This paper surveys the theoretical basis and empirical investigations of the value of travel time savings. It discusses the theoretical and conceptual problems involved in the evaluation of travel time savings. It presents a review of the theoretical treatment of the value of time and the mathematical techniques used in empirical studies designed to estimate the value of travel time savings. It summarizes the results obtained by various empirical investigations into the travel time savings and, based on these results, it provides a set of guidelines for integrating the value of travel time savings in the appraisal of transport projects.

The author would like to acknowledge the excellent assistance of Mrs. Betty Easter who edited the paper.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUMMARY AND CONCLUSIONS</td>
<td>i - x</td>
</tr>
<tr>
<td>I. CONCEPTUAL PROBLEMS IN EVALUATING TRAVEL TIME SAVINGS</td>
<td>1</td>
</tr>
<tr>
<td>A. The Need for Evaluating Travel Time Savings</td>
<td>1</td>
</tr>
<tr>
<td>B. Conceptual Considerations in Evaluating Time Savings</td>
<td>2</td>
</tr>
<tr>
<td>C. Travel Time Savings and Their Economic Value</td>
<td>3</td>
</tr>
<tr>
<td>D. Some Problems in Evaluating Travel Time Savings</td>
<td>4</td>
</tr>
<tr>
<td>II. A SURVEY OF THEORETICAL APPROACHES TO EVALUATION OF TIME</td>
<td>7</td>
</tr>
<tr>
<td>A. Introduction</td>
<td>7</td>
</tr>
<tr>
<td>B. Theoretical Analysis of the Value of Working Travel Time Savings</td>
<td>7</td>
</tr>
<tr>
<td>Objections to the Use of Average Wage Rates as a Measure of Working</td>
<td>8</td>
</tr>
<tr>
<td>Travel Time Savings</td>
<td></td>
</tr>
<tr>
<td>C. Theoretical Analysis of Non-Working Travel Time Savings</td>
<td>10</td>
</tr>
<tr>
<td>D. A General Theory of the Valuation and Allocation of Time</td>
<td>14</td>
</tr>
<tr>
<td>III. BEHAVIORAL MODELS USED IN ESTIMATING THE VALUE OF TRAVEL TIME SAVINGS</td>
<td>17</td>
</tr>
<tr>
<td>A. Introduction</td>
<td>17</td>
</tr>
<tr>
<td>B. Disaggregate Behavioral Travel Demand Models</td>
<td>17</td>
</tr>
<tr>
<td>C. Mathematical Techniques in Behavioral Models</td>
<td>19</td>
</tr>
<tr>
<td>Discriminant Analysis</td>
<td>19</td>
</tr>
<tr>
<td>Probit Analysis</td>
<td>20</td>
</tr>
<tr>
<td>Logit Analysis</td>
<td>21</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS (cont'd)

D. Different Interpretations of the Coefficients Estimated by the Models 22
E. Problems Raised by Time and Cost Data Used in Evaluation of Time 24

IV. A SURVEY OF THE EMPIRICAL INVESTIGATIONS INTO THE VALUE OF TRAVEL TIME SAVINGS 27
A. Introduction 27
B. Non-Work Travel Time Savings 27
   Modal Choice Studies 27
   Route Choice Studies 32
   Choice of Speed at which to Drive 40
   Choice of Residential Locations in Relation to Workplace 40
   Choice of Travel Destination or Frequency of Travel to a Given Destination 41
   Direct Approaches to the Value of Time 42
C. Working Time Travel Savings 44
D. Air Travel Time Savings 46
   General Consideration 46
   Empirical Research into the Value of Time Saved in Air Transport 49

V. USE OF ESTIMATED VALUES OF TIME SAVINGS IN ECONOMIC EVALUATION OF TRANSPORT PROJECTS 51
A. Travel Time Savings and Economic Assessment of Transport Projects 51
B. Use of Travel Time Savings in World Bank's Transport Project Appraisals 53

TABLES
Summary Table 1 Some Values of Commuter Travel Time Savings ix
Summary Table 2 Some Values for Non-Working Travel Time Savings Based on Non-Commuter Travel x
### TABLE OF CONTENTS (cont'd)

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Benefits of Time Savings in Dollars per Vehicle</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>for Personal Business Trips</td>
<td></td>
</tr>
<tr>
<td>4.2</td>
<td>Benefits of Time Savings in Dollars per Person</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>for Work Trips</td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>Benefits of Time Savings in Dollars per Vehicle</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>for Social-Recreational Trips</td>
<td></td>
</tr>
<tr>
<td>4.4</td>
<td>Benefits of Time Savings in Dollars per Vehicle</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>for Vacation Trips</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>Benefits of Time Savings in Dollars per Person</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>for School Trips</td>
<td></td>
</tr>
</tbody>
</table>
STIJLMARY AND CONCLUSIONS

1. The value of time saved in economic assessment of transport projects, particularly those of urban highways and airport facilities, can assume an overriding importance. Any selected value for the travel time saved can affect the economic justification of investment expenditure in transport facilities of this type. In Europe and North America a greater part of user benefits generated by most transport projects has been attributed to travel time savings.

2. However, in the Bank's past lending operations in the transport sector, the value of time has not been a highly crucial factor in most project evaluations, and has not been included in the benefit calculations. But, with increased lending operations in the area of urban transportation and airport projects, travel time savings can be expected to assume major importance.

3. The value of travel time savings arises out of two basic considerations: (a) Time savings make it possible to undertake an alternative activity; this is of particular importance in the case of working travel time savings. (b) It reduces disutilities associated with trip making. It means that all travel time savings have a value for trip makers. The available empirical evidence supports this. However, there is no general agreement that values for all travel time savings should be included in an economic appraisal of transport projects.

4. For one category of travel time savings, e.g. working time travel savings, there is no conceptual problem involved in including these in economic assessments of transport projects. Such time represents an element of cost of production. A reduction in travel time during working hours would enable employers to use the manpower released for additional productive purposes. In this manner travel time savings would be reflected in Gross National Product. In the case of non-working travel time savings, however, the value is reflected only in an individual's satisfaction from the shortened travel time. In this sense, these travel time savings are not related to the Gross National Product of the country. On this ground, it has been argued that such time savings should have no economic value. However, the prevailing opinion among most transport economists and planners is to assign a value to non-working travel time savings. The fact that changes in trip makers' satisfaction are not reflected in GNP indicates a shortcoming of national income accounting rather than a lack of value. All types of travel time savings will enhance the total welfare of the community to some extent and therefore have a value. It must also be pointed out that inclusion of the values of non-working travel time savings in economic appraisals is consistent with the underlying framework of cost-benefit analysis and the estimation of benefits by means of consumers' and producers' surplus concepts.

5. During recent years an increasing amount of attention has been given to the problem of the valuation of time. A number of studies have been carried out both in the theory of the value of time and in empirical measurement of the value of time. In valuing working time most transport economists accept the
marginal productivity theory of factor payments as a starting point. Despite the efforts of a number of capable theoreticians the theoretical models developed over the years have not been notably successful in providing a satisfactory framework for empirical measurement of the value of non-working travel time savings.

6. The conventional theory of consumer behavior has been the starting point for the theoretical studies of the value of non-working travel time savings. Although economic theory had not treated the value of time explicitly in relation to consumer choices, the prescriptions of this theory were applied to the determination of the leisure-work combination that would maximize the utility enjoyed by an individual. Accepting this approach it was inferred that the value of leisure time would be equal to the wage rate. Many authors have argued that the application of this result to evaluation of time saved in transport was wrong on the grounds that the disutility associated with travel had not been included in the analysis. The more recent efforts in this field were directed toward developing a more general theory of time. These theories show that it is not meaningful to think in terms of an absolute value of time, and the value is dependent on the activity that is engaged during that time period. However, these theoretical considerations have not been more successful than earlier efforts in providing a framework for the actual measurement of time.

7. Recent efforts in measurement of non-working travel time savings have been mostly empirical investigations designed to determine the willingness of trip makers to pay for a reduction in travel time. Most of these studies have incorporated a "revealed preference" concept in behavioral models developed for explaining the actual transport choices made by trip makers. Preferences shown by travelers in choosing between transport alternative involving different combinations of travel time and money cost have provided the basis for inferring the trade-off between them. The estimated trade-off represents some average of the extra cost that those trip makers are willing to incur in order to save some travel time and the extra cost avoided by those who are willing to spend more time traveling.

8. Most of the empirical research done in this area was carried out in the United States and in the United Kingdom. Commuter trips in situations involving modal choices with significantly differing money costs and travel times have been the basis of most of the empirical investigations into the value of non-working travel time. Route choice situations have also been utilized by many investigators in their efforts to derive a value of travel time for trip purposes other than commuting. Decisions of trip makers concerning destinations or frequency of trips to a given destination have also been used to derive a value of travel time, mostly in recreational trips. Summary Tables 1 and 2 given on pp vi and vii reflect the results obtained by some of the empirical investigations into the value of non-working travel time based on commuter and non-commuter trips respectively.
9. The basic limitations of the revealed preference approach is that rarely if ever does one encounter a choice situation where the only trade-off is between money and time; other factors also have a significant effect on the trip maker's decision. For example, differences in comfort, stress and strain involved in the trip making, the trip maker's perception of the hazards involved, etc. Despite recent advances in transport demand modeling, the evaluation of travel time savings by the use of such models still remains a highly tenuous undertaking. The estimates obtained are crude and are likely to have wide ranges of error. The findings of the studies also indicate that the values obtained by a particular study are valid for only those trip makers whose revealed preferences are used as the basis for evaluation. Therefore it is incorrect to assign a universal meaning to the estimates obtained by a given study. Another conclusion that can be derived from the findings of these studies is that it is erroneous to think in terms of a single average value of time. The value that travelers attach to travel time savings depends on the purpose of trips, the length of trips, mode of travel, the amount of time saved, as well as on the characteristics of trip makers, i.e. income level, age, sex, etc.

10. Given the fact that it is very difficult if not impossible to measure the "true" value of non-working travel time savings resulting from each and every transport project in determining the values to be used in economic assessments, a certain degree of discretion will have to be exercised. Such decisions may also be influenced by the "value" judgments of the community. The society may choose to attribute a value for non-working travel time savings different from that which is behaviorally revealed by the individuals themselves (e.g. a common value rather than a behaviorally revealed value differing according to income level). Notwithstanding these reservations however, most empirical investigations into the value of non-working travel time savings indicate a range of values which is fairly well defined and yield results that can provide a basis for estimating user benefits of transport projects. The tentative guidelines suggested in the following section must be viewed in this light.

11. There are still a number of questions that need to be answered. More specifically, present knowledge on the variations in the value of time by mode of travel including walking and waiting time and by type of trips is not adequate and requires further research. The problem of evaluating small time savings is another area which particularly needs to be explored. As most empirical studies utilized commuter-trip behavior there is need for further research on the value of time saved in longer trips. Another question that deserves study is the problem of forecasting variations in the values of time for future years. All empirical investigations to date have been used on the experience of trip makers in affluent developed countries. It is not at all certain that the results obtained by these studies would be valid for less developed countries. Therefore, there is a need for investigating the value of travel time savings in developing countries. In this area the Bank is in a unique position to make a contribution. In a developing country a research project can easily be incorporated in one of the urban transport projects being carried out, under the supervision of the Bank, without much difficulty or additional cost.
TENTATIVE GUIDELINES

Proposition (1) Value of Working Time

The average wage rate plus the various costs associated with employment such as social insurance, taxes and overheads should be regarded as the maximum value of working time. However, to the extent that severe restrictions on work hours appear to be present in a given case, approximate downward adjustments should be made. It should be noticed that this proposition does not allow for any difference in the disutilities associated with work and travel during work.

The proposition is likely to yield more reliable estimation of travel time savings for a highway project than for other transport investments, because in the case of highway users it is easy to distinguish the trips made for work purposes. This is not so in the case of air transport. A greater portion of air passengers are in the category of professions which do not have a clear-cut division between working and non-working hours. Another difficulty in evaluating the working time savings in air travel is the diurnal variation in the value of time. The available evidence suggests that the most critical time for an air traveler is before the trip begins. Many trip makers choose to leave the evening before and incur both time losses and hotel expenses at the destination if the scheduled departure time is too early in the morning. Furthermore, it appears that the last hours of the business day for an air traveler are less valuable. Clearly, estimation of the value of time savings by time of day is not an easy task. Assuming that data are available, the values assigned to each working hour saved should be varied to allow for the fact that the first hours of a working day are valued more by air travelers than are the last hours of the working day. Time savings below 10 minutes should not be assigned a money value on air journeys of longer duration.

Proposition (2) Non-working Travel Time Savings

As shown in Summary Table 1 most of the empirical investigations indicate that commuters value time savings somewhere between one-fourth and one-half of their hourly earnings. The available evidence also suggests that the value of time is a positive function of the earning levels of the commuters. It appears plausible to argue that because of the low relative earning powers of commuters in developing countries, the lower ratio, that is one-fourth of hourly earnings, should be regarded as the maximum value to be assigned to time savings in work trips in these countries. A figure between 20 percent 25 percent of hourly earnings appears to be a prudent value for the time savings in commuter trips. Wherever relevant data are available a distinction should be made between walking and waiting time and in-vehicle time: The theoretical discussions of the value of time suggest that the value travelers attach to time savings is partly the result of the disutility involved in travel. If this proposition is accepted then the
value of time saved in waiting or walking should be higher than the savings in in-vehicle time. Unfortunately because of the difficulties in data gathering many of the empirical studies of the value of time were unable to distinguish between different components of travel time. There is very little evidence to determine the value of walking and waiting time. The accepted practice based on the limited available evidence is to weight the walking and waiting time between two and three times as heavily as in-vehicle time.

Although there is evidence to suggest that the value of time varies according to trip purposes, no thorough investigations of the time savings in trips have been carried out so far. The available evidence (see Summary Table 2) is not sufficient to derive a definite relationship between the value of time and trip purposes. It appears that the starting point for the evaluation of income earners' time savings in trips other than commuting should be the same as the value of time in commuting trips. However, downward and upward adjustments in this value should be made if any evidence is available.

Proposition (3) Non-wage Earners' Travel Time Savings

The value of time should be the same for all adult members of a family. In the case of children time may be valued at some fraction of the adult rate. This proposition is based on no factual evidence, but reflects an assumption in social valuation of travel time saved. An argument, as a value judgment, can be presented to support it. In modern times all adult members of the family, principally housewives, are increasingly playing the role of equal partners. Also in all phases of socioeconomic life, housewives are increasingly being accorded a position equal to that of husbands. In the case of children, the fraction to be used will have to be arbitrary as no evidence, at the present time, is available to give guidance on this issue.

Proposition (4) The Value of Small Time Savings

The value of small time savings is still an unknown area. As trip makers find it difficult to perceive time differences of less than five minutes the empirical studies in this area have not been very successful. In view of this, even for commuter trips time savings of less than this amount probably should not be assigned a value. Clearly for longer trips time savings of less than five minutes will have even less value.

Proposition (5) Future Levels of the Values of Travel Time Savings

Future levels of the value of time should be predicted by reference to the expected rate of increase in income per capita.

In Proposition (1) it was suggested that the value trip makers attach to travel time savings is related to the level of income. The empirical work done in this area is unanimous on this point. Therefore it follows that in future predictions of the value of time the expected rate of increase in the income per capita should be used. However, the exact nature of the relationship
between the value of time and the level of income over all levels of income is not known. In view of the somewhat inconclusive evidence of this relationship maintaining a constant proportionality in predicting the future value of time seems to be a reasonable approximation.

**SUMMARY TABLE 1: Some Values for Non-Work Travel Time Savings Based on Commuter Travel**

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Study Location and Year</th>
<th>Transport Means of Travel Studies</th>
<th>Mean Hourly Income</th>
<th>Value of Travel Time Savings As Percentage of Hourly Income</th>
</tr>
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<tbody>
<tr>
<td>Beesley</td>
<td>London 1963</td>
<td>Public Transport</td>
<td>9/- 6/-</td>
<td>35 31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Car</td>
<td>9/- 6/-</td>
<td>49 31</td>
</tr>
<tr>
<td>Quarmby</td>
<td>Leeds</td>
<td>Car, bus</td>
<td>1/- 1/-</td>
<td>20 25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Car, train</td>
<td>1/- 1/-</td>
<td>20 25</td>
</tr>
<tr>
<td>Merlin &amp; Barbier</td>
<td>Paris 1962</td>
<td>Car, Public Transport</td>
<td>Fr. 1.86 Fr. 6.80</td>
<td>75 75</td>
</tr>
<tr>
<td>Lisco</td>
<td>Chicago 1967</td>
<td>Car, Public Transport</td>
<td>$5.00 $2.50</td>
<td>50</td>
</tr>
<tr>
<td>Barnett &amp; Saalmans</td>
<td>London 1964</td>
<td>All modes</td>
<td>29/- 20/-</td>
<td>14 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13/- 9/-</td>
<td>23 33</td>
</tr>
<tr>
<td>Lee &amp; Dalvi</td>
<td>Manchester 1970</td>
<td>Car, Public Transport</td>
<td>£1.64 £1.27</td>
<td>37 29</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>£1.64 £1.27</td>
<td>37 29</td>
</tr>
<tr>
<td>Lave</td>
<td>Chicago 1968</td>
<td>Bus, Car</td>
<td>$2.83 $1.19</td>
<td>42</td>
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<tr>
<td>Hansen</td>
<td>Oslo 1969</td>
<td>Car, Public Transport</td>
<td>Kr. 11.80 Kr. 3.10</td>
<td>26</td>
</tr>
<tr>
<td>Eden &amp; Hall</td>
<td>Portsmouth 1970</td>
<td>Ferry, Hovercraft</td>
<td>- 81.21p</td>
<td>68.5</td>
</tr>
<tr>
<td></td>
<td>Southampton 1970</td>
<td></td>
<td>- 215.60p</td>
<td>184.2</td>
</tr>
<tr>
<td>Mansfield</td>
<td>London 1968</td>
<td>Car, Public Transport</td>
<td>- 31p Male</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transport</td>
<td>- 21p Female</td>
<td>33</td>
</tr>
<tr>
<td>Dawson &amp; Everest</td>
<td>Rome-Milan 1971</td>
<td>Car, Bus</td>
<td>Lit. 0.70 Lit. 0.90</td>
<td>128</td>
</tr>
<tr>
<td>Thomas</td>
<td>California 1967</td>
<td>Car</td>
<td>$4.70 $2.80</td>
<td>61</td>
</tr>
<tr>
<td>Hensher</td>
<td>New South Wales 1972</td>
<td>Car</td>
<td>$2.58 $0.58</td>
<td>23</td>
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</tbody>
</table>

Note: All figures are expressed in the currency of the country of each particular study.
SUMMARY TABLE 2: Some Values for Non-Working Travel Time Savings Based on Non-Commuter Travel

<table>
<thead>
<tr>
<th>Study Location and Year</th>
<th>Transport Modes</th>
<th>Journey Purpose</th>
<th>Value of Travel Time Savings</th>
<th>Value of Travel Time Savings as Percent of Hourly Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watson Glasgow-Edinburgh 1969</td>
<td>Car</td>
<td>Social</td>
<td>43p (train)</td>
<td>67.5</td>
</tr>
<tr>
<td></td>
<td>Train</td>
<td>Recreational</td>
<td>63p (car)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>53p (mean)</td>
<td></td>
</tr>
<tr>
<td>Dawson &amp; Italy 1971</td>
<td>Car</td>
<td>All trips</td>
<td>125p</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>other than non-work non-commuter trips</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a/ Mansfield I. Forest of Dean 1970</td>
<td>Car</td>
<td>Recreation</td>
<td>77-96p</td>
<td>22.0</td>
</tr>
<tr>
<td>II. Anglezarke (Lancashire) 1970</td>
<td>Car</td>
<td>Recreation</td>
<td>55-63p</td>
<td>24.0</td>
</tr>
<tr>
<td>Gronau United States America 1968</td>
<td>United Air</td>
<td>Non-business</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

a/ Based on data collected by Colenutts.
A. The Need for Evaluating Travel Time Savings

In transportation systems the main effect of improvements consists of user benefits in which travel time savings assume an important role. This is particularly true of urban expressways, urban public transit systems, freeways along densely populated corridors, and airport projects. Therefore to include time savings benefits in cost-benefit analysis they must be expressed in monetary terms.

Another area where a value of time is required is the transportation planning process. In recent years an increasing amount of research effort has been directed toward improving the predictive aspects of travel demand models used in the planning process. On the assumption that travel time constitutes an important factor in the trip making decisions, the more recent travel demand models explicitly include time to travel, and demand modeling has been labeled as a generalized cost function. The generalized cost of a trip is defined

1/ The importance of time savings in transport projects is illustrated by the following examples: (1) Working time savings—excluding leisure time savings and time savings enjoyed by the generated traffic—accounted for about 69 percent of the total benefits of the expressway between London and Birmingham. The rate of return calculated for this project including time savings was 3.9 percent, when time savings were ignored it was reduced to 1.2 percent. (T.M. Coburn, M.E. Beesley, and D.J. Reynolds, "The London-Birmingham Motorway," Road Research Laboratory Technical Paper No. 46, 1960). (2) The Victoria Line of London underground system study concluded that, when working time is valued at 7s.0d. per hour and leisure time at 5s.0d., 80 percent of the first year's total benefits would come from time savings. (C.D. Foster, and M.E. Beesley, "Estimating the Social Benefits of Constructing an Underground Railway in London," Journal of the Royal Statistical Society, Series A, Vol. 126, 1963). (3) An Analysis of the U.S. interstate highway system indicated that time savings account for 70-80 percent of the total user's benefits on the urban part of the system and about 50 percent on the rural part. A.F. Friedlander, The Interstate Highway System: A study in Public Investment (Amsterdam: North-Holland Publishing Co., 1965).

as the total effort of making the trip expressed in monetary terms. This generalized cost is used in place of a single time in cost functions to define the friction involved in trip making. This new approach requires addition of elements of time and costs together. Therefore it became necessary to find a way by which travel time could be expressed in money equivalents.

A new trend during recent years in transportation planning technique has intensified the need for evaluating travel time in monetary terms. A growing desire within public agencies not only to obtain value for money invested in transport facilities but also to make comparisons between feasible alternatives led to a need to integrate the methodologies used in modeling travel behavior with that of economic evaluation of alternative projects. The London Transport Study was probably the first attempt to do this in network comparisons. 3/ The Road Research Laboratory has developed a scheme integrating travel behavior models with economic evaluation methods for road improvement schemes. 4/ The new approach to transport system evaluation is now beginning to be used widely in urban transport planning. 5/

It is clear therefore that there is a need to evaluate travel time to establish meaningful quantitative relations of the transportation system in a planning context, particularly in relation to modeling of travel behavior and evaluation of alternatives. This requires development of conceptually sound methods designed to attribute monetary values to the travel time characteristics of the transport plans.

B. Conceptual Considerations In Evaluating Time Savings

Time constitutes a continuous flow. The main property of time to be evaluated is its duration which is measurable by recording the elapsed time between two instants in the flow of time. This interval is unaffected by its activity content. Time in this sense may be labeled "absolute time." Absolute time, however, does not lend itself to a meaningful evaluation. The flow of time in itself cannot be stopped; neither can it be condensed or expanded. What is to be evaluated are the processes that take place during a time interval.


5/ The ongoing Singapore Mass Transit Study, financed by United Nations Development Program funds and executed by the World Bank is a good example of full-scale application of this new approach.
Time savings, therefore, should be considered as an opportunity for using the time allocated to a specific activity for another activity. In this sense, the value of travel time savings is equal to the opportunity cost of time.

Thus, it is not meaningful to speak in terms of a single value of time because individuals derive different degrees of (dis)utilities from different activities. The value that individuals attribute to time will vary depending on his or her satisfaction with the activity that takes place in that time period. It follows, therefore, that in the case of travel time savings there will be more than a single value of time, the value being determined by the trip purpose, mode of travel used, the time of trips, the duration of travel and many other such factors.

C. Travel Time Savings and Their Economic Value

It is clear that all travel time savings create an opportunity to engage in alternative activities and result in reducing disutility (with the exception of pleasure drives) involved in travel. Therefore all travel time savings result in increasing utility enjoyed by trip makers. But there is no general agreement that all travel time savings have a value and that this value should be included in an economic appraisal of transport projects. For one category of travel time savings, e.g. working travel time savings, there is little conceptual difficulty involved in assigning a value. Such time is paid for by an employer and constitutes an element of cost of production. A reduction in the travel time during working hours would potentially enable employers to divert the manpower and equipment saved to additional productive purposes. In this sense, travel time savings result in increasing productivity and thus increasing Gross National Product. This increase would ultimately be reflected in the national income accounts.

The value, on the other hand, that trip makers attach to travel time savings achieved during non-working hours, is related to an individual's perception of changes in his total utility. The value of travel time savings, in this case, depends on an individual's ability to use that time for some other purpose and is not directly related to the Gross National Product of the country.

Because time savings achieved during non-working hours cannot be directly converted into goods and services it has been argued that such time savings have no economic value and therefore should not be integrated into benefit calculations of transport projects. 6/ Similarly another opinion states that since savings of non-working time are not reflected in GNP, they cannot be considered in an economic assessment of a public project. For example,

in a recent review of the evaluation of highway improvements it is stated that "it is advisable to treat travel time as a separate item in economic studies in order that the decision-maker can readily see the amount of overall gains that are priced-out on the basis of the dollar value of time and those gains that are actual bona fide reductions in expenditure for travel." 7/ In general, however, the prevailing opinion among transport economists and planners is to accept the idea that non-working travel time savings have a positive value. Some trip makers when presented with an opportunity to substitute extra cost for time choose cost. This would indicate that they are better off with shorter journey times even at a higher money cost. The fact that such changes, resulting from time savings are not reflected in GNP, in turn reflects a shortcoming of national income accounting rather than providing a valid argument for the exclusion of non-working travel time savings in the economic evaluation of alternative transport projects. National product or income statistics are an imperfect measure of national welfare. This is because there is no unique scale for measuring the individual's satisfaction and comparing it with another person's satisfaction. But the fact remains that any policy measure or project generating a travel time saving will enhance the total welfare of the community and therefore has a value. Accordingly, at present in most transport project appraisals in North America and Europe all travel time savings are included in the benefit calculations.

D. Some Problems in Evaluating Travel Time Savings

Because of the differences in the theoretical foundations of valuation and also of the methodologies involved in measurement, a distinction is usually made between working and non-working time. Working time savings refer to time that is paid for by an employer and related to journeys made during the course of work. Non-working time savings, on the other hand, refer to time other than working hours and includes all journeys during which no payment is received from an employer.

In the case of working travel time savings the currently accepted procedure is to establish a value on the basis of the information obtained from the market mechanism. There is a market for labor so that values of travel time savings during work hours can be related to wage rates or earning powers. The theoretical basis of this evaluation process and the shortcomings of it are discussed in Chapter II.

The evaluation of non-working travel time savings presents formidable problems. In spite of the recent developments in theoretical treatment and in empirical measurements of the value of time there still remain several unresolved issues. Basically the current empirical investigations of the value of travel time savings during non-work hours attempt to infer a value by examining the

trip makers' behavior in situations where a choice between money and time exists. Given the fact that the value of travel time savings partly arises out of the disutility generally attached to traveling it means that travel time cannot be viewed independently of other trip attributes, particularly those relating to comfort standards. The disutility of trip making is presumably related to physical and mental effort expended in performing the activity of traveling. It is difficult to separate time spent and comfort as attributes to this effort as they are in the nature of joint attributes. For example, comfort or discomfort may depend on trip duration among other things. This problem has several implications with regard to investigations of the value of time on the basis of revealed preferences of trip makers. Extreme care must be taken to select those choice situations in which trip attributes other than trip duration are more or less the same. It is clear that it is not possible to find choice situations in which trip efforts are identical. This implies that the results obtained from empirical investigations will reflect the trip maker's perception of not only changes in trip duration but also changes in other attributes of trip making effort. As a result the values of time derived by empirical investigations must be viewed as proxies for those unknowns.

Another problem is related to evaluation of small time savings. In many transport projects, particularly those in the field of urban transportation, time savings achieved often represent only a small fraction of the time spent on the journeys. Must there be some minimum amount of time saved before a value can be attached to it? If we consider opportunities created for engaging in alternative activities as a result of travel time savings, it appears that there is strong argument for not attaching a value to time savings of all lengths. In reality, individuals enjoy only a limited flexibility in arranging and rearranging their activities. Individuals' daily activities are scheduled according to externally determined timetables. Time savings of five minutes or less between any given two activities do not offer much utilization of such time savings. Therefore it would appear that the greater the time saved, the greater will be the possibility of rearranging activities and thus increasing the value of the time saved.

On the other hand, because of the inflexibilities arising out of indivisibilities and fixed time schedules, it is likely that for most individuals there already is some margin of slack or idle time. Under these circumstances small travel time savings may enable them to make some real adjustment and thereby realize larger time savings. Therefore, whether small time savings are valued at the same rate as the larger savings would depend on the probability of rearranging activities to achieve a better pattern. Determination of this probability in a given situation is a difficult empirical question.

There is another argument for not ignoring small travel time savings achieved by transport investments. Transport investments represent only a small component of a comprehensive transport plan. This is particularly true of urban transport plans. In such comprehensive plans, each individual project contributes a small improvement to the total performance of the system. Travel time savings represent a component, often an important component, of benefits generated by
each individual project. Under such circumstances, if the values of small travel time savings are not included in benefit calculations of each individual project, total benefits resulting from the total system will be underestimated.

As reported in Chapter IV, in the empirical studies designed to estimate the values of zero to five minute time savings, serious difficulties were encountered. In these efforts the researchers could not obtain data on small time savings as most trip makers did not perceive time differences of less than five minutes. 8/

Still another problem is posed by evaluating a reduction in the variances of travel times. Very often a given transport project in addition to reducing travel time also reduces the variations in journey time caused by random events, such as accidents, disability of vehicles, etc. As shown in Chapter IV this type of travel time reduction assumes great importance in air transport projects. Any reduction in the variations in travel time has ultimately the effect of reducing the expected travel time itself. A given traveler, in order to reduce the probability of not arriving at his destination at a given time, will in general tend to allow himself the maximum expected travel time. Therefore, it is possible to save travel time by reducing the variations in journey time without any change in the mean journey time. This will result in time savings benefits independent of the benefits resulting from the reduction in travel time. However, it is more than likely that most transport improvements will reduce both the variance in travel time and the mean journey time. Isolating each of these two effects of a given transport investment poses a formidable problem in an empirical investigation.

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CHAPTER II
A SURVEY OF THEORETICAL APPROACHES TO EVALUATION OF TIME

A. Introduction

The economic theoreticians' main concern with time has been mainly confined to the problems related to the theory of capital dealing with the duration of productive process and the discounting of futurity. Only recently has there been some economic theorizing about those aspects of time which results from its scarcity. However, transport economists lacking a better source of information to estimate the value of travel time savings have sought answers in the prescriptions of the marginal productivity theory and the theory of consumer behavior. The former has been and still is the most commonly used basis for evaluating travel time savings during working hours. In evaluating travel time savings during non-working there have been attempts to utilize the equilibrium conditions specified by the theory of consumer behavior. However, these efforts have not been very fruitful.

Recent developments in economic theory in relation to time have been mainly concerned with its allocation and value. Efforts in this direction have led to formulation of a general theory of time which will be discussed below. First, the theoretical arguments used in evaluating value of working travel time savings will be presented.

B. Theoretical Analysis of the Value of Working Travel Time Savings

In evaluating working travel time savings the most generally accepted theoretical base is the marginal productivity theory. Approaches using this theoretical foundation have in general adopted an average of the prevailing wage rates as a measure of the value of working time. The rationale for this is simply that firms or employers in their efforts to maximize profits will hire labor or any other factor of production until it is no longer worth their while to do so.

Given the assumptions of a perfectly competitive market structure and a profit maximizing firm, it can be shown that the firm will be equilibrium when the value of the marginal product of an input is equal to the price of that input. Hence it is argued that given the assumption that all workers of a given type are paid the prevailing wage rate, this rate is a satisfactory measure of the value of production gained or lost by changes in the labor force, provided that these changes are small enough not to affect the markets in which the prices are determined. It must be noted that this approach views the benefits arising out of travel time savings during working hours as savings in the cost to the firm in hiring an employee. No account of the changes in
(dis)satisfaction of the employee are taken into account. Because of this, evaluation of working time savings at the average wage rate is often labeled as the "cost-saving" approach to time evaluation.

Objections to the Use of Average Wage Rates as a Measure of Working Travel Time Savings

Although the use of an average wage rate as a measure of savings in working time is widespread, this approach has some limitations:

(a) Market imperfections may make the wage rates paid to a given type of labor unequal to its marginal product, i.e., its opportunity cost. There are reasons to believe that market imperfections in most countries are a rule rather than an exception. In many countries, labor unions and restrictions imposed by the unions, customs and conventions, often have a strong bearing on the determination of wage rates. Such institutional arrangements may result in the establishment of wages above the opportunity cost of labor in many occupations.

(b) Restrictions on working hours may prevent utilization, by employers, of labor time released from a reduction in travel time. For example, in those countries where there is a fully developed road transport industry, the carriers are generally regulated with regard to origin and destination. In the United Kingdom regulations make the speeds at which truckers can haul commodities invariant to the road conditions. Under such circumstances improvements in the road system do not immediately lead to the release of resources. However, in the long run gradual adjustments of regulations covering average speeds and changes in travel time would normally take place. Similarly, in the United States, motor carriers by means of entry controls are restricted to specific routes with the result that savings in working time do not automatically lead to the release of resources to alternative uses. 1/ Because of such

1/ In the U.S., motor carriers are required to obtain certificates and permits before entering business. These certificates and permits always designate (i) the legal characteristics of the service authorized - common or contract; (ii) the routes or territories over which such operations may be conducted; (iii) the points to or from which a carrier may render the specified service; (iv) the classes of commodities which may be transported; and (v) the extent to which the authorized physical movement of truck is tied to specific highway routes and gateways. Route and territorial restrictions confine carriers to designated points along the specified routes or in the described territories.
in institutional restrictions savings in working time will generally be converted into free time and therefore should be valued as such. 2/

(c) The labor work hours released as a result of reductions in travel time during working hours may not be fully utilized by the transport using enterprises. The main reason for this, is the indivisibility that exists in the unit of work. Even fairly large investments in transport systems bring about savings in travel time that are both absolutely and proportionately small when compared with the unit of work. This may render such time savings of little or no value to these enterprises.

(d) The theoretical approach outlined above looks at the value of travel time -a:ved from the point of view of the employer only. The subjective valuation that an employee attaches to his work and to the time he spends traveling for work purposes is not taken into account. In this sense the cost savings approach to the valuation of working time saved looks at the contribution made to Gross National Product as a result of improvements in the transport system.

(e) The cost savings approach to the valuation of working time assumes that the time spent traveling is totally unproductive. However, in some instances travel time may be utilized in a productive manner. Time spent in a train or plane may be used for reading, for example. In recent discussions of the report prepared by the Third London Airport Commission, this fact has been used to argue that for the types of travelers who use air transport, the value of time saved when traveling in the course of work should be valued much below the average wage rate. However, no definite evidence has been provided to determine what the difference should be between the wage rates and the value of working time saved.

(f) For certain classes of occupation it is not easy to distinguish between working and non-working time. This problem arises in those occupations where payments are determined according to the work done. Also, self-employed persons pose a problem in distinguishing their working time and non-working time. If persons with such occupations save time during a work journey (if indeed it is possible to determine the category of the time spent at travel) they may utilize that time saved by engaging in further work or

2/ It is doubtful that the free time achieved by workers in this industry during their nominal working hours is a valuable to them as a leisure time under normal and free leisure periods.
engaging in a recreational activity or some combination of the two. Under such circumstances the cost savings approach is inappropriate for the valuation of working time saved. However, it is safe to say that persons in these occupations do not represent a significant proportion of total travelers during working hours.

These objections to using the average wage rate as the value of working travel time savings have a number of theoretical implications. Basically this approach equates the value of working time savings to the value of an increase in GNP. However, these objections indicate that contributions to GNP are not a complete measure as they neglect the fact that they may occur at the expense of the utility enjoyed by employees. These objections also imply that an alternative objective function expressed in terms of total utility enjoyed by consumer and producer including employees, should be utilized in the evaluation process. In other words, the suggestion is the adoption of an approach similar to the one used in empirical studies of non-working time values. It must be pointed out that the total utility approach to travel time evaluation is more in line with the normal practices followed in cost-benefit analysis. Acceptance of the total utility approach however, renders the simple guideline provided by the theoretical framework of the cost-saving approach incomplete.

During recent years several attempts have been made to incorporate the changes in the utilities enjoyed by trip makers as a result of reductions in travel times. These attempts have formulated general theories of time which can be applied to both working and non-working travel time savings. These theories are discussed at length in the next section.

C. Theoretical Analysis of Non-Working Travel Time Savings

The earliest efforts in evaluating travel time savings during non-working hours have sought answers in the consumer-choice theory developed by economic theoreticians. This theory was basically designed to explain an individual's preferences among "alternative baskets of goods." By applying the same approach, this theory can also determine the combination of leisure and work that maximizes the individual's satisfaction. The theory is straightforward, and full discussions of it can be found in several text books on microeconomic analysis. \(^1\) The theory states that at equilibrium the individual will divide his time between work and leisure so that the rate of substitution between income and leisure is equal to the wage rate. Often this result has been erroneously interpreted to mean that the value of leisure or non-working time is equal to the wage that the individual could earn by working. The traditional treatment of time in this manner provides

some understanding of the forces that influence an individual's decision regarding working hours. Thus, the theory predicts that when wages go up, other things remaining equal, work will become more attractive -- the substitution effect -- and at the same time, as earnings increase, the worker is richer and one of the things he will want is more leisure -- the income effect. These two "effects" operate in opposite directions. Thus at higher wages the worker may allocate, more, less or the same number of hours to work.

The erroneous interpretation of the results obtained by the traditional theory that an individual's leisure time should be valued at his wage rate has been subjected to various criticisms. It has been argued that the equality between a given individual's marginal value of leisure and the wage rate can only hold if the labor market is perfectly competitive. 4/ The labor market is often imperfectly competitive with the implication that there is no assurance that this equality will in fact hold in real life. It is therefore argued that the wage rate for which an individual offers his services is equal to or greater than his marginal value of leisure under conditions of full employment. 5/ The theory is also criticized on the grounds that its conclusions hold only if there are no standard working hours or standard work week. Moses and Williamson, addressing themselves to the problem of the value of time saved as a result of improvements in the transport system, concluded that the results of the theory are valid only if the individuals enjoy the freedom to choose the number of hours to work. 6/ With a fixed standard workday or week, the value of travel time may be more than equal to, or less than the wage rate, depending on the preferences of the individual.


5/ The marginal value of the leisure curve, or "price-offer curve" (Scitovsky) or "individual labor supply schedule" (Boulding) are identical and have the following well-known shape:

![Image of a curve showing the relationship between wage rate and leisure surrendered.]

6/ L.H. Moses, and H.F. Williamson, "Value of Time, Choice of Mode and the Subsidy Issue in Urban Transportation," Journal of Political Economy, Vol. 71, No.3, June 1963. L. Wingo op.cit. also recognized the fact that the existence of a standard number of hours would affect the value of time and that this should be therefore be taken into account.
The conclusions of traditional economic theory have also been criticized on the grounds that the utility function in the neoclassical theory is misspecified, in that hours of work are not explicitly introduced as variable in the function. Arguing along these lines M.B. Johnson modified the theory by introducing work activities as well as leisure time into the utility function. C.J. Oort was also critical of this theory on similar grounds. Both Johnson and Oort start out with a utility function:

\[ U = f(L,W,Y) \quad (2.1) \]

where

\[ L = \text{leisure time} \]
\[ W = \text{working time} \]
\[ Y = \text{money income} \]

The individual is still under the time \( T \), and budgetary constraints:

\[ T = L + W \quad (2.2) \]
\[ Y = rW \quad (2.3) \]

In order to derive the first order conditions for utility maximization by means of the Lagrange multiplier, a new function would be obtained:

\[ V = f(L,W,Y) + \lambda (rW - Y) + \mu (T - L - W) \quad (2.4) \]

where \( \lambda \) and \( \mu \) are the Lagrange multipliers. By setting the partial derivatives of 2.4 to zero:

We obtain:

\[ \frac{\partial F}{\partial L} = -\mu \quad (2.5) \]
\[ \frac{\partial F}{\partial W} = \lambda r - \mu \quad (2.6) \]
\[ \frac{\partial F}{\partial Y} = \lambda \quad (2.7) \]


The Lagrange multipliers $\lambda$ and $\mu$ are the marginal utility of money and marginal utility of leisure time respectively. 9/

Equation (2.6) states that, when the individual achieves an equilibrium, the marginal utility of time spent at work is equal to the marginal utility of leisure time minus the marginal utility of the wage received. Expressed differently, marginal utility of leisure time is equal to marginal utility of the wage received minus marginal disutility of work time. The results of traditional theory would hold only if the marginal disutility of work were equal to zero. But there is no reason to suppose that the marginal disutility of work is equal to zero in all cases as is implicitly assumed in the earlier formulation of the theory. Unfortunately, the result obtained by Johnson and Oort has no operational content. Even though wage rates are known or measurable, it is difficult to design a procedure that would yield meaningful estimates of the second term in equation (2.6) i.e., the subjective valuation of the disutility of labor.

Even if the problem of empirical estimation of the value of time is disregarded, the reformulation of this theory along these lines is still open to criticism. The theory implies that the individual's marginal valuation of time is constant and independent of the activity in which he may be engaged at any particular time. The marginal utility derived from relaxing the budgetary constraint is given by $\lambda$, and the marginal utility derived from relaxing the time constraint by $\mu$. 8/ As was illustrated above any values can be given to $\lambda$ and $\mu$ provided that the $\frac{H}{\lambda}$ remains constant. In the Johnson and Oort formulation of the theory this fraction indicates the monetary value to the individual of small changes in time constraint. This implies that no matter how the relaxation of time constraint comes about, the individual's marginal valuation of time is constant. This conclusion confuses the value of a relaxation of the time constraint with the value of time used in an activity. For example, Johnson states that "to ask about the value of travel time, the value of leisure or, indeed, the value of time is to ask about the individual's equilibrium marginal rate of substitution of these two currencies." Oort similarly states that "the total available time $T$ which is regarded as a fixed parameter by the individual,... may be changed by an exogenous event (such as a God-given increase of the day from 24 to 25 hours or, more down to earth, the opening of a nearby shopping center)."

9/ Note that the terms "marginal utility" does not imply cardinal measurement of utility. Any values can be associated with $\lambda$ and $\mu$ provided that remains constant.

10/ In a more general case, the solution of the $i^{th}$ Lagrange multiplier corresponds to the marginal rate of change of the optimal value of the objective function with respect to a small relaxation of the $i^{th}$ constraint. In other words it represents the marginal value of relaxing the $i^{th}$ constraint. (See K. Lancaster, "A New Approach to Consumer Theory," Journal of Political Economy April 1966, pp. 132-157.)
Because of these weaknesses several attempts have been made to develop a more general theory of the valuation and allocation of time. These theories integrate time used in an activity undertaken by an individual explicitly into the argument. As such, they are more consistent with the approaches taken in the empirical studies designed to evaluate time saved in a particular activity, such as travel. The essentials of this new approach to the theory of the valuation of time are given below.

D. A General Theory of the Valuation and Allocation of Time

Several authors, arguing that a distinction must be made between the value of time in absolute sense and that of time allocated to a particular activity, developed a new theoretical framework. The work done by Becker, 11/ Evans, 12/ and Gronau 13/ is notable and will be examined below.

These new approaches view time elements in the individual consumption decision-making process in the same light as time in the production process. In effect it is argued that individuals or households could be regarded as producers of activities combining time with goods and services purchased in the market. The utility function in this approach is generalized so that work, leisure, and consumption are defined as activities. The individual's utility function is:

\[ U = U (a_1, \ldots, a_n) \]

Where \( a_i \) denotes the number of units of time the individual spent in the \( i \)th activity. 14/ The consumer maximizes utility subject to a budget and a time constraint.

\[ T = \sum_{i=1}^{n} a_i \]  

(2.8)

\[ O = \sum_{i=1}^{n} r_i a_i \]  

(2.9)


14/ For simplicity all activities are measured only in units of time, This helps to present the argument more clearly.
Where \( r_i \) is positive if the individual pays for the activity, negative if he receives a payment, and equal to zero if the activity is free.

If the utility function is maximized subject to the two constraints (2.8) and (2.9) the following \( n \) equations are obtained:

\[
U_i = \mu + \lambda r_i \quad (2.10)
\]

Where the Lagrange multiplier \( \mu \) represents the marginal utility of time and \( \lambda \) the marginal utility of money. Equation (2.10) states that the hours spent in each activity are dependent on its utility and the rate per hour paid or received. In the case of travel time a distinction can be made between the amount of time the individual must spend traveling and the amount of time he is willing to spend traveling, since hours spent traveling are not independent of the amount of time the individual wishes to spend in any other activity. Ordinarily the individual would tend to set a limit to the amount of travel time he would like to spend in order to participate in an activity. Given this assumption let \( t \) denote the time spent attending a ball game and \( a_t \) the time spent traveling to the ball game. The individual's travel time limit may be represented by a linear inequality.

\[
a_t = g a_b \quad (2.11)
\]

where \( g \) is a constant.

The maximization of the individual's utility function subject to the additional constraint given by (2.11) would yield:

\[
U_w = \mu + \lambda r_w \quad (2.12)
\]

\[
U_t = \mu + \lambda r_t - K \quad (2.13)
\]

\[
U_b = \mu + \lambda r_b + g K \quad (2.14)
\]

Where \( r_w \) is the individual's hourly wages, and \( r_t \) and \( r_b \) are the direct cost per hour of time spent traveling and of the time spent at the ball game. The Lagrange multiplier \( K \) represents the marginal utility resulting from a relaxation of the constraint on the individual's limit to the travel time. If strict inequality holds, the constraint is inoperative, i.e. the time the individual is willing to spend traveling is greater than the time he must spend.

The value of the fraction \( K/\lambda \) is expressed in dollars per hour since \( K \) is expressed in terms of "utils" per hour and \( \lambda \) in "utils" per dollar. Therefore this fraction represents the monetary value to the
individual of a small change in the amount of time he must spend traveling. By dividing (2.13) into (2.14) and rearranging the first order conditions for the utility maximization:

\[ \frac{K}{\lambda} = r_t - \frac{U_t - \mu}{U_m - \mu} \quad r_w \]

(2.15)
is obtained. 13\footnote{See A.W. Evans, Op.Cit.} Equation (2.15) states that the individual's valuation of a reduction in the amount of time he must spend traveling is equal to the direct financial cost of the time spent traveling plus his time savings valued at \( r_w(U_t - \mu)/(U_w - \mu) \) which is positive since \( r_w \) is negative.

This theoretical formulation of the value of travel time savings allows for variations in this value with the mode of travel or with the purpose of trips. Therefore it yields more plausible results than the earlier theories of time values. However, like the earlier attempts, it is not suitable for empirical estimation of travel time savings. In fact most of the recent efforts in this area have utilized models that are based on pragmatic considerations rather than the theoretical formulations.
CHAPTER III

BEHAVIORAL MODELS USED IN ESTIMATING
THE VALUE OF TRAVEL TIME SAVINGS

A. Introduction

Most of the empirical investigations into the value of travel time saved have been based on the revealed behavior of trip makers when faced with choice situations. Basically these efforts have adopted the same general approach: estimating the trade-off between time and money cost dimensions of travel packages. A travel "package" is defined by such dimensions as the total travel time, in-vehicle time, walking and waiting required in making the trip, comfort, safety, and the cost of travel. Alternative routes, or alternative modes to a given destination, or alternative destinations represent different travel packages involving different combinations of time, money and other trip attributes. The following travel choice situations have been examined in these efforts to estimate the value of travel time:

(a) choice of mode to travel
(b) choice of route to travel
(c) choice of driving speed
(d) choice of residential location in relation to the location of work
(e) choice of travel destination or frequency of travel to a given destination.

Although a variety of mathematical and statistical techniques have been employed in empirical investigations of the value of travel time savings, the majority of recent efforts in this area have adopted the disaggregate travel demand model approach. The efforts using this approach to trip makers' behavior have yielded more reliable estimates of the value of travel time than the earlier studies. At the present time most of the empirical investigations of the value of travel time, particularly those of non-working travel time, are built on this general approach. In the following section, the main elements of disaggregate behavioral travel demand models are briefly discussed.

B. Disaggregate Behavioral Travel Demand Models

Although the transport demand model techniques in the conventional urban transport planning process are still widely used there has always been
a general dissatisfaction with the realism and accuracy of the results obtained. The shortcomings of the conventional approach included a lack of ability of the submodels of the system to interact fully, dubious validity of the model relationships obtained from aggregated data, weaknesses in predictions obtained from these relationships and the lack of geographical transferability. 1/ Because of these and other weaknesses a number of attempts have been made to construct improved demand models particularly for application to urban transport planning. A disaggregated behavioral approach is one such effort.

The type of models developed by this approach are disaggregated and stochastic. They are stochastic in that the predictions obtained from them are probabilities that individuals will make a specific choice with regard to travel. The probabilities are assigned on the basis of the characteristics of the choice environment as conceived and evaluated by the individuals. They are disaggregate in that the basis of models is the individual trip-maker rather than zonal aggregates. The basic hypothesis underlying these models is that decisions of trip-makers are based on the relative attributes of the available alternatives evaluated in terms of the trip maker's own preference functions and enable the analyst to estimate the rate of trade-offs between different transportation system attributes. More specifically, if measures of both time and cost of alternative transport decisions are included in the model, the rate of substitution of money for travel time can be determined. 2/ Let:

\[ Z_i = \alpha_o + \sum_{p=1}^{n} \alpha_p T_{pi} + \sum_{q=1}^{m} \beta_q U_{qi} \]  

represent the preference function. Where

- \( Z_i \) = the preference function of the \( i \)th individual
- \( T_{pi} \) = \( p \)th characteristics of a travel package for individual \( i \)
- \( U_{qi} \) = \( q \)th characteristics of individual \( i \) 3/
- \( \alpha_s, \beta_s \) = coefficients to be estimated.


2/ A short summary of the essentials of this new approach to travel demand modeling is to be found in "Modeling Travel Demand: A Disaggregate Behavioral Approach: Issues and Applications." Op.cit.

3/ \( \sum \beta U_{qi} \) represents the trip maker's weighing of the characteristics of alternative packages. An alternative way of expressing this would be to assume that \( \alpha_s \) are a function of \( U_{qi} \) and the \( \beta_s \) are all zero.
By including cost and time difference between two alternative transport packages it is possible to infer a value of time. Thus:

\[ Z_i = \alpha_0 + \alpha_1 (t_{i1} - t_{i2}) + \alpha_2 (C_{i1} - C_{i2}) \]  

(3.2)

Where

\[ t_{i1}, t_{i2} = \text{the travel times by alternative 1 and alternative 2 for the individual} \]

\[ C_{i1}, C_{i2} = \text{the cost by alternative 1 and alternative 2 for the individual i} \]

Equation (3.2) can be used to derive a value of time by investigating the changes in \( Z_i \). A unit change in the time difference will bring about a change of \( \alpha_1 \) in \( Z_i \). The same change in \( Z_i \) could come from a change of \( \alpha_2 \) units of cost. Therefore, \( \alpha_1 / \alpha_2 \) indicates a value of travel time.

Equation (3.2) may also be expressed in an alternative form to give a compound cost and time difference of two alternatives for the evaluation of \( Z_i \):

\[ Z_i = \alpha_0 + \alpha_1 \left[ (C_{i1} - C_{i2}) - \frac{\alpha_1}{\alpha_2} (t_{i1} - t_{i2}) \right] \]  

(3.3)

In this alternative formulation the factor \( \frac{\alpha_1}{\alpha_2} \) is the "conversion factor" allowing cost and times to be added together. Therefore this ratio represents the monetary value of a unit of time.

It must be pointed out, however, that the values of \( \alpha_1 \) and \( \alpha_2 \) used to derive a value of time depend on the specification of the model and on the accuracy of measurement of the parameters \( \mathcal{T}_i \) and \( \mathcal{U}_i \). The error variance of the coefficient will have to be much smaller than is needed for a satisfactory fitting of the basic relation of equation (3.1). Because of the error variance of \( \frac{\alpha_1}{\alpha_2} \) is a complex function of the error variances of \( \alpha_1 \) and \( \alpha_2 \), even very small error variances in these coefficients can produce a very large range in time values. 4/ Therefore the results obtained from such models are highly dependent on the accuracy of the models. It must be mentioned also that the development of behavioral models is still in its infancy. A number of problems are still involved in the application of behavioral models to the derivation of values of time. Some of these problems are discussed in the following section.

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C. Mathematical Techniques in Behavioral Models

The first and most crucial step that must be taken, in developing these travel demand models, is to determine a mathematical function that approximately represents the basic hypothesis and assumptions underlying such models. The attempts made in this field have utilized discriminant analysis, probit analysis, and logit analysis as discussed below.

Discriminant Analysis

Discriminant analysis was the first of the techniques used in developing a behavioral model. Quarmby's analysis of choice of model by commuters was based on discriminant analysis. 5/ McGillivray 6/ and Mongini 7/ also utilized this technique in their analysis of modal choice situations.

Discriminant analysis has been used in many fields, particularly in biology and botany where there are special problems of classification. In the context of modeling demand for transport it is utilized to determine a function of user and transport system characteristics that best discriminates between sub-populations of trip-makers on the basis of the transport package they use. The choices analyzed are binary choices, i.e. the choice involved between two alternative packages. Thus the problem becomes that of determining a set of discriminant functions $D_{ij}$ (where $Dij$ is the discriminant function between travel package $i$ and $j$) that minimizes the number of members of the population that will be misclassified by the model, in terms of their choice of transport package.

The discriminant function used in transport demand modeling comprises the attributes of the alternative transport packages and the characteristics of the trip makers. These attributes and characteristics can be used in different forms. For example, Quarmby 8/ used differences in the attributes of the alternative system, and McGillivray 9/ used their ratios. The discriminant function in general terms can be expressed as:

$$Z_{ij} = \sum_{k=1}^{n} \alpha_k [f(x_{ki}, x_{kj})] + \sum_{l=1}^{m} \beta_l U_l$$  \hspace{1cm} (3.4)


where \( X_{ki} \), \( X_{kj} \) = the values of the \( k^{th} \) attributes of \( i^{th} \) and \( j^{th} \) travel packages.

\( U \) = user attributes.

\( a_k \) = parameters associated with the alternative systems.

\( \beta \) = parameters associated with user characteristics

\( f (X_{ki}, K_{kj}) \) is a function that may take either of the following forms:

(a) \( (X_k - X_{kj}) \)

(b) \( \frac{X_{ki}}{X_{kj}} \)

The solution to such a problem can be approached from two standpoints: (a) that of minimizing misclassification with respect to some predetermined threshold, or (b) seeking to find conditions in which the separation between the two populations, as measured by the square of the difference between their means, is greatest in relation to the variance within each population. In the second approach the ratio of "variance between" the populations to variance within each population is maximized by using the weighting coefficients as variables. Consequently optimal value of the weighting of coefficients can be found directly. The ratio of the weighting coefficient of the time attributes of the travel package to that of cost indicates the value of time.

Discriminant analysis was originally developed in the biological sciences as a criterion to classify species. Therefore, the principal concern has been to minimize misclassifications by correctly assigning a single member of the population to the appropriate sub-population. This means that the main concern is the single individual rather than the whole population. In transportation analysis, and in the investigations of the value of time, the main concern is classifying the whole population in terms of their transport choices, therefore the main objective is to achieve a maximum accuracy in the estimation of the summed probabilities over all trip makers. Misclassification criteria may not necessarily exclude this, but the available evidence suggests that it may do so in many situations. Also the results obtained by Stopher and Lavender show that discriminant analysis was clearly inferior to either probit or logit analysis \(^{10/}\) in explaining and predicting the trip maker's choice of behavior.

**Probit Analysis**

Probit analysis was originally developed and used in works on toxicology. \(^{11/}\) The basic premise of this approach is that if members of a population are subjected to a stimulus that can range over an infinite scale,

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the frequency of responses (assuming that the response is a 0,1 response, i.e. it either occurs or does not occur) will be normally distributed. It follows therefore that the cumulative distribution curve of members of a population who have already responded, drawn against the value of the stimulus, will be a normal sigmoid curve. In the field of transportation demand this analysis is applied mainly to the modal choice situation.

Lisco 12/ and Lave 13/ have applied this technique in their analysis of modal choice. The attributes of the alternative modes in a binary situation and the characteristics of the trip makers are assumed to be stimuli, and the choices made are responses. The probit equation used by these authors was in the following form:

\[ Y = \sum_{k=1}^{n} \left[ \alpha_k (x_{1k} - x_{2k}) \right] + \sum_{i=1}^{n} \left[ \beta_i (u_i) \right] \] (3.5)

\[ x_{1k} \text{ and } x_{2k} = \text{the values of the } k^{th} \text{ attribute of modes 1 and 2 respectively.} \]

\[ u_i = \text{user attributes} \]

\[ Y = \text{the value of the probit} \]

The value of probit represents the number of standard deviations away from the mean of a normal distribution. By using standard statistical tables of the cumulative normal distribution, the probability corresponding to this number of standard deviations from the mean can be determined. This probability represents the probability that the individual being considered will choose mode 1. The calibrating technique involves fitting a cumulative normal sigmoid curve to the information on response and stimulus values for each member of the sample. (The ratio of the coefficient of travel time to that of cost gives the implied value of time.)

**Logit Analysis**

The basic principle underlying this mathematical technique is that the probability of the occurrence of an event or choice varies with respect to a function \( G(X) \) as a symmetrical sigmoid curve, labeled the "logistic curve." Mathematically the model is expressed as:

\[ p_1 = \frac{e^{G(x)}}{1 + e^{G(x)}} \] (3.6)


This model is used in transport demand analysis by defining the choice made by an individual trip maker as an event. In a binary choice situation \( P_1 \) refers, for example, to the probability (or the proportion) of trip makers choosing mode 1 in preference to the other. The function \( G(X) \) can be expressed in a number of different ways. The model developed by Stopher was based on the \( G(X) \) function expressed in terms of the differences in travel times and travel costs:

\[
G(X) = \alpha_1(c_1 - c_2) + \alpha_2(t_1 - t_2) + \alpha_3
\]  

(3.7)

The model developed with this \( G(X) \) function lends itself to calibration by several methods. Stopher used the maximum likelihood method developed for probit analysis. He also demonstrated that logit analysis is simpler and quicker to calibrate than probit analysis and appears to yield estimates of similar accuracy. Also the sigmoid curves of both the probit and logit analyses are similar and tend to differ only in the rate at which they finally approach the asymptotes.

D. Different Interpretations of the Coefficients Estimated by the Models

The empirical studies designed to estimate the value of time, in spite of the differences in the choice situations analyzed and the mathematical techniques used, have one feature in common, i.e. inferring a value of time from the coefficients of the time and cost dimensions of the travel packages examined. This, in essence, involves associating certain behavioral meanings with the coefficients of the models employed, i.e. the \( \alpha 's \) and \( \beta 's \) in terms of the notations employed here. Such behavioral interpretations of the coefficients of the model variables are a natural extension of these models, which are intended to replicate the trip makers' behavior in transport choice situations. Because the efforts in the valuation of time explicitly introduce time and cost dimensions of the travel packages into the models constructed, the meanings of the coefficients of these variables will be examined below.

In the discussion of the general behavioral model of travel demand, it was shown that the preference functions used incorporate the user characteristics as well as the dimensions of the travel packages (see equation 3.1).

For example Lave 15/ and Thomas and Thompson 16/ use the income levels of the users as a multiplicative term with time differences. This formulation simply means that the coefficients of the time difference variable is regarded as a linear function of the income levels of the users. Furthermore in this model it is assumed that the users' choice behavior is determined by the characteristics of the travel packages, but the user characteristics, in this case, the income levels, inject an individual bias into the outcome of the choice process. In this sense the user characteristics have an additive value in the model. However, an alternative assumption is possible. This assumption is that the coefficients of the travel package attributes depend on, and are a function of, the characteristics of the trip makers. In other words the importance of each dimension of the travel package in the choice behavior of individuals depends on the characteristics of the users. In this alternative assumption the individual bias is on the importance of the characteristics of the travel packages, whereas in the former assumption individual bias is on the final choices made by the individuals. However, the constant term in the preference function is not affected by such assumptions. Examine the following preference function:

\[ Y = \alpha_0 + \sum_{i=1}^{n} [\alpha_p (T_{p_i} - T_{p_2})] \] (3.8)

where

\[ \alpha_p = F(U_1, U_2, \ldots, U_m) \] (3.9)

Assume, also, a logit model of the form:

\[ P_2 = \frac{e^Y}{1 + e^Y} \] (3.10)

As the preference function is expressed in terms of the differences in the characteristics of the alternative travel packages, two such packages with identical characteristics should yield a 50-50 split. That is half of the trip makers would utilize one package, and half would use the alternative package. But equation (3.8) shows that this result would come about when \( Y = 0 \), which also means that \( \alpha_0 = 0 \). If the constant term \( \alpha_0 \) is not


equal to zero, then alternative packages with identical system characteristics yield a value of $P_2$.

$$P_2 = \frac{e^{\alpha_0}}{1 + e^{\alpha_0}}$$ (3.11)

In this case the constant term reflects individuals' bias for or against the alternative package $P_2$ without any effect from the characteristics of the available alternatives.

The preference function in models sometimes includes both the transport package attributes and the user characteristics in linear terms:

$$Y = \alpha_0 + \sum_{i=1}^{n} [\alpha_i (T_{p_i} - T_{p_2})] + \sum \beta_i U_i$$ (3.12)

In this formulation of the preference function, $\alpha_0$ has two possible interpretations. If again the characteristics of the travel packages are fully specified, $\alpha_0$ will represent individuals' bias for or against one of the alternatives. However, if the alternatives are not fully specified, $\alpha_0$ will contain a combination bias resulting from incomplete specification and the individual biases. In the former case the constant term $\alpha_0$ will have no bearing on the value of the coefficients of the travel characteristic variables. In the latter case, however, the incomplete specification will affect the values of these coefficients. For example, certain dimensions of the travel package are time-dependent. This is particularly true of such dimensions as comfort. The individuals may tolerate a 5-minute waiting/standing, but they probably would not tolerate a 30-minute wait. If comfort as a travel package dimension is not included in the model then choice variance explained by the time-dependent comfort dimension will be included in the travel time coefficient. As some of the attributes of comfort vary with modal choices, route choices, and trip purposes as well as with the time of day, the derivations of a single value of time from such incompletely specified models is a highly questionable practice. This weakness of the models built to derive a value of time is demonstrated in De Donnea's work. 17/

E. Problems Raised by Time and Cost Data Used in Evaluation of Time

Despite serious investigation, there remains much controversy surrounding the type of data to be used in behavioral travel demand models. Most of the controversy is focused on the relative merits of using perceived or subjective data vs. measured or objective data to calibrate such models. These two sets of data on time and cost dimensions of alternative travel

packages often differ. Such differences can be attributed either to inadequate information about the travel alternatives so that individuals making a choice fill in the missing information on a subjective basis, or to a bias that persists even with full knowledge of the alternatives. The former source of discrepancy between the objective and subjective values of the model variables is more critical in determining the predictive validity of the models employed than the latter because the latter type represents a bias that is a stable preference function of the individual trip makers.

Clearly there are many sources of data error other than perception errors. For example, errors also result from rounding the values of the variables. Many travelers find it difficult to distinguish small units of time. As a result, travel time is viewed in, say five-minute blocks. In longer journeys travelers generally think in terms of ten-minute blocks or even hourly blocks. Similar tendencies have been observed with regard to the cost of travel.

Another source of error can occur in the reporting of times and costs. Trip makers modify the perceived values of time and cost when they report them to an interviewer or in a questionnaire. Such modifications arise from the individual's desire, conscious or unconscious, to make his choice appear more reasonable or impressive. It has been argued that travelers in general will attempt to make either the time savings for a given expenditure seem greater or the expenditure for a given time saving seem smaller or both. Therefore it has been further argued that there will be a tendency for under-reporting times and costs of the chosen alternative or over-reporting times and costs of the rejected alternative. The trip maker's desire to correct an atypical journey time or journey cost may make them report the "normal" time and cost. There is also the possibility of measurement errors. In general, measured times and costs are estimated from standardized data based on test runs, average speeds, assumed routes, and published cost estimates. The result is that the measured values correspond not to the actual values experienced by the trip makers but to the values corresponding to an average for a given journey.

It is clear that errors in data used will present serious problems in building travel demand models and affect their predictive powers. The implications of the existence of errors in the data used in the travel demand


models will not be pursued here. However, it is sufficient to say that, if
these errors result in values that are normally distributed around the true
values, the sum of the errors will be equal to zero. But the brief discussion
of the sources of errors show that in many cases there are possibilities for
a consistent divergence between the "true" value of the variables and the
values used.

The errors in the data used in these models, particularly in time
and cost data, will greatly affect the value of time derived. The implica-
tions of such errors in the value of time studies is examined by Watson.20/
Watson, by making certain assumptions about the ways in which the measured
values might differ from the "true" value of travel time, analyzed their
implications. His conclusions were that such errors lead to serious biases
in the value of time. Even with specific types of error he found that it
is not possible in some cases to determine the direction of the bias. Obviously
it is a more difficult task to determine the magnitude of the bias in the time
value derived. Clearly, under the circumstances where all types of error are
present, the problem is much more serious and complex. Watson concludes that
there is no single correct value of time, as the definition of "correct" depends
on the context within which the model is built. He asserts that a value of
time derived from perceived data even though it may differ from true data is
correct if the model used is built on the hypothesis that the choices made by
travelers are related to the values of times and costs as perceived by them.
Similarly a value of time derived from the measured data is correct if the
model used is based on the hypothesis that the travelers make a choice among
alternatives on the basis of expectations of time and cost values that are
based on their knowledge and that can be represented by measured data.

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20/ P.L. Watson, "Problems Associated with Time and Cost Data Used in
Travel Choice Modeling and Valuation of Time," Highway Research Record
No. 369, 1971, pp. 158-158.
A SURVEY OF THE EMPIRICAL INVESTIGATIONS INTO
THE VALUE OF TRAVEL TIME SAVINGS

A. Introduction

It is noted earlier that the theoretical approaches to evaluation of non-working travel time savings have not yielded results that can be readily interpreted in an operational manner. As a result, the efforts in this area have been directed mainly toward empirical estimation. These efforts have utilized five different transport possibilities for trading-off time and financial costs. In the following section some of the more notable investigations in this area are discussed.

In the case of working travel time savings, despite the general acceptance of the prescriptions of the marginal productivity theory, there have also been several empirical studies to evaluate such travel time savings. These are briefly outlined in the next section.

Finally, empirical research into the value of travel time saved in air transport is discussed. Air transport presents unique problems in that often it is difficult to distinguish work trips and non-work trips. The empirical investigations therefore have attempted to treat business and personal trips together.

B. Non-work Travel Time Savings

Modal Choice Studies

Beesley was the first to attempt to estimate a value of time by means of the modal choice data of the commuter. In this study, it was assumed that commuters choose their mode of travel so as to minimize disutility associated with traveling. Beesley derived an implied value of travel time savings by comparing commuters who choose faster mode at extra cost with commuters who choose slower mode at lower cost.

Figure 4.1

The method used by Beesley involves finding the linear function drawn from the origin that minimized "bad" choices, i.e., those commuters who, by choosing the alternative mode, could have either saved time by paying less money than the value of time implied by the slope of this linear function, or saved money at the expense of a smaller time increase than the implied value of time. Such a linear function can diagrammatically be obtained by superimposing the two categories of commuter, and determining the ray from the origin which causes the fewest misclassifications.

The time values derived by Beesley were 2s.0d for the civil servant with average hourly earnings of 6s.6d and 3s.2d for those with 9s.0d hourly earnings. However, the findings of subsequent studies carried out in England suggest that these values are high. One possible reason for this may be the fact that Beesley did not distinguish between walking time, waiting time, and in-vehicle time. Many studies have shown that walking and waiting time have higher values than in-vehicle time.

The method employed by Beesley is essentially a crude version of discriminant analysis. It is a simple method and easy to apply. However, it has several weaknesses: the analysis of the modal choice situations is limited to only two variables because this technique operates graphically in two dimensions, and this approach does not lend itself to any formal tests of significance or goodness of fit. Also as the line of minimum misclassification emanates from the origin, it is implied that average and marginal values of time are equal. As will be shown later this assumption is not supported by other empirical studies.

However, the method is simple and useful in providing a good idea about the trade-off technique employed in the value of the time studies. As it requires no elaborate calculations it can be carried out by hand for quick preliminary studies. The same approach was used by Barnett and Saalmans in a Greater London Council study of travel to and from work at County Hall. The values obtained were slightly lower than those found by Beesley.

Quarmby's work was the first rigorous application of the discriminant analysis to the problem of value of time. His model is expressed in terms of the disutility associated with travel by alternative modes:

$$Z = a_1 x_1 + a_2 x_2 + \ldots + a_n x_n$$  (4.1)

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Where \( x_i \) (i=1, ... n) are relative measures of the dimensions of the alternative modes. Discriminant analysis is employed to find the best values of the coefficients, \( a_i \), to explain the observed choices of a sample of trip makers. The sample included only commuters. The modal characteristics and the commuter characteristics included in the model were: (a) ratio of overall travel times by each mode; (b) cost ratio; (c) walking and waiting times; (d) economic status of commuter. Quarmby's analyses showed that formulation of the variables in terms of differences gave the best results, implying that the value of time is independent of the total time or cost of the journey. The general conclusions of the study are:

(a) The average value of time is between about 3s.0d and 3s.6d.

(b) The values of time are very nearly a constant proportion of wage rates (between 21 percent and 25 percent of the wage rate).

(c) Walking and waiting times are worth between two and three times in-vehicle waiting times.

(d) There is insufficient evidence to conclude that bus time and car time have significantly different values.

T. Lisco analyzed the modal choice behavior of commuters in the Skokis and Merton Grove suburbs of Chicago by estimating time-cost trade-offs in choices between public and private transport. The statistical technique employed was multiple probit analysis; the value of time is obtained by comparing the coefficients of time differences and cost differences. However, Lisco in his study did not distinguish between waiting time, walking time, and in-vehicle time. Nor was there a distinction made between time spent in private transport and time spent in public transport. The time values used in the model were not perceived times, as these were not considered accurate. The values of time obtained were about 40 percent to 50 percent of the average hourly earnings of the trip makers or between $2.35 and $2.67.

Lee and Dalvi using the data obtained from a sample of commuters to the central business district of Central Manchester attempted to estimate a value of time. Initially the authors utilized an approach similar to that used by Beesley. Because of the unreliability of the information on car operating costs, the analysis was limited to the modal split between public transport.


transport modes only. They attempted to establish maximum and minimum values of time for each individual in the sample. For this they employed a questionnaire in which they asked each respondent to indicate the increase in cost of travel of the mode they were using that would be sufficient to make them switch to the alternative mode. After obtaining these maximum and minimum values. The results obtained from this study indicate that the average value of time is slightly above 3s.0d hour representing about 30 percent of the average gross hourly earnings of the commuters. The study also shows that "time preferrers" and "cost preferrers" should be examined separately and not lumped together as Beesley has done in his study. The analysis indicates that time preferrers value their time savings substantially higher than cost preferrers with similar income, personal and household characteristics. Income was found to be consistently significant as an explanatory variable in the case of time preferrers. Furthermore the results suggest that time values increase slightly with journey length, but the evidence for this is not conclusive.

The methodology employed by Lee and Dalvi is open to criticism: the value of time obtained is for a mixture of in-vehicle, walking, and waiting time and the information on the actual point of indifference between additional cost and time savings is obtained from responses of individuals rather than from their actual revealed behavior. The authors, however, do not claim any general validity for the results they obtained. The sample they worked with is rather small, 36 for time preferrers and 68 for cost preferrers. In addition they argue that the value of time is very much determined by the circumstances in a given situation and that there are real dangers in applying the results obtained in one situation to another.

The same authors subsequently applied the same technique to commuters with access to private cars. They also utilized discriminant analysis to compare the results obtained from these two techniques. Again, the authors determined the point of indifference from the responses by the commuters to the questions asked. The car sample was drawn from the pilot survey of persons commuting into central Manchester in 1967. The analysis was confined to those respondents who were car drivers on either the preferred or alternative mode. Altogether 132 completed observations were used.

The estimated average value of time was about 5s to 6s/hour representing slightly less than 40 percent of individual hourly earnings. This is higher than the figures obtained for public transport--3s/hour and approximately 30 percent of hourly income.

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The authors applied discriminant analysis to the same data and investigated three different choice situations:

(a) car and public transport
(b) car and train
(c) car and bus.

The values of time obtained from the first choice situation was about 5s/hour and from the second choice situation about 8s/hour. The first value is almost identical to that found in the diversion-price method. In view of the small sample used the authors do not interpret this result as evidence for the reliability of the diversion price. In the case of the third choice situation the cost variable was not significant, and as a result the estimate of the value of travel time could not be obtained.

The Local Government Operational Research Unit of the United Kingdom analyzed commuters' modal choice behavior in central Liverpool, central Leicester, central Manchester and in an industrial suburb of Manchester. 9/ Discriminant analysis was used to calibrate the models. When no distinction was made between the in-vehicle time and walking or waiting time, the average value of time was found to be in the range 6s.0d to 8s.0d/hour. When a distinction was made, the value of in-vehicle time was in the range of 2s.6d to 3s.6d/hour. With an average annual income of £1,400 these values were 50 percent and 20 percent to 25 percent of hourly earnings.

In France, L'Institute d'Amenagement et d'Urbanisme de la Region Parisienne carried out an analysis of the choices made by commuters between bus and metro when they arrived at the main line stations of the S.N.F.C. from the suburbs, for the final part of their journey to work. 10/ In this study both the modal splits between public transport agents, bus and metro, and between public transport and private transport were examined. The estimates showed that the trade-off between costs and travel time on bus and metro was about £5.10/hour. The findings of the study also indicated that waiting and walking times had about twice the effect on modal choices as in-vehicle times.

Stopher analyzed the modal choice behavior of commuters to University College, London, and Country Hall Commuters. 11/ He utilized a linear estimating equation to represent modal and user characteristics, G(X), similar to those


employed in logit analysis. However, estimation of the coefficients was not carried out by means of logistic transformation. Instead, Stopher grouped the respondents into cells corresponding to a certain time difference bracket and cost difference bracket, and then measured the proportion using one mode for each cell. In the next stage of the analysis he used this measure as the probability associated with using that mode for those time and cost conditions, and regressed it on the time and cost differences for each person.

In essence this methodology limits the number of explanatory variables to two. Furthermore, the use of a linear function directly as an estimator of the probability or proportion rather than employing the logit transformation tends to introduce distortions into the estimation of coefficients. As most of the recent studies indicate, the distributions of probabilities or proportions are more like an S-shaped curve. Stopher in his analysis used reported times for the preferred mode and objective estimates of time in characterizing the rejected mode. The use of a mixture of both types of data in the same study is likely to introduce serious biases into the study and affect the value of time derived by it. His findings suggest that travelers with annual incomes of £3,000 valued time at 20 percent to 25 percent of their hourly earnings.

Stopher realizing the flaws in the model he employed in his 1968 study, modified it by using logistic transformation to estimate the probabilities associated with the use of alternative modes. In his 1969 experiment he again utilized a linear relation between the probability of taking a mode, in this case a car, and cost and time differences between the modes.

Applying this simple model to the data obtained from University College, London, Stopher estimated the value of time as 42 percent of the wage rate for the income group £2,400 a year. He also used this model to explain the modal choice behavior of the commuters to County Hall, the Central Office of the Greater London Council. The values of time obtained from the County Hall, London, data were 32 percent of the wage rate for the income group under £1,000; 26 percent for £1,000 to £1,499; 23 percent for £1,500 to £1,999; and 21 percent for £2,000 to £2,999.

Route Choice Studies

These studies examine choices of trip makers with regard to route when they travel to a given destination. The most easily observable binary choice situation involves using a fast toll road or a relatively slower all-purpose road. Also, paying a toll to cross a bridge or to take a longer

route on a free road offers a possibility for observing and explaining the binary trade-off made by the individuals between time and cost dimensions of the travel package. However, empirical studies based on these route choices face a number of difficulties.

One of the difficulties that raises important statistical problems is the high correlation that is generally found between the time and financial cost variables. The probability of a high correlation between these two variables is much greater in the route choice situations than in the modal choice situation. Furthermore, in the route choice situation the variations in the values of the variables are likely to be too small to allow a reliable estimate of the equation to be derived.

In those cases where the route choice situations involve mostly non-regular or occasional trip makers such as vacationers, there is the additional problem that most of them are not likely to have full information about all the dimensions of the alternative routes between which they can choose.

Earlier efforts to derive a value of time from choices of trip makers between alternative routes in general utilized rather simple analytical techniques. One of the first studies in this area was carried out by Dawson and Smith for the United Kingdom Road Research Laboratory. In it the trade-off made by recreational travelers between time and cost involved in two alternative routes was analyzed. One of the routes consisted of a long road journey up an estuary and across a bridge, the other a shorter journey in time by a ferry at a higher cost. Time and cost differences were calculated from the requests given by a sample of motorists on the road and on the ferry. The technique used to derive a value of time involved simply taking the average rates at which the ferry users were trading cost for time and the average rates at which the road/bridge users were trading time for cost savings. The former was argued to represent the maximum value of time and the latter, the minimum. The estimates of these averages gave 7s.2d/hour per motorist, for the minimum and 9s.4d/hour for the maximum. The Mathematical Unit of the Ministry of Transport of the United Kingdom later applied the Beesley method and obtained 8s.6d/hour/vehicle. There are a number of weaknesses in this study. First, the time spent for waiting for ferry and on the ferry is valued at the same rate as time spent driving. Also the method used to determine the minimum and maximum values of time is highly suspect. The averages of the widely differing actual rates of exchange between time and cost reported by the trip makers cannot be said to represent the maximum and minimum boundaries of the value of time without further analysis.

Another attempt to derive a value of time from route choice analysis was carried out by Claffey. The study was essentially designed to determine the benefits enjoyed by motorists as a result of improvements in the highway network. Therefore the scope of this study was much wider than estimating the value of time saved by trip makers. The investigation was carried out during the summer of 1959 by driving a passenger car 1/2,000 miles on primary highways in 17 different states. Among the routes traveled were 14 locations where a major free route and a toll road could be used by the same motorists. At each of these locations several comparison runs were made on both the free roads and the tolled facilities.

The analysis of the value of travel time saved was based on the arguments that travelers using a tolled facility where a free road is available do so because they expect to benefit by an amount equaling, at least, the toll charge. These benefits apart from the savings in operating costs consist of time savings, increased driving comfort, and reduced accident costs. A regression analysis was carried out using the cost difference as the dependent variable. The estimates showed the value of time to be $1.42/per hour/vehicle. The formulation of the regression analysis in this form has been criticized. The variable that one wishes to explain is not the cost differences but the proportion of the travelers taking the tolled facility. The results obtained from this investigation, therefore, are regarded as unreliable.

Bevis attempted to infer a value of time from diversion curve data that were obtained during the early 1950s. As the data used are rather old, the absolute values of time obtained from this study cannot be compared with the results of more recent studies. However, the study is of interest in terms of indicating the development of analytical techniques in urban transport planning in general, and in deriving a value of time in particular. Therefore a brief summary of this study and the results obtained are given below.

Bevis tried to explain the proportion of travelers using freeways and alternative all-purpose roads by means of the variables (time, distance, etc.) of a generalized cost function. The proportion of freeway users for each of a large number of zonal interchanges in four areas of the United

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15/ Both the Mathematical Advisory Group of the U.K. Ministry of Transport and the Road Research Laboratory carried out regression analysis using the proportion of traveler taking the tolled facility as the dependent variable. The results showed that time was significant in explaining the choices made by the travelers.

States were included in the study. A multiple regression analysis was employed with the proportion of travelers using the freeways as the dependent variable and time and distance differences as explanatory variables. From this analysis the parameters for the different components of costs as well as time were derived. The generalized cost function developed from the study was scaled down so as to correspond with known levels of total cost in order to arrive at a value of time. The values obtained ranged between $1.25 and $1.40/hour.

In this study the data used for automobile operating costs were perceived costs. But by scaling at the end to known objective levels of car operating costs, it is implicitly assumed that drivers behaved as if they were aware of total car operating cost. More seriously, the probability or proportion of travelers taking a freeway is estimated directly from the linear regression equation. As was pointed out in relation to the modal split studies carried out by Stopher, 17/ this is likely to introduce distortions in the values obtained.

The 1967 study carried out by Thomas at Stanford Research Institute represents the first full application of behavioral modes to commuters' route choices and the derivation of a value of time. 18/ In this study the value of time is estimated in two stages. The first stage of the study consisted of an estimation of the motorists' route choices from the characteristics of the alternative routes and characteristics of the motorists themselves. A standard logit function of the familiar form was employed. The function $G(X)$ was restricted to a linear function of the motorists and route characteristics.

The information on route characteristics was obtained from the responses of the motorists to a questionnaire and test vehicle measurements. These two sets of data were considered as distinct and independent and used to obtain separate estimates of time. About 37 models were estimated using the values of route characteristics taken from the test vehicle data, and 12 models were based on the responses of the motorists. From these alternative runs the best model was selected in each group according to the following criteria:

(a) The coefficients of income, toll per person, and all the route characteristic variables such as difference in travel time, had to be significant at the 95 percent confidence level when compared to their standard errors.

(b) The higher the percentage of correct prediction, the better the model.


From the best model based on data generated by the test vehicle, the value of travel time by taking the ratio of the coefficients of time and cost was estimated to be $1.82/person/hour. With 95 percent confidence limits, the value of time ranged from $1.04 to $2.60/person/hour.

The best model from the responses of the motorists showed the value of time obtained to be $3.82. The 95 percent confidence limits gave a range from $2.82 to $4.86/person/hour.

The study was unable to produce any further evidence to narrow the limits of the values of time obtained. The value $1.82 obtained from the test vehicle data and $3.82 from the interview data were used as the limits. The simple average of these two limits, $2.82/person/hour was designated as the value of time saved in travel. In the sample, average annual income of the motorists was about $9,200, and the average trip length was about 5 miles.

Thomas explains the wide difference between the values of time obtained from the two different sets of data in terms of a bias in the interview toward the route chosen by the motorists. Analysis of the data indicates that the magnitude of this bias is about 1 to 2 minutes upward in travel time differences if the free road is taken and about 1 to 2 minutes downward if the toll road is taken. As most motorists reported the travel times in multiples of 5 minutes such bias is quite expected. However, this indicates one possible weakness of the study: the results are highly sensitive to small variations in the travel times. The study recommends that for time savings above 10 minutes the value suggested here should be adjusted upward.

The study does not claim that the value of time arrived at has universal validity. The fact that the sample was not a random sample eliminates the use of statistical confidence limits on the expected value of travel time for motorists—even for commuters facing a toll road/free road choice.

In order to analyze the effects of the amount of time saved and the level of income of commuters on the value of time, Thomas and Thompson further analyzed the data obtained for the earlier Stanford Research Institute Study. 19/ The main objective of this study was to relate the value of time to income and amount of time saved variables. The study was limited to

time savings of 30 minutes or less. The authors further attempted to show that the use of a single value of time in transport project evaluations would lead to serious errors. The results obtained indicate that both income level and the amount of time saved are important variables in determining the value of travel time saved. For example, the estimates showed that for annual income levels between $10,000-$12,000 the total value of a 5-minute travel time saving was about $0.079 and that of a 30-minute savings was about $0.984. The findings of the study also suggest a benefit curve for travel time savings. Time savings less than 5 minutes or greater than 15 minutes have a smaller value per minute than those between 5 and 15 minutes. This creates problems in evaluating transport projects, involving a series of improvements in the transport network. If each step is evaluated separately, then the total benefits of a given step may be in the first part of the curve, and therefore the sum of benefits would be insignificant. However, if all steps are taken together they may yield total time savings in the steeper portion of the S-shaped curve indicating a high benefit.

Another problem is that the authors in their efforts to obtain a better fit incorporated polynomial terms into the mode. This has resulted, as the authors themselves state, in high inter-correlations between the variables. As a result, the model was less reliable than the original simpler model.

Thomas and Thompson carried out a further study to estimate the value of time by trip purpose and as a function of trip makers' income levels and the amount of time saved. Their model again utilized a logit function to estimate the route choices made by the trip makers. However, the G(X) function was, this time, restricted to a linear function of the characteristics of the route and the trip makers. As the approach used to evaluate time savings is the same as in the earlier studies it is not repeated here.

The benefits of time savings are given in Table 4.1 for personal business trips, in Table 4.2 for work trips, in Table 4.3 for social recreational trips, in Table 4.4 for vacation trips, and in Table 4.5 for school trips. The values indicated in these tables show the total value of the specific amounts of time saved rather than the value per hour.

Thomas in his previous study reported here points out this danger. Also (see D.G. Haney, "The Value of Time for Passenger Cars: A Theoretical Analysis and Description of Preliminary Experiments," Stanford Research, May, 1967) cautions against using a single value of time for benefit calculations.

### TABLE 4.1: Benefits of Time Savings in Dollars per Vehicle for Personal Business Trips

<table>
<thead>
<tr>
<th>Time Savings (Minutes)</th>
<th>1</th>
<th>3</th>
<th>5</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>5</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
<td>0.006</td>
</tr>
<tr>
<td>10</td>
<td>0.000</td>
<td>0.002</td>
<td>0.018</td>
<td>0.756</td>
</tr>
<tr>
<td>15</td>
<td>0.001</td>
<td>0.058</td>
<td>0.950</td>
<td>2.004</td>
</tr>
<tr>
<td>20</td>
<td>0.004</td>
<td>0.463</td>
<td>1.994</td>
<td>3.450</td>
</tr>
<tr>
<td>25</td>
<td>0.011</td>
<td>1.079</td>
<td>3.027</td>
<td>4.896</td>
</tr>
<tr>
<td>30</td>
<td>0.025</td>
<td>1.706</td>
<td>4.060</td>
<td>6.361</td>
</tr>
</tbody>
</table>

**a/** Income Levels: 1 = less than $4,000 per annum; 3 = $6,000-$7,999; 5 = $10,000-$11,999; 7 = $15,000-$19,999.

### TABLE 4.2: Benefits of Time Savings in Dollars per Person for Work Trips

<table>
<thead>
<tr>
<th>Time Savings (Minutes)</th>
<th>1</th>
<th>3</th>
<th>5</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.001</td>
<td>0.003</td>
<td>0.006</td>
<td>0.013</td>
</tr>
<tr>
<td>5</td>
<td>0.006</td>
<td>0.013</td>
<td>0.028</td>
<td>0.056</td>
</tr>
<tr>
<td>10</td>
<td>0.036</td>
<td>0.126</td>
<td>0.299</td>
<td>0.505</td>
</tr>
<tr>
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<td>0.135</td>
<td>0.412</td>
<td>0.727</td>
<td>1.033</td>
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<tr>
<td>20</td>
<td>0.158</td>
<td>0.521</td>
<td>0.939</td>
<td>1.338</td>
</tr>
<tr>
<td>25</td>
<td>0.182</td>
<td>0.639</td>
<td>1.156</td>
<td>1.642</td>
</tr>
<tr>
<td>30</td>
<td>0.208</td>
<td>0.763</td>
<td>1.373</td>
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</tr>
<tr>
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<td>0.265</td>
<td>1.020</td>
<td>1.805</td>
<td>2.545</td>
</tr>
</tbody>
</table>

**a/** Income Levels: 1 = less than $4,000 per annum; 3 = $6,000-$7,999; 5 = $10,000-$11,999; 7 = $15,000-$19,999.
TABLE 4.3: Benefits of Time Savings in Dollars per Vehicle for Social-Recreational Trips

<table>
<thead>
<tr>
<th>Time Savings (Minutes)</th>
<th>Income level of motorists a/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>5</td>
<td>0.000</td>
</tr>
<tr>
<td>10</td>
<td>0.001</td>
</tr>
<tr>
<td>15</td>
<td>0.002</td>
</tr>
<tr>
<td>20</td>
<td>0.007</td>
</tr>
</tbody>
</table>

a/ Income level breakdowns are the same as shown for Table 4.2.

TABLE 4.4: Benefits of Time Savings in Dollars per Vehicle for Vacation Trips

<table>
<thead>
<tr>
<th>Time Savings (Minutes)</th>
<th>Income level of motorists a/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>10</td>
<td>0.249</td>
</tr>
<tr>
<td>15</td>
<td>0.283</td>
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<tr>
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<td>0.320</td>
</tr>
<tr>
<td>25</td>
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</tr>
<tr>
<td>30</td>
<td>0.400</td>
</tr>
</tbody>
</table>

a/ Income level breakdowns are the same as shown for Table 4.2.

TABLE 4.5: Benefits of Time Savings in Dollars per Person for School Trips

<table>
<thead>
<tr>
<th>Time Savings (Minutes)</th>
<th>Income level of Motorists a/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>5</td>
<td>0.000</td>
</tr>
<tr>
<td>10</td>
<td>0.000</td>
</tr>
<tr>
<td>15</td>
<td>0.000</td>
</tr>
<tr>
<td>20</td>
<td>0.000</td>
</tr>
</tbody>
</table>

a/ Income level breakdowns are the same as shown for Table 4.2.
The implication of the findings of these two studies for the evaluation is this: if the value of time as revealed by trip makers is to be incorporated in estimating the benefits, the analyst will have to have considerably more data. A mere knowledge of the amount of time saved, the volume of traffic, and the level of the trip makers' incomes is not enough. Cross tabulated information on the trip makers' incomes, trip lengths, amount of time saved, and trip purpose are also needed.

Choice of Speed at which to Drive

As the cost of running a car increases at higher speeds, it is conceivable to think of a trade-off between time and higher costs. But any empirical work designed to evaluate the value of time in terms of this particular trade-off situation must assume that individuals are fully aware of the relation between cost and speed so as to be in a position to determine their optimal speed of driving. There is very little evidence to suggest that individuals in fact recognize the behavior of operating costs as a function of speed.

Mohring attempted to evaluate the value of time by means of speed/cost trade-off. 22/ Using standard data on United States operating costs/speed relations, and mean and standard deviation of vehicle speeds on high-quality roads under free-flow conditions, he estimated the value of time at $2.80 per vehicle hour. However, because of the rather unrealistic assumption stated in the preceding paragraph, this result must be regarded as rather suspect. Furthermore there are many other factors that influence free-flow speed. If the basic premise of this study is accepted, it must follow that cars with more passengers travel faster than cars with fewer passengers. There is no empirical evidence to suggest that this is so in real life.

Choice of Residential Locations in Relation to Workplace

In urban centers with a well-defined core it is possible to formulate an economic model indicating trade-off between commuting costs including time costs and the costs of housing. However, it is not an easy problem to isolate this trade-off. A number of factors other than the cost influence a person's decision with regard to location of his residence. Also the value of land is a given location and therefore the rent depends on a number of factors. It is difficult to isolate the effect of distance to the center of town on land values and rents.

Mohring carried out a study based on data from Seattle. He assumed that house prices reflect, given all other things remaining the same, the capitalized value of time and other operating costs of the journey to work. His study yields a range of values of $0.50 to $1.00/person/hour. However, as house values varied widely and the appropriate level of social rate of discount was not certain, the result is questionable.

More recently Wabe attempted to derive a value of time in terms of variations in housing prices with distances from Central London. In the model, a one penny decrease in the cost of trip to the center was associated with an increase of £18.74 in the level of house prices. Similarly, a one minute reduction in travel time to the center brought about £20.38 of difference in house prices. The ratio of time and price coefficients indicates that one minute is valued at 1.087 of a penny or one hour at 65.25 pence.

Wabe's approach provides a useful insight into the long-run valuation of travel time savings. In the model the effects of variations in environmental quality and amenities of residential locations on house prices are taken into account. In this respect this effort represents an improvement over Mohring's study. However, the basic assumption used in this study is that transport decisions are made *ex ante* to locational decisions, both with respect to residence and employment location. In many cases this assumption may not be valid. To this extent, the value of time derived by Wabe is open to criticism.

Choice of Travel Destination of Frequency of Travel to a Given Destination

This choice situation differs from the previous ones in that the choice is not between different transport packages but between alternative destinations or between making a trip or not making it. The basic methodology utilized by these studies relates trip making decisions to travel impedances, i.e. the time, cost and discomfort associated with getting there. These studies, in general, have utilized some form of trip generation function in modeling the trip makers' choices.

Plourde's work represents an application of trip generation functions to the estimation of value of time. In this study an abstract mode model was developed for the Boston Metropolitan Area. In this model, relative times and


costs were used to distinguish alternatives available for the commuters. Also the best mode in terms of costs, times and other dimensions of the alternatives was determined. The value of time obtained from the rate of trade-offs made by the commuters choosing shorter journey times but higher costs was significantly different from the values derived from the rate of trade-offs of the commuters choosing longer journey times but lower costs: $2.63/hour and $0.22/hour respectively. These results may have been due to a number of statistical problems within the model. But they appear to support the hypothesis put forward by Lee and Dalvi that "time preferrers" and "cost preferrers" should be treated separately in the derivation of a value of time.

Mansfield has applied the trip distribution functions to derive a value of time for recreational trips by analyzing the demand for day and half-day pleasure trips to holiday areas. It is hypothesized that the trips made to a given holiday resort are a function of its attractiveness and the relative cost of reaching it. The cost of a trip is expressed in money as well as time. Mansfield utilized the survey done by the National Parks Commission and the British Travel Association in the Lake District of Great Britain. The value of time obtained from this study was 2s.7d/hour. Mansfield argues, however, that this value is highly sensitive to the level of operating costs of motor vehicles—if operating costs were taken as 4d/mile, instead of 3d, the value of time would be increased to between 3s.8d and 3s.11d.

In another study Colenutt analyzed data on recreational trips to the Forest of Dean. In this study a dummy variable was used to isolate the marginal effects of journey time on the demand for recreational trips. The deviations from the average expected journey time, labeled "excess time," was found to be statistically significant in affecting trip distribution. When interpreted as a rate of trade-off between money and time, the value of time was found to be between 13s.0d to 15s.11d/hour/vehicle. However, 95 percent confidence limits yielded a much wider range of values: 5s.2d to 31s.7d. Because of this Colenutt concluded that not much confidence could be attached to the values he obtained.

Direct Approaches to the Value of Time

(a) Interview Techniques

The various methods of analyzing empirical trade-off situations to measure the value of time thus face a number of statistical problems as well
as problems with regard to data. Furthermore the results obtained from these studies are shown by and large to be specific to a given group of travelers, in most cases commuters, or to given vehicles. Therefore the additional problem of deriving a more general value of time remains.

To avoid some of the problems faced by the trade-off techniques, and also settle the issues involving interpretation of the results obtained by these techniques, a more direct approach in the form of personal interviews specifically on the problem of value of time is possible. So far very little empirical work has been done using this approach. Although interviews might avoid the many problems encountered in interpreting the choice behavior of individuals, they have different problems of their own, some of which are formidable. In interview situations it is quite possible that persons will respond to the questions in a biased manner. Despite employment of sophisticated forms of interviews and questionnaires, the responses may be unreliable. Also they may not be able to consider such things as value of time in the abstract and therefore cannot give reliable answers. Furthermore there is the possibility that their responses to the questions and their behavior may not be the same.

In the face of these serious potential shortcomings of the direct interview methods it is not surprising that they have not been widely used. But if they are not particularly appropriate for deriving quantitative results, these techniques may, however, have their uses as an additional tool in helping to interpret the results obtained by other techniques. They also may be useful in deriving hypotheses to be empirically tested and verified. Finally, direct interviews may provide a basis for the extrapolation of results obtained from certain specific travel choices to other travel situations, e.g., commuting travel to, say, recreational travel.

In the latter area the Ministry of Transport, United Kingdom, has carried out a pilot study. The study aims at testing a number of propositions:

(i) that the value of time is the same for all journey purposes;

(ii) that the value of time is a function of income level;

(iii) that the value of time is the same, on average, regardless of the period of time saved.

The findings of this study were mixed. In the case of some hypotheses the results were confused. There were apparent inconsistencies between the observed behavior and the described behavior, particularly in the case of the size of time savings: individuals appeared reluctant to admit that even sizable time savings were of some value to them. There was evidence that they valued travel time savings because of the disutility associated with travel and that the value of time was a function of the total travel context.

of a given journey. Particularly the existence of a deadline or other activities to be engaged in within a given period of time emerged as important determinants of the value of time. These results suggest that the value of time in commuting trips may be higher than in trips for other purposes where these factors are less likely to be prevalent.

(b) Simulation Methods

The possibilities offered by simulation methods have not been fully explored. The basic approach is simple, at least at the conceptual levels, and is the same as the basis of the revealed preference theory of consumer behavior. Individuals are presented with a hypothetical situation, preferably resembling the one that they are likely to face in real life. By varying the values of the dimensions of this situation the various choices made by individuals are simulated. The situation in this case involves a given trip. The components of the trip, vehicle trip, vehicle time, various costs, walking time, and waiting time are changed, and the "individuals" are asked to make a choice under each hypothetical situation. From the responses of the "individuals" then, a value of time can be derived. Even though this technique has not been fully explored it appears that it offers real possibilities. Clearly all of the problems faced by direct questioning will be present in this case also. The initial experiments in this area have been confined to commuting as this is the most thoroughly explored area. If the approach appears valid and promising, then the next step will be to apply it to other situations.

C. Working Time Travel Savings

Empirical studies carried out to determine the value of working time may be classified into two groups: (a) behavior studies utilizing an approach similar to that employed in examining commuter trips, and (b) case of survey studies.

(a) Studies of Choice Behavior of Trip Makers

The empirical investigations of working travel time savings has adopted behavioral approaches similar to those used for non-working travel time savings. Virtually all of these efforts have been in the field of air transport.

The investigation carried out by the U.S. Institute of Defense Analysis represents the first serious effort to derive a value of working time. 29/ In this study the percentage of trip makers using the faster but more expensive mode was related to the percentage distribution of travelers' income over a large number of domestic air/rail/car routes. The best equation obtained explaining the effects of time and cost contains distance as one of

the variables. This casts some shadow on the validity of the estimates of the coefficients for those variables. Another shortcoming of the study is the fact that the combination of working and non-working time is used in the same equations. The results obtained are comparable with the values of time arrived at by simple cost-saving approach.

Perhaps the most sophisticated study carried out to date is that of Gronau. 30/ He employed trip generation functions between pairs of points of origin and destination. This study is more fully discussed in relation to the valuation of time in air transport. At this point it will suffice to state that the equation estimated for explaining the demand for personal trips assumes its highest explanatory power when the price of time is assumed to equal zero. On the other hand, in the case of business trips the best explanation of the demand function is obtained when the value of time is 1.15 to 1.25 times the hourly earnings. 31/ Even though this study can be criticized on a number of grounds, it provides useful confirmatory evidence that the value of working time is in the neighborhood of the hourly earnings of the travelers and that it differs markedly from the value of time for personal trips.

(b) Case or Survey Studies

The earlier attempts using survey techniques were concerned with determining the manner in which working time savings were utilized. They examined mainly trucking firms and commercial vehicles. Fleisher surveyed the long distance trucking operations in the U.S. and attempted to trace the changes in their operating schedules over time as successive improvements on the highway network used by them. 32/ The Fleischer study showed that, because of the constraints on driving time, time saved on the road could not always be immediately utilized. However, as successive improvements in the highway facilities and savings in time occurred, the carriers were able to benefit from such time savings by completely changing their schedule of operations.

Hanning and McFarland 33/ in their efforts to determine the value of time saved by commercial vehicles, reached the conclusion that the common

carriers 34/ were able to utilize only about 40 percent to 60 percent of the potential benefits arising from time savings; private carriers between 80 percent and 100 percent, and the specialized carriers about 60 percent and 80 percent.

D. Air Travel Time Savings

General Consideration

High speed of travel by air transport is virtually the sole advantage of this mode over other modes. As a result the time saved by travelers represents a significant portion of the benefits resulting from improvements in airports, air traffic controls, and navigation facilities as well as in terminal buildings. Therefore, the problem of evaluating time saved by air travelers assumes great importance in appraising air transport projects. As in other modes of transport, improvements in air transport facilities may save time for the passengers in the following three ways:

(a) Increased speed makes time available at origin or destination instead of en route.

(b) Increased frequency of service by scheduled carriers makes time available at origin or destination for the intended purpose instead of waiting for a later scheduled departure or passing time at the destination after an arrival too early for the purpose of the trip. The time saved in this manner cannot easily be measured meaningfully. In general the extra time enjoyed by the passenger is related to the specific trip undertaken.

(c) Improved reliability of the scheduled operations would save time for both airline and aviation travelers. The amount of such time savings can be measured by considering the smaller allowance of time that the prudent passenger would allow for delays under conditions of greater reliability.

The last source of time savings is generally ignored in land transportation. But in air transport the time savings resulting from a reduction of the uncertainties surrounding the time schedules of carriers is more

34/ This class of carriers appears in the regulation of motor carriers in the U.S. Common carriers are basically for-hire carriers, and they differ from contract carriers, another class of for-hire carriers, in that common carriers undertake to serve the public generally.
important. The reason for this is simply the fact that air transport is incomparably faster than any other generally available method of transportation. If for any reason the scheduled flights are delayed or canceled, the average traveler would be stranded without any comparable alternative means of transport. Consequently passengers may experience considerable time loss, especially if the amount of time lost is expressed as a percentage of the regularly-scheduled time. By contrast, in surface travel a shift to the next-best method of land transportation may involve little loss of time.

Unreliability of scheduled services in air transport can come about in a number of different ways:

(i) delay in arrival at destination;

(ii) cancellation of flights with or without the possibility of getting on the next flight if it is not canceled;

(iii) delay that occasions the missing of a connecting flight to the final destination;

(iv) diversion of scheduled flight to an alternative airport, requiring additional time for surface transportation back to the desired destination.

(a) Delay in Arrival at Destination

Actual delay times in essence are the same as any other time savings and therefore should be valued at the same rate. However, it is also true that reduction or elimination of delays has a significant psychological effect on passengers. The uncertainty and aggravation resulting from non-scheduled delays are considerable and are likely to reduce the effectiveness of the traveler at his destination. However, at the present time a value cannot be assigned to these psychological effects with any degree of confidence.

The amount of time saved by reducing the probability of delays can be measured by obtaining information on how much extra time would be built into the scheduled carriers' time-tables as a routing allowance for uncertainty under improved conditions and comparing this with the time allowed.

under existing conditions. Also the differences between scheduling into and out of congested and non-congested airports can provide guidance on the amount of time saved by reducing uncertainties.

(b) **Cancellation of Flights**

The complete cancellation of a flight produces even more serious delays. The simplest way to measure the time that could have been saved is to assume that the canceled flight passengers would have been able to take the next scheduled flight for the desired destination. However, this is an over-simplified view of the situation. Cancellation often occur in series, or space may not be available on the next flight if all the passengers cancelled out on the original flight.

(c) **Delays Causing Missed Connections**

Quite often air passengers take more than one flight between their point of origin and the destination. As the number of connecting flights is not generally known, it is highly difficult to assess the loss of time caused by missed connections. However, it is possible to obtain some idea about the magnitude of time lost resulting from the uncertainties involved in making connection by means of:

(i) determining the time-spread between arrival and departure on certain connecting flights with the minimum time-spread that could be feasible if uncertainty were not a factor;

(ii) determining the extent to which transfer passengers do, and do not, reserve passage on the closest connection they could make if all went well and scheduled times were, in fact, achieved;

(iii) assessing the actual time expenditures of passengers involved in unusually slow or late flights.

(d) **Diversion to Alternative Airports**

The amount of time lost resulting from a diversion to an alternate airport depends on the location of the alternate airport, the distance between the two airports, and the availability of surface transport. Very often such diversions result in the loss of a whole working day and therefore should normally be valued as subtracting an entire working day from the time at destination.

Another aspect of the value of time saved that causes particularly serious problems in the case of air transport is diurnal variability of the value of time. This problem is more acute in the case of the value of working time. A business trip by air transport can be considered as unusual
because of the following reasons: it does not take place every day for the vast majority of business air travelers and it typically involves some disturbance of the standard daily rhythm of home-to-office travel. There is evidence to suggest that business air travelers value waking at the normal time very highly. 36/ Many travelers are generally willing to sacrifice a great portion of a working day at their destination in order to start their journey around normal commuting hours. Also the information gathered by these surveys indicates that departures at night are the most preferred alternative to an early morning departure.

This information with regard to the preferences of air travelers suggests that the use of a single value of time in air transport project appraisals may lead to distortions. The time saved by passengers therefore should be valued at different rates depending on the hour of the day. This clearly makes the task of project appraisal far more difficult.

**Empirical Research into the Value of Time Saved in Air Transport**

One of the earliest studies in this area was conducted by the U.S. Institute of Defense Analysis as a part of the work done on the potentialities of the newer types of aircraft: STOL, VTOL, and Supersonic. 37/ The approach taken by this study was to employ a trip distribution function of the Cobb-Douglas type to explain the volume of air travel. However, the use of multiplicative relations among the independent variables--average journey time, price, and airline distance--were treated together causing problems of multicollinearity. Business and personal trips were treated together. Consequently the results obtained are not very reliable. The value of time was estimated by the ratio of the elasticities of demand with respect to both time and price. The study concluded that the average value of time was 66 percent of the average hourly earnings of the air travelers. The study also, on the basis of the mix of travelers, suggests that the income-time ratio in the case of business travelers would be between 0.8 and 0.9 and that of personal travelers between 0.4 and 0.5.

Gronau more recently attempted to derive a demand function for air transportation and estimate the value of time for air passengers. 38/ He also


utilized a Cobb-Douglas-type trip distribution function. Gronau argues that the demand functions for trips to various destinations differ depending on the attraction of the destination, which in turn is determined by factors affecting the demand for visits, the degree of substitution between trips and related inputs, the price of these inputs, and the share of the trip's price in the total cost of the visit. But he assumes that these factors affect only the level of the demand curves and not the elasticities. To calibrate his model, Gronau used the data obtained by the Port of New York Authority Survey carried out in April 1963-March 1964. He estimated a series of regression equations with arbitrarily chosen values of time. By selecting the value yielding the highest explanatory power he obtained estimates of both the price and income elasticities. In this way, he was also able to determine the ratio of the value of time to hourly earnings of the trip makers.

The results obtained showed that for business travelers the highest explanatory power is obtained ($R^2 = 0.88242$) when the value of time is between 1.15 and 1.25 times the average earnings. For personal trips the results obtained were somewhat puzzling because the highest explanatory power was obtained when the value of time is equal zero. Gronau argues that this may be partly explained in terms of the low degree of substitution of time between work and non-work activities. The data used in this study showed that of all personal trips, over half were taken during a weekend or a holiday, and almost half were taken by unemployed travelers.

Gronau's work, even though it has been criticized on the grounds of the several simplifying assumptions used, represents a major effort in the field of modeling travel demand. It has been argued that these criticisms are not sufficient to invalidate his major findings that time is a considerably less important determinant of intercity travel patterns than of commuting trips. 39/

CHAPTER V

USE OF ESTIMATED VALUES OF TRAVEL TIME SAVINGS IN ECONOMIC EVALUATION OF TRANSPORT PROJECTS

A. Travel Time Savings and Economic Assessment of Transport Projects

As noted earlier the results obtained by theoretical investigations into the value of travel time indicate that quantification, in monetary terms, of such benefits of transport projects is still an uncertain exercise. Theoretical approaches have not yielded results that are operationally useful, with the exception of work travel, in determining the value of travel time savings. Even in the case of work travel, the prescriptions of the economic theory are accepted only because of the absence of better methods to derive a value directly on the basis of empirical evidence. In the case of non-work travel time, despite the advances made in transport demand modeling, the empirical investigations based on such models have yielded results that are crude and subject to error. However, the problems of including travel time savings in cost-benefit analyses of transport projects do not end there. Assuming that reliable and correct values of travel time savings are available many problems must still be overcome in using them in an economic evaluation of transport projects.

These problems mainly arise in relation to forecasting of the future values of travel time savings. Clearly this problem is not unique to travel time values. Because basic transport facilities have a long economic life, the economic assessment of investments in such facilities necessitates forecasting of the future values of various cost and benefit items. In the case of travel time savings enjoyed by the facility users this requirement gives rise to two problems:

(a) estimating future travel time savings; and
(b) estimating the future monetary values of travel time savings.

The first involves the estimation of traffic volumes to determine traffic speeds for the system under consideration. The prediction of future traffic volumes is often highly tenuous. Even in the case of urban highways where advanced forecasting methods have been developed, predicting travel for a particular time in the future is difficult and involves a cumbersome procedure. To estimate travel time savings the estimated travel volumes must be substituted into a speed-volume relation. Differences of speed from one year to the next are likely to be small, giving rise to the possibilities of considerable inaccuracies. These inaccuracies will be compounded by the errors generated in producing the forecast travel volumes.
Estimation of the future values of travel time savings also presents formidable problems. Several studies, as was shown earlier, suggest that the value of travel time is related to the individual's income level. If this is the case, values of travel time will change as per capita real income changes. As a result, in applying values of travel time to economic assessment of transport plans it is necessary to estimate the future levels of real income, and to determine the relationship between values of travel time savings and income levels. This problem is compounded by the fact that there is no such thing as a single value of travel time and that values of travel time depend on several factors including the purpose of trips, trip lengths, and amount of time saved. If such variations in value of travel time are significant, then it is necessary to incorporate the separate values in the estimation of benefits of a transport project. This requirement makes the forecasting of future values of travel time savings virtually an impossible task. The estimation of benefits accruing to "generated" traffic creates additional problems. The first problem in this area is to be able to estimate the amount of induced traffic. The estimation techniques involve the use of values of travel time since demand for travel will be related to generalized cost functions. The second problem involves the specific values of travel time and not just of travel time savings. Available evidence suggests that travel time savings and total travel time have different values. 1/

In recent years an alternative evaluation technique has been introduced for the economic assessment of alternative transport systems, i.e. cost-effectiveness analysis. This approach to economic assessment of transport projects does not replace cost-benefit analysis but supplements it. Cost effectiveness analysis is a method for comparing the social and economic effects of alternative schemes that cannot be quantified in monetary terms. The application of this method requires that the objectives sought from a given undertaking are clearly and explicitly stated. Once these objectives are known, this technique can be used to analyze the effectiveness of each alternative in terms of these objectives. Within the framework of this technique, travel time savings can be expressed as one of the goals of transport projects and this can be directly assessed. By this way the problem of converting time savings into money can be avoided. Also problems of equity, of whose travel time should be considered, of the times of day when travel times should be affected, etc., can all be handled adequately by goal formulations.

It should be noted, however, that even cost-effectiveness analysis at times requires expressing travel time savings in terms of money. Such a need may arise when the goals set are such that achievement of all goals is not possible within the available budget or under any feasible transportation project. Under such circumstances particularly when goals are mutually exclusive some modifications of the goals are necessitated. Modification

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generally involves setting lower levels of achievement for one or more goals. The modification of goals in this manner is, effectively, a value judgment process. The decision-maker is put in a position of determining which goals to hold unmodified, and which ones to modify and by how much. If different goals can be represented by a common measure this task could be made easier. In the case of travel time savings a knowledge of values of travel time could be instrumental in assisting goal modification by making explicit the value of one goal, against which modification of another goal could be made.

In summary, the use of cost-effectiveness analysis will lead to changes in the use of values of travel time in economic evaluation but will not reduce their importance. Instead of being used as a conversion mechanism for travel time savings, values of travel time and travel savings will assume an increased importance in assessing the degree of achievement of the objectives sought from the project.

B. Use of Value of Travel Time Savings in World Bank's Transport Project Appraisals

A number of Bank appraisal reports of transport projects were examined by the author to assess their treatment of travel time savings. In many of these appraisals time savings accruing to passengers are not included in the calculation of the total benefits of the projects. For example, in the appraisal of the Second Highway Project, Syria, it is stated "Unquantified but important benefits attributed to the project are time savings for passengers on business and other trips ... " 2/ Similarly, in appraisal of the Fourth Project, Mexico, it is stated "... no passenger time savings have been included in the benefits." 3/

By contrast in the appraisal of the Tocumen International Airport Project in Panama, the value of passengers' time has been explicitly recognized and included in the benefits of the project. 4/ Two values for time are used based on the following assumptions:

(a) Passengers consider their leisure time as valuable as their working time.

(b) Passengers consider their leisure time at one-third the value of their working time.

3/ PTR - 47a, 1 June 1970.
On these alternatives, the value of time is estimated at $8.10 and $2.70 respectively. The estimated economic return on the investment using these two values of time ranged from 17 percent to 13.5 percent. When zero value was attached to the time saved on those who are not gainfully employed (e.g., housewives), then the rate of return fell to 13 percent.

In the appraisal of the Third Highway Project, Finland, the value of time for passengers is set at Fmk. 1.65 (US$0.39) per person per hour in 1967. The figure arrived at is about 20 percent lower than the value established by an interview evaluation carried out in the greater Helsinki area. The US$0.39 represents one-third of the hourly wage of the users.

Most highway loans have been utilized for developing the primary and secondary road system where time savings have not been crucial. In most of these projects, as was noted above, the passenger time savings have not been included in the estimation of the economic returns of the project. They are simply mentioned as one of the unquantified benefits generated by these projects. Similarly in appraisals of railway and port projects the values of passenger time savings have not been crucially important in economic evaluation and therefore have not been included in the estimation of the economic return. In air transport, particularly in airport development where passenger time savings are important, lending has been rather limited.

Therefore, it is apparent that up to now time savings have not been a crucial factor for most of the transport projects that are partly financed by the Bank. But what about the future? According to the Transport Sector current operation program for the period FY1971-75, the modal distribution of loans will remain very much the same as in the past with the notable exceptions of air transport financing and urban transport. Highway lending during this period will continue for primary and secondary road systems linking important centers of economic activity and population. Once the main networks of highways are gradually completed, the next stage in the lending program is expected to be in the area of feeder roads. Therefore it seems highly unlikely that in such projects the value of passenger time will have a crucial importance in project evaluations.

However, during the current operations program (FY1971-75), about 14 percent of the total loans in the Transport Sector will be made for air transport. Since the time saved for passengers is of value, particularly in airport developments, the value of time will have a significant place, in the immediate future, in the Bank's lending activities in this area. Passenger travel time savings also have an important place in the evaluation of urban expressways as well as urban public transit systems. The rapid urbanization that has been taking place throughout most of the world and the resulting urban transportation problems will require investment of big sums in these facilities. The Bank has been increasingly interested in urban transportation problems, and it is likely that loans for such projects will grow in the future. Therefore urban transportation is the second area of the Bank's operation in which the value of time will be crucial.

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