Conceptual Problems in Evaluation of Travel Time

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A number of conceptual problems in the evaluation of time as currently practiced are discussed. A number of assumptions implicit in a theoretical approach to the value of time are stated explicitly, and two economic analyses of the value of time are compared. This involves, in particular, a critical discussion of the validity of the modified consumer behavior theory as it is currently being applied to this problem. A suggestion for broadening the issues involved is made stressing some properties of time that have so far not been included in the research effort.

The principal tool that specifically deals with time and cost attributes of the transportation system as they relate to travel demand is the mode choice model (1, 2), which is an element of the set of travel demand models, commonly referred to as the urban transportation planning (UTP) process (3). Among other properties, the UTP process enables an assessment of savings in time associated with various modal characteristics and network configurations for given spatial distributions of origins and destinations. Both the gravity (or trip distribution) model and the mode choice model have been applied to intraurban travel, although an extension of the comprehensive UTP process to interurban movements has yet to be sucessfully formulated (4, 5).

More recently, the urban transportation planning process was reformulated in a more economic framework, where the various stepwise models, such as generation, distribution, and mode choice, were described as a decreasing order of consumer choice situations. Thus, trip generation models reflect choice between various activities, assuming that these can be performed only at different geographical locations and by using various transportation modes. Trip distribution refers more explicitly to the choice between different locations, and mode choice models are even more restricted in the sense that they determine only the selection of the transportation mode to be used (6, 7).

CONCEPT OF TIME EVALUATION

To establish meaningful estimating relationships of the transportation system in a planning context, particularly in the predictive and evaluative elements, conceptually sound methods have to be developed to attach monetary values to the travel time characteristics of the system. A variety of approaches to this problem have been suggested that usually relate concepts of two general bodies of economic theory: consumer behavior theory and macroeconomic theory (8, 9). However, a number of assumptions about the properties of the temporal dimension, which are implied in both approaches, need to be specified.

The first premise is that the main property of time to be evaluated is its duration. Assuming that time constitutes a continuous flow, the duration of elapsed time between two instants can be measured, and an interval can be defined that is affected neither by the passage of time nor by its activity content. A common characterization of such a content-independent time interval is objective or absolute time.

For a meaningful evaluation of objective time, a second premise is necessary. Since the flow of time per se cannot be arrested, condensed, or expanded at will, the activity content, or the process taking place in time, is subject to evaluation because it can be controlled (10, 11). Travel time reduction should therefore be considered as a deliberate substitution of the time allocated to a specific activity, namely, movement over space, for another activity, conveniently classified as work (production) or leisure (consumption). In this sense, the value of travel time is frequently referred to as the opportunity cost value of time. One definition of the value of travel time is, therefore, "that amount of money which an individual is prepared to forego in order to save himself one unit of his journey time" (12).

It is the third premise, that activities have different values or utilities in an economic or social sense, that causes much difficulty. Otherwise, the value of time would have simply been the national income divided by the total time of all individuals in the nation (13). This difficulty arises not only because different values necessarily cause problems in terms of measurement, but mainly because the value of time measured macroeconomically and that derived from consumer behavior theory are fundamentally incompatible.

THEORETICAL BASES FOR CURRENT ESTIMATIONS OF VALUES OF TRAVEL TIME

One major area of application of the macroeconomic approach to the evaluation of travel time lies in the appraisal of transportation system improvements. The problem consists essentially of an efficient allocation of resources in the economy, in general, and in the transportation system in particular. For a variety of reasons, public agencies provide services to the public free of charge or at prices unrelated to the costs of providing them. For assessing the effects of the expenditure and for evaluating it, the technique of cost-benefit analysis has been used (14). In transportation systems, the main effect of improvements consists of user benefits, primarily in terms of travel time savings. This is particularly true of improvements in air traffic control and navigation systems and in virtually all highway improvements (15, 16, 17). Alternatively, a conceptually identical approach is to evaluate the annual economic losses due to unproductive travel time (18, App. 1).

For one category of time-consuming human activity, one can establish a value based on the market mechanism. A market for labor exists so that time saving in journeys undertaken during working time can be assigned a value related either to the wage rate or the earning power, assuming that productivity during the trip is nil. Similarly, when productivity during the trip is positive, as in the case of commercial vehicles' travel times, there is little conceptual difficulty to determine the value of time savings due to improvements in the infrastructure (19). Some questions remain unsettled about the stratification by occupation and the nature of the overheads to be assigned, but this does not necessarily affect the theoretical soundness of the estimating procedure.

The main difficulty arises, of course, when the same theoretical approach is used for the evaluation of nonproductive, or leisure, time. In fact, even that most frequent of all trips, the daily commuting to work, cannot strictly be considered as part of the productive time that has an objective market value. A variety of solutions have been suggested to this problem; none of them is entirely satisfactory. One approach is to apply a dollar value to travel time on the basis of the constant money wage rate. Its implicit underlying assumption is that all the time saved in travel could be invariably used for productive purposes. Such an assumption is untenable both from an intuitive, common sense approach and from empirical data derived from consumer choice studies. In other words, empirical consumer choice studies, which usually include many commuting trips, may generate different working time values than those obtained from wage rate studies.

Another approach has been to apply the concepts of the value of time as derived from the individual consumer choice theory to justify public investments. The assumption here is that transportation improvements have an important social, in addition to a strictly economic, benefit. Whereas economic benefits may be considered solely in terms of the combination of time with labor services in the production process, social benefits include the whole set of activities for which people deliberately make use of their time and money budgets. Thus, the social benefits accruing from a reduction of traveling time can be regarded as the sum of money values that all individual beneficiaries of the project attach to their time savings (9, 20, 21). The main advantage of this approach lies in the possibilities to measure empirically revealed values of time savings in situations where a choice between money and time exists. These empricial studies and their conceptual basis will be discussed in detail later. It should be noted, however, that, by accepting the values of time as determined from empirical choice situations for project evaluation, a number of additional assumptions have to be made: (a) Small increments of time saved by individual travelers can be added up when viewed as an aggregate for a large number of travelers (22), and (b) economically defined savings can be added to socially determined savings. In other words, time savings that resulted in an increased productivity of resources in the economy are assigned a monetary value in the same currency as the national accounting system. If social or welfare benefits from travel time savings are included in the evaluation of investments, then they are presumed to be valued in terms of this currency, although in reality they are not reflected in the national accounts. Not surprisingly, the following words of caution are found in a recent review of the evaluation of highway improvements (23):

> It is advisable to treat travel time as a separate item in economy studies in order that the decision maker can see readily the amount of over-all gains that are priced out on the basis of the dollar value of time and those gains that are actual bona fide reductions in expenditures for travel.

VALUE OF TRAVEL TIME IN PREDICTING TRANSPORTATION DEMAND

Recently a considerable research effort has been directed toward an elaboration of the traditional consumer behavior (or individual utility) theory so that the problem of travel time evaluation could be incorporated (20, 21, 24, 25, 26, 27, 28). In the typical consumer choice situation, a good is purchased for its utility, which is a function of the sum of its attributes or characteristics (29). Any given trip may be considered as a good, associated with a set of attributes such as time and comfort, which are on sale for money at the marketplace (30, 31). The choice situation usually consists of the possibility of marginally substituting a certain attribute for money within the general constraints of income and time scarcities inherent in economic decision making. According to the theory as reformulated above, the marginal utility of any activity can be inferred from the wage rate and the utility of other foregone activities. In the case of a trip, a reduction in time spent on travel is valued at the margin as being equal to the free wage rate and another usually negative factor, consisting of either the disutility of work or the disutility of travel or both. The important contribution lies in the clarification of the conceptual inequality of the various monetary values of activities on the basis of their individual utilities. In other words, the modified consumer choice theory explicitly identifies conceptually many values of travel times, rather than a simple, constant value for the working time travel and the leisure time travel. This allows for a wide range of values, based on the traveler's preferences (32).

An important corollary to the new approach in evaluating travel time is the possibility of measuring empirically the revealed trade-offs of travel times saving for money (27, 31). However, a number of conceptual problems still remain to be solved, so that results obtained from the field cannot yet be considered as generally applicable. The first problem relates to the definition of the utility of travel time savings. We have already introduced one element of the utility of travel time savings, in the form of pure opportunity costs. According to this approach, although no positive or negative utility is being attacted to the time devoted

to transportation, a generally positive utility is attached to the alternative uses of the time saved for leisure or work.

However, the value of travel time depends both on the use to which such time saved would be put and on the disutility generally attached to traveling (26, 27, 31). In the evaluation of the disutility of traveling, travel time cannot be viewed independently of other trip attributes, particularly those relating to comfort. Let us suppose that we were in a position to establish a composite measure of the disutility of a trip, in terms of the physical and mental effort required to perform the activity of traveling. It would be difficult to separate time spent and comfort as attributes to this total effort; they are joint attributes because the comfort and discomfort may depend, among others, on trip duration

The problem of separating trip duration as an attribute of the disutility of traveling has several practical implications. These can be recognized in the great care that is being taken to find ideal choice situations in which travel time savings can be evaluated on the basis of real-world evidence. In the first choice situation, which involves time savings due to change in modes, it may be difficult, conceptually, not only to determine value of time saved but even to predict the actual mode chosen. Let us assume that there is a person with positive income, who faces two alternative means of travel with identical money outlays for a trip from his or her hometown to another town for an important meeting: a 10-h overnight sleeper train journey as opposed to a 3-h air trip early in the morning of the meeting. If the trip duration is the main element of disutility, then it is probable that the traveler will choose the air trip. However, if the degree of measurable comfort on the train greatly exceeds that of the airplane, so that the total effort of traveling by air is greater than that required for the train journey, then the prediction would be for the traveler to use the train.

The second choice situation that has been suggested in the literature (33) involves similar modes, along identical routes, but with varying speeds, such as a normal train versus the Trans Europe Express or a subsonic versus supersonic air trip. The faster mode usually requires a greater money outlay so that, a priori, this might be a good choice situation to determine the value of travel time savings. Still, even in this case, the assumption has to be made that the level of comfort is identical in both trips. Now, when the train substitution is made, it is clearly demonstrable that the level of comfort in the faster train is higher than in the normal train. For the supersonic transport, the assumption would be that the level of comfort is independent from trip duration or that to remain confined to a seat for 3 to 4 h does not differ much from a 6 to 7-h confinement. This again may well be an unrealistic assumption.

The same problem exists in the freeway-tollway choice situation, which involves small time savings, say, less than 5 min. From the disutility viewpoint of minimizing effort, these time savings, provided adequate measurement techniques are devised, could not be ignored, but again it is unrealistic to assume similar driving conditions on both routes. No attempt will be made in this paper to resolve this problem. It may be that time savings combine benefits from both opportunity costs and disutility of travel and thereby provide a solution. However, the internal consistency of evaluating time savings as a sum of these two effects has still to be investigated so that it can be determined that problems of double accounting of the time duration do not arise. Both Phillips (28) and de Donnea (31) conclude that, in effect, such an approach makes it impossible to estimate the pure opportunity cost value of time. Instead, they suggest values for bus, expressway, and individual travel and for different trip purposes. In other words, they provide time saving evaluations for given comfort levels.

Another problem raised by the application of a modified consumer choice theory to the evaluation of time concerns the equivalence of average and marginal time savings. Strictly speaking, the derivation of the equilibrium conditions is based on Lagrange multipliers that necessarily use marginal rather than average or total terms. It is this characteristic that differentiates clearly between individual consumer behavior theory and macroeconomic theory, in which weighted average or total values of time may be derived.

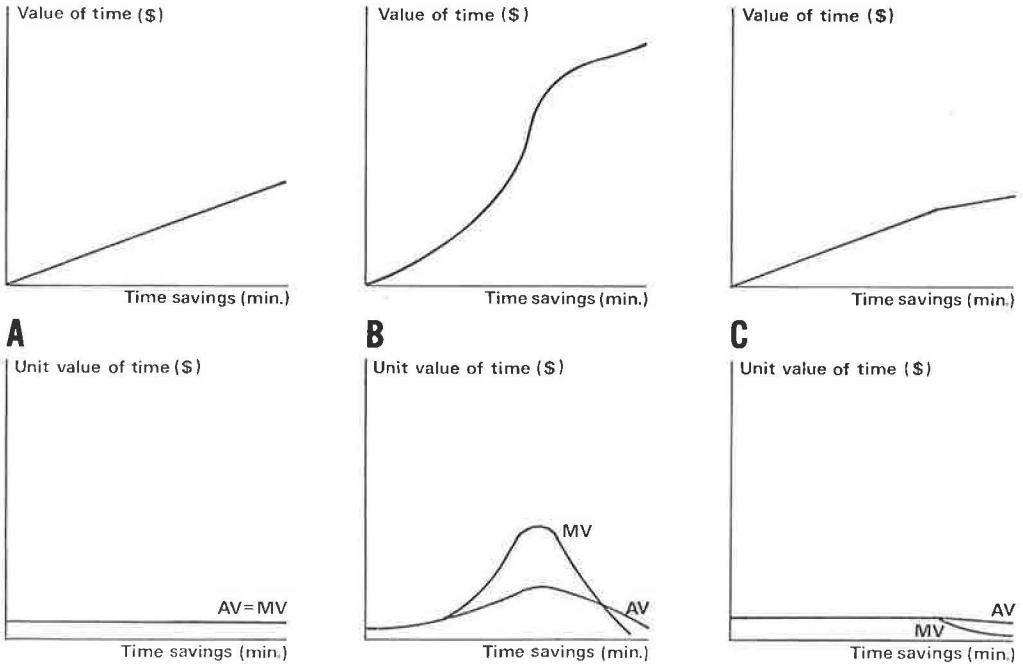
To begin with, one must determine what constitutes marginal time savings. Ideally, since time is a continuum, measured unit intervals may be infinitely small. Alternatively, a practical marginal time interval could be 1 min, or, if some perceptual or behavioral bases are allowed for, this could be stretched to 5 min. This would admittedly sacrifice a rigorous marginal analysis. In reality, however, there is a great deal of confusion between marginal time savings as described here and time savings resulting from the differences between travel times by mode or route in the real world. Time differentials constitute marginal time savings in the theoretical sense only if they are small, probably of the order of 5 min or less. Any time saving above this interval may be considered marginal only if it is assumed, a priori, that average and marginal time savings are equivalent. There are obvious implications from this observation in terms of the compatibility of travel time differentials within urban regions and those of interurban travel, which may vary by at least an order of magnitude. A typical example of the lack of distinction between average and marginal time savings is found in a recent empirical study of interurban travel in Italy (34). In this case, the value of time was the difference between the value of x min spent on making a journey on the Autostrada plus y min spent on some other activity and the value of x + y min making the same journey by the ordinary roads.

It has been indicated that a general application of the marginal value of time concept to the real world depends largely on the relationship between these marginal values and the average value of time. A preliminary assumption of continuity simplifies the nature of this relationship. If the value of time remains constant, irrespective of the amounts of time saved (when even the smaller amounts of time saved are evaluated), then marginal time savings are equivalent to average time savings. In such a case, the relationship between time savings and their value is linear and starts from the origin (Figure 1a). A number of studies have implicitly or specifically made this assumption (27, 28, 35), although Harrison and Quarmby (27) admit that

> At a theoretical level it has to be allowed that the valuation determined at the existing margin may not adequately reflect the importance of all changes in aggregate, since there can be no general reason to suppose the equality of marginal and average values.

Actually, at least two other assumptions on the relationship between average and marginal value may be made with some degree of plausibility: (a) Marginal and average values are not two indentical functions of time saved, although they may occasionally interesect; and (b) at that point they have similar values (Figure 1b). Conceptually, divergent values of marginal and average time savings may be inferred simply by using

Figure 1. Marginal versus average values of time savings with a continuous time value function.



the same assumption generally applied in consumer behavior theory. This assumption suggests that the utility or value of a good or an attribute of a good depends on its relative scarcity or abundance, and, therefore, the typical shape of individual preference-indifference curves is produced. In an updated analysis, Thomas (36, 37) indicates that automobile commuters' marginal values of time, measured minute by minute, vary considerably, and reach their maximum at about the fourteenth minute saved. In this empirical study, it appears that both small and large amounts of time have less marginal value than intermediate amounts. This nonmonotonic property of value of time savings still requires theoretical or behavioral foundations.

Based on this general premise, another assumption may be suggested, that both average and marginal value of time savings should be smaller on interurban trips, when there is a large use of travel time and greater amounts of time saved than in urban travel when there is generally less travel time. A graphical representation of the view that marginal and average values are constant in urban travel, but slowly decrease in interurban trips, is shown in Figure 1c. In fact, Harrison and Quarmby (27) suggest that this type of relationship may exist, although they derive it from a different approach altogether.

Finally, an argument could be made in favor of relaxing the continuity assumption in the relationship between time savings and their values. This would help explain the various suggestions made about evaluating time savings by air as a function of the hour of the day or the number of hours saved and also why very small amounts of time saved may be disregarded (17, 38). In other words, the possibility that the function of time savings, or value of time, has a stepwise nature should probably be seriously explored.

In this analysis of the use of the consumer choice theory in travel demand prediction, a fundamental weakness in the property of the theoretical constructs used in the equations of the value of time is that both sides of the equation cannot be measured independently. Since cardinal utility has been rejected as a quantitative tool in economic evaluation, what remains is an equation that can be solved directly only in terms of the opportunity cost value of time; however, the utility of leisure, the disutility of work, and the disutility of travel are unknowns. This has led, in several cases, to a tendency to use time and value of time as a proxy for these unknowns, and, thereby, the problem of cardinal utility is bypassed (39). The use of value in such cases is based on the assumption that, when activity contents of alternative time uses are being traded, value can be attached to differences in each activity content. However, such procedures cannot per se improve on the evaluation of time itself, and great care should be taken in interpreting results derived by these methods because possible errors may be compounded.

DIRECTIONS FOR FURTHER RESEARCH

Future research on the theoretical aspects of the value of time may develop along a number of interrelated lines. First, a taxonomy of values of time will likely be available based on the work of the U.K. Ministry of Transport (22) or Burco and Thomas (40), in which a matrix of values of time will be designed along two dimensions: (a) density of trips from urban core to intercity and (b) trip purpose from commuting to vacation or recreation. User attributes would appear as coefficients of the system characteristics, particularly time and money outlays (41). Such a matrix would probably represent the end product of the theoretical constructs as they exist today and take into account the limitations referred to above.

An entirely different approach to the evaluation of time, which may eventually broaden the theoretical basis for the evaluation of time in a significant way, is to reconsider the basic philosophical and socioeconomic premises of time and their evaluation. Because time is treated in terms of its duration and activity content, perhaps other properties of time are being obscured. Specifically, the property of the irreversibility of time or its unidirectional flow and its cyclical nature are of

particular importance if the utility of time is being considered. For example, it is clear that one hour, between 5 and 6 a.m., is not strictly equivalent to another hour, between 5 to 6 p.m., although in terms of duration they are necessarily equivalent. Incidentally, this is implicitly recognized in the modified formulation of the consumer behavior theory, as suggested by Foster (30), in which constraints are placed on income and time budgets but not on the nonpecuniary advantages and disadvantages of the activity for which time and money are involved. In other words, the utility of an activity will vary according to the time of day or generally to the period in which it is undertaken; therefore, the additional properties of time do not appear in the simple time budget constraint but rather in the utility or disutility level of the various activities.

A possible way to approach the structured use of time in individual and social behavior could be by means of time budgets, in terms of either total travel time budgets or specific travel time budgets, according to the daily, weekly, or yearly cycle of human activities in a social context. An interesting problem, in this context, would be the evaluation of travel by the elderly. On the one hand, since they are mostly retired, alternative uses of time do not generate income. On the other hand, travel time budgets of elderly people appear to be particularly constrained to certain modes, routes, and hours of the day (42).

Another direction for further research, apart from the more social orientation suggested above, is behavior-oriented studies of travel time. As Reichman and Stopher, in a paper in this Record, point out, it is hoped that more understanding will be achieved on the perceptual and attitudinal problems related to travel time savings versus total travel time. This question relates to the value people place on the fact that they can control their time, irrespective of its utility or opportunity costs.

It is hoped that these suggestions might lead to a better understanding of human allocation of time. The inclusion of time into travel demand models will probably necessitate a significant shift from current consumer behavior theory to a different type of modeling. At present, there are indications that concepts based on analogies to energy conservation flows may provide some useful insights into the more general problem of time budgets and human control over time.

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