148.154

PROBLEMS ASSOCIATED WITH TIME AND COST DATA USED IN TRAVEL CHOICE MODELING AND VALUATION OF TIME

Peter L. Watson, The Transportation Center, Northwestern University

The aim of this paper is to clarify some of the issues raised by the current disagreement as to whether it is more appropriate to use "perceived" or "measured" data in models that estimate modal choice. The procedure adopted is to consider the hypotheses that can underlie the modal-choice models and to discuss which data type is more appropriate, given the suggested hypotheses. From the basic premise that the data used to estimate the model should correspond to the variables specified in the hypothesis, 2 hypotheses are derived. The former relates choice of travel mode to the times and costs of the journey as perceived by the traveler, with the implication that perceived data should be used to calibrate the model; the latter is a special case of the former that relates choice to the expected times and costs of the journey, and it is suggested that the best available approximation to the expected values is the measured data. Problems arise when it is difficult to decide which hypothesis is more appropriate in a given case or when the group of travelers is heterogeneous with respect to the hypothesis that underlies their choice behavior. The problem resolves to one of the effects of using the wrong data set. In the case of predictive models, it is suggested that the choice of data is relatively unimportant because models based on perceived data are not recommended for predictive purposes, given the absence of information on the stability of the relationship between perceived and measured values and in the light of the problems of predicting perceptions. In the case of models used for the derivation of a value of time, the problem is more acute. A preliminary investigation indicates that the use of each data set produces a value of time that is biased with respect to the true value. It is argued that such a bias is not a problem provided that 2 conditions are fulfilled: (a) The data used are consistent with the behavioral hypothesis; and (b) care is exercised in the use of the value of time so that a value derived in 1 situation is not used to value time saved in a different situation. In conclusion, the answer to the question as to which data type is correct lies not in dogma but in the careful use of logic in the selection of the hypothesis and the use of the information derived from the model.

•THE PROBLEM considered in this paper arises from the use of different types of data to calibrate modal-choice models. To understand the problem, it is necessary to consider some aspects of the development of modal-choice models. In essence, the aim of such a model is to explain an individual's choice of travel mode (or route) in terms of a series of variables that describe the characteristics of the trip, the alternative modes, and the traveler and his household. Because the analyses are identical, the exposition will proceed in terms of modal choices.

Sponsored by Task Force on Value of Travel Time.

For the purposes of this exposition, it is unnecessary to describe in detail the statistical techniques that have been used in modal-choice models. Suffice it to say that the most commonly used techniques have been discriminant, logit, and probit analyses. The basic procedure is to relate a dependent variable, representing the choice made, to a number of independent variables as described in the preceding. The problem then arises as to which explanatory variables should be used. As a basic research technique, the analyst selects his explanatory variables on the basis of received theory or postulates about the relationship or does both of them, combines them in the light of previous work and his own experience, and then tests the model to investigate the explanatory power displayed by his selection. In the case of modal-choice models, the most commonly selected variables have been the times and costs of the journey by each of the alternative modes. (Because these variables pose the largest problems in this area, the analysis will assume that they are the only variables under consideration. It should be kept in mind that the discussion may apply to other variables.) The task of the researcher is then to collect data on times and costs by each mode for a sample of individuals to test the model. The problem arises because it quickly becomes clear that the time or cost of a journey is not a unique value. If the analyst measures the time for a given journey, he obtains 1 value. If he asks the traveler how long the same journey has taken, he might obtain a different value. The same findings emerge when data on costs are collected. It is evident that the individual traveler does not always know exactly how long a journey has taken or how much it has cost, and this fact leads to the dichotomy between perceived values and measured data. It should be noted at this point that much confusion has been caused by the use of multiplicity of terms to refer to these 2 values. For the purposes of this paper, the terms "perceived" and "measured" will be used where "perceived" refers to the time or cost as perceived by the traveler (such values have variously been called "behavioral" or "subjective" data) and where "measured" refers to the value obtained by the analyst replicating the journey either physically or by means of printed matter such as timetables or fare schedules (such values have been called objective, real, engineering or actual values). It is intended to further distinguish the true times and costs that may differ from both the perceived and the measured times and costs.

The following discussion considers the problems that may arise in the collection of perceived and measured data that arise in the collection of such data or that may be inherent in the data. The analysis that follows these findings will consider whether perceived or measured values are more appropriate for inclusion in a modal-choice model. It will also consider the effects of the biases on the modal-choice modeling process and on the derivation of a value of time.

BIASES IN THE DATA

The word bias is perhaps a misnomer in the sense that it implies a degree of undesirability that is not intended. The term bias is used to refer simply to the differences between the various measures and estimates of times and costs; for example, the true times and costs of a journey and the traveler's perception of those times and costs. There is ample evidence (2, 3) to demonstrate that such differences do occur. The problem is to identify their magnitude, their direction, and any factors that might cause them. Initially, only biases in the perception process will be considered. At a later point the possibility will be introduced that further biases may appear when the perceived value is reported and when objective measurements are made. The postulated bias may be different in different circumstances: notably whether the times and costs refer to the chosen or the rejected mode, or whether the traveler is familiar with the mode. The following discussion will consider several types of error in turn and will contain comments on the ways in which each might be affected by changes in circumstances.

Perception Bias

The bias to be considered in this section is the cornerstone of the errors generated in the perception process. Other biases may aggravate the situation, but it is suggested that, at best, they only modify the perception bias. The typical traveler is not a work-study engineer; i.e., he does not travel with a briefcase in 1 hand and a stopwatch in the other. As a result, he often does not know how long a certain journey has taken because it is notoriously difficult to estimate elapsed time accurately. Therefore, his perception of the time taken on a journey may differ from the true time taken. As a best approximation, it may be assumed that such errors will be random, be approximately normally distributed, and have an expected value of 0. There is some evidence to suggest that this may be so (3), but it is by no means an established fact.

It may be thought that the problem might be less acute when perceptions of costs are concerned because actual payments are involved, and there is some evidence to support this view (2). The conclusion is somewhat obscured by the problem of allocating costs to different journeys, both when the car is involved and when some type of season ticket is used for transit movements. Little can be said about the biases resulting from such allocative problems. Lansing and Hendricks (2) found that people consistently overestimated the running costs of their cars, a result that conflicts with the often-postulated view that such costs are always underestimated. It is possible that, like time biases, cost biases can be assumed to be random, normally distributed with 0 mean.

It is, of course, possible that the perception bias could be affected by the learning process. One could postulate that the bias is a decreasing function of the traveler's familiarity with the modes. This would mean that the perception bias would be smaller for the greater degree of the traveler's familiarity with the mode. In other words, the traveler may misperceive the time taken to drive to work, but his perception bias is likely to be greater for a journey that he has undertaken only a few times, and even greater for a journey that he has never undertaken. In the limit, it would approach a guess based on little or no information about the journey, e.g., if the journey involved traveling to an unfamiliar destination over unfamiliar roads, when even the distance to be traveled may be unknown.

Such a postulate would not necessarily imply that the relationship varied as the mode was chosen or rejected. For the work trip, it seems likely that the traveler would be familiar with his chosen mode, but, for an infrequent trip, he may be unfamiliar with all the possible modes. It seems not unlikely, however, that, even for a frequent trip, the traveler may be ignorant of the characteristics of the mode that he does not habitually use.

Rounding Bias

The rounding bias arises from the fact that people appear to find difficulty in distinguishing small units of time, like a minute. This leads them to perceive time in lumps of, say, 5 min. It is clear that a motorist, for example, does not think in terms of an 18-min journey, but in terms of one of 15 or 20 min. Thus, there is an observable tendency to round journey times up (or down) to multiples of 5 min. It is possible that on longer journeys, times are rounded to 10 min, 30 min, 1 hour, or even larger units.

Whereas it is quite clear that rounding biases exist for journey times, it is less clear that they exist for costs. However, it seems possible to assume an analogous process in which people round their costs to multiples of, say, 5 cents. In the Edinburgh-Glasgow area modal-split study, that is currently being conducted under the auspices of the British Ministry of Transport, this was not observed, and costs were typically not rounded; but the phenomenon may be observed for longer trips.

Given the postulate that five is the rounding unit, it would be simple to predict the rounding bias if the direction of bias were known. It has been suggested that people are more likely to round down for the chosen mode and up for the rejected mode, but no substantial evidence exists on the subject. Because discussion of this possibility leads into consideration of reporting problems, it is intended to deal with it at a later point. In the present context, it is sufficient to say that rounding as part of the perception process seems as likely to follow a simple rule (e.g., round to the nearest multiple of five) as it is likely to follow a more complex one.

Antimodal Bias

It is possible to postulate that the traveler's perceptions of times and costs for the rejected mode may be subject to a bias that results from the traveler's feelings about the mode. Should the traveler dislike the rejected mode intensely, his perception of the times and costs by that mode may be subconsciously influenced by that dislike. If he is unfamiliar with the mode, the unfamiliarity, combined with the adverse feelings, could account for the large errors that have been observed to appear when times and costs by rejected modes are reported.

Such a bias could be referred to as an attitudinal bias, based as it is on the traveler's attitude toward a given mode of transport. It should be emphasized that little or no work has been done on this subject, and therefore, little can be said about the nature of the bias. This may, however, be an important feature of the perception process.

Reporting Bias

The discussion so far has proceeded on the assumption that the perceived times and costs are the numbers collected by interviewing travelers. It is now appropriate to relax that assumption. It is postulated by Thomas (5) that a bias appears in the reporting of times and costs. In other words, the times and costs of a journey as perceived by the traveler are modified when he reports them either to an interviewer or in a questionnaire. The reporting bias arises from the traveler's desire, conscious or (more probably) subconscious, to make his actions (i.e., his choice) appear more realistic, more reasonable, or more impressive or to gain the interviewer's approval for his actions. Given a trade-off situation, it is argued, he will attempt to make either the time saving for a given expenditure seem greater or the expenditure for a given time saving seem smaller or both. These objectives can be achieved in a number of ways that reduce to various combinations of underreporting times or costs by the chosen mode or both, or the overreporting times or costs by the rejected mode for both.

Thus, the postulate that this bias exists implies the direction in which it will operate. It is, however, not possible to say anything about the magnitude of a bias because the perceived times and costs are not known.

Normalizing Bias

It is possible that, for a given journey, the traveler may try to correct for atypical journey times; e.g., he may report the time normally taken for the journey. (Clearly, this problem can only arise when the subject is familiar with the mode and the journey.) It is felt that careful designing of the questionnaire and training of the survey staff can eliminate this problem.

In the previous sections, a number of possibilities have been suggested that might explain discrepancies between the true times and costs and the times and costs as perceived and reported by the traveler; these biases could be interactive or cumulative. However, it cannot be too strongly stressed that little work has been done on this topic, and, therefore, the postulated biases are based on a mixture of propositions and casual empiricism that may not be demonstrable. The strong evidence that exists (4, 5) shows only that the data, as reported by the travelers, differ from the data as measured by the analyst. It is possible that both sets of data differ from the true value and it is, therefore, appropriate to consider the ways in which the measured values may differ from the true values.

Measurement Bias

It may be assumed that biases in measurement derive from the manner in which the measurements are made and not from the incompetence of the person taking measurements. This being the case, it follows that, if the measurer accompanied the traveler on his trip and measured all the time and money expenditures, then the measured times and costs would correspond exactly with the true times and costs. In practice, such a procedure is not practicable and the so-called measured times and costs are usually estimated from standardized data, based on fifth-wheel test runs, average speeds, assumed routes, fare schedules, and published automobile operating costs. In other words, the times and costs are derived on the basis of a series of conventions. For example, the time spent walking to a station may be based on the distance and an average walking speed; the time spent driving a given route may be based on the distance and average driving speeds; the cost of a trip may be based on the distance and an average mileage cost for the given vehicle; and the time spent waiting for a bus may be based on half the scheduled headway or 10 min, whichever is greater. The result is that the measured time corresponds not to the actual time taken by the traveler but to the time that he would take on an average for the given journey.

CHOICE OF THE CORRECT DATA BASE

Given that some combination of the biases outlined previously leads to a difference between perceived and measured times and costs, the question arises as to whether perceived or measured data are more appropriate for use in the testing of a modal-choice model. Considerable controversy has arisen over this point, with the combatants polarizing into 2 camps that may be characterized in the following way. The advocates of the use of perceived data argue that the modeling procedure attempts to delineate a statistical relationship between the choice of an individual and the factors influencing that choice. Given such a starting point, it is logical to argue further that, if factors such as times and costs are to be included, the appropriate times and costs to use are those perceived by the traveler. In such a situation, it is illogical to use measured data because the traveler does not know what the measured values are, and the use of such data implies that he bases his choice decisions on data that he does not possess a conclusion that is curious, to say the least.

The advocate of the use of measured data, on the other hand, would argue that the precise process by which the modal-choice decision is arrived at is irrelevant and that the important feature of his model is that people behave "as if they based their choices on measured data." Moreover, a model based on measured data can predict what people do with a high degree of accuracy. Such an argument, combined with the reduced problems of data collection associated with measured data, constitutes the case for its use.

It would be easy at this point to dismiss the problem as an insoluble controversy between the theorist on the one hand, who wishes to explain or replicate the decision-making process and the pragmatist on the other hand, who simply wishes to predict or replicate observable behavior. Such a solution to the problem is, however, unsatisfactory in the sense that prediction is a more satisfactory procedure if the model to be used for prediction is based on a sound hypothesis. The fact that a model predicts may well be a statistical accident, and the absence of a sound hypothesis may inhibit the analyst's confidence regarding the stability of the relationship and, hence, his confidence in the predictions. It would clearly be more satisfactory if the use of measured data could be justified on the basis of a behavioral hypothesis, similar to the one that underlies the use of perceived data.

Such a hypothesis is now suggested. The basic hypothesis that the individual bases his modal-choice decision on times and costs as he perceives them is maintained, but a special case of perception is defined. In the situation where a trip is undertaken regularly, it is argued that a learning process will operate such that the times and costs as perceived by the traveler can be represented as the times and costs he expects to be faced with on the given trip. This is to imply not that decisions will be based on "expected values" in a rigorous statistical sense (with all experiences being given equal weight) but simply that the traveler, as a result of frequent travel, comes to expect that a journey will take a certain time and cost a certain amount. Moreover, the discussion on measurement biases concluded that the measured times, for example, correspond to the time that the traveler would take on the average for the given journey. Thus, a close relationship is demonstrated between measured data and perceptions in the special case, where perceptions can be interpreted as expected values based on a learning process and repeated exposure to a given trip. It is clear that the special case of hypothesis lacks some of the generality of the perception hypothesis, because the fact that the expected values are based on experience implies that the traveler has some degree of familiarity with the trip characteristics.

Having given the use of measured data a certain degree of respectability in the form of its own hypothesis, we should appropriately return to the question of which data base is correct. It is argued that the use of a given set of data is only correct when it represents the variables included in the model. Given such a test of correctness, the use of measured data in a model that represents infrequent trips is clearly incorrect. However, the converse is not true. Because the hypothesis supporting the use of measured data is a special case of the perception hypothesis, either of these types of data may be held to be correct in a model representing a familiar journey, and the choice may be based on other factors that will also be of importance in choosing the data types when the population does not fall into a familiar or unfamiliar category but contains some of each type. These factors may be pragmatic, such as ease of collection or the avoidance of reporting biases, or, preferably, may be based on a consideration of the implications of using each of these types of data for constructing modal-choice models and for the values of time that may be derived from such models. These implications are considered in the following sections.

IMPLICATIONS FOR MODAL CHOICE

Perhaps the most important use of a modal-choice model is in prediction. A model can be used to predict what will happen to the modal split in a given situation if the trip characteristics are modified in terms of either the costs or the times of the journey. The policy-maker may wish to know what will happen to the relative numbers of people using each mode if, for example, rapid transit is made faster or cheaper, or if, on the other hand, traffic restrictions make automobile travel slower. In such situations, data corresponding to the new state can be fed into the model to estimate the modal-split changes.

In the same way, data from a different location could be used to estimate the modal split given the characteristics of the new location. Thus, the model can be used to analyze data that are different either temporally or spatially from the data on which the model was based.

For such a procedure to be effective, certain conditions must be met. There must be some degree of confidence that the relationship represented by the model remains constant over time and space. If there is reason to believe that the relationship may change, then the procedure is meaningless. Furthermore, the data from the new situation or location must be of the same type as the data used to calibrate the model in the first place. Given the fact that it is frequently difficult to obtain data, which reflects precisely the variables sought to be included in the model, the success of the estimating procedure may be partially dependent on the precise nature of the data. For example, many economic relationships depend on an income variable, and, in many cases, it is not often possible to measure, say, disposable income precisely. Therefore, an estimate must be used, and the relationship may be established by using 1 estimate and shown to be spurious by using another. In the same way, a modal-split model calibrated with perceived data might be dependent on the nature of the variable. A change to a new location or situation could change the nature of the variable because it is unknown whether the difference between perception and reality (perception bias) is constant over time or space. To the extent that it is not constant, the analyst could have less confidence in his predictions.

These problems seem likely to be most acute when analysis of new modes or major service changes is undertaken. It is difficult, if not impossible, to envisage a method by which the public's perception of the reality of a new situation could be predicted. Thus, the problem reduces to a very simple one: To predict future values of the dependent variable in a relationship, one must first know the values of the independent variables. It is, given present knowledge, not possible to predict future misperceptions.

It should be noted at this point that the use of measured data obviates this problem because, if the model were calibrated with measured data, there would be no reason to believe that the nature of measurement biases would vary from place to place or from time to time. Moreover, the problem would be greatly simplified if a stable relationship between perceived and measured data could be found.

IMPLICATIONS FOR THE VALUATION OF TIME

An important spin-off from the modal-choice model is a value of time, which is often used to evaluate time savings in cost-benefit types of analyses of transportation investments. Because time savings frequently represent a high proportion of total benefits, the total value of benefits, and, hence, acceptance or rejection of a project is very susceptible to small changes in the value of time. This section analyzes the effects of using the different data bases to estimate the modal-choice models from which values of time are derived.

To analyze the effects on the value of time of using different types of data requires a consideration of the mechanism by which the value of time is derived. The discussion can be simplified by considering the simplest type of model, one that represents a linear relationship between the probability of a given choice and the times and costs of the alternatives expressed as differences:

$$P(x) = \alpha_1 \Delta T + \alpha_2 \Delta C$$

The value of time is then defined as the rate at which time would be traded for cost to leave P(x) unchanged, i.e., α_1/α_2. It is contended that, because the relationship is based on the observable behavior of the individual travelers, the trade-off ratio represents the rate at which the population as a whole, aggregated by the chosen statistical procedure, will trade time for cost, i.e., the value that is placed on time.

The question that then arises concerns the effects of using different types of data on the value of time thus derived—a question that reduces to a problem of assessing the effects of the different data types of the coefficients estimated by the model. The following example, which is a modified and extended form of one used by Thomas (5), shows some of the effects that might be expected.

The exposition can be clarified by considering in isolation the effects on the coefficient related to the time difference variable because such a procedure greatly simplifies the problem and permits a graphical treatment in 2 dimensions. The situation envisaged is one in which a number of motorists have faced a choice between a free road and a 10-cent toll road. Faced with a difference in travel time between the 2 roads, all other things equal, a choice has been made. Figure 1a shows the observed modal split for each time difference and the curve that is estimated by using the true time differences. It should be noted that this curve is a theoretical construct to be used only as a yardstick; because the true values are unknown, it is not possible in practice to estimate this curve. This curve represents a part of the choice model, namely,

$$P(x) = \alpha_1 \Delta T$$

and thus the slope of the curve, which represents the rate at which P(x) changes for a unit change in ΔT, is equivalent to α_1 or to the numerator in the expression for the value of time:

$$VOT = \frac{\alpha_1}{\alpha_2}$$

For the purposes of this example, it is assumed that, if the cost difference (or toll) is held constant, the coefficient corresponding to $\Delta C(\alpha_2)$ will remain constant; and thus changes in α_2 due to the use of different data types will involve changes in the value of

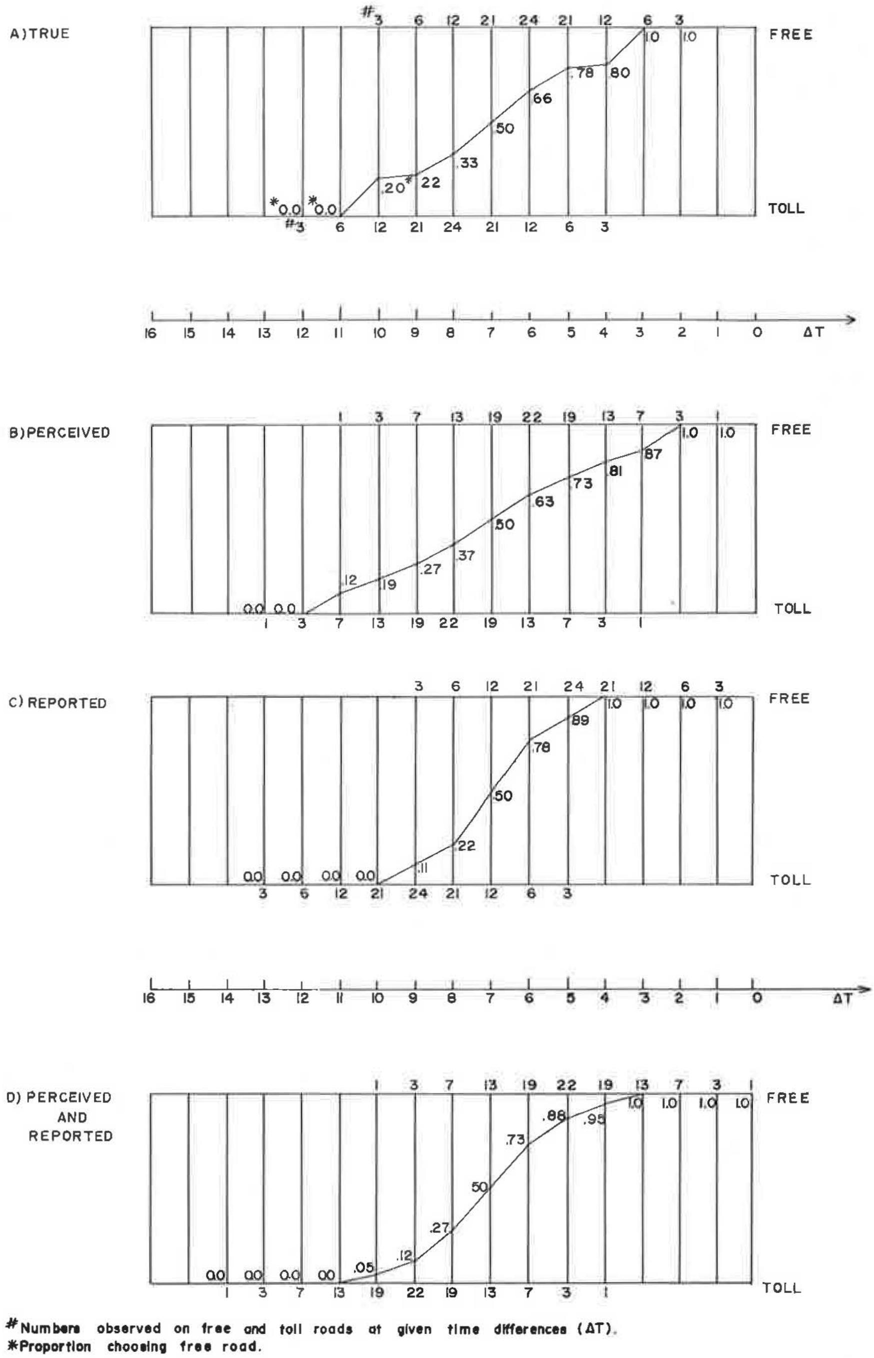

Figure 1. Effects of biases on a_1.

time. Moreover, because the slope of the curve relating P(x) to ΔT is equivalent to α_1, a change in the slope of the curve will change the value of time, a steeper slope implying a higher α_1 and, hence, a higher value of time. It is recognized that this assumption will not hold because only the true value of α_2 will remain unchanged whereas its estimate, $\hat{a}_2$, may vary. It is argued that, even given the heroic nature of the assumption, the analysis will indicate the directions of changes in the value of time and the magnitude of the resultant problems.

Figure 1 shows the effects on the slopes of the curves developed by using different data types. Figure 1b shows the effects of misperceptions of the "true" times. In the absence of any better information about such biases, it was assumed that, for each time difference, one-third of the travelers would perceive the time difference as 1 min greater than it really was, one-third would perceive it as 1 min less, and one-third would perceive it correctly. (It is not claimed that this representation of bias has behavioral validity; it is used merely as an example.) It will be clear that the effect of these hypothetical biases is to render the slope of the curve less steep and thus to reduce the value of time derived from such data compared with the value derived from the true data.

Figure 1c shows the effect of a reporting bias, as a result of which each traveler misreports the true time difference by 1 min in favor of his chosen mode. Thus, the toll-road chooser makes it appear that he gained more time as a result of paying the toll, and the free-road chooser makes it appear that the time saving he gave up was smaller than it really was. The effect of such a systematic bias is to make the slope of the curve steeper and, thus, the value of time higher.

Finally, Figure 1d shows the effect of combining the perception and reporting biases. The resultant slope is less steep than the reported slope but steeper than the perceived slope. It is clear that the steepness of the slope will be dependent on the degree to which the resultant biases offset each other, because they work in different directions.

The use of notional perception and reporting biases in the example reflects the author's view (based on little more than casual empiricism) that these biases are likely to be of greater importance than the other biases outlined in the section on possible biases. Should the reader disagree, the mechanism for analysis is still valid and different propositions about the nature of the biases can be tested.

After this consideration of the biases that might occur in data collected from the travelers themselves, it is now possible to proceed to a consideration of the biases that might occur in the measurement process. This was done by following the same procedure. A number of assumptions were made about the ways in which the measured values might differ from the true values. Three assumptions were made:

1. It is assumed that the necessity of duplicating test runs will lead to some level of aggregation of travelers, with a resultant reduction in the time differences at which travelers are observed. The aggregation is arbitrary in that all the odd-numbered time differences are reallocated equally to the even differences above and below them.
2. Lest the experiment be influenced by the nature of the aggregation, No. 2 aggregates to the odd-numbered time differences.
3. In this measure, the reasoning used by Thomas is followed, and it is assumed that the mean time difference of each group remains unchanged while the variance of each group increases.

It can be shown in all 3 cases that the slope is observed to be less steep than the slope based on the true data, reflecting that the value of time is less than the value that would be derived from the true data.

It should be remembered that, so far, the problem has been very much simplified, in that we have assumed a route-choice problem with a fixed cost difference, ΔC, and no difference in operating costs between the routes. If the operating cost assumption is relaxed, or if the analysis is extended to a modal-choice situation in which the traveler may well be faced with costs as well as times that vary from mode to mode, the problem becomes very much more complex. It does not seem unreasonable to expect that the biases appearing in the time data should also appear in the cost data.

If this is so, it is not only the numerator of the value of time expression

$$VOT = \frac{\alpha_1}{\alpha_2}$$

but also the denominator that may vary. The implications for the value of time derived from a model under such circumstances are very serious because the interactions of the various types of time and cost biases lead to complex effects on the value of time. The following data give the direction of the effect on the value of time of different combinations of time and cost biases. It should be noted that in some cases not even the direction of change can be predicted because it is dependent on the relative magnitudes of the biases.

Time (α_1)	Cost (α_2)	VOT (α_1/α_2)
Increase	No bias	Increase
Decrease	No bias	Decrease
No bias	Increase	Decrease
No bias	Decrease	Increase
Increase	Increase	?
Decrease	Decrease	?
Increase	Decrease	Increase
Decrease	Increase	Decrease

It should be stressed that, if the problem of cost biases appears to have been given a rather cursory treatment, it is not because it is felt that such biases are unimportant but rather because the arguments put forward in the discussion of time biases apply equally to cost biases, and it would be tiresome to repeat them. It should be noted, however, that the problem of time biases, complex as it may be, is but a part of a problem whose complexity is greatly increased by the introduction of cost biases. This increase in complexity is due to the multiplicity of interactions and cumulations that are possible among the different biases.

Is it, then, possible to select 1 value of time as the correct one? Indeed, it is furthermore necessary to decide what is to be meant by "correct." It is contended that a value of time based on perceived data (different though it may be from one derived from true data) is correct if it is derived from a model whose hypothesis is such that it relates choice to the values of times and costs as perceived by the traveler. In the same way, a value of time based on measured data is correct when it is derived from a model whose hypothesis is of the special case that relates choice to an expectation of times and costs based on familiarity, which can be represented by measured data. Thus, 2 values of time may both be correct in the sense that they are both derived from properly constructed models.

CONCLUSIONS

A number of interesting conclusions can be drawn from the preceding discussion:

1. The development of the special case hypothesis means that the use of both measured and perceived data can be considered correct for use in modal-choice models in the sense that a meaningful hypothesis about traveler's behavior can be suggested to justify the use of each type of data. Because the appropriate hypothesis can be selected on the basis of traveler's familiarity with the trip under consideration, the selection of the data types poses no problems in cases where a traveler is familiar with the trip. In other cases, 3 factors are of importance: the stability of the relationship between measured and perceived values and the effects of using the inappropriate data types on predictions and on values of time. In terms of the use of the model to predict travel behavior, the problem is less acute as a result of the conclusion that the use of perceived data can lead to serious problems in the prediction process (i.e., that instability

in perception errors over time or space could lead to a lack of confidence in the predictions).

2. If it can be demonstrated that the relationship between measured and perceived data is stable, a procedure might be developed for modifying measured data into perceived data for those cases for which the use of perceived data was indicated. Should a procedure prove impossible to establish, or if it is impracticable to operate, it is concluded that an investigation of the effects of perception errors on predictions must be undertaken before models based on perceived data can be used with confidence for prediction purposes.

3. In terms of the use of the model for the provision of values of time, it is felt that models based on both perceived and measured data can produce values of time that are correct in the sense that they are derived from properly constructed models. It is suggested that, in the same way as values of time are beginning to be classified by income group and trip purpose, they be further classified by familiarity with the choice situation. (It is, of course, possible that this variable is linked with trip purpose.) In this way, each value would only be used in a situation similar to the one in which it was derived. It is argued that, just as it is wrong to apply the value of time derived from a commuting trip to time saved on a pleasure trip, or to apply a value of time saved derived from the choices of upper income group travelers to time saved by lower income group travelers, it is equally wrong to apply a value derived from a familiar situation to time saved in an unfamiliar situation. The conclusion that values of time based on both perceived and measured data can be regarded as correct represents the addition of a further dimension to the growing matrix of values of time.

4. The answer to the question as to which data types are correct cannot be answered by dogma but must be answered by analysis of the choice situation under consideration and a decision as to which hypothesis about traveler decision-making behavior (and, hence, which data types) is more appropriate in a given situation.

REFERENCES

1. Harrison, A. J., and Quarmby, D. A. The Value of Time in Transport Planning: A Review. European Conf. of Ministers of Transport, Round Table, 1969.
2. Lansing, J. B., and Hendricks, G. Living Patterns and Attitudes in the Detroit Region. Detroit Region TALUS Report, 1967.
3. Lisco, T. E. The Value of Commuter's Travel Time. Univ. of Chicago, unpublished PhD dissertation, 1967.
4. Quarmby, D. A. Choice of Travel Mode on the Journey to Work. Jour. of Transport Economics and Policy, Sept. 1967.
5. Thomas, T. C. The Value of Time for Passenger Cars. Stanford Research Institute, Menlo Park, Calif., 1967.
6. Thomas, T. C., and Thompson, G. I. The Value of Time for Commuting Motorists as a Function of Their Income Level and Amount of Time Saved. Highway Research Record 314, 1970, pp. 1-19.
7. Watson, P. L. The Choice of the Data Base for Modal Split Modelling and the Valuation of Time. Planning and Transport Research and Computation Company, Urban Traffic Model Research Symposium, London, 1970.