, a legitimate query may be raised as to its applicability to nontraders. We already know that nontraders usually belong to categories of travelers who face extreme choices or even do not have real-world alternatives. Can it be assumed that, even for those mode-captive travelers, the evaluation of system characteristics is based mainly on generic attributes? An argument can be put forward, for example, that the tendency to treat costs and times as generic attributes may be income dependent. Stated alternatively, at very low and possibly at high incomes, attributes might tend to be rather mode specific. A logical conclusion would, therefore, be that time-cost comparisons between modes in the case of nontraders are conceptually similar to those made with respect to abstract new modes for which empirical evidence of mode-specific effects is lacking.

Closely related to this issue is the third assumption that is inherent in the consumer behavior approach and is based on stochastic utility maximization, namely, separability between alternatives. In the context of value of travel time, this assumption implies that effective choice alternatives can be identified as being separate or independent, provided that they have attributes different from those of any existing alternative. However, in a binary-choice situation a problem arises when another alternative is added that has similar attributes to either one of the previous alternatives. Should the new alternative be regarded as a separate alternative and, consequently, reduce the probability of choosing any of the former, or should it instead be "lumped" together with the existing alternative that has similar attributes? In the latter case, which is contrary to the separability assumption, the probability of choosing each of the 2 lumped alternatives will be reduced, while that of using the alternative with dissimilar attributes will remain virtually unchanged.

When the assumption is applied to nontraders, who presumably have relative choice odds of 1 or 0, the question arises, Of what should a new alternative consist so that it might affect this probability? The problem can be reformulated in a different way: If a train is added as an alternative to a car and a bus, then whenever the bus and train have similar time and cost attributes they should be lumped together as a single alternative. In the case of nontraders such a procedure might intuitively be the real-world procedure, though it violates the conditions of the separability assumption.

So far we have discussed some problems related to the extension of assumptions of consumer behavior theory to cover the extreme cases of mode usage, that is to say nontraders, whenever choices are presumed to be made on the basis of measurable system characteristics, such as by category 1. These assumptions are no more helpful, and indeed less so, when we consider categories 2 and 3. It is assumed a priori that factors other than ratios of measurable system characteristics affect mode choices of both comfort-oriented and latent travelers, and consequently the use of value-of-time models to predict their behavior is irrelevant.

For categories 2 and 3, it is not possible to simply add a random (or error) component to the quantifiable relations. Categories of nontraders have been explicitly made on the presumption that in 2 categories the nonquantifiable elements, either in the identification of system characteristics or in the evaluation process, form separate and indeed major components of the revealed behavior.

In summary, consumer behavior theory and its component of value of travel time are based on a set of assumptions that are less tenable when applied to nontraders than to traders. In view of the fact that most travelers are probably nontraders, alternative methods should be sought to predict the behavior of nontraders, preferably in the area of decision-making theory. Some new developments in this field, which are relevant to our argument, will be briefly discussed below.

THEORY OF DECISION-MAKING AND ITS RELEVANCE TO NONTRADERS

Decision-making theory focuses on the process by which a course of action is chosen, irrespective of the context of such an action. Transportation choice clearly represents such a process and is characterized by the need to identify and evaluate multiple attributes. There are numerous procedures for selecting alternatives with multiple attributes. MacCrimmon (8) reviewed 10 different approaches to the selection of multiple-attribute alternatives and then suggested that a combination of procedures is probably more reasonable than selecting merely one specific procedure. In our case, the question naturally arises, Which additional decision-making procedure should be modeled to predict the deterministic choice of nontraders, which results in the selection of a unique mode?

As suggested by the discussion in the preceding section, simple choice mechansims appear to provide reasonable accounts of the decision-making process of certain categories of nontraders, perhaps even better than the existing consumer behavior.

The notions of dominance or satisficing, for instance, may explain the behavior of nontraders as a special case of utility maximization. Dominance can be suggested as the main mechanism whenever mode k is better than mode l in all compared attributes, or system characteristics. Instead of reducing the dimension of the choice situation, as is the case of adding utilities, one should retain its full dimension, compare attributes separately, and reject the alternative that has no attribute better but at least one worse than the other alternative.

Satisficing, on the other hand, appears to be the appropriate choice mechanism when the weights of the attributes may be difficult to determine. Here a tolerable level of each attribute is assumed to be present in the decision-maker's mind, and after an attribute-by-attribute comparison of the alternatives, the alternative that has an attribute below the accepted level is rejected. Again there is no need to assume additivity of utilities.

On the basis of this argument, the behavior of mode-captive travelers, whose alternatives are virtually nonexistent, can be explained by a dominance or satisficing decision-making procedure that requires no information on value of time.

Many nontraders, though, face alternatives that are not disjoint in the sense that the various transportation modes share several attributes, nor are they dominated so that other decision-making procedures would have to be used, depending on the nature of the alternatives. Here we might distinguish between car owners and noncar owners as 2 fundamentally different decision-making situations. Alternative modes, namely, trains or buses, for noncar owners are characterized by similar attributes that probably have similar ranges of scales. Also, the use of each mode may complement rather than be independent of the other. In view of these characteristics, additive utility, or else trade-offs, may indeed represent choice procedures of noncar owners.

Our main interest, however, lies in the decision-making procedure of car owners, particularly in the binary choice of car or transit modes or, more specifically, in the trinary choice of car, train, or bus. Here we can identify 2 transit modes that are similar, and one mode that is partly disjoint. In these situations, the decision-making procedure or rule might take the form of the modified lexicographic approach recently developed in the elimination-by-aspects (EBA) model (9).

According to the lexicographic approach (similar to the method of finding a word in the dictionary), attributes are assumed to be ranked on the basis of their (unknown) importance, and a search procedure is initiated to find out whether each alternative possesses the required attribute. This is repeated by a decreasing order of importance of attributes until any alternative without all required attributes is rejected.

The EBA model goes beyond the lexicographic approach in several major ways. No fixed prior ordering of attributes is assumed, and the similarity of alternatives can be ranked on the basis of the grouping of shared attributes. Furthermore, with the addition of a probabilistic choice process, these properties of the EBA theory provide a major departure from the principle of independence of irrelevant alternatives. Instead, a more general choice theory is presented that is based on the property of multiplicative inequality, whereby the probability of choosing 1 alternative x from a set of 3 alternatives x, y, and z is at least as large as the probability of choosing x from a binary choice of x, y and x, z in 2 independent choices.

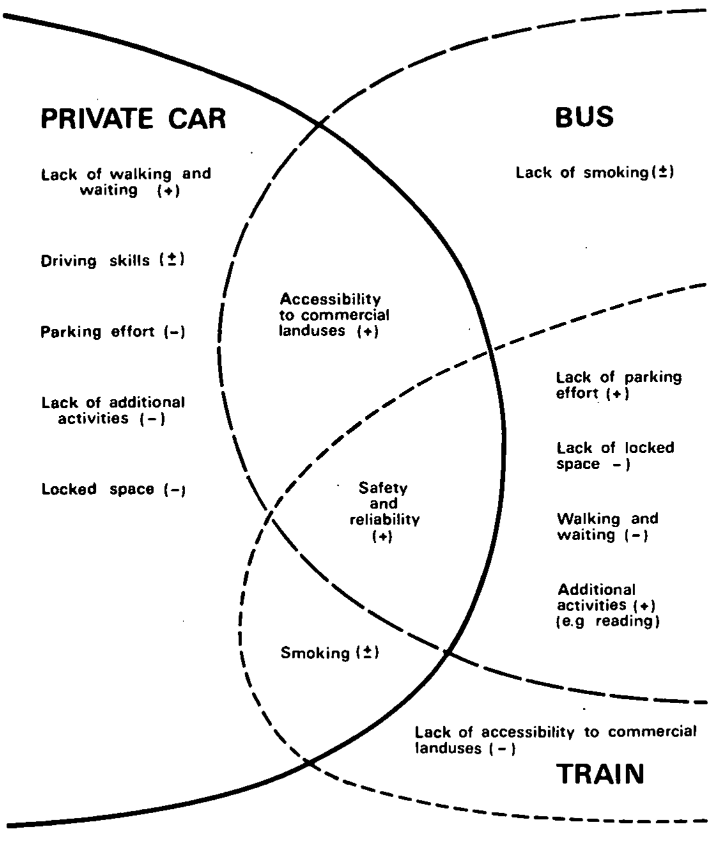
The intent here is not to elaborate on the various mathematical properties of the EBA model. Instead, concepts of EBA will be used primarily to indicate an alternative procedure to the modal choice procedure of car owners; the alternative procedure might complement the existing trade-off approach implied by value-of-time studies. More particularly, the behavior of nontraders will be examined on the basis of the shared and nonshared attributes of private car owners.

Let us assume that trip times and trip costs of transportation modes can be readily measured and scaled (10) and that there are other attributes that are difficult to measure. Some of these attributes are desirable (+), others are undesirable (-), and certain ones are desirable or undesirable (±), depending on the preferences of the traveler.

Figure 2 shows some arbitrary and discrete attributes of the 3 modes. Three groupings emerge: (a) attributes shared by all modes, (b) attributes shared by pairs of modes, and (c) attributes not shared by any other alternative.

The hypothesis to be investigated in this choice situation is that the more unshared attributes an alternative has, the more likely it is to be uniquely accepted or rejected, depending on the desirability of the attributes and on the preferences of the decision-maker. For car owners, whose alternatives have the largest amount of unshared attributes, the decision rule might include several steps: the elimination of alternatives on the basis of a few aspects, which are so important that their presence or absence is

Figure 2. Representation of attribute groupings for 3 transportation modes.



sufficient to eliminate an alternative, and subsequently the compensation between measurable aspects (time and costs) or between these and the nonmeasurable aspects.

DISCUSSION OF APPROACHES

The relative merits of the 2 behavioral approaches presented in the preceding sections may be compared with respect to the mode-choice situation in general, the specific weight of time and cost savings in mode choice, and the policy implications for reducing the population of nontraders.

The differences between the utility and lexicographic (or EBA) approaches in a mode-choice situation lie in at least 2 main areas.

1. Reduction of the complexity of multiattribute choice situations. It is a well-observed phenomenon that individuals tend to simplify the complexity of problems (11). In the case of a mode-choice problem, the decision rule according to EBA procedures is likely to be simpler than that of utility maximization. The first approach includes only unshared or partly shared attributes, and in the latter approach no reduction in the number of considered attributes is specified.
2. Rationality of the decision rule. For dominating choices, there should be no significant difference between the 2 behavioral approaches. On the other hand, when unshared discrete attributes are compared, different decision criteria can be envisaged, depending on the behavioral approach that is assumed to be operating. If an alternative is rejected because it does not possess a desirable attribute or else possesses an undesirable aspect, then according to the strict rationality of the utility approach it follows that the weight of this attribute is necessarily more important than the sum of all other attributes that were not yet considered in the decision procedure. The modified-lexicographic approach does not require such a strict interpretation of rationality, so that people may indeed make "wrong" decisions by giving to a certain attribute more weight than they would in other circumstances.

The second problem area where significant differences between the 2 approaches might occur relates more specifically to the way times and costs are considered in the choice situation. Here the lexicographic approach is clearly more tractable in reflecting real-world decision-making. To begin with, it allows a distinction to be made between "vital" attributes, which are so important that each may in fact eliminate an alternative, and "compensatory" attributes, each of which can be traded off for other compensatory attributes. For instance, absolute values of travel time and money may belong, in theory, to the group of vital attributes, while time and cost savings may belong to the group of compensatory attributes. This classification might be useful, to begin with, in distinguishing between urban and interurban trips. Interurban trips are characterized both by the considerable money and time outlays and by the wide variations in these attributes between modes. Hence, absolute costs and times on interurban trips can be viewed as unshared or unacceptable attributes between modes.

In most urban areas, on the other hand, it can be argued that absolute levels of cost and time outlays for an average trip do not exceed a satisficing or acceptable threshold for all modes. Consequently, according to the lexicographic approach, these attributes may be considered as shared attributes and, therefore, should not play a determining part in the decision procedure of mode choice. Time and cost savings, however, are presumably important compensatory attributes in urban trips. What probably occurs in the case of urban mode-choice situations is that time and cost savings are considered with other unshared or partly shared discrete attributes, such as those given in Table 1. If any of these other unshared attributes happen to belong to the group of vital attributes, then time or cost savings may not play any role in the decision procedure since alternatives could be eliminated a priori on the basis of the presence or absence of vital attributes.

Two important policy implications might evolve from the above discussion. First, value-of-time studies have limited relevance not only for nontraders facing dominant

Table 1. Discrete attributes shared and unshared by 3 transportation modes.

Type	Shared by All Modes	Shared by Pairs of Modes	Not Shared by Other Modes
Desirable	Safety and reliability	Lack of parking effort, accessibility to land uses, additional activities (e.g., reading)	Locked space
Undesirable		Walking and waiting, lack of locked space	Parking effort
Mixed		Smoking	Driving skills

choice situations but also for a wider population of travelers, particularly those who are mode captive. If indeed decision-making procedures are performed on the basis of EBA concepts, mode-captive travelers will likely eliminate alternative modes on the basis of vital attributes rather than compensatory aspects.

Second, the present policy of developing additional transit modes appears to run contrary to the logic of the lexicographic approach. The more similar 2 alternatives are, vis-à-vis a third one that has fewer shared attributes, the more likely that they will hurt each other more than affect the dissimilar alternative. Consequently, improved transit modes are not likely to succeed in significantly decreasing the level of car-owner, nontrader traffic. On the other hand, transportation modes that share more attributes with private cars, such as personal rapid transit and car rentals, are more likely to reduce the number of nontrading car users. Alternatively, a policy of suppressing some of the existing unshared attributes of private cars, such as lack of walking and waiting, might achieve similar results in enhancing the attractiveness of transit modes.

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