

ECONOMIC RESEARCH CENTRE

EXEMPLAIRE

CENT

SIXTH ROUND TABLE

(13th-14th November, 1969)

REPORT OF THE SIXTH ROUND TABLE

ON TRANSPORT ECONOMICS

held in Paris, on the following topic:

**theoretical
and practical research
on an
estimation of time-saving**

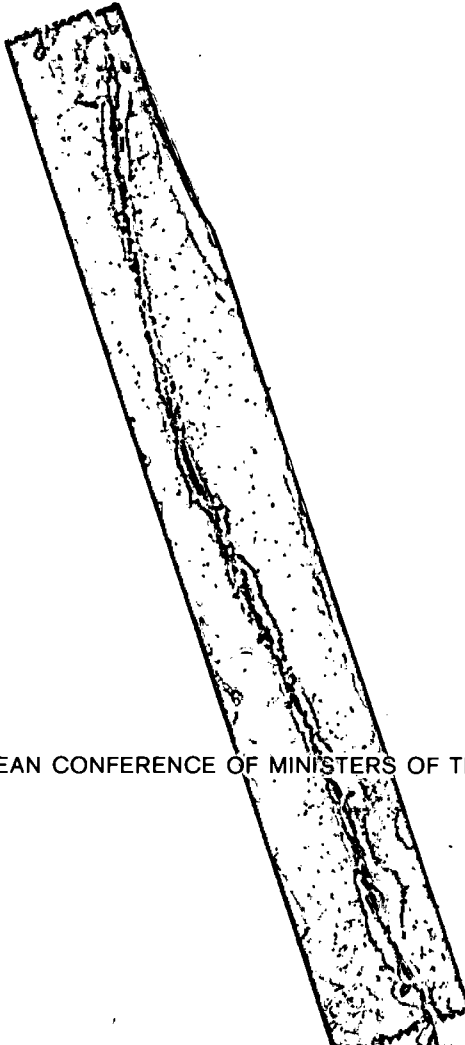
EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORTS

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EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORTS

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	i
THE VALUE OF TIME IN THE TRANSPORT PLANNING: A REVIEW	
A.J. HARRISON and D.A. QUARMBY	1 - 118
SUMMARY OF THE DISCUSSION (Round Table debate on the report)	119

INTRODUCTION

The topic dealt with at the Sixth Round Table, i.e. the evaluation of time-savings, is vitally important for the functional guidance of investment policy.

Studies on this aspect of transport economics in recent years have paved the way for much progress. Some ten years ago, the concept of time-saving was rather like a general gambit for proving the profitability of well-nigh any investment. It is cheering to see that clearly defined concepts and evaluations have been successfully developed in this field.

The participants in the Sixth Round Table unanimously expressed their keen appreciation of the excellent introductory report produced by Mr. HARRISON and Mr. QUARMBY. The E.C.M.T. endorses this tribute all the more readily because the contribution of these two economists has a true and direct bearing on transport policy. The E.C.M.T. is above all concerned to trace those elements of theoretical knowledge that can be of practical use. There can be no doubt that the present report is well consistent with this essential objective.

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THE VALUE OF TIME
IN TRANSPORT PLANNING:
A REVIEW

A. J. HARRISON & D. A. QUARMBY
MINISTRY OF TRANSPORT
LONDON

SUMMARY

	<u>Page</u>
0.1. INTRODUCTION	1
0.2. DEFINITIONS	2
1. THEORY OF VALUATION	5
1.1. Working Time	5
1.2. Non-working Time	11
1.3. General Theoretical Problems	16
2. MEASUREMENT	21
2.1. Working Time	21
2.2. Non-working Time	24
3. SELECTING TIME VALUES	57
3.1. Working Time	57
3.2. Non-working Time	59
4. USING TIME VALUES	68
4.1. Time values in the appraisal of transport projects	68
4.2. The use of values of time in traffic models	69
5. PROGRESS	78
BIBLIOGRAPHY	81
ANNEXES	
A: Review of 14 studies (Extract from Ministry of Transport Document)	85
B: Marginal and Average Values: an empirical note	114
C: Vehicle Time.	117

THE VALUE OF TIME IN THE TRANSPORT PLANNING: A REVIEW

A. J. Harrison and D. A. Quarmby

MINISTRY OF TRANSPORT LONDON

0.1. INTRODUCTION

SCOPE OF PAPER

0.1.1. This paper will be concerned primarily with the selection of time values for use in the appraisal of transport expenditure and in the prediction of demand in the transport sector, and within that sector, principally with roads and road users. The reasons for this selectivity are as follows; first, road provision is in the hands of public authorities but, unlike industries such as electricity supply, it is not subject to the price mechanism, consequently there is no financial test of the worthwhileness of investment. Instead cost benefit methods must be employed, which involve imputing values to the physical effects of road investment and converting them to a monetary equivalent. Because the most important single effect of most road investment (and of any policies towards road users, involving for example, vehicle regulation) is to change journey times, the value to be attached to these savings is central to any economic judgment of the value of this type of public expenditure.

0.1.2. Second, in considering general prediction problems concerned with the overall pattern of tripmaking or particular ones, concerning the demand for an individual link in the road network, journey times are a major element in whatever model is employed. Where more than one factor is involved, for example, time and money cost, some weight, or value, must be attached to time to assess its affect relative to these other factors.

0.1.3. Third, while other public sector expenditures effect queuing or waiting time, these expenditures are small (except for telecommunications which is, however, charged for) and no research has been conducted on their particular problems.

0.1.4. A further restriction is that the paper will deal almost entirely with the person, and not vehicular time, first, because many of the problems involved in assessing values for vehicular savings are the same as far as valuing person time, but second, the problems in valuing person time are much more extensive and complex, and finally, person time is by far the most important component of total costs and benefits.

BRIEF OUTLINE OF PAPER

0.1.5. The paper is divided up into five parts. Part 1 deals with the theory of valuation. The basis in economic theory of deriving values for time is considered and the nature of the assumptions underlying the derivation of values from the analysis of choice behaviour is described and the validity of these assumptions assessed. A final section deals with some general theoretical problems. Part 2 is concerned with the empirical realisation of the theoretical approaches discussed in Part 1. The methods used by recent workers in the field are described and the conditions under which valid empirical results can be obtained are defined, and the possible contribution of each methodology assessed. Part 3 sets out the values which in the authors views and in the light of available empirical evidence should be used in the transport sector. Part 4 describes, firstly, the problems of using these values to assess projects in isolation, and secondly, using time values to predict behaviour and assess network investments in the context of traffic models. Part 5 concludes the paper with a consideration of major research needs.

0.2. SOME DEFINITIONS

0.2.1. Before beginning the main text, an explanation of some of the terms used in the paper may be helpful.

0.2.2. The expression "the value of time" is commonly used as a short hand for the value to be attached to saving time. But even this expression can be misleading, since this in turn is compressed and potentially ambiguous.

0.2.3. There are two basic reasons why time savings are valued: first, the obvious reasons, above all for working time, that time savings allow further activities to be engaged in. In the case of working time this is the predominant reason; if working time is saved then in general more economic value can be produced with the labour released. In the case of leisure time similar reasoning applies: if time is saved, other existing activities can be conducted at a more leisurely and pleasant pace, or alternatively, other new activities can be engaged in. The second reason is particularly important for leisure time. For most occasions, travel can be assumed to have positive disutility, different conditions of travel will result in different degrees

of disutility to the traveller and hence different values of time. Thus a typical commuting journey, involving walking, waiting, travel and interchange time, is best treated in terms of the different components, since each of these stages will, to a given traveller, convey different amounts of disutility because of the basic conditions under which the time is spent. In these circumstances a change in the composition of overall journey time may be accounted valuable even where total journey time remains unaltered. Thus "Time saving" is a composite entity taking on different attributes in different situations - freedom from irritation at delays, freedom from physical effort, from overcrowding. Reductions in the lengths of time that have to be devoted to enduring these various conditions may be accounted valuable in themselves even though no explicit consideration is given to expanding a traveller's range of activities and hence "saving time" may be valued, even though the savings are not seen in any way as productive. This point will be seen to be important below where certain types of time saving are considered which do not obviously allow further activities to be undertaken.

0.2.4. One important consequence of their being different degrees of disutility attached to time experienced in different ways, is that it is desirable wherever possible to refer to these conditions explicitly: hence a distinction will be made frequently in the paper, between walking time, waiting time and in-vehicle or overall travel time. In principle, a much finer categorisation of time would be desirable reflecting the wide range of conditions surrounding travel, but these are all it is practicable to make at the present time.

0.2.5. In the whole of the paper a basic distinction will be made between working and non-working or leisure time. Working time includes all journeys made in the course of work, i.e. during time which is paid for by the employer; non-working time includes all other journeys, i.e. during time which is not paid for including in particular journeys to work as well as journeys on personal business, holidays etc. As we will see below, there may be a case for further sub-dividing this category.

0.2.6. While the distinction between the two categories is obvious enough, there are some categories of trip maker which fall uneasily between the two, e.g. the self-employed or certain

categories of employee whose salaries are invariant with the length of time actually spent working. Such people may take time savings in the form of leisure or extra work. This problem is, however, essentially a practical one and in principle could be overcome by applying some of the methods of analysis described below. Once these have established the division in practice, then it is a matter of convenience into which category they are placed. Apart from a brief discussion in Part 1, this group will be ignored.

PART 1

1. THEORY OF VALUATION

1.1. WORKING TIME

1.1.1. A number of approaches have been suggested for the evaluation of working time*: Haning and McFarland (1963) for example employ the net operating profit method. This method identifies time values with the increase in profits that a firm may earn with the extra time, i.e. gross average revenue per hour minus (mileage) variable costs. For various reasons, this method is unacceptable. On one interpretation it implies demand to be implausibly responsive to changes in journey time, or alternatively that obstacles existed to the expansion of demand before the time saving was experienced. If, however, it is intended to rest on an assumption of rising secular demand then the relevant measure is the opportunity cost of the resources that would have had to have been brought into the industry.

1.1.2. The most usual approach has been to estimate value by reference to wage rates often known as the cost savings approach: the obvious theoretical backing for this approach is the marginal productivity theory of factor rewards. Employers hire labour until it is no longer worth their while to do so. As it is normally assumed that all workers of a given type are paid the same, then the average wage equals the marginal value product; hence the wage rate is a satisfactory measure of the value of production gained or lost by changes in the labour force, as long as the changes under consideration are small relative to the markets in which the prices are set, and as long as there are no subsequent changes in wage levels.

1.1.3. A first qualification is that the wage rate must be taken to mean the total cost to the employer of employing the class of labour under consideration. Thus for purposes of practical calculation such costs as social insurance, employment taxes and costs such as the provision of uniforms etc. which are borne by the employer are included as wages. The following paragraphs review a number of objections to the cost savings method.

* For a listing, see National Co-operative Highway Research Programme Report 33.

1.1.4. Objection 1: Imperfections in the labour market may mean that the value in other uses of labour using road transport is not adequately represented by the wage rate.

Comment

There are many reasons why the wage paid to a class of labour may inadequately reflect its opportunity cost: union restrictions, customary relativities sometimes based on convention, notions of equity etc., or the special conditions pertaining in the profession e.g. the armed forces or other jobs subject to discipline or special dangers. There may, too, be groups who are paid less than their opportunity cost - possibly nurses or other workers giving personal service (cf. Evans 1969). None of these factors are likely to be of major importance for those occupational groups who make up the bulk of the travellers in working time - professional drivers, salesmen, service engineers etc. These are all groups where there is a high degree of mobility in and out of the profession, strong unionism in some cases, but not in the sense relevant here restrictive and not subject to notions of 'service' or status. Obviously as nearly all occupations travel in working time, though by no means to an equal extent, a proportion of this category of time saving must accrue to those whose time is 'wrongly' valued, but for practical purposes this effect may in our view be discounted.

1.1.5. Objection 2: The release of resources assumed in theory may not take place, because of labour restrictions.

Comment

In some cases, however, labour restrictions are in force which do have implications for the economic value of working time saved. In the United Kingdom some agreements among specialist haulage firms provide for a fixed average speed of working which is invariant to the specific conditions obtaining on a given route and which are only gradually responsive to overall changes in travel time while in the United States, hauliers are licensed on, and restricted to, individual routes. In this situation, gains in working time are converted into leisure time and should be valued as such (although one may doubt whether the value of free time during nominal working hours is equivalent to leisure time under genuinely free conditions). However, the situation becomes more complex if one considers the normal context in which

time values are adopted for the purpose of evaluation i.e. an on-going continuing investment process, not typically an isolated scheme. Over time, restrictions are relaxed, productivity agreements negotiated and the time savings realised at their face value. There may therefore be a case for making some assumption about the date at which savings are fully realised - though tests run on the present values of schemes have shown that the effect is not large especially when one allows for the fact that the savings have value at least at leisure time and that most users of roads in working time are flexible and hence responsive to change. In certain circumstances, however, one may doubt if there is any justification for assuming deferment. If, because of previous investment, or other changes such as improvements in vehicle performance, there is already scope for adjustment of schedules as such, then the effect of a further lump of investment may be to 'tip the balance', and consequently lead to a greater than expected saving. Thus, unless it is the case the negotiation of schedules is on a regular 'n' year basis and one makes the further restrictive assumption that one is only considering investment over a period which does not include negotiation, the use of the average values at their face value may be justifiable even where labour restrictions are obtained. It has, however, to be conceded that the counter-arguments rest on a number of assumptions (e.g. on the distribution of the probabilities of realising time savings) which may not be empirically valid.

1.1.6. Objection 3: The same problem may arise because of inability of road using enterprises to convert time savings into resource savings.

Comment

The same type of argument may be applied to the next problem. Firms may be unable to convert time saved into economic value for many reasons, including managerial incompetence, but the major problem raised in this context is that of indivisibilities. Thus, typically, even fairly large investment yield savings that are both absolutely and proportionately small in relation to the effective unit of work - the trip or the working shift. In this situation, it is frequently alleged that the savings have no or little value. As this problem is common to all types of time savings, it will be discussed in a separate section below on general theoretical problems.

1.1.7. Objection 4: The assumption that resources have other alternative uses may not always hold.

Comment

Time savings accruing to commercially used vehicles represent an increase in the potential capacity of the road transport industry, but there is, at the same time, no necessary increase in demand to take up the extra capacity for work. Hence, if all other things were equal resources would be released for other purposes. In practice, however, the general growth in demand for road transport common to all countries is such as to prevent this happening in most cases and hence the issue does not arrive. In certain cases where there is persistent structural or localised unemployment and demand is growing slowly, if at all, the opportunity cost of driving time may be less than wage rate by a considerable amount, and it may be appropriate to use a shadow price adjusted to allow for the less than unit probability of the displaced driver being employed elsewhere (it would of course be appropriate in this circumstance to use a similar shadow price for local labour when estimating the cost of the construction of the road concerned for purposes of investment appraisal. The implicit assumption of this argument, is, of course that wages are, for institutional reasons, sticky downwards).

1.1.8. Objection 5: While the marginal productivity theory may hold in micro-economics, it is less easy to accept its macro implications.

Comment

The difficulty here can be seen by considering the implications of an increase in employment tax payments. This would on the principles outlined above, automatically lead to an increase in the value of working time since taxes on employment are part of the cost of the labour to the employer. But this, if the increase is, say 100 per cent, is clearly absurd. The implications of this depend on the model of employment and wage determination assumed to be appropriate. There are three possible lines of analysis. First, one could argue that if the government is pursuing an overall full employment policy while taxing labour in order to encourage substitution by capital intensive methods, it could mop up the employment that results from the too high, i.e. taxed, level of wages by increasing the size of the public sector.

In this case it could be the case that the marginal value product of the new public sector employees would fall below the marginal value product in the rest of the economy and (assuming their re-deployment in the public sector) any saving of their time should not be valued at the public sector wage rate. However, the labour employed in the rest of the economy (including of course the main transport using industries) would still be producing its marginal value product, since being subject to the price mechanism it has no alternative, in which case the methodology proposed here would remain valid. Second, if the tax increase were modest, it may be assumed that the only effect is to reduce the rate of increase in money wage rates i.e. the tax falls directly on wages, in which the proposed method still holds, or, thirdly, it could result that the effect of the tax increase is to produce a new level of wage costs which is unstably high and an inflationary movement is begun which produces a new equilibrium level of prices and wages, where employment is at its pre-tax level. In this case, the cost of labour immediately on the imposition of the tax would be inappropriate at the time it was assessed, but would become appropriate when the inflationary process had worked through, at the new higher level of prices. Despite all these complexities, none of the three lines of analysis raises any serious doubts, except in extreme conditions about the validity of this method.

1.1.9. Objection 6: It values working time purely from the point of view of the employer and does not consider the value the employee might place on the savings in journey time and hence the way his work time is spent.

Comment

The degree of disutility which the employee attached to his work varies with a wide range of factors; one relevant factor is the actual task he is involved in: for those who spend only part of their working day driving e.g. delivery or salesmen, a reduction in the driving task means an increase in the amount of time spent on other tasks. In principle therefore, an allowance should be made for their perception of this difference. In the long-term, the difference should show in the wage paid i.e. if more driving were welcomed, then wages would fall or rise less fast, and the benefit could be estimated this way. In practice, this solution appears non-feasible, but so also is direction attribution of changes in the disutility of work, since it is not clear which way the adjustment should go.

1.1.10. Objection 7: It treats time purely as a disutility: in some cases travel time may be used productively.

Comment

In some cases journey time may be used productively, e.g. where the mode of transport allows work to be carried out in the course of a journey, e.g. time spent on a train may be used for reading. This case is likely to be unimportant for road transport since (except for bus travel which is little used in working time) there is little opportunity for such activities. Passengers may at times use their time productively, e.g. if chauffeur driven, but this is relatively rare.

1.1.11. Objection 8: For some classes of worker, no distinction can be drawn between working and non-working time.

Comment

The problem posed by those whose hours of work are fixed, or who are paid according to work done, or who are self-employed. If such people save time during a work journey (if indeed it is possible to determine into which category the journey falls!), they may choose to work more, or they may prefer to have more leisure, or probably, a combination of the two. In this situation the theory outlined here is inappropriate and the derivation of values must rest with the empirical methods discussed below. The objection must be allowed in principle: on what information is available in the United Kingdom, this group is unlikely to form more than a small proportion of total travellers in working time.

PREDICTION OF VALUES

1.1.12. Most investment appraisal involves a prediction of future levels of benefits, hence a method of predicting future values of time is required. This problem is relatively straightforward with working time; given the theoretical framework outlined above, the value of working time is determined by its productivity and hence all that is required for predicting future values is a view as to the future rate of growth of labour productivity in real terms (per man hour). This rate can then be applied to the total wage cost i.e. it may be assumed as suggested above that if taxation or pension payments rise faster than productivity, then wage payments are reduced accordingly. A similar argument may be applied to other costs associated with the employment of labour. The normal method of desiring a rate of growth of productivity produces

an average value of time if this figure is used for predicting marginal value, there is an implicit assumption that marginal and average values will grow at the same rate. While it is difficult to justify this assumption, it is more difficult to find a better one.

1.1.13. For most transport purposes, this treatment is satisfactory: in some contexts, however, it is necessary to consider what the reaction of the system would be to the predicted increase in costs. In the case of goods transport, if there were no corresponding increase in labour productivity (or any other countervailing factor cost changes) and thus if productivity in road transport was assumed to be lagging behind the national average, then the level of demand might be effected because of the resultant increase in absolute and relation prices. In most contexts, it would be appropriate to assume explicitly some countervailing productivity increase in response to the increase in the cost of labour inputs, for example, in making projections of maintenance costs, it would be appropriate to assume increasing mechanisation in the face of increasing labour costs.

VEHICLE TIME SAVINGS

1.1.14. The theoretical basis outlined above for labour time has to be adapted for vehicle time savings which present some problems of their own. These are discussed briefly in Annex C.

1.2. NON-WORKING TIME

CLASSICAL THEORY

1.2.1. The traditional economist's starting point for the consideration of the value of leisure time has been the labour market: it would appear obvious that in a free market for labour the marginal value of leisure to the consumer is equal to what he foregoes by way of extra earnings. This theory has come in for some criticism (of Moses and Williamson) on the ground that the length of the working week is given as far as most individuals are concerned: hence all that can be said from the observations that people do in fact work is that the total utility gained from earnings outweighs the total loss of leisure, nothing about marginal values (and there can be no presumption that marginal and average values are equal).

1.2.2. Recent theoretical development, has, however, shown that this simple formulation (to be found for example in an elaborate version in Becker) is wrong for a further reason in that it ignores the disutility attached by the consumer to the work situation per se: the fact that different categories of work gave rise to different degrees of disutility has been recognised in economic theory since the last century at least, but has not, until recently, been embodied in the theory of the allocation of time. When this is allowed for the equilibrium situation is defined by an equation of the form

$$\frac{U_i}{U_y} = P + \frac{U_w^*}{U_y}$$

where the marginal rate of substitution between income and leisure, $\frac{U_i}{U_y}$, is defined as the sum of two terms, the first, as in traditional theory, the money wage P , and the second, the marginal rate of substitution between income and time spent at work $\frac{U_w}{U_y}$. Thus the marginal utility of leisure time is equal to the marginal utility of money less the marginal disutility of work. Accordingly the value of leisure time should be some amount below the average wage rate, even in a free market but the extent of this divergence is determined by the value of the second term, in which a priori considerations shed no light. The value of travel time will again differ from this measure to the extent that the disutility attached to travel is different from that attached to work. Where disutility of travel is negative (i.e. the journey is valued for itself) then a time saving can have zero, or even negative value.

1.2.3. Further considerations supply further reasons why the traditional marginal equivalence should not hold. These can be seen from considering the consumer also as a producer in the sense that he may (a) buy certain commodities not for their utility but because of their ability to create it as intermediate goods, and (b) choose to supply services directly to himself or

* An equation of this form has been developed independently by a number of authors. See Johnson (1966) Oort (1969, Evans (1969) and also Philips (1969). See Evans for a general development of the theory of consumer behaviour and Philips for a consideration of the implications of the Johnson/Evans/Oort approach for empirical studies.

buy them in (e.g. household repairs). The longer a consumer works, the more he is likely to have to buy convenience goods labour saving devices, obtain domestic help and not do it himself. Thus his effective net wage at the margin is much less than what he actually earns. It may in fact be negative if he prefers work to housework: - not an implausible situation for the married, childless wife.

1.2.4. Thus, to sum up, the classical theory even when adapted and extended does not yield a method for deriving a value for leisure time, still less of travel time specifically. Other methods must therefore be adopted.

BEHAVIOURAL APPROACHES

1.2.5. While some have accepted traditional theory, most of the empirical workers in the field have ignored it, on the presumption that the value of personal time is best measured by observing how people in practice trade off travel time savings against cost. The traditional theory does not of course imply a particular value. The problems of this approach as a METHOD will be discussed below: here all that is relevant is an appreciation of it as a principle of valuation. Before it is acceptable as an applied principle certain empirical conditions should be satisfied: for example, that the choice makers were aware of their choice and had had time to adjust to the alternative facing them. It would probably be considered unacceptable for example, to infer values from behaviour where people had little notion of what they were 'purchasing' or where emotions were strongly involved, as would arise in connection with safety or health. In this case, it might be thought that an 'administrative' judgment was preferable, partly because one would not expect much stability in the values obtained from such circumstances and partly because it was held that in the circumstances the consumer was not the best judge of the value of what he was consuming and while resources may be allocated in the private sector according to the iron whim of the consumer, it is frequently an aim of public policy to reduce the extent to which it occurs (e.g. by legislation on trade descriptions, advertising etc.).

1.2.6. Second as the section on definitions indicated the value of time savings depends not on the use to which such time saved would be put, but on the disutility attached to the travelling time saved. Walking time and waiting time are examples of types

of time which may well have different disutilities to the traveller, and different again from actual travelling time in a vehicle. Hence as a second requirement any method for deriving values of time using empirical analysis of travellers' choices in trade-off situations, should be able to disentangle the effects of the different time types in the whole journey; otherwise the value of time measured is a specific average of the values of the different time types occurring in the situation being analysed and is not, unless the 'mix' is constant, a meaningful number. Early studies using the revealed trade-off technique did not make this distinction between types, and their results contain significant biases (see Section 2:2).

1.2.7. Not only are different time types a source of different values of time; any empirical situation will contain a population of choice-makers who in general will collectively exhibit a distribution of values of time. Much of the variability can be attributed to real differences in personal or household circumstances - for instance, income - and some indeed may derive from differences in psychological attributes which lead to fundamentally different attitudes to the trade-off situation. Insofar as any or all of such EX HYPOTHESI sources of variability may exist in the empirical situation under view, a further requirement in the approach to the trade-off method of valuation is to establish by whatever means possible the effects of such factors, if any, on the overall average value of time. This can sometimes place considerable demands on the skill and ingenuity of the researcher; more than one of the earlier studies lacks generality because no check was made at the time of the effect of factor which even without the benefit of hindsight one might have suspected to have affected the derived time values.

1.2.8. A third requirement is that the individual's judgment as to the value of his time can be accepted as valid in a social calculation. In many fields of public expenditure, e.g. health and education, government policy is designed to correct, as much as cope for, certain trends in consumer behaviour. In the field of transport there appears to be no reason why such principles apply; it is not obviously an aim of public policy that travel time should be reduced except insofar as people wish it to be. This would not be true if it could be shown that productivity, health etc. or other facts not taken into account by the individual were important, but there appears to be no reason to think that they are.

1.2.9. A fourth and much more difficult requirement is that the income distribution implications of accepting values based on this method are acceptable. It is obvious that observed prices are likely to be a function of ability to pay, and hence income; in fact all empirical studies have shown that the rich are more inclined to pay to save time than the poor. Some very familiar economic arguments suggest that this observed fact should not be accepted normatively. Consideration of the usual proposition about the declining disutility of money or, less abstractly, notions of equity or a more desirable distribution of income, would suggest that some counter-weighting should be employed. Some theoretical work on cost benefit analysis* has discussed the case for explicit consideration of income distribution i.e. that the beneficiaries should be identified according to whatever are the appropriate groups; the issue here is similar but the proposed treatment is different as it is concerned with the effect on the pattern of investment of choosing a particular valuation method and it is the method itself which has inherent income distribution implications. There is no subsequent correction or weighting of benefits according to beneficiary. The issue is particularly acute since, by their very nature cost benefit appraised investment are not paid for directly by beneficiaries, hence employment of this basis of evaluation will tend to shift investment towards the richer sections of the community, without any compensating increase in payments from them. Thus, by normal criteria, the distribution of income will be worsened**.

PREDICTION OF VALUES

1.2.10. Finally the 'measurement' approach may also be applied to the problem of predicting future values, where it is possible to associate values with independent variables which can themselves be predicted. One obvious candidate is income since it is apparent from the theoretical considerations outlined above that future income levels will be a prime determinant (and this confirmed by empirical studies). However, it is also necessary to consider the other terms in the equation given above. "If they remain constant, then the value of non-working time will grow at the same absolute rate as working time i.e. proportionately faster. However it is perfectly possible that the disutility of

* Cf. Weisbrod in S. B. Chase (ed): Problems in Public Expenditure Analysis.

** For a more extended discussion see Harrison (1969 ii).

work and the disutility of travel will alter, partly for reasons of change of taste (which may relate to income) and partly because of changes in objective conditions, such as work environment, average congestion levels etc. As between modes a further relevant factor is the extent to which other activities may be engaged on in travelling. If it is possible to read or otherwise use time productively then there will be a damping effect on growth in values, and vice versa. This has obvious implications for the values of time as between transport modes.

1.3. GENERAL THEORETICAL PROBLEMS

1.3.1. This section discusses a number of aspects of time valuation common to both working and non-working time.

SIZE OF TIME SAVING

1.3.2. This problem is put in two basic forms: first, is one saving of ten minutes worth ten savings of one minute; and second, do savings under some given amount have any value at all. Before these questions can be tackled, some theory must be developed as to the way in which time savings are of value to people. In the introduction it was pointed out that time might be valued for two reasons: first because of the opportunities it presents for other activities to be undertaken and second because of its relative disutility. The full theory obviously comprises both these reasons in one utility maximising model.

1.3.3. If we consider the first reason, it is apparent that it would be naive to suppose that time savings of all sizes could be, on all occasions, recognised as economically valuable at the same rate. This would be to suppose an unreal degree of flexibility among transport users. An obvious development is some sort of probabilistic model on the following lines: if we assume that there exist indivisibilities and constraints which prevent users adjusting perfectly to the traffic situation facing them, then we may also assume that some margin of slack or idle-time exists within their current arrangements. We may further assume a continuous and uniform distribution between perfect adjustment and some maximum level of maladjustment. Thus if we consider a ten minute time saving in relation to ten one minute savings, it is obvious that the probability of the large saving allowing readjustment to take place is greater than any of the individual one minute savings. However, on the assumptions given, there is no reason to suppose that the former probability is greater

than the sum of the probabilities over all the one minute savings, since even a small saving would be sufficient to allow those just below the margin of maximum maladjustment to make some rearrangement and realise time savings much larger than the single minute saving. In fact a model of this sort is equivalent to assuming a continuous demand curve, on which there are always marginal users, ready to respond to small changes in the conditions facing them. It is not difficult to construct simple arithmetic examples which show the equivalence of the numerous small savings with the single large saving, but it is apparent that any argument for equivalence must depend heavily on the validity of the probability distribution assumed. A number of plausible alternative distributions would not produce the required equivalence, and there is little or no empirical evidence one way or another. We are concerned here mainly with pointing to the existence of a theoretical justification of some plausibility for disregarding size of time saving.

1.3.4. It is obvious that this line of argument can be deployed to justify attaching value to small time savings even where these are much smaller than the unit of output (say the journey). A further and important line of argument may also be addressed to this problem. The normal context in which time values are used is that of a continuing expenditure programme or a total traffic plan. Such programmes typically consist of large numbers of individual items which may be analysed separately. Let us take the example of a traffic management scheme for an urban area: each component may be small and present very small gains: similarly some of the measures brought in to increase pedestrian safety (e.g. crossings) may impose very small delays. In these circumstances it would obviously be fallacious to ignore small time savings on the grounds that they were too small to be noticed; if this were done, there would be pedestrian crossings everywhere and no vehicular traffic. Thus to deny value to small time savings is to start on a very slippery slope since it is by no means obvious by reference to what criteria time savings would become worthwhile.

1.3.5. Consideration of the second basis for valuing time savings suggests a further reason for not ignoring small savings. In the case of pedestrian crossings, roundabouts etc. the main effect (at moderate levels of flows) is to interrupt free flow and lead to an irregular and more tiring driving experience even

where total journey time is not affected (as these may not be in certain conditions). Thus as far as leisure time is concerned, the main source of benefit from this kind of saving may lie with factors correlated with time saving rather than time saving per se. This implies one of two courses, (a) to attempt to disaggregate time savings into components such as 'reductions in discomfort', reduced tension etc., or (b) to develop a series of specific values of time, the appropriate ones to be selected according to the situation concerned.

1.3.6. Finally a different kind of consideration. In both public and private sector resources are devoted to saving consumers small amounts of time: for example, telephone switchboard capacity is determined by reference to acceptable very small delays in obtaining service. Similarly, a large number of convenience goods or labour saving devices are purchased which produce similar orders of saving.

VARIANCE IN JOURNEY TIMES

1.3.7. One effect of replacing a congested road by a road on which free flow speeds are attainable is to increase the probability that a journey can be achieved within a given time limit. Congested conditions can of course be anticipated, but the effect of random events - breakdowns, accidents etc. - is much greater when roads are near or in excess of the capacity, than when there is plenty of capacity spare. It is not difficult to show that a reduction in journey length variance is equivalent to a time saving of similar (though normally rather less) extent. Thus we assume extreme conditions when a deadline or schedule must be adhered to and the probability of not achieving it reduced effectively to zero by the traveller, then the time allowed for the journey must be the maximum expected time, however infrequent that is. If the variance is reduced even without any corresponding reduction in mean journey time, users will experience a benefit - in this extreme case equivalent to the whole of the reduction. Normally of course, mean times will be reduced simultaneously, but this effect remains an independent source of benefit, which has been, as far as we are aware neglected. Again, alternative distribution will produce different answers.

MARGINAL AND AVERAGE VALUES

1.3.8. The question is often raised, though rarely answered: are marginal and average values of time identical? Sometimes this is a version of the first problem discussed above, but the treatment

suggested has effectively evaded the issue since it suggested that a small time saving may lead to a large one being realised and a large one may lead to only a small effective saving. Hence no inference with regard to marginal and average values may be drawn.

1.3.9. An alternative interpretation of this question concerns the validity of using the same unit values for isolated schemes as for large investment programmes: a small scheme may have only a small effect on any individual, but large schemes e.g. the creation of an intercity motorway network may be felt to represent more than marginal changes. One may on empirical grounds question the force of the distinction. Long journeys are infrequent in leisure time, and hence even a large programme has only a small effect on the majority of individuals, even though it may have a large effect per unit of long distance trip making. And with regard to journeys in working time even a large motorway network will carry less than 5-10 per cent of total trips and no remarkable change in the labour force required in the road haulage industry and hence in the wage rate to be paid is to be anticipated. At a theoretical level, however, it has to be allowed that the valuation determined at the existing margin may not adequately reflect the importance of all changes in aggregate, since there can be no general reason to suppose the equality of marginal and average values. In the case of working time, it is, of course, normal to draw rising labour supply curve to an industry, not a horizontal one (at least in developed countries); while with regard to non-working time, the classical theory as reformulated suggests a similar conclusion. In our view, however, the effect of even a large investment programme is insufficiently large for there to be large divergences in practice between marginal and average values.

1.3.10. A final problem is put in the form of the question; is it always marginal time which is saved? There are obvious cases, where intra marginal time is involved - for example where hold-ups are unexpected and where as a consequence time may be valued very much in excess of its values where time tables were adhered to. But it is not customary (perhaps wrongly) to assume any variation in the unexpected; what can be said of the expected?

One model of behaviour suggests that firms (with regard to working time) and individuals (with regard to non-working time) will adjust their behaviour so that the marginal value of time is equal at the margin of each activity*. Thus the firm will adjust its labour force and its schedules while the individual will adjust his pattern of behaviour.

1.3.11. Where constraints exist - for example because of fixed hours of work and fixed hours of a participation in certain leisure activities such as theatre going, it is probable that adjustment will not be perfect and time will possess different values at different times of day and hence it could be argued that on some occasions intra-marginal time will be saved. This only presents difficulty if (as is in fact the case at present) valuations can only be obtained for 'constrained' time of day. If a wide enough range of trips is observed, then this difficulty disappears.

* See Evans (1969) for a more precise formulation.

PART 2

2. MEASUREMENT

2.1 WORKING TIME

2.1.1 If the marginal wage theory is accepted then problems of measurement are relatively simple; what problems exist as far as wage and related elements are peculiar to the statistical deficiencies of each country; nothing of general interest arises. We do not wish to imply that the practical problems may not be severe. They can be, but it is not appropriate to discuss them here, since little of a general nature can be said.

2.1.2. An exception to this is the estimation of the proportion of overhead cost - the marginal wage increment as defined above, for which no readily available statistics are available from standard series. Overhead wage cost ratios are often quoted for production workers of higher executives, but these are of little interest, since they are normally obtained by dividing some total cost figure by the number of employed in the relevant class, and hence bear little relation to the required measure, which refers solely to those costs which vary with the level of employment, but not with the level of production.

2.1.3. Some pilot work on this problem has been done in the United Kingdom for the Ministry of Transport (See Harrison 1969 iii): basically there are three approaches: interviewing accompanied by case studies of firm's actual costs: development of a production function from historical or cross-section data: estimation of a production function from engineering cost accounting data.

2.1.4. All of these are difficult to apply as general techniques although they may be successful in some cases. In M.O.T's own investigations, the first and third approaches were tried, the second failing for lack of relevant data. The first yielded meagre results; most firms found it difficult to recognise the concept being investigated - and certainly had not measured it themselves. But some were able to provide information on particular cost items, associated closely with the employment of staff - personal equipment such as tools and

uniforms, rest rooms etc. Severe difficulties arose however when attempting to estimate savings of long-run costs and no firm estimates have been possible.

2.1.5. The third method has so far been employed in a limited basis, by considering the cost structures of firms using road transport and attempting to estimate by a prior reasoning and informed judgement exactly which cost components might be expected to vary with the output/employee ratio. This method seems practical for commercial vehicles, since cost structures are relatively homogenous: it is less easy for users of car transport, since such users come from a wide range of industries and carry out, when off the road, very different functions. Little progress has been made with this type of road user.

2.1.6. Very little work has been done on the problems listed above in the discussion of principles. Some work has been done in America by Fleischer (1962) and Haning and McFarland (1963) and in the United Kingdom by one of the present authors (Harrison 1967) on the question of the utilisation of time savings, but this is, for various reasons limited in its scope. The work by Fleischer is a detailed case study of a particular long distance trucking operation, tracing its development over time, as successive improvements occurred to the highway on the route it involved. The study brought out the fact that because of the constraints under which trucking operations take place - limited driving periods in particular - time saving on the road could not always be utilised immediately but had to wait until further improvements took place and an entire rescheduling of the operation took place.

2.1.7. The obvious point to make about this finding is that the case study is of a case scarcely a typical type of road transport operation, especially in the smaller countries of Western Europe, and it is typical in another sense, the degree of regulation to which it is exposed. Most road using operations are more flexible, being over shorter distances, where the impact of hours regulations etc. is slight. And of course for commercial road users of cars, there is no restriction whatsoever. These, in United Kingdom conditions, and including only time savings to persons are more important than all heavy goods vehicle operations.

2.1.8. It is difficult to assess the work reported by Haning and McFarland - or at least that part concerning the utilisation of time savings. Using 'scaling measurement and subjective judgement', they suggest that (in the short-run) common carriers (route restricted to the United States) enjoyed only 40-60 per cent of potential value, private carriers from 80-100 per cent, with specialised carriers in between 60-80 per cent. They point out, however, that all time savings are of value - they may be used for additional maintenance, better service etc. but it is difficult to assess how valuable. It remains unclear how long the short-run is, how valuable these other activities are and finally how the scaling measurements turn out in practice to compare with actual experience.

2.1.9. The work done by one of the present authors (Harrison 1967) on the London-Birmingham motorway was much less thorough than the Fleischer study and laid no claim to statistical rigour: it was rather a pilot survey to assess the problems involved. From it only an impressionistic judgement could be reached.

2.1.10. In some way the Fleischer findings were confirmed; about 150 operators provided information, but among these one-third said that although they used the motorway it was a minor influence and its effect had not been noticeable. There was some evidence that it was the hauliers for whom the motorway represented the largest relative savings (i.e. those with a London or Birmingham base) who were most likely to be able to turn time savings into resource savings. Nearly one-third of the respondents mentioned labour relations as an obstacle to the utilisation of time savings. This was especially true of the trunk haul operators. In only a very small number of cases was precise information forthcoming.

2.1.11. The empirical methods so far employed in assessing the value of working time illustrate some of the problems of working in this field: the large number of firms involved, the range and variety of their operations, their general lack of cost consciousness as well as the ever present problem of *ceteris non paribus*. The problem is made even more difficult if the theoretical model outlined in the above of the utilisation of time savings is accepted, particularly if the proportion of firms

actually utilising any given saving is a small proportion of the total. For if this were so, the sample required to obtain statistically satisfactory solutions would have to be very large. One may doubt whether, in the face of the difficulties which empirical work is faced with, if such a sample could be obtained and analysed satisfactorily.

2.1.12. One obvious method, of which more will be written below, is to observe the reaction of commercial vehicle users and those using cars in business time in those circumstances where a time trade off is present. No systematic analysis of these seems however to have taken place in recent years with one exception of dubious worth (Gronau 1967). Pace the difficulties facing studies of this type, which will be gone into in detail below. It would seem worthwhile to attempt to verify the current values by this means*. The appropriate statistical methods are discussed in the next section.

2.2. METHODOLOGY OF MEASUREMENT OF NON-WORKING TIME THE BEHAVIOURAL APPROACH

2.2.1. In Section 1.2 above, it was established from classical theory that the value of non-working time was likely to be less than the average wage rate, but it was not possible to say by how much. The principle was put forward that given certain conditions, the value of non-working time was best estimated by discovering empirically what value people themselves placed on their travelling time outside working hours.

2.2.2. In this section we discuss at some length various empirical methods for determining values of time from analysing the revealed behaviour of travellers. This has over the past few years proved itself to be a fruitful area of work, and a considerable number (over a dozen) of empirical studies has been carried out. First of all, we discuss some general characteristics of the methods of analysing revealed behaviour, with a note on the empirical conditions which, as a distillation of the various studies done, appear to be necessary for deriving "good"

* This may be attempted in studies being commissioned by the Ministry of Transport.

values. Next, specific methodology is reviewed in each of the main areas where empirical work has been done, and various studies are assessed for their methodology. Then, there is a discussion of some general issues on the use of input data and on the interpretation of outputs. Finally, there is a short discussion on the usefulness of direct interview techniques for throwing light on a number of behavioural and socio-psychological assumptions which implicitly lie behind the more quantitative approach. In principle, all these methods could be used for deriving a value of working time - i.e. by analysing the behaviour of those travelling in working time. But as made clear in Section 1.1, there are good reasons for choosing as a value the opportunity cost of time to the employer.

2.2.3. There are a number of different methods that have been used in recent years, but they nearly all have one fundamental approach - to derive a value of time by analysis of situations where people can make choices between different "packages" of time, cost and other travel characteristics. For instance, workers who choose trains rather than buses to travel to work, are buying a particular travel package, in which they are prepared to pay to save time, compared with travelling by bus. There are a few quite distinct kinds of travel decisions, and each one is potentially susceptible to this sort of analysis. This list is of areas of choice where work has been attempted.

- (i) Choice of destination to travel to,
or frequency of trip-making to a particular destination.
- (ii) Choice of mode of travel.
- (iii) Choice of route.
- (iv) Choice of speed at which to drive.
- (v) Choice of relative locations of home
and work.

We shall examine each of these choice areas in turn subsequently; firstly we discuss some general characteristics of methods of analysing choices.

GENERAL CHARACTERISTICS OF METHOD AND EMPIRICAL CONDITIONS

2.2.4. When travellers make choices in any one of the choice areas mentioned above, they may well not be making a conscious trade-off between time and money; indeed there are usually very many other factors that both consciously and unconsciously effect their choices. For the researcher intent upon estimating a value of travel time, there is a danger in principle in trying too hard to find a value of time in situations where time or cost may not be important variables at all. All of this points to the need to approach the analysis of a choice situation with the primary object of trying to explain the choice, rather than trying to derive a value of time. If in fact a value of time emerges from the explanation of choice - then the effort is rewarded; if it does not, then nothing can be gained by twisting the explanatory relationships so as to yield a time value. This is an obvious point of research methodology and does not need labouring, but it is worth noting that the point could be made of more than one of the empirical studies reported on later.

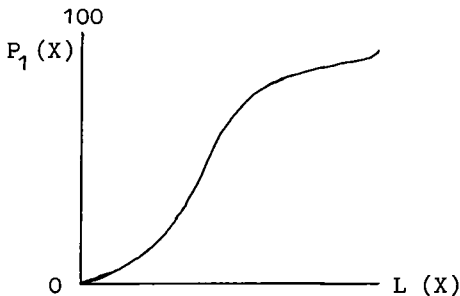
2.2.5. Basically the method is to formulate some models for topography which purports to explain rationally either the collective or, on a probabilistic basis, the individual behaviour of travellers, and to assign relative weights to different factors. Because such a model may well not appear to explain behaviour in specific individual cases, we must deal statistically with large numbers of people, and we then use statistical techniques to derive quantitative values for the model or hypothesis. Immediately, this imposes certain conditions which both the model and the data must meet if the method is to yield valid results. In order to demonstrate these conditions, and to illustrate the sorts of behavioural model and statistical techniques that are being referred to, a particular model in a particular choice area will now be described.

2.2.6. This is a relatively successful model that has been used in recent years to explain choice of travel mode, in nearly every case for commuters travelling to and from work. It is based on a linear function of the relative characteristics of one mode

with respect to the other - which some researchers (including the present authors) like to think of as a "relative disutility of one mode with respect to the other" - and a relationship for the probability of choice of one mode with respect to the other as a logical function of this relative disutility:

$$L(X) = a_0 + \sum_{i=1}^n a_i x_i$$

$$\text{and } P_1(X) = \frac{e^{L(X)}}{1 + e^{L(X)}}$$



Where X_i is a vector of values of relation characteristics of the two modes (time, cost, etc.), a_i a vector of parameters whose values are to be determined by analysis, and $P_i(X)$ is the probability of a traveller (or proportion of a group of travellers) characterised by the vector X choosing mode 1 for this journey. This general approach has been used, with variations in the statistical methodology, by Warner (1962), Quarmby (1967i), Lisco (1968), Thomas (1967 [This was for route, not mode, choice], Research Projects Ltd. (1969), Local Government O.R. Unit (1969), Lave (1968), Mercadal (1968).

2.2.7. This model has been used by most researchers in the first instance to explain modal choice rather than to derive a value of time; the emphasis has therefore been largely on obtaining as good an explanation of choice behaviour as possible with whatever variables have been available in the data and have been shown to be significant. The model itself is something whose form can be

derived ex hypothesi, either from economic concepts of disutility (see Phillips, Quarmby 1967ii) or from statistically based analogies in the physical sciences (see Wilson 1968). The statistical methods to establish a set of significant x's and a set of a's to go with them are various: discriminant analysis, multiple linear regression, and probit methods have all been used. The value of time is then, the ratio of the appropriate co-efficients: a_i/a_j where i is the time variable, j is the financial cost variable.

2.2.8. The model has generally been used by researchers to analyse individual choices, that is, using as data the actual choice made by each individual together with the values of travel characteristics facing that individual. It can also be used to analyse the behaviour of groups of people on a zonal basis: for instance, in a typical urban transportation study, where there is data from surveys about the movement of people between different pairs of zones, by the various modes available. The study would also normally throw up the times and costs of travel between each pair of zones for each available mode. For the purpose of illustration we assume only two modes are available. In this case, the vector x_i represents the values of relative travel characteristics between modes for a particular zone-to-zone journey, as they apply to the group of people making that journey (where the zones represent unit areas into which a conurbation may be divided, for the purpose of analysing and modelling the complete travel patterns of the conurbation). And $P_1(X)$ is the proportion of travellers choosing mode 1, so that multiple regression can be performed by transforming as follows:

$$\text{from } P_1(X) = \frac{e^{L(X)}}{1 + e^{L(X)}}$$

$$\text{then } L(X) = \log_e \left\{ \frac{P_1(X)}{1 - P_1(X)} \right\}$$

Thus with observed data about $P_1(X)$, since $L(X) = a_0 + \sum_{i=1}^n a_i x_i$

$$\text{regress } \log \frac{P_1(X)}{1 - P_1(X)} \text{ on } a_0 + \sum_{i=1}^n a_i x_i$$

2.2.9. We can use this model to illustrate various empirical conditions distilled from empirical studies carried out in this area and from other work by the authors. These conditions apply to the situation of choice in which travellers are being analysed to the travellers themselves, and to the model or hypothesis around which the explanation of behaviour is being built. Many of the conditions appear obvious when stated - but many studies can in fact be faulted in respect of them.

(i) THERE MUST EXIST REAL CHOICES

In cases where a choice between car and public transport is being considered, not only must all respondents own or have the use of a car, but it must be available for use - unless some index of availability is included as a variable in the model. In the case of drivers' route choice, where for instance the trade-off between faster travel and either a toll or greater distance on a motorway is being made against slower travel and shorter distance on all all-purpose road, then there must be no legal prohibitions on the drivers in question, choosing one or the other (e.g. learner-drivers, certain motorcycles, on motorways etc.), nor should any data be used for respondents who have overriding personal objections against using motorways (e.g. on grounds of fear). In the use of home and work locations, choices may well not exist if respondents or people in aggregate represented by data do not have enough income to afford more than a very limited range of housing.

(ii) CHOICES, WHERE THEY EXIST, MUST BE FULLY PERCEIVED, AND THERE MUST BE GROUNDS FOR BELIEVING THAT TRAVELLERS KNOW SOMETHING ABOUT THE ALTERNATIVES

In practice this is a fairly restrictive condition: it partly explains why all the successful trade-off studies have been, of commuting (journey to work), since someone making the same journey every day knows much more about the alternatives

than for any other journey; and can be presumed nearer to the state of rational equilibrium which most models imply. It means that modal choice and route choice studies of "one-off" journeys such as holidays and many shorter, social-recreational trips start at a disadvantage, and it may be impossible to achieve a good explanation of behaviour with a "rational" model. Besides the lack of knowledge about the characteristics of alternatives, it may also be that the traveller may not be himself in a situation of choice, even though real choices exist. This may occur where the particular choice is psychologically intrinsic to the wider purpose for travelling: for instance, driving down country lanes rather than on fast roads may be an automatic choice when on holiday and the alternative may never be considered. Again, the choice of flying to a holiday area may be made in the same way. The Research Projects Study (1969) already referred to contains, in addition to some analytical work on modal choice, reports of group discussions held with different groups of travellers in Greater London; one of these groups was of office cleaners, who were psychologically committed to travelling by bus to work, even though underground or Southern Region railway was entirely feasible as an alternative. They did not feel socially confident to travel on anything but a bus. This may be an extreme example, but it indicates the potential importance of this condition.

(iii) THE ORIENTATION OF THE ANALYSIS IS TO EXPLAIN BEHAVIOUR, AND ATTEMPTS MUST BE MADE TO EXTRACT THE EFFECTS OF OTHER RELEVANT VARIABLES.

Once more this is a condition which favours analysis of commuting trips in modal choice, because the other potentially important variables

besides time and cost can be quantified more easily than for other journey purposes, where qualitative aspects of car convenience (ability to carry shopping, children, etc.) may be important. In the work and housing location method, in which location rent in core-orientated urban areas is said to reflect the time cost and financial cost of travelling to work, there are a great number of variables which influence housing location relative to work, even when taking groups of people in aggregate, and some of these - such as environmental quality and amenity - are difficult to quantify. Where other relevant variables can be included quantitatively, there are techniques associated with the statistical methods which can be used to drop unimportant variables.

(iv) DIFFERENT TYPES OF TIME SHOULD BE
DISTINGUISHED

It has already been mentioned that time savings have a value not only in terms of what they can be used for, but also for any disutility of travelling that is saved. There is no reason why the disutility of travelling time spent in different ways - walking, waiting, queuing, standing in a bus, sitting in a car, etc. - should be the same, and analyses of choice situations should take account of the different amounts of time spent in different ways in the alternative options, whether in choice of mode, route, or where to travel to. Two of the early modal choice studies (Warner 1962, Beesley 1965) failed to distinguish between time types, and Beesley obtained a value of travelling time rather higher than that obtained by subsequent British studies - which may well be associated with the fact that his "travelling" time included a proportion of walking and waiting as well as travelling time in a vehicle. One of the early route choice studies (Road Research Laboratory: Dawson 1959) failed to distinguish between travelling time on the road round the end of the Forth estuary and queuing time

for the ferry to go across the Forth. To have allowed for this would not in itself have provided a reliable value of travelling time, but it was one factor that militated against obtaining one. Most of the modal choice studies have been unsuccessful in determining independent values of travel time by different modes, principally because the high collinearity between travel times by each mode in the observed data prevents separation of the effect of each in any of the analysis techniques used.

- (v) THE FORM OF MODEL IMPLICIT IN THE ANALYSIS TECHNIQUE MUST BE CONSISTENT WITH THE BEHAVIOURAL HYPOTHESIS UNDERLYING IT.

One of the early route choice studies (Claffey 1961) constructed a linear equation representing the proportions of drivers choosing toll roads or free roads in various states in the United States, as a function of costs, travel times, etc., and then estimated the parameters by regression. However, the dependent variable was one of the costs, and the proportion of drivers choosing a toll road was in the regression as an independent variable. No hypothesis about behaviour is consistent with the causality implicit in this form of the model.

- (vi) THERE MUST BE PERCEPTIBLE DIFFERENCES BETWEEN ALTERNATIVES.

In the absence of tolls on British motorways, there is often little perceptible difference in both time and cost simultaneously between fast but longer routes and slower but shorter routes. This as much as anything militates against successful route choice studies in the United Kingdom. Without perceptible differences, it would be impossible to relate behaviour to observed characteristics.

- (vii) EACH VARIABLE WHICH IT IS BELIEVED MAY BE IMPORTANT IN AN EXPLANATORY EQUATION SHOULD EXHIBIT SUFFICIENT VARIANCE IN THE DATA, AND THE VARIABLES EXPRESSING TIME AND COST SHOULD NOT BE COLLINEAR.

These are essentially statistical conditions but their importance can be intuitively appreciated. If a variable such as say difference in travelling times by two routes has a very similar value for all respondents, then it cannot appear in the analysis as an important variable nor can a meaningful co-efficient be assigned to it - even though in reality changes in this variable would bring about big changes in behaviour. This is another contributing factor to the lack of success of analyses based on route choice where data has been gathered at the roadside at one or two points. If the relevant choice is between a motorway and an all purpose road, or between a ferry and making a detour, it often turns out that the alternative facing different drivers are very much the same. In such conditions this is less of a problem with studies where data has been gathered at work places or at home; a sample so organised will tend to exhibit considerable variance in reported travel characteristics. The problem of collinearity between variables - particularly time and cost - is frequently severe, and can completely upset the derivation of a time value. It can be important in certain kinds of empirical situations, and it can arise with certain formulations of empirical model. For instance, in Claffey's route choice study (see (v) above) even when the model is switched round into a more plausible form, time differences for toll road/free road repairs are very highly correlated with cost differences (over 80 per cent). In modal choice studies where observations refer to individuals not to groups of travellers, the use of time differences and cost differences (or other expressions of relativeness such as ratios) usually avoids the collinearity problem, although absolute times and

costs by particular modes generally show high correlations. It is this effect which also tends to militate against obtaining reliable values of time for different modes, because the variables representing time by different modes tend to be highly correlated.

- (viii) THE ANALYSIS TECHNIQUE MUST SHOW A SUFFICIENTLY HIGH LEVEL OF EXPLANATION OF BEHAVIOUR.

Normal significance tests will enable this condition to be tested where conventional statistical methods are used. The danger lies in interpreting values of time from graphical or other non-statistical methods - e.g. Beasley - where the level of significance is not easily measured.

- (ix) THE POPULATION ANALYSED MUST BE ASSUMED HOMOGENEOUS IN THE CHARACTERISTICS NOT MEASURED.

This is obvious, yet without this condition no conventional statistical techniques applied to the whole population will yield valid results. There is some evidence that in the modal choice situation there are real differences between uses of different modes. Mercadal describes attitudinal tests carried out on a sample of long-distance travellers whose modal choices were being analysed, and there were definite personality tendencies towards a concept of "time-consciousness" among those who chose the faster mode, and of "price-consciousness" among those who chose slower and cheaper modes. The only ways to handle this are either to express these tendencies as variables on a scale and put them into the explanatory model, or to divide up the population according to ranges of measured tendency, and analyse each sub-group independently. It might well be that in the first method these variables would run away with most of the explanation, and that in the second method the sub-groups

as divided might consist almost entirely of users of one or other modes. If so, then we should know of it. Unfortunately Mercadal does not analyse his data in this way. The only British study to attempt to account for psychological rather than socio-economic or system variables is the LGORU commuter modal choice study: in this, the sample was sub-divided according to how much people said they liked or disliked travelling by different modes. It was found that there was slight but not conclusive evidence of bias. It is a fruitful area for further research.

(x) THE SAMPLE ANALYSED MUST SHOW NON-TRIVIAL PROPORTIONS MAKING THE DIFFERENT CHOICES.

This is important from the view-point of obtaining sufficiently large numbers making both choices to rule out gross sampling errors. But even with large absolute numbers, the proportions should still be non-trivial, since there will always tend to be overriding reasons which may not have been picked up in survey (or, if they have, cannot be quantified), which will explain why - say - 5 or 10 per cent of a population will ALWAYS travel by car (for instance). Thus in order to avoid having to try and explain the behaviour of a sub-sample in terms which probably do not apply to that particular group, it is safer to look for empirical situations where the population splits into proportions no more extreme than about 25-75.

2.2.10. These ten conditions do not in any way pretend to be the last word: each could be expanded to a much longer discussion. In addition, a number of particular conditions specific to certain statistical techniques have not been discussed, nor have particular conditions specific to certain choice areas been covered. Such conditions are often explicitly or implicitly covered in the write-ups of the more sophisticated studies.

A REVIEW OF METHODOLOGY AND RELATED EMPIRICAL STUDIES

2.2.11. We now examine at some length the five choice areas mentioned in 2.2., and discuss both the general methodological approach in each area, and the ways in which various researchers have attempted to derive time values. No attempt is made at this stage to review studies for their actual empirical results - we are only concerned with reviewing studies for their methodology.

2.2.12. (i) CHOICE OF DESTINATION TO TRAVEL TO, OR FREQUENCY OF TRIP MAKING TO A PARTICULAR DESTINATION.

The alternatives in the title exist because of different hypothesis about the substitutability of trips to A for trips to B, and because of real differences in substitutability between different trip purposes. The basic approach is the same, however - to relate the amount of trip making to a particular place to the time and distance costs (and any other components of "cost") associated with getting there, using as data either trip making to many different places from one origin, or trip making to one place from many different origins. One of the many alternative forms of the "gravity distribution model" will provide an a priori model to establish an explanation of the observed data, in cases where some substitutability of trips can be assumed. One such form is:*

$$T_{ij} = \frac{O_i \cdot A_j^f (c_{ij})}{\sum_k A_k^f (c_{ik})}$$

Where T_{ij} is the number of trips in unit time made from area or zone i to area or zone j; O_i is the TOTAL number of trips generated by zone i, and A_j is a measure of the attractiveness of zone j. $f(c_{ij})$ is a decaying function of the overall cost of disutility of travel c_{ij} between zone i and zone j. The bottom line serves to "balance" the model, i.e. to constrain that $\sum_j T_{ij} = O_i$. In the case where the data refers to trip making to

* Gravity-type distribution models, as used in a transport context can take a number of forms, depending on the precise conditions and constraints which the model-builder wishes to impose. The model described here is reckoned by the authors as suitable for modelling travel movements in either urban or inter-urban areas for journeys other than to or from places of work. For a discussion of alternative forms, see Wilson (1968).

several destinations from one origin, then $O_i / \sum_k A_k f(c_{ik})$ is constant for all observations, and the model reduces to:

$$T_{ij} = k \cdot A_j f(c_{ij})$$

The most common algebraic forms of $f(c_{ij})$ are $e^{-\lambda c_{ij}}$ and c_{ij}^{-n} , and sometimes the two in combination. Then the model reduces to:

$$\frac{T_{ij}}{A_j} = k \cdot e^{-\lambda c_{ij}} c_{ij}^{-n}$$

Whence $\log \frac{T_{ij}}{A_j} = k^1 - \lambda c_{ij} - n \log c_{ij}$

We suppose the travel "cost" from i to j can be represented as a linear function of in-vehicular time, distance, other types of time (e.g. walking), parking charges, etc., describing the journey from i to j . It is the relative weights (a_j) of the different components (x_h) that we want to find:

$$c_{ij} = a_0 + a_1 x_1 + \dots + a_h x_h + \dots + a_n x_n$$

since the ratio of a for travelling time to a for cost gives us the value of time. With several observations of T_{ij} , A_j and the associated x 's, then multiple regression can be performed with the following, where substituting for C_{ij} :

$$\begin{aligned} \log \frac{T_{ij}}{A_j} &= k^1 - \lambda(a_1 x_1 + \dots + a_n x_n) \\ &\quad - n \log (a_1 x_1 + \dots + a_n x_n) \end{aligned}$$

With both power and exponential functions in combination, as here, we have to take starting values of a_h and substitute them under the log on the right hand side, regress to obtain a_h under the λ , then substitute those new values back under the log, regress again and so on. With the exponential function alone, the right hand term drops and a straight linear regression is left. With the power function alone we have to do two regressions and iterate between them. Firstly choose starting values of a_h and substitute in the following, then regress to find n :

$$\log \frac{T_{ij}}{A_j} = k^1 - n \log a_h x_h$$

Then substitute n in the following, and regress to find a_h :

$$\left\{ \frac{T_{ij}}{A_j} \right\}^{-1/n} = a_0 + a_1 x_1 + \dots a_h x_h + \dots a_n x_n$$

Then back to the first one to find n again, and so on till convergence. There are problems with this method for road trips: firstly, times and costs are often highly collinear - the exceptions occurring if there are large stretches of motorway for reaching some destinations. Secondly, the level of explanation may be poor and convergence may not be achieved. Thirdly, a value for each A_j must be estimated and used together with observations for each T_{ij} . To some extent A_j is an artefact of the model, and while satisfactory formulae can be found for estimating a value to use in these models for many kinds of trips, the usefulness of the method depends on how reliable the A_j is. An alternative direct estimate of A_j is the total number of trips arriving at zone j in unit time, but this will not be readily available if the survey work is done at the origin end.

Furthermore, there must exist variations in speed between routes to different places, otherwise the time and cost variables in the C_{ij} will be so highly correlated that no meaningful regression co-efficients, and hence no implied time/cost trade-offs can be derived (see condition (vi) above).

There are no published studies of attempts to establish values of time from this method applied to data on trip making from one origin to several destinations.

The alternative approach, using data on trip making to one destination from several origins, has recently been attempted by Mansfield (1969i) on recreational trips to the Lake District.

In terms of the gravity distribution model above, much less is now constant over the data: since the $O_i / \sum_k A_k f(c_{ik})$ is different for each origin, only the A_j is constant over the data. However, if insignificant substitutability between the Lake District and other destinations can be assumed, then the model effectively reduces to something of the form

$$T_{iL} = k.O_i f(c_{iL})$$

Where T_{iL} is the number of trips from zone i to zone L , the Lake District etc. Proxies for O_i , in the form of population and car ownership levels, can be used to facilitate data gathering about many different origin zones. C_{iL} can be decomposed into its time, cost and other parts, and regressions similar to those above performed.

For a more detailed methodological discussion of trip distribution models and the value of time, see Mansfield 1969 ii. Generally this is an interesting method which with care could throw light on certain values of time not readily obtainable by the more "classical" methods as applied to modal choice - for instance, on social and recreational trips, and on long distance trips.

So far it has hardly been tried at all by researchers - probably because data is not easily available or easily obtainable, and probably because the task of meeting the empirical and statistical conditions, could be formidable. However, the objective of this method could be described as trying to formulate a "generalised cost" function - i.e. to set up a good, reliably quantified linear function for c_{ij} . This is discussed at greater length in Part 4 on Using Time Values.

2.2.13. (ii) CHOICE OF MODE OF TRAVEL

As has already been indicated, this has been one of the most successful areas for value of time work. Although Warner (1962) was the first to develop an individual-based model to explain the binary choices of commuters, the structure of his variables did not yield a value of travel time, as he used the logarithm of ratios of costs and of times as a measure of the relativeness of one mode against another. In other words, where the model is of the form discussed above, i.e.

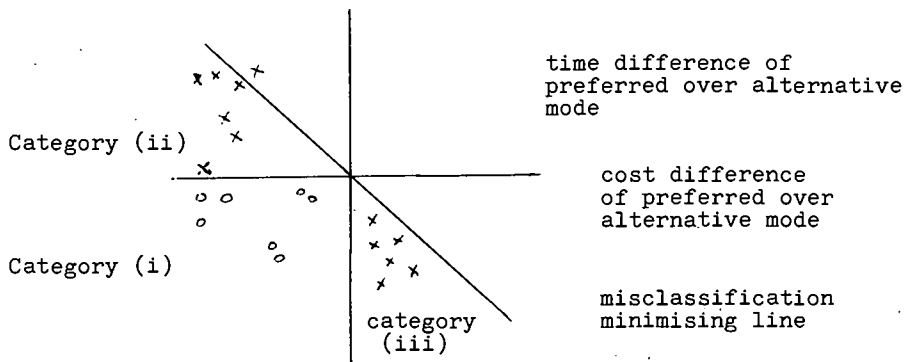
$$L(X) = a_0 + \sum_i a_i x_i$$

$$\text{and } P_1(X) = \frac{e^{L(x)}}{1 + e^{L(x)}}$$

x_1 would be $\log \frac{\text{time by mode 1}}{\text{time by mode 2}}$, x_2 would be $\log \frac{\text{cost by mode 1}}{\text{cost by mode 2}}$

The interesting implication of this form of variable structure is that time is valued solely in proportion to the total journey time, and cost is valued in proportion to the total journey cost. So it would be possible to say that for a journey of so many minutes and so many pence, there is a trade off between time and money of so much. But that trade-off is only defined for that particular journey cost and time. Now it may be that the value of time saved does vary with the total journey time but unfortunately Warner tested no other variable-structures to see if they gave better explanations of behaviour. Beasley was the first to attempt to derive a trade-off value for time and cost from modal choice data, only he did not explicitly use a model of the above form: his method can, however, be shown (Quarmby 1967 ii) to be formally equivalent to the discriminant analysis method of determining the parameter a_i in the $L(X)$ equation above where x_i are the DIFFERENCES between time, cost, etc. However, it actually operates much more simply and more crudely. Using information about the times and costs for preferred and alternative modes of travel, for each member of a group of travellers (for their journeys to work) then rational choices made would fall into one of three categories:

- (i) those choosing cheaper and faster modes
- (ii) those choosing cheaper but slower modes
- (iii) those choosing more expensive but faster modes.



The method depends on being able to find a straight line through the origin of the graph shown, so as to minimise the proportion of observations on the "wrong" side of the line. The basis of the method is that if the line is to represent the rate at which people will trade-off time savings against money savings, then none of those (or at least a minimum) actually choosing - say - a cheaper but slower mode (i.e. in quadrant ii) should be in a position of incurring more extra time than they are willing to incur for the money they are saving. So none of those in quadrant ii should be on the north-east side of the line (they should be in quadrant ii using the other mode then), and none of those in quadrant iii should be on the north-east side of the line. The first results on British data showing a value of time between 30 per cent and 50 per cent of gross personal income of the commuters, were obtained using this method, but were found in the light of subsequent modal choice studies to over-estimate the value of travelling time itself. Apart from the fact that Beesley was using very small samples (less than 40 observations), the travelling time which he valued actually contains some walking and waiting time. Subsequent studies have shown walking and waiting to have rather higher values of time than in-vehicle: this may help to explain why Beesley's value of time is higher than the values of in-vehicle time obtained by other researchers in the United Kingdom.

As a method, there are three main criticisms: firstly, it can only deal with two variables, since it operates graphically in two dimensions. Secondly, it offers no formal tests of significance or goodness of explanation. Thirdly, it cannot reliably obtain a straight line other than through the origin; although this can in theory be done by transposing the quadrant iii, points over into quadrant ii and finding the minimum misclassification line without fixing it through the origin, in practice there is too much "noise" in the data to permit it to be found with any degree of confidence. In consequence, it must always be assumed that at zero time difference and zero cost difference, the traveller is indifferent between modes. It is like forcing a_0 to be zero in the formal analytical method.

However, the method can give a very good intuitive idea of what the trade-off technique is all about, and since it can be done quickly without a computer it can be useful for looking at data prior to computer analysis. The Beesley method was used by

Barnett and Saalmans in a G.L.C. study (1967) of travel to and from work at County Hall: they obtained slightly lower values of time than Beesley did, but the same basic criticisms apply.

Since then there has been a rash of modal choice studies using the formal model structure already outlined. Nearly all have been on commuters travelling to and from work. In the United Kingdom, the first was one of the present authors, Quarmby (1967 i and 1967 ii, see also 1966 for a readable summary of the method and results) and in the United States Lisco (1968). Quarmby used discriminant analysis to obtain a_i in $L(X)$ function for explaining choices between car and bus, and between car and train and distinguished between total travelling time, walking time and waiting time; it was found that variations in the rate per mile attributed as a cost of running a car had a very large effect on the implied value of time, and since no information was obtained about the travellers' perceptions of car running costs, indirect methods were resorted to for finding the cost rate that most closely explained observed choice behaviour. It was much lower than the "engineering" costs of running cars. Sub-dividing into income groups showed values of time as a very nearly constant proportion of income. Various variable-structures were tested: x_i was tried as differences of time and cost between modes, as ratios, and as logs of ratios. Overall, the "differences" method came out best, implying a value of time independent of the total time or cost of the journey. Due to high multicollinearity it was not possible to isolate independent values of time for car, bus and train. One criticism of discriminant analysis is that it imposes fixed (i.e. normal) distributions onto the variables - the data is used to establish means and a common variance-covariance matrix for the independent variables and the analysis is done entirely in this. Quarmby did not test his data sufficiently thoroughly to see how far it justified this kind of treatment. Probit analysis is an alternative method which can be made to use each observation directly: using an initial starting set of a_i 's, it uses an iterative process for fitting each observation incrementally to $P_i(X) = \frac{e^{L(X)}}{1 + e^{L(X)}}$ where $P_1(X)$ is deduced from the data for X -intervals for the previous set of a_i 's. Warner found on his data that there was very little difference in the results between using discriminant analysis and probit analysis on the $P_1(X) = \frac{e^{L(X)}}{1 + e^{L(X)}}$ model; this has also been found by the Local Government O.R. Unit (1969) in their work on modal choice data for four British towns.

Lisco used "multiple probit regression analysis"* in his work on Chicago commuters; unfortunately he did not distinguish between travelling time and walking and waiting time, although in the same reference he describes a separate analysis of parking charges which suggested a value of walking time three times greater than travelling time. The sample was small (159) but acceptable values of time were obtained and the work does demonstrate the ability of this sort of model to describe commuter modal choice; his value of time of 40-50 per cent of average hourly income corresponds well with the Beesley finding and also the values that Quarmby obtained in a version of his model with explicit walking and waiting times deliberately omitted.

Also in the United States, Lave (1968) has used this model form and probit analysis; however the only written document - his Ph.D thesis - is not available for quotation yet.

In the United Kingdom, further work using the same model, and discriminant analysis, has been done by Research Projects Ltd. (1969) and the Local Government Operational Research Unit (1969). The former used data on travel to two different locations in central London (this was part of a larger study on travel to work generally in London), and interestingly were unable to obtain any really satisfactory estimating equations of the $L(X)$ form. On the whole the levels of significance both of the whole discrimination and of particular variables were too low, and certainly no reliable values of time could be deduced. The authors attribute this to a number of factors, including very non-normal distributions of some of the independent variables, and a belief that not many of the respondents saw themselves in positions of real choice between modes. The LGORU study, of commuters in Leicester, Liverpool and two areas of Manchester, has yielded good discriminating equations, but it was only in the third stage of the study - which is still going on - that variables were structured in such a way as to yield reliable values of time. Nothing us published on the third stage yet**, but the indications are that the values of time obtained are much the same as those from other British studies.

* The form of the implied model is almost identical to Warner's and to Quarmby's, and the statistical method is very similar in its results to discriminant analysis, and to regression analysis with dummy dependent variables, subsequently transformed to express probability as a logit function.

** But see Annex A.

The only study to embrace other than commuting trips is one currently in progress by Watson at Edinburgh University to explain modal choice between pairs of car, bus and train for the Edinburgh/Glasgow journey. At the time of writing, the survey work is being completed. No decision has yet been taken on the precise statistical method to be used, but it will be applied to the same formal model as already described.

Three other studies deserve mention - they both use more ad hoc methods. Usually they are not generalisable to more variables than two or three. A study by IAU RP (1963) of choices made by Paris commuters on the final stage of their journey to work, i.e. between bus and metro from the SNCF main line stations, derived a value of time by finding those different combinations of time, costs and number of changes which gave rise to the same proportions of travellers to particular destinations using one mode. The values of time were higher than for any British study, possibly attributable to relatively high discomfort on both bus and metro at these times of day.

The other study, by Stopher (1968), used a linear estimating equation $L(X)$ directly for the probability of choice of mode, instead of via the logistic transformation

$$P(X) = \frac{e^{L(X)}}{1 + e^{L(X)}}$$

The method of deriving the parameters in $L(X)$

was to divide respondents into cells, where each cell corresponded to a certain time difference bracket and cost difference bracket: the proportion in each cell using one mode was regressed on time and cost differences. This method is really limited to two variables unless the sample is very large because of the number of cells. Because no account was taken of walking and waiting times, the same criticism applies as to the Beesley method. In addition, using the linear function directly as an estimator of probability or proportion (instead of the logit transformation) tends to introduce distortions into the estimation of co-efficients - largely because the real world behaves more like S-shaped curves than straight lines which when projected can give "probabilities" of more than 1 and less than zero. Stopher also used reported times for the preferred mode and objective estimates of time in characterising individuals' alternative mode. Problems of whether to use perceived or objective values are discussed later; one probably should not use a mixture of both. The third is a recently published study of commuters in Manchester by Lee and Dalvi (1969).

The method which they spend most time discussing is one in which commuters with a choice between bus and train were asked to say how much increase in financial cost on their preferred mode would JUST make them switch to the other mode (i.e. make them indifferent). Using the overall cost and time differences only, the implied value of time was then calculated (separately for "time preferrers" and "money preferrers" - see the discussion earlier on Beesley's method). The authors then attempted to explain variations over the sample in the values of time so calculated, in terms of variables chosen from a list including overall time differences, walking, waiting, in-vehicle time differences, the same including the return journey, and many others, by regression analysis. The method for establishing the initial value of time estimates is suspect because based on what people say they would do instead of on revealed behaviour, and it is open to two of the same criticisms as Beesley's original work - namely, that the calculated value of time embodies a mixture of in-vehicle, walking and waiting times, and that the method of calculating the value of time assumes all persons indifferent between modes when times and costs are the same. However, the idea of trying to relate variations in a value of time to system and socio-economic variables is interesting; as is the attempt to determine whether there are significant differences between "time preferrers" and "money preferrers" (See Mercadal on price - and time-consciousness).

The methodology of the majority of studies in the modal choice are - the linear estimating equation and the logistic probability function - is probably the most satisfactory to use in this area. Because it is not restricted to a small number of variables, it is possible to set out to explain modal choice first, and THEN derive a value of time if possible. As a method of deriving parameters, probit analysis is theoretically more satisfactory because it imposes fewer conditions on the data, but when the data is well-behaved (which it probably was not in the Research Projects study) there is little difference between using probit analysis or discriminant analysis (or its multiple regression equivalent).

2.2.14. (iii) CHOICE OF ROUTE

This is concerned with drivers' choice of route over a road network. The most easily identifiable binary trade-off situations are between fast motorway and slower all-purpose road, and between paying tolls to cross estuaries by bridges or ferries and driving more mileage round the end of the estuary. As has already been mentioned in the Section on empirical conditions, this area is fraught with empirical difficulties. Generally the same methodology as for modal choice is applicable here - the linear estimating equation and logistic probability transformation - and the only successful derivation of a value of travelling time from route choice did in fact use this (Thomas 1967).

The principal empirical difficulties, which Thomas was mostly aware of and went to great lengths to try and overcome, are that the time and cost variables are usually even more highly correlated than in modal choice; secondly there is often too little variation within the variables to allow a reliable estimating equation to be derived - this usually happens at tolled estuary crossings where nearly everyone is faced with the same time and cost differences; thirdly, the cost differences are largely made up of differences in car running costs (e.g. between crossing an estuary or going "round the end") which are difficult to estimate as perceived by the driver, and it is found that values of time are even more sensitive to the mileage cost rate used than in modal choice analysis; fourthly, most of the route-choice situations in the United Kingdom that could lend themselves to this sort of analysis have a high proportion of non-regular journeys such as holidaymakers who cannot be presumed to have particularly accurate information about the alternatives facing them.

Mention has already been made of the Claffey study, in which the analytical model was inconsistent with the behavioural hypothesis; however, even when re-analysed in a consistent model (Quarmby 1967 iii) no reliable values of time were obtained, principally because of very high multi-collinearity between travel time differences and cost differences for the different pairs of tolled motorways and free all-purpose roads examined. Annex A contains a more complete description of the study. The Road Research Laboratory study (Dawson 1959) has already been mentioned too - this did not distinguish between different kinds of time,

and with a somewhat unsatisfactory analytical method obtained a very high value of time. However, even when re-analysed using discriminant analysis, no reliable value of time was obtained (Quarmby 1967 iii) as the overall level of explanation was too low - probably because many of the travellers did not have sufficient information in which to make rational choices. See Annex A for a more complete description of the study.

The Thomas study was of commuters choosing between tolled motorway and untolled all-purpose road for their journeys to work. Thomas attempted to get round the within-variable variation problem by getting information at places of work to embrace people travelling different distances to work; the car running cost problem was reduced in importance by using respondents for whom the car running costs were assumed to be identical by either route; and the fact that they were commuters suggests a good knowledge of the preferred and alternative routes. However, Thomas found large differences in implied values of time according as to whether he used the reported differences in journey time or some independently measured journey times. In any case the values were all high compared to British values: this is discussed at greater length in the next section of the paper. Annex A contains a more complete description and assessment of the study.

Bevis sets up a "generalised cost" function (see 4.2 below) for travel along a road, and then attempts to explain the proportions of travellers making particular interzonal trips (in four different areas of the United States of America) who use a freeway rather than an alternative road, in terms of the difference in generalised cost between the two routes. This is done by multiple regression, with proportion using freeway as the dependent variable, and the independent variables being the differences in the components of generalised cost for the two routes - e.g. time difference, distance difference, etc. Two main points can be made about this: firstly, Bevis assumed that car operating costs are perceived "correctly" - i.e. that there is a fixed per mile component, a per mile component that varies with the square of the speed. This is based on evidence that costs are parabolic with respect to speed. But he does not, as other researchers have done, impose actual cost rates on these components - he lets them, or some cost proxy, emerge from the regression. However it is not possible to put a very direct interpretation on the various coefficients since the evidence suggests (see Mohring 1965) that

drivers are not really aware of the dependence of costs on speed. The second point is that, as in Stopher's modal split work, the probability estimator is taken as the direct linear function instead of via a probit or logit transformation, although Bevis does discuss these transformations. This matters to the extent that obscured proportions extend much beyond the middle range of values (40 per cent - 60 per cent). Although not explicitly described, it would appear that much of it does. Since the regression equations themselves neither contain nor yield any cost data, the equation is scaled to approximate cost magnitudes obtained in other studies.

It appears that with considerable care it is possible to overcome the numerous empirical difficulties associated with route choice studies - though it is doubtful whether a successful study (in terms of obtaining a value of time) could be carried out in the United Kingdom, because no tolls are levied on motorways (except at certain estuary crossings), so it is not possible to obtain a cost difference other than by differences in mileage. Mention should be made of a feasibility study to investigate the possibility of doing a route choice study in the United Kingdom, about to be launched by the Ministry of Transport, under the direction of one of the present authors (Harrison). A recent paper by Mansfield (1969 iii) discusses both the modal choice and route choice methods for obtaining values of time.

2.2.15. (iv) CHOICE OF SPEED AT WHICH TO DRIVE

On the face of it this is a legitimate area of choice in which drivers trade-off increased operating costs with higher speeds and therefore lower travel times. However, it presumes that drivers are sufficiently well aware of the relationship between speed and operating cost so as to choose an "optimum" speed. But there is no evidence that drivers have a sensitive enough awareness. It could be argued that there are many other factors that influence free-flow speed - such as safety. There is no evidence that cars with more passengers travel faster than those with fewer. Mohring (1965) attempted to derive a value of time on this basis: while it turns out to be not a ludicrous value, it can hardly be accorded much weight because of the method.

2.2.16 (v) CHOICE OF RELATIVE LOCATIONS OF HOME AND WORK

For core-orientated cities, it is possible to establish an economic model to indicate trade-off between commuting costs (including time costs) and location rent of housing. The main difficulty about using such a model empirically is firstly that the location rent is difficult to extract from all the other factors that influence the rent or value of a housing package - such as amenity, quality of building, and so on. Secondly, accessibility to a single area of work is not the only accessibility that the location rent is likely to be dependent on - even in many heavily core-orientated cities like London, accessibility to non-central work places is important except for very high income commuters, and accessibility to other facilities can be important as well. However Mohring (1960) did carry out analysis with this basic model, and obtained values of time which are not out of line in percentage terms with British values but rather less than other American values. Mohring himself recognises important shortcomings both in the data and in the use of this model. A study by Pendleton (1963) obtains a value by the same general method as part of an attempt to explain real estate values. While there is no definite conclusion on time values, there is a useful discussion of the problems of using this method: e.g. treatment of vehicle operating costs, costs, the appropriate discount rate, the level of trip-making of accessibility with other variables, e.g. age and density of the housing stock. Generally this is not likely to be a fruitful area until much more comprehensive general urban models exist, out of which sub-models for time-cost trade-off analysis might be carved.

2.2.17. The authors know of no studies aimed at deriving values of time empirically in any other areas of choice; they would be glad to receive details from any researchers who are attempting to do so in other areas.

2.2.18. SOME GENERAL ISSUES ON INPUT DATA AND INTERPRETATION

This section is concerned with some general problems that are common to a number of different studies, and methods already discussed, and which are not intrinsic to the methodology but substantially affect the resulting values of time. The first problem area is concerned with perceived values as against objectively assessed values; the second with interpretation of values of time for individuals or vehicles, earners or all adults, and so on.

2.2.19. Most of the early studies - whether on route or modal choice - used "objective" estimates of car operating cost, and it was never actively considered by any of the researchers that drivers might not in fact be aware or want to be aware of the actual costs of running their cars: except that Dawson, in the RRL study of 1959, did discover that he had to reduce the car costs to petrol costs alone, otherwise nearly all the drivers who opted to drive round the Forth estuary would have found it quicker AND cheaper to cross by the ferry. The question of car mileage costs matters for two reasons - firstly, because there is a big discrepancy between the "real" marginal costs of car mileage and the costs which, by a variety of direct and indirect methods, researchers have found that motorists "perceive", or at least base their behaviour on. Including fuel, oil, maintenance, tyres, and mileage-dependent depreciation, most private cars show a marginal cost of between 4d. and 7d. a mile. Various empirical methods indicate "perceived" costs between 2d. and 4d. a mile (in the period 1966-1969). These methods range from direct interviews - asking people the cost of particular journeys (see Harrison 1969 iii) and Local Government OR Unit (1969) - to finding those mileage costs which best explain their travel behaviour (see Quarmby 1967 ii). The second reason all this matters is that in both route choice and in modal choice (involving a car alternative), the value of time derived is extremely sensitive to the car mileage rate used to derive a travel cost by car. In the Leeds modal choice study (Quarmby qv) it was found that the derived value of time was over twice as large when 4d. a mile was used compared with when 2d. a mile was used, although there was relatively little movement in the value of time between 1½d. and 3d. a mile. Three different analytical methods were used to find the mileage rate which most appropriately explained commuters' decisions, and a value of 2½d. a mile was finally arrived at (this was from a survey in Spring 1966, when petrol cost 4/6d. to 5/-d. a gallon; compared mid-1969 petrol prices of 6/-d. to 6/8d. a gallon).

2.2.20. In any trade-off situation where use of a car is involved (except in the carefully chosen case like Thomas', where mileages were the same by either route), it is clearly absolutely essential to use a mileage cost rate which is known or believed to reflect the drivers perceptions of cost, or to reflect the revealed behaviour of drivers.

In the absence of an on-the-spot method of determining perceived or "behaviour" mileage cost in a particular empirical study, the researcher should at least explore the sensitivity of his derived value of time to a range of mileage cost rate inputs. In any case, the researcher should not use an objective marginal cost as his best estimate, if there is no local empirical evidence as to perceived costs, unless the situation is so far removed from circumstances where there is empirical evidence (like a different country where the pattern of costs of fuel, maintenance, tyres, etc. is very different). In arriving at a good initial estimate for another European country, it would seem from the direct interview studies that the best way to interpret the United Kingdom perceived mileage cost of 3d. a mile or so is as the cost of petrol plus ½d. or so for other dimly perceived mileage dependent costs such as oil, etc.

2.2.21. Most of the American studies have yielded values of time rather higher - as a percentage of income - than the British studies. Part of this difference may be explained by the use of a higher mileage cost in these studies than the above discussion would warrant (except in the case of Thomas' study). Although Lisco, in his modal split study of Chicago commuters, found that the value of time did not vary much with two different levels of car operating costs, his lower figure was still as high as 6 cents per mile (higher 9 ¢) which with gasoline at 30-35 cents a (United States) gallon is still very much more than gasoline costs. It would have been interesting to know how the value of time varied with mileage costs lower than 6 cents a mile. Although Lisco is one of only a few American researchers to allow some uncertainty in what the mileage costs should be, he does not go very deeply into the actual problem of estimating what their perceived value is.

2.2.22. The difference between reality and how people perceive it - and indeed the difference between how people perceive it consciously and how their perception of it actually influences their behaviour - is at the heart of the above problem on mileage costs, but it also potentially affects every item of input data into a behaviour-explaining model. In modal and route choice studies of individual behaviour (as opposed to behaviour of groups), the researcher can use either the individuals' reported travel time and costs, or some objectively measured times and costs.

2.2.23. The problem is: which is more likely to give a reliable explanation of the individual's behaviour? We have already discussed the problem of the car mileage rate, but this alone can be reduced to a single unit quantity for which evidence can be sifted. No such treatment can be given to estimates of time - travelling, walking, waiting - and we are at the present time reduced to a priori arguments. There are arguments on both sides:

- (i) objectively measured times can only be averages, and there may be real differences in the experience of individuals, for which their reported times are better approximations in each case.
- (ii) if there are real discrepancies between reported and the directly equivalent objective time, it may be that people rationalise their choices (of mode or route) by underestimating their preferred alternative and overestimating their rejected alternative.
- (iii) travellers may really not have reliable information about their rejected alternative; but it could be said that this is the information they base their decisions on, reliable or not.
- (iv) behaviour may not be best explainable in terms of either the consciously perceived characteristics or the objective measurements, but it is likely to be nearer the former than the latter.

2.2.24. Until research is done on this particular topic, the issue cannot be fully resolved; the authors generally prefer to use reported characteristics, in spite of the important argument about rationalisation (ii above). It can be important: in Thomas' study, the value of time using perceived differences in travel time was over twice that using measured differences. In the case of a route choice study, where results are highly geared to smallish differences in driving times, there is a case for using perceived or reported times, if only to express the real variations (even in the United States) in driving speeds and time experiences by drivers.

2.2.25. The other major question in this section refers to the interpretation of a value of time, and the specific issue of how a value of time derived for a vehicle and for an earner (and particularly a value derived from commuting studies) can be generalised to a value for people in general, for whom a planning agency might wish to estimate the value of time savings. The route choice studies in general derive a value of time for a vehicle, and the question is whether this wholly represents the value of time for the driver, or for all the occupants equally; the modal choice studies in general derive a value of time for a commuter who earns - while this value can be attributed to him, what can we deduce about the value of time for other members of his household, and insofar as the value of time is empirically found to relate to income, should it be linked to personal income of the earner, or to the household income?* And what can we say about non-commuting journeys? These are important issues where there may be, between studies and between countries, differences in car occupancy, in earners per household, in household size, etc. and where we wish to generalise between studies, and particularly where our most reliable values derive from commuting studies. All these questions relate in principle to the social psychology of the household and of its members, and while it is possible to argue on a priori grounds whether husbands treat their wives like themselves or not, in terms of spending money on saving time, it is also possible to carry out psychologically based research studies to find out. This is discussed in the next part.

NON-TRADE-OFF TECHNIQUES: THE USE OF DIRECT INTERVIEWS

2.2.26. The last part discussed various interpretational problems which the numerous empirical trade-off studies have done little or can do little to solve. There is a case for attempting to use psychological techniques to investigate these, and indeed to test out some of the basic economic assumptions about disutility implicit in most of the models. There is also a case for experimenting with "simulation" methods, in which people are presented with various kinds of choices in a laboratory situation, in order to extend the means available for deriving values.

* Lee and Dalvi discuss this briefly: they argue that a household-based quantity is probably more appropriate for describing behaviour, but that a personal-based quantity is more accurately obtainable as data in surveys. The authors tend to agree.

2.2.27. PERSONAL INTERVIEW TECHNIQUES FOR A VALUE OF TIME

These methods can be more or less sophisticated ranging from simple questions "what do you consider your free time is worth?" to depth interviews conducted by trained psychologists. There is little experience of using them, but the general difficulties involved are obvious; people may give biased answers because they wish to influence the results in a given way: they may never consciously consider the abstraction: value of time, and be unable to discuss it: what they say may bear no relation to what they would or do in practice. Some work that has been done confirms these fears*.

2.2.28. Given these difficulties, it would not be reasonable to expect that interview techniques have much to offer by way of quantitative answers; they may nevertheless be useful in an ancillary role: one, in aiding the interpretation of the purely statistical results, and two in suggesting hypotheses which might be tested by statistical methods. The need in both contexts can be seen by considering the points made above on the composite nature of time saving and hence the need to attempt to discover of what, in particular situations, it consists of, if this is not apparent from the travel situation. A further and important use is to attempt to derive support for the extrapolation of results obtained from certain specific areas of travel experience (e.g. commuting) to other travel situations, not yet researched into.

2.2.29. Some work to this latter end has been carried out by the Ministry of Transport, London, as a pilot study, in particular to test the following propositions:

- (i) that all adult members of the family have the same value of time.
- (ii) that the value of time of non-adult members can be taken as one-third of that of adults.
- (iii) that the value of time is the same on average no matter when during the week it is experienced.

* See Harrison 1969 (ii).

- (iv) that very small savings are, on average, valued at the same rate as larger savings.
- (v) that the value of time is higher for higher income groups.
- (vi) that the value of time is the same for all journey purposes.

These propositions underlie the Ministry of Transport's current practice with regard to time values.

2.2.30. The results of this experiment were mixed. Some of the propositions were readily discussed, others proved virtually impossible and on others there was evident confusion about the meaning of the terms involved. Furthermore, there was evident divergence between described and observed behaviour, in particular in discussion of the question of size of time savings where people appeared reluctant to admit that even quite sizeable time savings were of value to them. The apparent explanation of this was that value was presented to them at this stage in terms of "what else could be done with the time", a question to which the answer was usually "very little". What the results suggested was that the main reason for value travel time savings lies in the disutility of travel per se. This simple basic point may as seen above, have important point implications for research into certain aspects of time values, in particular the value of small time savings. A further general point suggested by the enquiry was that the value of time was a function of the total context of a given journey, in particular the existence of a deadline or of other activities competing to be performed within a given period. Both these considerations suggest that values obtained from commuting situations would be higher than those from some other trips, where these factors are less prevalent; however, it was also apparent that these factors were also obtained for important categories of leisure trips.

2.2.31. SIMULATION METHODS

These methods do not appear to have been explored, and like the methods just described there are obvious difficulties and limitations involved in them. Some tentative investigations are, however, underway under the auspices of the Ministry of Transport, London, to explore the usefulness of these methods.

The basic method is very simple; subjects are presented with a situation as near as possible to one with which they are familiar and are given various (notional) opportunities of improving this situation. The situation may be a long, crowded journey involving interchanges and a long walk to the means of public transport used. Various sets of relative prices and different budget levels may be used and the subjects choices observed under each. Experimental work so far has been limited, though it has been sufficient to show that the technique is practicable in the sense that people are prepared to go along with the simulation. Initial tests are being carried out in commuting situations precisely because this is the best researched into and hence there is no 'objective' evidence of relative values to be referred to. If the technique appears valid on the basis of consistency checks and tests against actual behaviour the next step will be to apply it to other situations, where such evidence does not exist. For preliminary results see Social and Community Planning Research 1969.

PART 3

SELECTING TIME VALUES

3. INTRODUCTION

3.0.1. Previous parts of this paper have first assessed the possible theories on which time value might be based and the objections to them, and second, considered the merits of a number of pieces of empirical work designed to determine time values. The purpose of this section is, on the basis of these theoretical and empirical considerations, to suggest what time values should be used at the present time. The values currently in use in the British Ministry of Transport will be quoted for illustration, but it follows from the nature of the argument that these particular values are not recommended for general use.

3.0.2. This part will consider merely what value should be attached to each category of time saving that can currently be distinguished, i.e. the unit values of time. The values actually used in a particular evaluation will depend on many factors, for example, vehicle occupancy rates, the mix of various categories of time and so on. These aspects will be briefly discussed in the following Part.

3.1. WORKING TIME

3.1.1. PROPOSITION 1: Working time should be valued at the average wage rate together with associated costs such as social insurance, employment tax etc., and an allowance for overheads of 10 per cent of the wage cost. Only where any of the objections listed in Part 1 above are felt to be particularly important should any modification be made. The need for divergence from this practice will obviously depend on the particular circumstances obtaining for the expenditure under consideration. For purposes of illustration, the current British values for working time are given in the following table:

	(a)	pence per hour (b)	(c) (= 10% of (a))
All workers	203	11	20
Car Drivers	225	14	22
Car Passengers	192	14	19
Rail Users	242	14	24
Bus Users	115	10	12
Light Goods Vehicle Drivers	100	10	10
Heavy Goods Vehicle Drivers	101	10	10
Bus Drivers	100	10	10
Bus Conductors	90	10	9

The first column shows the pure wage element; it is, where evidence is available an average weighted by the mileage travelled in each income class (this method of weighting makes a significant difference to the values of car time). The second column shows the value of pensions and employment taxes borne by the employer and the final column the allowance for overheads. The same value of time is used for all categories of travel time i.e., in vehicle, walking and waiting (on the ground that the employer is indifferent to the way the employee spends his working time) and a growth rate of 3.25 per cent per annum is employed, which is in line with recent increases in productivity per man hour in the United Kingdom.

3.1.2. COMMENT: this proposition is put forward in the belief that the underlying theoretical case, as discussed in paragraph 1.1.2. is strong and that what limited empirical work has been done is inconclusive and does not necessarily constitute a refutation of the position adopted here, when this is appropriately defined (see paragraph 1.3.3.). The strongest reason for suggesting a modification is the possibility of systematic lags in the utilisation of savings (Objection 3). If demand for road transport is rising slowly, if traffic conditions are static (in the sense that there is no secular trend towards increased congestion) and if labour or statutory restrictions are particularly severe, then it may be appropriate to allow for this factor. This proposition may be less secure for modes other than road. For example, objection 8 (paragraph 1.1.11 may be of greater consequence for rail and air, because a higher proportion of

total usage is made up of the classes of traveller (e.g. businessmen) for which the working time/non-working time division is hard to make. But at present no alternative value can be suggested which is other than arbitrary. The figure of 10 per cent suggested for the overheads mark-up is based on recent work carried out for the Ministry. (See Harrison 1969 iii). The other figures are derived from more or less accurate official statistics.

3.2. NON-WORKING TIME

3.2.1. In order to arrive at a set of propositions regarding the value of non-working time, we need to assess and compare the various empirical studies whose methodologies we have already reviewed. In Annex A, 13 empirical studies are reviewed individually and it is from these that the propositions will very largely be drawn. They do not comprise all the studies which impinge methodologically on the value of time problems, and they do not necessarily comprise all the studies mentioned hitherto. They consist of those in which the author set out to obtain, and did obtain, a value of time as such. In each review, the author and reference has been listed: the method and coverage of the study are described and its reliability assessed. Then an account is given of how each study contributes to possible classifications of travelling time value by:

- (i) Mode of travel
- (ii) Journey purpose
- (iii) Whether the findings refer to earners, all persons, or vehicles
- (iv) Whether there is evidence of variation with income
- (v) Whether there is evidence of variation with journey length.

Finally, any reference to waiting and walking time is mentioned and each result is summarised. The studies themselves are classified into the choice areas used in Section 2.2. above:

- (i) choice of mode of travel
- (ii) choice of route
- (iii) miscellaneous, including choice of speed at which to drive, and choice of work/home location.

GENERAL REVIEW

3.2.2. As one would expect from the discussion in Section 2.2., model choice is the most fruitful area of research into value of time, and in spite of the large number of studies (8) yields the most consistent set of estimates. Each study refers to a sample of commuters travelling to and from work, but generally the samples have different socio-economic characteristics and are drawn from different populations (3 in London, 1 in Chicago, 1 in Paris, 1 in Leeds, 1 in Manchester, and 1 study drawing samples from Leicester, Liverpool and Manchester again). It is possible to compare them on the basis of the absolute values of time in shillings and pence, or dollars, or francs, but it is difficult to reach any reasonable conclusions. Since four of the studies suggest that the value of time is related to income, and 2 of them that it is proportional to income (personal), we propose to use the proportion of income (as an hourly rate) as a basis for comparing the results obtained by different studies.

3.2.3. Two British studies obtain values in the range 20-25 per cent of personal income (Quarmby, Stopher); a third suggests 15-30 per cent (Barnett and Saalmans); another 15-45 per cent (Lee and Dalvi); Beesley obtains 30-50 per cent, and LGORU about 20-25 per cent. As the analysis of each study makes clear, most of these estimates are for travelling time which involves a mixture of walking and waiting time, and the evidence suggests that the value of in-vehicle time would be lower and of waiting and walking time higher than the "mixed" value. In fact, only the Quarmby and the LGORU estimates are for travelling times in vehicles. In the light of this evidence, the authors choose 25 per cent of personal income as the best consensus estimate for in-vehicle travelling time. There is no particular pattern of variation with income (other than proportionate) of the sort which could explain the differences in values of time above; indeed considering the variety of methods used and the general level of statistical uncertainty, it is surprising how close the estimates are.

3.2.4. The results of the American study (Lisco) were about 40-50 per cent of average hourly incomes for the middle income group* (a reliable value was obtained only for this group). This was for "mixed" travelling time, and so would tend to be an over-estimate of in-vehicle travelling time. Even so it is

* A similar result is found in Lave.

somewhat higher than the British studies. The high value obtained by the French study (about 75 per cent) may be explained by the nature of the journey involved - short, probably highly uncomfortable public transport trips (at the end of a long-haul commuter rail journey).

3.2.5. As has been mentioned already (2.2.), in the case of choices involving a car as one alternative, the mileage cost rate chosen for the costing of the journey by car can have a large effect on the derived value of time. Quarmby manipulated his explanatory model in various ways to discover how, if at all, commuters were in fact imputing costs to their cars and obtained a rate rather lower than the "objective" marginal costs. Lisco, however, tried 6¢ a mile and 8¢ and found very little difference in the value of time, but did try a value lower than 6¢ which could still be well above the perceived marginal cost. It is possible that his derived value of time is higher than the British values for this reason. Stopher had to estimate car costs for those of his respondents for whom a car was not the preferred alternative. LGORU asked their respondents what they thought their car costs were (1968) and obtained by implication values between 3d. and 4d. a mile. Beesley used reported costs, as did Barnett and Saalmans; for Lee and Dalvi it is not known. So those studies which may show values somewhat inflated for this reason are principally Lisco, and possibly also Stopher.

3.2.6. The values for walking and waiting time proposed are based on the French study and Quarmby, which are, in close agreement in suggesting a value 2 to 2½ times the value of in-vehicle time; this is also supported by Lisco and by some "pure" model choice studies.

3.2.7. The route choice studies are more difficult to evaluate. The first two (Dawson, Claffey) produce values per vehicle, not per person, hence to convert their results into terms equivalent to the model choice group, some assumption on occupancy must be made. If this conversion is done, using national average occupancy figures, and each individual is weighted along the lines suggested in the main paper, then the values obtained in route choice tend to be higher than those for model choice. To explain why these results have been rejected it is convenient to take Dawson and Claffey together and discuss Thomas separately.

The first two, for reasons explained in detail below, are not considered to be reliable for primarily statistical

reasons i.e. although the methods used purport to obtain a value for time, because of the nature of the data and its method of analysis, they do not do so, and the values actually obtained cannot be regarded as reliable. One important consequence of this conclusion is that the basis for the value of leisure time used earlier by the Ministry of Transport (equivalent to 75 per cent of the hourly wage rate for earners only), i.e. the results of Dawson's study, is removed.

3.2.8. The final study in this group, by Thomas, cannot be subject to the same criticisms. It is possible for reasons explained below and elaborated in the study itself that the results obtained which show a minimum value equivalent to 40 per cent of hourly earnings, and a maximum of 83 per cent, are the results of measurement errors, or statistical identification problems, but from the published evidence, this study is no more likely to error than the model choice studies. A further possible and partial explanation is that the differences reflect the higher levels of American income (even the minimum being above the average of the British results), i.e. they imply an income elasticity of demand for time greater than unity. The same comment could apply to Lisco. There is no inherent plausibility, in this case as far as the lower values are concerned.

For the time being, the evidence of these American studies has been rejected for British conditions, mainly because of the wide gap between their results and those quoted for the model choice studies, which cannot be put down to those factors quoted above tending to make for divergencies WITHIN that group. It may well be however, that as the range of British studies is built up to cover different trip-making conditions then the results of this study will be shown to be more closely compatible than appears at the present time (alternatively some direct evidence on income elasticity will be discovered) and it will be possible to make use of the evidence offered by it. These studies do, however, lend support to the relationship proposed between income growth and the value of time.

3.2.9. Of the miscellaneous studies, the evidence of the first, using a trade-off between time and other costs of travel is rejected, because for reasons explained below, the method is considered inadequate. The second produces a range of values,

which is broadly in line with the results of Group A studies, but on which it is considered little reliance can be placed because of possible deficiencies in the way the method, involving an analysis of commuting time and site values, was employed.

3.2.10. These empirical studies have enabled us to reach a certain number of conclusions, some more certainly than others. In order to provide a general scheme of propositions, we have had to reach judgements on a number of issues for which there may be or may not be direct evidence. The rest of this section expounds a set of propositions, with appropriate comment. They do represent the state of the art and our understanding at the present time, and it is to be hoped that future research will assist in their verification or otherwise.

PROPOSITIONS

3.2.11. PROPOSITION 1: Earners' commuting time (in vehicles) should be valued at 25 per cent of their wage rates.

COMMENT: this proposition is only intended to be valid for the United Kingdom or similar conditions (e.g. Europe), and may well not apply to the United States, for example, where average incomes per head are much higher. The American studies produce consistently higher values and hence a higher proportion would seem to be appropriate in the United States: the relation between the British and the American results is discussed below. Note that it may be appropriate to express the value of time as a percentage of household income. All the British studies referred to used personal incomes, but there is evidence from studies of trip generation that the household rather than the individual is the preferred unit of analysis: this would be expected to hold true for the valuation of time. Using a figure for mean earners per household, and a figure for mean income of the second and subsequent earners as a proportion of that of the first earner, and some assumption about the occurrence of "first" earners in the British samples, then Proposition 1 can be restated as 19 per cent of the household income expressed as an hourly rate (per 40 hour week).

3.2.12. PROPOSITION 2: The other non-working time of an earner should be valued at the same rate as his commuting time.

COMMENT: There is an important exception to this proposition, trips where the travel is an end in itself e.g. sightseeing. In most conditions this type of trip will not be affected by road improvements during that part of it where the travel can be regarded as a final good, (i.e. there would be no reason to use this argument for the journey to and from a sightseeing area). Most other kinds of trip share the characteristic of commuting trips that they are intermediate products, part of the price, as it were, for obtaining the final goods - a visit, a show, etc., and there seems no strong reason to suggest that time savings should be valued at a rate much different (if at all) from commuting situations. Because virtually all empirical work has been based on commuting no evidence exists to suggest otherwise. One study (Mansfield) of long distance pleasure trips produced a value close to the figure proposed here.

Further more abstract arguments may be adduced: it would seem irrational, unless the individual operates under severe constraint in arranging his pattern of activities, to pay more to save time on one occasion rather than another (emergencies apart): for if activities are substitutable through time, then time saved at any one point can be transmuted into time saved at another (this is obviously less likely to be true for non-anticipated savings): thus the only reason why time values should differ from one journey type to another (apart from that mentioned above) would be due to some correlation between journey type and traffic conditions e.g. congestion or overcrowding, which may make the individual more inclined to reduce travel time because of its greater disutility. If activities can only take place at certain times and other activities cannot be rearranged accordingly so that there is, as it were, excess demand for a particular span of time (e.g. daylight hours) then there may be systematic variations of time values between different times of day. Given the present stage of empirical knowledge, it seems preferable to use what is known and to diverge from it only on the receipt of contradictory empirical evidence. For any alternative position adopted is likely to be as open to criticism as that adopted here.

3.2.13. PROPOSITION 3: All adults should within a household be accorded the same value of time; the time of children should be valued at some fraction, say one-third, of that rate.

COMMENT: No direct empirical evidence can be presented for either part of this proposition. The first part may be argued for on two very different grounds: first, one may adopt a simple equity position (extending the argument of section 1.2.8. above) and assume, as a value judgement, that there should be no differentiation. Alternatively one might refer to sociological considerations and to modern developments within the family which suggest that non-earners, principally housewives, are increasingly accorded equality or are in a position through control over family funds, to obtain it. This factual assumption (see Harrison 1969 ii), may not hold for all classes, but it is likely to become increasingly valid with rising incomes, and continued social change. The valuation of children's time must remain arbitrary: it may have value, in the case of teenagers for the same reasons that an adult's time may be valuable or it may have value (or rather the saving of it) to parents if the journey is made more tedious through the presence of the child.

3.2.14. PROPOSITION 4: Walking and waiting time during non-working hours should be valued at a higher rate, probably twice, than in vehicle travel time.

COMMENT: Empirical work, principally in the modal choice area, is unanimous in according more weight to these types of time than to travel time. There is less agreement about the precise amount and the figure suggested here lies approximately in the middle of the estimated figures. Some evidence (see Quarmby 1967 iii) suggests that waiting time may be worth rather more, and walking time rather less than twice in-vehicle time, but the evidence is not substantial enough to support departing from this proposition.

3.2.15. PROPOSITION 5: Public Transport time is probably valued at a rate greater than private car time, but in the absence of a precise quantitative relationship, it should be taken as the same for all modes.

COMMENT: the suggestion must remain as an inequality, since the empirical evidence (see Quarmby, LAURP) is not thick on the ground nor is it, at least in the former case, statistically reliable. Intuitively the proposition is reasonable enough given that public transport is normally less comfortable than private; it may not be true for long distance journeys. Given the nature of the evidence this proposition cannot be applied in practice, and time by all modes should at the present time be reckoned the same. (This is obviously so if specific allowance is made for changes in comfort).

3.2.16. PROPOSITION 6: The value of time is proportional to income and its future levels may be predicted by reference to the expected rate of increase in income per head.

COMMENT: Empirical work is unanimous in suggesting the value of time rises with income level; there is less agreement about the shape of the relationship. The cross section results reported in British studies for example show proportionality (Quarmby) and also more complex relationships (e.g. Stopher) with the proportion rising up to a certain level and declining subsequently; a similar result (at a higher average level) is found in Lisco. Neither of these relationships is sufficient to explain the divergence between average levels in the United States and those in the United Kingdom. These may be explained by statistical weakness in the studies (as analysed in Annex A), but it is more likely since the results are so consistently different that real factors are at work. These could be a fundamental difference in attitudes (i.e. in economic jargon, and tastes) between the two countries or, as with so many economic phenomena, it could be that the cross section is not a good guide to the trend. The only piece of work which sheds any insight into trend (see Wabe 1969) does suggest a rapid secular rate of increase in time valuation.

Further theoretical considerations (see Philips) confirm the reasonableness of a more rapid increase in leisure time values than in income. And it is of course possible that the fact that some studies show the highest income groups to display lower proportional values is due to inadequate sample size (see Stopher, and Barnett and Saalmans) or to the presence of other high income specific factors entering into the trip making decision at higher income levels.

The proposition put forward here is a compromise between the cross section evidence and the inter-country comparisons.

3.2.17. PROPOSITION 7: The value of time is invariant with journey length. This implies that marginal time values are equal to average time values.

COMMENT: There is little direct evidence from modal choice studies of any variation or constancy in values with journey length except insofar as explanatory models based on absolute differences in trip times rather than relative or ratioed differences have been found to be more successful. This carries the implication that time differences are perceived in absolute and not in relation to the total journey times themselves. Note also that Quarmby shows fair constancy of time values for journey distance ranges less than and more than six miles. Hence for short and medium journeys this assumption has some support. However, Lee and Dalvi suggest that a higher value of time may be associated with longer distances, but the evidence is not all that conclusive, and their methodology is open to question (see Annex A). They are concerned with urban commuting trips. The proposition is less well supported for long journeys and Annex B explores a line of analysis which suggests that values may decline with journey length (although there is some as yet unpublished data referring to Italian toll road usage which runs counter to this). In the absence of firm evidence to the contrary it seems appropriate to assume constancy over all journey lengths.

3.2.18. PROPOSITION 8: All time savings whether marginal or significantly large should be valued at the same unit rate.

COMMENT: There is no direct empirical evidence for this proposition: the case for it rests with the theoretical arguments set out in section 1.3. above.

3.2.19. PROPOSITION 9: The value of leisure time should, for the purposes of economic evaluation of transport projects, be treated as the same for all income groups.

COMMENT: This proposition apparently runs counter to the factual findings related above. It is, however, based on a value judgement that it is inappropriate above all where free public goods are concerned, such as roads, to give more weight to the time savings of the rich rather than to the poor; this argument is referred to in section 1.2. above. It has recently been adopted as the policy of the Ministry of Transport.

PART 4

4. USING TIME VALUES

4.1. TIME VALUES IN THE APPRAISAL OF TRANSPORT PROJECTS

4.1.1. In general the use of time values in the evaluation of transport projects is straightforward. Once travel time savings are estimated (and major errors may arise at this stage; indeed the uncertainty to be attached to future levels of time saving is probably greater than the uncertainty attached to the value of them) then it is a matter of arithmetic to derive the required values, for the current year, provided satisfactory information is available on vehicle occupancy rates and trip purpose. For many schemes ad hoc surveys will be required to obtain this information. At the moment it is a fairly undemanding requirement, but as a knowledge of time values builds up, and if, as we expect, further categorisation is suggested beyond that currently practicable, then this aspect will increase in importance.

4.1.2. There are similar problems connected with prediction. The simple rules suggested in Part 4 can be complex to apply in practice if the composition of the travellers/vehicles concerned is expected to change; for example, the average income of car-owners will not change at the proposed rate of 3 per cent per annum if there is a tendency for lower income groups to make up a greater proportion of the total car-owning class. Similar, separate theories may be required to predict the future split between working and non-working time. Most predictions have concerned themselves with the future level of car-ownership and use, and relatively little work has been done on the use of the car for business purposes and on the prediction of the volume of commercial goods vehicles on the road (as opposed to the total to be transported, on which a great deal has been done). Again we would suggest that the potential inaccuracies involved here are greater than those of the unit values.

4.1.3. There are also some deeper problems for example, one important area of problem concerns the treatment of measured time savings on a road section which accrue to traffic which did not, previous to the investment under consideration, use the section. (See however Neuburger 1969). Another very wide range

of problems concerns the comparability of benefits measured using imputed values with those measured through a revenue stream. While cost-benefits methods purport to simulate financial appraisals, they fail to do so completely. For example, the fiscal implications of £100 worth of time saving are quite different from those of £100 revenue from visitors to national monuments. So also the macro-economic implications - the consumptions/savings functions for example may react quite differently to savings accruing in the non-monetary form of time savings from what they do to the monetary form of reduced vehicle operating costs. As far as we are aware econometric work on these functions has not considered this problem at all, but if a difference were established then there would be a case for shading the monetary benefits up or down according to the effect their non-financial nature has on the value of savings forthcoming. A similar shading may be appropriate to allow for the fiscal superiority of a revenue stream.

4.1.4. While these problems - and those to which they lead, for example the general issue of the comparability of rates of return obtained according to different criteria - are potentially important and neglected up to now, their consideration would lead us far from the main aims of the paper and they are therefore merely noted and subsequently ignored.

4.2. THE USE OF VALUES OF TRAVEL TIME IN TRAFFIC MODELS

4.2.1. This section describes briefly the way in which time values are being increasingly used in traffic and transportation planning models, both for the prediction of transportation demand, and for the evaluation of transport projects in a modelling context. At this stage we introduce the concepts of "behavioural" and "resource" costs.

4.2.2. For some time, traffic engineers and transportation planners have used travel time to characterise the travel "effort" of going place i to place j on a road or rail network, and the travel time t_{ij} has been used in the conventional sub-models used by the engineer to describe different aspects of travel behaviours:

$$\text{- Gravity distribution model: } T_{ij} = O_i \frac{A_j^f (T_{ij})}{\sum A_k^f (t_{ik})}$$

where T_{ij} is the number of person trips or vehicles travelling from place i to place j , O_i is the number of trips originating in zone i , A_j the attractiveness of zone j , $f(t_{ij})$ is a decaying function of the travel time t_{ij} (see 2.2.12. above and the footnote).

- Assignment model: drivers choose the fastest (i.e. minimum travel time) route through a network.
- Model split model: proportion of transit users is related to the ratio of travel time by transit to travel time by auto, by family of curves specified for different income levels, cost ratios, etc. (Traffic Research Corporation model, in use since 1961).

4.2.3. Increasingly it is being realised by practitioners in the transport planning field that travel time is a poor proxy for the travel "effort" which acts as a deterrent to travel: models using time cannot distinguish between, for instance, a slow route on an all purpose road, and a longer distance but faster route on a motorway; they cannot distinguish between different modes of travel which have very different time-cost profiles - for instance commuter, rail and private car in urban areas; a model using time alone cannot readily distinguish the deterrent effect of walking, or waiting or transfer time in contrast to in-vehicle travelling time, nor can it easily account for parking charges or bridge tolls. These different items become increasingly important as the sophistication of traffic predictions models is improved, and as planners begin to concentrate less on simply road network alternatives and more on other sorts of policy alternatives (investment in transit, parking or road pricing policies) as options in tackling the urban transport problem.

4.2.4. It happens that many of the models that have been discussed in earlier sections for estimating values of time provide both a language and a means for characterising travel "effort"

much more comprehensively than by travel time alone. Most of the model split models, for instance, rest explicitly on an explanation of behaviour related to the "relative disutility" of one mode with respect to another:

$$L(X) = a_0 + a_1 x_1 + \dots + a_n x_n$$

where a_0, a_1 etc. are parameters to be determined by statistical analysis of observed choices, $L(X)$ is the relative disability of one mode with respect to the other, and x_1 are measures of relativeness of one mode with respect to the other. Now this can be expressed as:

$$L(X) = a_0 + (a_1 t^1 + a_2 c^1 + a_3 w^1 + \dots) - (a_1 t^2 + a_2 c^2 + a_3 w^3 + \dots)$$

where a_i are co-efficients as before, but now x has been split into the differences of travel times $t^1 - t^2$; x_2 into the differences of travel (financial) costs $c^1 - c^2$; x_3 into the difference of walking times between modes $w^1 - w^2$; and so on. Since a_i represents the relative weights of times, costs etc. expressed as differences, they also express the relative weights of times, costs, etc. of EACH MODE AT A TIME.

In other words, the function

$$a_1 t + a_2 c^1 + a_3 w^1 + \dots$$

can be regarded as expressing the disutility of travel by mode 1. It is a linear function of the time, cost and other factors which influence the travellers for that journey by that mode, and is the nearest to characterising the travel "effort" for that journey.

4.2.5. So we have, from - say - the model split model, a general form of travel disutility function which can be used in traffic models instead of travel time alone, and provides a framework for coping with all the objections to travel time alone in paragraph 4.2.3. above. We call this function "behavioural" cost, since it is a cost function which on the evidence available is likely to give the best representation of travel behaviour. In fact we are generalising from a model which best explains model choice behaviour, i.e. from a function which gives a disutility of a mode in

the context of model choice, and saying that this particular disutility function will apply for describing route choice (the assignment procedure) and for describing the choices of places to travel to (the distribution model). But all this commonality is implicit in our attempts to derive a single value of time FROM analysis of choices made by travellers in each of these three areas.

4.2.6. The establishment of general propositions about the value of travel time, and of walking and waiting time, is therefore essential if "behavioural costs" are to be used generally instead of travel time in prediction models, since the appropriate values of travel time can rarely be derived empirically on the spot in a conventional transportation study, and must be provided as input data along with various cost rates.

4.2.7. An operational form of behavioural cost function (b) would take this form, on the basis that time, (both in-vehicle and walking and waiting), and financial cost are the only important components of disutility for the purposes of traffic prediction models:

$$\text{for private car: } b = a_1 t + a_2 wt + a_3 d$$

$$\text{for public transport: } b = a_1 t + a_2 wt + a_4 c$$

where a_1/a_4 is the chosen value of travel time, a_2/a_4 the chosen value of walking and waiting time ($2 \times a_1/a_4$) and a_3/a_4 is the chosen value of mileage cost rate for private cars (d is the distance), and c is the monetary fare by public transport. a_4 could be chosen to be 1, so that the behavioural costs would be scaled in pence. Or a_1 could be chosen to be 1m so that the behavioural costs would be scaled in minutes. The authors have a preference for the latter, since over time, as real incomes change and price levels change, people's marginal utility of time is likely to change much less than their marginal utility for money, corrected for price changes or not. So if a traffic model is calibrated at a base year, and the principal parameters assumed to remain constant over into the forecasting period, there is a much stronger case for calculating the new behavioural costs with (say) new networks and higher values of time (because of rises in real income) in time units, and predicting behaviour on the basis of a relative constancy in the reaction to time units, than for doing whole exercise in monetary units.

4.2.8. To appreciate this point intuitively, let us see what happens in a particular case. Scaled in time units, behavioural cost is:

$$\text{in-vehicle time} + \frac{\text{cost}}{\text{value of time}} + 2x \text{ walking/waiting time}$$

If a particular rail journey of 30 minutes costing 5/- is made by someone with a value of time of 4/- per hour, then the behavioural cost in time units is:

$$b = 30 + (12 \times 5) \frac{60}{4 \times 12}$$

$$= 30 + 75 = 105 \text{ equivalent - minutes.}$$

If that person is earning $2\frac{1}{2}$ times as much in 10 years (or consider another person earning this $2\frac{1}{2}$ times as much now), the behavioural cost is, since the value of time is assumed 10/- per hour:

$$b = 30 + (12 \times 5) \frac{60}{10 \times 12}$$

$$= 30 + 30 = 60 \text{ equivalent - minutes.}$$

Thus the effect of raising the value of time is to decrease the importance of cost in a journey, but by actually decreasing the cost component itself rather than increasing the time component.

4.2.9. The most convenient way to express the costs in a traffic model is for each link of the network; so that for a highway network, each link would be represented by a time and a distance, (and possibly a package charge if it were a terminating link into a zone), and a behavioural cost is derived using a value of time as in 4.2.8. Then in tree-building or route selection, part of the modelling process, not fastest but "cheapest" or minimum behavioural cost routes are established. Incidentally, in deriving the financial cost element private car mileage is more appropriate costed at a "perceived" rather than an objective marginal cost, since the former is closer to explaining how people behave. Public transport links in a network can be handled in the same way, using value of time to convert fares to time-equivalence.

4.2.10. With a behavioural cost specified in this sort of way, clearly, a modal split model for use in traffic studies is immediately evident and is extremely simple: if b^1 is the behavioural cost by mode 1 and b^2 the behavioural cost by mode 2, for a particular interzonal trip from i to j , then the proportion using mode 1, out of the total making that i - j journey, T_{ij} , is

$$\frac{T_{ij}^1}{T_{ij}} = \frac{1}{1 + e^{-\lambda(b^1 - b^2)}}$$

Since this derives from the modal split models established empirically.

$$\text{Alternatively } \frac{T_{ij}^1}{T_{ij}} = \frac{e^{-\lambda b^1}}{e^{-\lambda b^1} + e^{-\lambda b^2}}$$

It can be shown theoretically that the value of λ is that obtained from the travel deterrence function in the gravity model:

$$T_{ij} = \frac{O_i A_j (e^{-\lambda b_{ij}^1} + e^{-\lambda b_{ij}^2})}{\sum_k A_k (e^{-\lambda b_{ik}^1} + e^{-\lambda b_{ik}^2})}$$

Wilson (1968) postulates a statistical mechanics analogy for deriving from scratch the equations to describe people's travel behaviour under certain constraints and in response to a network or series of networks characterised by behavioural costs (called "generalised" cost in his paper). The forms of the distribution model and modal split model above can be derived by this approach.

4.2.11. Behavioural costs derived in this sort of way are in use in preference to time in all transportation modelling work within the Ministry of Transport now (particularly the SELNEC study), and increasing numbers of consultants are beginning to use the concept. Various papers are available from the Mathematical Advisory Unit of the Ministry of Transport describing their use (see Bibliography).

RESOURCE COSTS

4.2.12. We have concentrated so far on the sorts of cost functions that can best describe people's travel behaviour. For the evaluation of transport projects, we need to be able to describe the changes in resources used consequent upon a particular investment (or change in a network). Section 4.1. described briefly how time savings and operating cost savings are accounted for in conventional ad hoc methods of highway investment appraisal.

4.2.13. A highway investment appears in a traffic model as a change in the characteristic of one or more links in the network, or as a completely new link that comes into existence. The existence of this link may alter a number of best routes, and will in general reduce the behavioural costs of travel from i to j from b_{ij} down to b^1_{ij} - either through re-routing or simply a reduction in travel time or distance along the existing route. The benefits to traffic, however, are derived on the basis of how the community values the reductions in cost of travel (putting aside at this stage any changes in utility due to a redistribution of traffic) - and this is not necessarily how the traveller himself sees the cost reductions. So we need to have a different set of costs rates which represent the community or social valuation of the reduction in resources consequent upon this improved network. The principal differences are:

- (i) the "perceived" mileage cost is different from the objective mileage cost to the user, which again is different from the cost in resources of each mile travelled by the car - since fuel tax, paid for by the user, does not represent a consumption of resources. Manuals produced by the Ministry of Transport (including Road Research Laboratory) for the appraisal of highway investments give, as operating costs for vehicles, the net resource costs, i.e. the costs to the user less the tax element. As far as private car rates are concerned, the resource cost per mile is very similar to the perceived cost of 3d. per mile or so.

- (ii) Since it has been decided (see 3.2.19. above) to use a single common value for the value of non-working time in investment appraisal where the Ministry of Transport is concerned, the value of time in a resource cost function will generally be different from that in the behavioural cost function where non-working time is a component. For instance, if the study concerns a highway project, then values of non-working time for the behavioural costs will be based on 25 per cent of the mean personal income of earners in the population reckoned to be making trips on the network, which will be predominantly car owners. The Ministry's single common value for evaluation is based on 25 per cent of mean personal income of earners in the whole population which will be less than that of car owners.

4.2.14. The resource cost function has the same basic form as the behavioural cost function, but the parameter values are different. For a particular i-j journey, the resource costs of travel r_{ij} are calculated by adding up ALONG THE BEHAVIOURAL COST PATH the component link resource costs. A particular highway improvement will be evident as a change in r_{ij} to r^1_{ij} , again added up along the behavioural cost path. Where T_{ij} is the amount of traffic modelled between i and j, then the benefits to the change in the network are $\sum \sum T_{ij} (v_{ij} - v^1_{ij})$ assuming no redistribution of traffic (i.e. no change in T_{ij}). Where changes in T_{ij} do occur, the process of evaluation is very much more complex and it is not proposed to discuss this problem here.

4.2.15. In a particular traffic study, the derivation of parameters for behavioural and resources costs is a fairly lengthy process, requiring the establishment of many properties of the study, such as the units for forecasting (persons or vehicles?), the nature of the split (if any) between journey purposes, and the implied split between working and non-working time, socio-economic characteristics of the population in the area under study (such as household incomes, sizes, workers per household, etc.) and dates for both model calibration and forecasting, and a date for the price index base, and a rate of growth of real

income. Behavioural and resource costs have been calculated for use in a few studies both inside and outside the Ministry, and write-ups are available from the Ministry on application (see Bibliography).

4.2.16. As yet, little is known about how much improvement the use of behavioural costs brings to the performance of traffic models (except model split, where the model is defined only in terms of behavioural cost). Intuitively it is more elegant and in fact more accurate than the use of time alone - but it may in fact not be worth the effort for certain simplified kinds of traffic study. Certainly the work on values of time has been a very necessary impact into any operational expression of the generalized cost concept, and it is to be expected that the continuation of research and the increase in knowledge about the time values will enable us to refine continually the definitions and uses of behavioural and resource costs. It is clear too that an increasing amount of transport investment appraisal will be carried out with models of that kind described here, and it is important in the design of future work on time valuations that the particular needs of traffic models be borne in mind.

PART 5

5. PROGRESS

5.1.1. The paper so far has revealed at least two things about our current state of knowledge: first as far as values of non-working time are concerned, empirical work has almost entirely been confined to commuting trips: second, any attempt to obtain a set of values for general use over all trip types and all categories of the population rests on a number of assumptions which may be claimed to be plausible but which are certainly far from being proven. Hence we see it as a major general requirement to extend the scope of the problems tackled. While it is clear that no-one has yet carried out the perfect commuting study, we see relatively little virtue in further studies of this kind, at the present time.

5.1.2. In our view the following are the major problem areas to be tackled next:

- (i) Time savings on long trips
- (ii) Value of very small savings
- (iii) Value of time through time

- (iv) Value of time for non-earners (unless a simple value judgement is held to apply to this group)
- (v) Value of time on non-working trips other than commuting
- (vi) Value of time by mode

5.1.3. No mention here has been made of working time values. The problems here are rather different and are not amenable to research, rather to the appropriate data collection. Considerable practical difficulties may exist to prevent easy application of the approach proposed above. For example, there may be little information on the incomes of travellers or on the average hours worked. (In the United Kingdom the income data itself is fairly good, but the conversion of this to an hourly wage rate is subject to considerable uncertainty, for accurate figures of hours worked are not available for many classes of traveller in working time). Further, some of the overhead items may require ad hoc data collection, or they may be readily obtained from surveys conducted for other reasons. The only problem therefore which we would pick out as being of general interest is that of the utilization of time savings, and because so little is known of its possible importance, variance in journey times.

SCOPE FOR FURTHER WORK

5.1.4. The bulk of the work carried out so far has relied on model or route choice situations where commuting trips have been involved and some of the difficulties of extending this approach to other types of trip have been outlined above. It is not possible to say anything general about the scope for further empirical work using these methods since the choice situations available depend on the physical situations which happen to obtain in each country, except to the effect that it seems unlikely that methods of this type as used so far will be able to resolve successfully all the problems listed above. For this reason therefore further effort is required to develop the less well-established techniques, among which we regard as most promising extensions of the trip generation method and, among the less conventional methods, simulation techniques.

5.1.5. Apart from extending the type of trip considered a further major requirement is to extend the scale of the data collection. Many of the studies reported here rely in very small samples (Cf. Lisco: less than 200) and hence it is only possible to analyse the determinants of time valuation in terms of a few variables, e.g. time cost etc. With samples of this size it is not possible to attempt to relate the individual's observed behaviour to his own, or his household characteristics or at the same time to analyse journey length, size of saving, mode differences etc. If these problems are to be tackled, situations must be found different in the relevant respect but homogenous in others, or which allow a very large sample to be collected, which may in practice be impossible. These considerations lend further strength to the contention that it may be necessary to devise new means of analysis.

5.1.6. Probably the most difficult outstanding problems are those concerning very small savings and the value to be attached to time in future years, (assuming that sufficient choice situations can be found to allow the other problems to be tackled). The difficulties of applying conventional statistical techniques to very small time savings e.g. the removal of an intersection delay are obvious; they are the difficulties described above in full. Hence one may doubt whether reliable answers will ever be obtained in this way. Simulation methods may in principle be applied to this problem, but they are very far from being proven techniques. Hence, for the present, this problem may have to be regarded as potentially insoluble.

5.1.7. Further work may sort out the problem of determining the true cross-section relationship between income and time value, but this will only go a small way to solving the prediction problem. If inter-country comparisons cannot be relied on (because of assumed differences in tastes) but are sufficiently striking to make the projection of the cross-section dubious, then the best alternatives may simply be to sit back and wait for the number of studies to accumulate. The alternative way of attempting to predict the components embodied in the theoretical framework outlined above seems unlikely to be fruitful since the variables concerned are difficult to measure now and inter-related with each other.

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NOTE: The M.A.U. and Time Research Notes are obtainable from the authors at the Ministry of Transport, Southwark Street, London S.E.1. These notes do not necessarily represent the views of the Ministry.

ANNEX A

ANALYSIS OF EMPIRICAL STUDIES

[The following analyses were originally prepared for, and published in 'The Value of Time Savings in Transport Investment Appraisal' (1969), a paper prepared by the authors in collaboration with other members of the Economics Directorate, Ministry of Transport, London.]⁷

A. Modal Choice Studies of the urban journey to work

1. Author: M.E. Beesley

Reference: The value of time spent in travelling;
some new evidence. *Economia*, March 1965.

Method: Analysis of time-cost trade-offs in choice between public transport modes, and between public transport and private car, for the journey to work. Method was to find that value of time which best explained the observed choices of a sample of employees working in the Ministry of Transport, in terms of minimizing the number of people who apparently were making "bad" choices - i.e. who by choosing the other mode could have either saved time by paying less money than this value of time implied, or saved money at the expense of a smaller time increase than the value of time implied. Values were derived for two different income groups as follows:

Mean Hourly Income	value of public transport time	% of income
9/-	3/2	35%
6/6	2/-	31%

Similar analysis of choices where a car was available (or was used) gave:

Mean Hourly Income	value of car time	% of income
9/-	4/4	49%
6/6	2/-	31%

Comment: This method assumes it is possible to explain modal choices in terms of (overall) travelling times and costs alone. There is evidence [see Quarmby (5)] that this is not necessarily so. In fact, differences in walking and waiting times (which in (8) and (5) are shown to have a different value, see also Section 1) may partly account for observed choices. This effect is probably more important for car-public transport choices, where even more factors may affect people's choices.

Mode: Public and private car transport.

Purpose: Commuting only.

Earner/Dependant: Earners only.

Income: There is some evidence that value of time is about proportional to hourly earnings, although 6/6d. - 9/- is rather a small range to permit a strong assertion about this.

Length: No information. Urban trips.

Results: See method above. In summary 3/2d. per hour for hourly income of 9/- and 2/- per hour for hourly income of 6/6d. About one-third of the wage rate.

2. Author: Institut d'Amenagement et d'Urbanisme de la Region Parisienne.

Reference: Choix du moyen de transports par les usagers, October 1963. Also published in Vol. 4-5 of Transports Urbains.

Method A: Analysis of the choices made between bus and metro for commuters arriving at main line stations of the S.N.C.F. from the suburbs, for the final part of their journey to work. The method was to find those different combinations of times, costs and numbers of changes which gave rise to the same proportion of travellers to a particular destination using one mode. The trade-off between cost and travelling time on bus or metro was about Fr. 290 per earner per hour (1961). It was also found that waiting and walking times had about twice the effect on choices of vehicle travel times.

B - Similar to A: Combinations of time and cost were found which produced the same percentage utilization of private transport.

Comment A: This seems quite a reliable result: the numbers in the samples were large, and explicit account was taken in the analysis of bus and metro frequencies, and of walking and waiting times. Since the analysis was centred primarily on those with season tickets, one might assume that the commuters' decisions were quite well in equilibrium with their travel opportunities (the season tickets were by the week).

B: This result relies crucially on estimates of operating costs. Their method of calculation would tend to produce a figure which, on British experience, is higher than that which people think are the costs of running a car. No sensitivity tests are reported. Further, it is surprising that collinearity between times and costs did not prevent satisfactory estimation of the required co-efficients.

Mode A: Public transport only.

B: Private and public transport.

Purpose: Commuting only.

Earners/Dependant: Earners only.

Income: Value of time appears proportional to average hourly earning.

Length A & B: All urban trips, of short length, although (A only) in the context of relatively long (i.e. mainline) train commuter trips.

Results A: Fr. 2.90 per hour)
B: Fr. 5.10 per hour) about 75% of hourly income

The former figure appears reliable: the latter does not.

3. Authors: N. Lee and M.Q. Dalvi.

Reference: Variations in the Value of Travel Time.
Manchester School, September 1969.

Method: Analysis of time-cost trade-offs in choice between public transport modes (data on choices involving cars was collected but not used in the analysis reported in the reference). Method was to ask respondents what increase in travel cost on the preferred mode would make them indifferent between modes. Each individual value of time was then calculated using total time and travel costs by each mode at the point of indifference. The authors then proceeded to examine the variations in values of time so calculated across the sample, and across sub-samples of "time preferers" and "cost preferers" (see also Beesley's study for an explanation of these terms); they attempted to relate these variations, by regression analysis, to various factors such as journey length, walking and waiting time, income, etc. Overall, an average value of time of 30% of travellers' gross personal hourly earnings was obtained (a range in sub-groups of 15 - 45%).

Comment: The method for deriving the values of time is open to the same criticisms as for Beesley's work - namely that the value is really for a "mix" of in-vehicle, walking and waiting time, and that there is an implicit assumption of indifference between modes at the time and cost differences. Furthermore, the actual point of indifference in terms of time and cost differences that is used for obtaining a time value is based on individuals' responses to hypothetical situations, not revealed behaviour. This being said, the attempt to relate variations in time value to different factors is extremely interesting: the analysis suggests for instance that value of time may increase with income but in decreasing proportion, and that value of time may increase with journey distance.

Mode: Public transport.

Purpose: Commuting only.

Earner/Dependant: Earners only.

Income: Some evidence that values increase with income, though in decreasing proportion, may not be reliable.

Length: Some suggestion that values increase slightly with journey length, may not be reliable.

Results: Average over the whole sample: 30% of gross hourly income. May tend to understate the value of in-vehicle time.

4. Author: T. Lisco.

Reference: The Value of Commuters' Travel Time: a Study in Urban Transportation. Dissertation submitted to the Social Sciences Faculty, University of Chicago.

Method: Analysis of time-cost trade-offs in choice between public and private transport. The data refer to a group of 159 commuters in the Skokie and Merton Grove suburbs of Chicago selected to eliminate such factors as use of car during work, car pooling and non-peak travel. The statistical technique used was multiple probit analysis and the value of time is obtained by comparing the co-efficients of time (differences) and cost (differences). Two similar values were obtained according to different estimates of driving costs. Other variables included were income, sex, age and family structure.

Comment: This study was carried out with great care and considerable ingenuity is apparent in the application of the statistical methods employed. Various possible points of criticism are as follows. First, no distinction was drawn between various types of time waiting, travelling, or by each mode. This may have led to a bias upwards in the value obtained if this is taken to apply solely to travel time. Second, the times used were measured not perceived times. The latter were rejected mainly on the grounds of their inaccuracy: however, it can be argued that it is the perceived times which are relevant to the individual decision taken. (Also the method of obtaining perceived times was clearly deficient since it was not based on the traveller himself). Third, the range of car mileage costs used may well be higher than those actually perceived by travellers. This was not tested; if so, the results would be biased upwards. An analysis of parking charges is presented which suggests a value of walking time three times greater than travel time.

Mode: Average over car and rapid transit.

Purpose: Commuting only.

Earners/Dependant: Earners only.

Income: Evidence that the value of time is positively related to income levels is given. The values are estimated to rise more than in proportion from lower to middle income groups, and less than in proportion in the higher groups.

Length: Medium distance commuting from suburb to city centre, with an average length of about 15 miles.

Results: The values obtained were about 40 - 50% of average hourly incomes for the middle income groups. The average values obtained were \$2.53 and \$2.67 according to two different levels of assumed car operating costs.

5. Authors: Local Government Operational Research Unit.

Reference: Modal Split: Factors determining the choice of Transport for the Journey to Work. Report No. C32, August 1968 (L.G.O.R.U., 199 Kings Road, Reading). (This does not contain the results quoted below).

Method: Using methods very similar to that used by Quarmby and Lisco, discriminant analysis (and also public analysis) was used to explain the modal choices of commuters in four areas (central Liverpool, central Leicester, central Manchester and an industrial suburb of Manchester), both separately and in combination. The particular models tried in the work described in the above reference did not readily yield a value of time; the results quoted here are based on subsequent work which is still (at the time of writing) in progress. The value of "mixed" time - i.e. from a model in which overall travelling time only was used, with no variables describing component times - was found to be in the range 6/- to 8/- per hour. In a model in which in-vehicle time, walking and waiting times were distinguished, the value of in-vehicle time was 2/6 to 3/6 per hour. With a mean annual income of £1,400, this is about 50%, and about 20 - 25% respectively.

Comment: Statistically, the same points can be made as about Quarmby's study and Lisco's study. Generally the sample sizes were larger than most other studies (for some mode pairs, nearly 1,000 observations were used). Further detailed comment must await publication.

Mode: Averaged over bus, car and train.

Purpose: Commuting only.

Earners/Dependant: Earners only.

Income: No evidence available as yet; some may be in the analysis when published.

Length: See as for Income.

Results: Value of travelling time in-vehicle: 20 - 25% of gross personal income.

6. Author: Planning Department, G.L.C. (C.A. Barnett and P.D. Saalmans).

Reference: Report on County Hall Journey to Work Survey 1964. January 1967. Unpublished, but available from the authors. Greater London Council.

Method: Analysis of choice of mode on journey to work; first method of analysis identical to Beesley's [See (1)]; second method similar, but criterion was the minimization of the number of misclassified people, where each was weighted by the amount by which he was misclassified. Sample was County Hall employees. Values of time were derived for five different income groups, as follows:

Mean Hourly Income	Value of time (averaged over all modes)	% of Income
29/-	4/-	14%
20/-	3/-	15%
13/-	3/-	23%
9/-	2/-	33%
7/-	2/-	28%

The second method gave almost identical results. The numbers in the high income samples were very small, which casts some doubt on the reliability of the high income values.

Comment: The same general comments apply to this as to Beesley's work in (1), that it is assumed that modal choice can be sufficiently well explained in terms of times and costs alone, and that the influences of these variables are not distorted by their having to stand proxy for other factors not explicitly mentioned.

Mode: Averaged over public transport and car.

Purpose: Commuting.

Income: Some evidence that values of time increase as income increases, though not in constant proportion. Difficult to judge, however, as higher income values of time are less reliable.

Length: No information about variation with journey length of time.

Results: Value of time appears to be a declining proportion of employee's income, from about 30% for those under £1,000 p.a. down to 15% for those earning £2,000 p.a. and above. The latter figures may be unreliable because of the small sample size.

7. Author: D.A. Quarmby.

Reference: Choice of travel mode for the journey to work: some findings. Journal of Transport Economics and Policy, Vol. 1, No. 3, September 1967. Results are given in more detail in 'Factors affecting commuter travel behaviour'. Ph.D. Thesis, University of Leeds.

Method: The values of time are derived from the results of applying a discriminant analysis model to explain the choices made between car and public transport for a sample of car owners working central Leeds (1966). As a source for values of time, this model has the advantage over (1) of being able to take explicit account (in explaining modal choice) of a number of other factors - besides overall travel time and costs - such as walking times, so that the trade-off between cost and travelling time is somewhat "purer". On one run of the model which used seven such variables to explain modal choice, the trade-off between travelling time and cost (for the four income groups into which the sample was divided) were:

Mean Hourly Income	Value of Time	% of Mean Income
23/-	4/10	21.1
14/9	unreliable	
10/6	2/7	24.6
7/2	1/9	24.0

There is thus good evidence of proportionality of value of time to income. Taking all income groups together, values of time for the whole sample for four slightly different ways of setting up the model were obtained as follows:

<u>Mean Hourly Income = 14s.7</u>			Value of Time	% of Mean Income
Method	i)	}	2/10	20.6
	ii)		3/1	21.4
	iii)		3/3	23.6
	iv)		3/6	24.9

There was further evidence, from further analysis that bus time is valued more highly than car time:

Value of Car Time	1/10	13.5
Value of Bus Time	4/10	33.7

However, a high intercorrelation between variables makes these estimates somewhat unreliable; although it is interesting to note that the bus value of time is higher than that averaged over both modes, and is moving some way towards the French estimates (see 3). Some analysis additional to that described in the reference was carried out to see whether there was a significant variation of values of time with distance travelled to work. Out of five distance ranges, three significant values of time were obtained as follows:

0 - 3 miles	}	no significant values obtained
3 - 4 miles		
4 - 5 miles		3/3 per hour
5 - 6 miles		2/8 per hour
Over 6 miles		2/9 per hour

It is considered that this result is insufficient to base any differentiation of values according to journey length. Results for walking and waiting time suggested a value 2 - 2½ times that for travelling time.

Comment: The method is rather more sophisticated than that of (1), (4) and (6) however, a statistical method such as this does need the data to meet certain requirements of normality and homoscedasticity, which it can be argued are not strictly met in this study.

Mode: Averaged over bus and private car. Some evidence (not too reliable) that bus has a higher value of time than car - possibly expressing the higher level of discomfort in public transport relative to car travel.

Purpose: Commuting only.

Earners/Dependant: Earners only.

Income: Some evidence that the value of time is about a constant proportion of income. Results are expressed as a per cent of earner's gross income, not household.

Length: Some evidence that absolute time in minutes is more important than time increments as proportion of total journey time. All urban type trips - mean length about 5.5 miles.

Results: Best estimate of value of time is 2/9 to 3/6 or 20 - 25% of hourly earnings.

8. Author: P. Stropher.

Reference: Predicting Travel Mode Choice for the Work Journey Traffic Engineering and Control, January 1968.

Method: Based on analysis of choice of mode for journey to work; two samples, University College commuters, and County Hall commuters [survey subsequent to that in (4)]7. Basic data and the same type as that used in (1) and (4) - overall times and costs by the two modes. Method of explaining choice of mode slightly different - first split down the sample into cells, where each cell corresponds to a certain time difference bracket and cost difference bracket, then measure the proportion using one mode in each cell - treat this as the probability of using that mode for those time and cost conditions, and regress it on the time and cost differences for each person.

Comment: Method is more reliable than (1) and (4), in the sense that it uses all the data, and not just that near the margin of change. However, this study is subject to the same comment as that made on (1), that it ignores differences between travelling and walking and waiting times.

Mode: Average over public transport and car.

Purpose: Commuting only.

Earners/Dependant: Earners only.

Income: Some evidence that values of time are a declining proportion of income. If income is associated with distance travelled, then the value of time may really be varying with distance (or time). No evidence available.

Length: No information urban trips. But see Income above.

Results: The values obtained were equivalent to 20 - 25% of the wage rate. A lower proportionate value was obtained for the very highest income group (over £3,000 per annum) but the sample size and the statistical significance of the results for this class were relatively low.

B. Route Choice Studies:

9. Author: Howard W. Bevis.

Reference: Estimating a Road User Cost Function from Diversion Curve Data. Highway Research Record 100.

Method: Using data from four early 1950's studies in the United States of America, Bevis attempts to explain proportions of travellers using freeways and alternative all-purpose roads (1 Freeway per study) in terms of the differences in the components of a "generalized cost" - time, distance, etc. Unlike Claffy's study, which only has one "observation" for each Freeway, Bevis uses the proportions of travellers for each of a large number of zonal interchanges in the areas for which the study data was gathered. No automobile mileage cost rates as such were applied; instead it was assumed that drivers perceived their car operating costs as parabolic with respect to speed, with fixed per mile element varying with speed, and a per mile element varying with square of the speed. The regression analysis was used to devise parameters for these various components of cost as well as for time. The object of the work was to derive a road user cost function; the generalized cost function from the regression was scaled so as to correspond with known levels of total cost, and the value of time was found to be in the range \$1.25 to \$1.40 per hour.

Comment: The method assumes some sophistication of driver's perception of their car cost functions, and by scaling, at the end, to known (objective) levels of car operating cost, the method assumes drivers behave according to the total of car operating costs. Moreover, the method could be used to find a perceived car operating cost. Also, the linear regression equation is used directly as a probability estimator - which may introduce distortions since, as Bevis himself shows, there is an S-shaped relationship in reality. Unfortunately the results lack generality, because no other information is presented to enable the particular values to be compared with anyone else's estimates - e.g. car occupancy, journey purpose split, and most important, income. Since the data is now more than 15 years old, the absolute values of time cannot be compared with more recent values without some idea of income levels then.

Mode: Car.

Purpose: Not known.

Earners/Dependant: Not known.

Income: Not known.

Result: \$1.25 - \$1.40 per vehicle, averaged over 4 studies in the early 1950's.

10. Author: F. Claffey, C. St. Clair, N. Weider.

Reference: Characteristics of passenger car travel on toll roads and comparable free roads, H.R.B. Bulletin 306, 1961.

Method: Time and cost trade-offs in choice of route between toll roads and free roads. Attempts were made to take account of the difference in accident rates on the two types of road, and of the driver discomfort (measured by "speed change units" - see the reference) as well as the time and cost differences. The method was to regress the cost difference on the time difference, difference in cost of accidents (expected) and the function expressing the proportion using one route. A value of time was estimated 2.37 ϕ per minute per vehicle (1959). This is \$1.42 per hour per vehicle. At the then exchange rate of \$2.80, this is 10/1d. per hour; at \$3.40*, this is 8/4d. per hour. There was no information about occupancy. Gross hourly earnings can be taken as \$2.20 per earner per hour.

Comment: The form of the regression function used in the analysis is open to criticism. The main point is that the dependent variable in Claffey's regression, cost difference, is really an independent variable, while the proportion using one route (put in as an independent variable) is really the dependent variable. Both the Mathematical Advisory Unit and the Road Research Laboratory have conducted re-analysis of the data, and conclude that with the regression function in its more plausible form (with the proportion using one route as the dependent variable) time is shown to be unimportant in explaining choices. Hence no reliable value of time can be derived from this study. Additionally, the extremely high multi-collinearity between the "independent" variables would cast doubt on the reliability of the regression co-efficients, even if they had been significant.

Mode: Private car.

* This is an estimate of the then purchasing power parity rate.

Purpose: About half the trips analysed were holiday and social/recreational trips; less than one-third were on work or journey to work. In fact the authors did not distinguish between different trips purposes in the analysis, but concluded from the answers to attitudinal questions that different trip purposes would not have a significant effect on the inclination to use the toll roads. This perhaps needs greater verification before we can conclude that the results are valid for leisure journeys.

Earners/Dependant: The value of time is obtained per vehicle. Nothing in the study indicates how it might be split between earners and dependants.

Income: No information on occupancy of earners, nor on incomes of the sample. No information on the variation of values of time with income.

Length: These routes were all inter-urban "turnpikes", so that trip length will be "long".

Results: At \$2.80, value is 10/1d. per vehicle per hour (1959). At \$3.40, value is 8/4d. per vehicle per hour. Because of the points made in Comment, no reliance can be placed on these values.

11. Author: R.F.F. Dawson and N.D.S. Smith (Road Research Laboratory).

Reference: Evaluating the time of private motorists by studying their behaviour: report on a pilot experiment. Research Note 3474/RFFD.NDSS. May 1959.

Method: An analysis of the trade-offs between time and cost in the choice of route: between a long road journey up an estuary and across a bridge and a journey shorter in time but often more expensive by ferry (at Queensferry). Time and cost differences were calculated from a sample of motorists, some of whom were interviewed taking the longer road route, some interviewed at the ferry. The Research Note reports that the likely value of time lay between 7/2d. and 9/4d. per hour "per motorist". It is less arguable to state that this is a value per vehicle per hour. This was in 1957; the mean income of "motorists" was estimated at £985 per annum or 9/10d. per hour assuming a 2,000 hour year.

The values of time quoted were obtained by taking the average of the rates at which the ferry users in fact were trading off time and cost in choosing to use the ferry, and again for the bridge users similarly. The first average was taken as the minimum likely value for time (7/2d.) and the second as the maximum likely value (9/4d.).

Comment: The field work was careful and efficient. The three criticisms detailed below refer to the method of analysis and interpretation of results. Firstly, there was in fact a very large range of actual rates of trading off time against cost (from 0 to infinity) for both ferry users and bridge users. There seems to be no basis for saying that the average rate for the ferry users and the average rate for bridge users should be the bounds of likely values. An alternative approach is to use what has become known as the Beesley method (see (1) below), which introduces the concept of a threshold of change, and is concerned to minimize the number of people whom a model of route choice has predicted wrongly. The Mathematical Advisory Unit (M.A.U.) in the Ministry of Transport has carried out such an exercise, on summarized (not raw) data available in the back of the reference. The value yielded by this is 8/6d. per hour per vehicle.

Secondly, both these methods assume that the time waiting at a ferry travelling on the ferry is valued at the same rate as time spent driving. If the former can be valued at more than driving time, the real value of time driving is higher than the above estimates; if lower, the real value of time driving is lower. M.A.U. has recently re-analysed the data from this study, using discriminant analysis to assign weighting co-efficients to the factors:

(i) difference in driving time by the two routes, (ii) differences in costs, (iii) waiting time for the ferry, in such a way as to achieve the best possible explanation of observed choices. The multiple correlation co-efficient was 25%, which indicates a rather poor level of explanation in terms of these three variables. A rather high correlation was indicated between driving time difference and cost differences, so that the discriminant co-efficients themselves are not particularly reliable. In fact the time co-efficient was found to be insignificantly different from zero, while the cost co-efficient was significant (t - ratio 3.45). But the presence of high correlation between the two variables prevents any useful conclusions about the effects of those two variables individually and certainly prevents the derivation of a reliable value of time from this study.

Thirdly, in interpreting the results, it was assumed that there was one earner per car, and by quoting the results as "per motorist", it assumes that all other occupants of the car have no value of time. It is suggested a more satisfactory interpretation is "per vehicle".

Mode: Private car.

Purpose: Leisure travel (commuting and on-business journeys were eliminated from the sample analysed).

Earners/Dependant: No information; value was per vehicle.

Income: No information about average income per car, as nothing about the occupancy of earners. However, using a different hypothesis (see discussion in text) about how people and households spend their money, value of time can be expressed as a proportion of the vehicle's "income" as occupancy data is available.

Length: These are what could be called inter-urban trips, and would have been more than 15-20 miles in length generally. No information on variation of values of time with length.

Results: R.R.L.'s method - between $7/2d.$ and $9/4d.$ per hour (1957) Beesley's method - $8/6d.$ per hour. Neither the original results nor the subsequent discriminant analysis are reliable for the reasons given.

12. Author: Stanford Research Institute (Thomas C. Thomas).

Reference: The Value of Time for Passenger Cars: An Experimental Study of Commuters' Values, Stanford Research Institute, 1967. A short report on this study is contained in Highway Research Record 245, 1968.

Method: Analysis of time-cost trade-offs in the choice of route. A number of different physical situations were analysed where car commuters were faced with a choice between a tolled and an untolled route. Two variants on the basic method were used: the first used measured differences in journey times (differences in cost were calculated directly from the toll rate) and the second, perceived differences, i.e. motorists' estimates. These were used in a route choice analysis where the dependent variable was the probability of the user taking the free road. The first variant produced a value of time of \$1.82, the second of \$3.82, and a mean of \$2.82 was recommended on the grounds that both methods were subject to measurement error and consequently the best estimate of the true value lay half way between the two values obtained. The mean income of the motorists surveys was \$9,200 per annum and the time values as a proportion of mean income were 40% (first variant) 83% (second variant), and 61% (average).

Comment: The fieldwork and statistical analysis were carried out with great care and the study cannot obviously be faulted on these grounds. The main difficulty lies in the difference between the results obtained from the two variants. While the lower result is rather high, but broadly in line with results obtained in Group A studies, the upper value is completely out of line with other results, and there would appear to be no reason, on an examination of the study which would suggest that the one value should be preferred to the other. The one possible weakness is the obvious sensitivity of the results to small difference in perceived or measured costs - the very large difference in time values obtained results from fairly small differences in measure and perceived times. But a priori this could have as well biased the results one way or another.

There are, however, three possible reasons why the results obtained in this study should be so high relative to others. The first is that the demand or time savings is income elastic. The lower value is consistent with the values proposed in this paper if an income elasticity of demand of about 1.5 is hypothesised, a not unreasonable figure. But the upper figure and even the average is too high to explain away on these grounds. The second is that the time values obtained may reflect factors not present in the urban studies, for example, a bonus for specifically freeway/motorway driving conditions. An attempt was made to express these in the route choice model but it was not found to add significantly to the level of explanation. It is possible however that the failure of this item to appear separately was a result of collinearity. It is unlikely that the value of the motorway bonus alone could explain the differences in levels, but if it did exist but could not, because of collinearity, be detected by the analysis, it might have affected the values obtained to a larger extent than its own importance would imply. The time differences were relatively small, but the bonus would be felt throughout all the journey length, and might therefore be significant relative to the time differences, even if of low unit value. Finally, some bias in the estimation of both the time and cost co-efficients may have occurred through the inclusion of income in the equations used. The significance attached to both of these factors is likely to be a function of income and it would have helped had it been possible to stratify the sample by income group (this was rejected on the grounds of insufficient numbers) to allow a check on the effect of income on the co-efficients. Without this disaggregation it is not possible to say anything about the possible direction of the bias.

Mode: Private car.

Purpose: Journey to work.

Earners/Dependants: No information: all occupants treated identically.

Income: Motorists were divided up into income categories. Income categories were found to be significantly and negatively correlated with probability of taking the free road.

Length: The trip length was fairly lengthy by average British commuting standards, but could not be classed as 'long'. No information on variation of values of time with trip length.

Results: At \$2.80, the value of time obtained was 13/- (1st variant) and 27/2d. (2nd variant). At \$3.40; 10/8d. and 22/5d. These are respectively 40% and 83% of average incomes.

C. Miscellaneous Studies.

13. Author: H. Mohring.

Reference: Highway benefits: an analytical framework.
Northwestern University, The Transportation Centre.
June 1960.

Method: The trade-off between commuting costs and rent. Mohring assumed that house prices reflected, ceteris paribus, the capitalization of the time and operating costs of the journey to work. Using data from Seattle (Washington State, United States of America) he estimated that the value of time indicated was in the range \$0.50 - \$1.00 per person per hour at 1960 prices. At an exchange rate of \$2.80, this is 3/7d. to 7/2d. per hour. At \$3.40, this is 2/11d. to 5/10d. per hour.

Comments: The existence on a range of values reflects an initial 20% uncertainty about the capitalized values, and uncertainty about the appropriate discount rate (5 - 10 per cent). Mohring recognizes important shortcomings in the analysis, the data, and the model. The method assumes, for instance, that there are no other important factors affecting house prices, such as accessibility to other activities (shopping, etc.) and the general housing environment, even if similar housing types have been identified. With average gross hourly earnings at \$2.32 per earner, the value of time can be expressed as 22 - 43% of gross earnings.

Mode: Not specific, but probably applies to private cars primarily.

Purpose: Commuting only.

Earners/Dependant: Earners only.

Income: Expressed as a proportion of gross hourly earnings, there is no evidence that the value of time varies in any particular way with income.

Length: Typical urban work trips.

Results: \$0.50 - \$1.00 per hour. As a proportion of gross hourly earnings, this is 22 - 43%.

14. Author: H. Mohring.

Reference: Urban highway investments; In measuring the Benefits of Government Investments, e.g. Dorfman, Brookings Institution, 1965.

Method: Uses an assumption that a driver chooses his speed on a road (in free flow conditions) so as to minimize his total journey costs. Above 40-45 m.p.h., operating costs increase with speed, time costs decrease. Using standard data from American operating cost relationships and mean and standard deviation of vehicle speeds on high quality, straight and level roads in presumed free-flow conditions, he derives a value of \$2.80 per vehicle per hour (1963). At the exchange rate of \$2.80 to the £, this is 20/- per vehicle per hour; at \$3.40 it is 16/6d. Average gross hourly earnings were \$2.44 in this year.

Comment: This method is highly suspect, as there is no evidence that drivers are sufficiently well aware of the relationship between speed and operating cost so as to be able to choose speeds to minimize total cost. Even if they did, one can argue that there are many other factors which influence free-flow speed. There is no evidence, for instance, that cars with more passengers travel any faster, as should happen if speed were determined purely by time consideration.

Mode: Private car.

Purpose: Presumably averaged for all purposes.

Earners/Dependant: No information; value only for vehicle.

Income: No information about average income per car, or occupancy of earners.

Length: No information about possible variation of value of time with length. Rural type roads, so likely to be fairly long trips.

Results: At \$2.80 each, value of time is 20/- per vehicle (1963); at \$3.40 each, value is 16/6d. per vehicle per hour.

D. Papers communicated to the Round Table by
Mr. DANET (CERAU, Paris):

1. CERAU

- Etudes et recherches sur la demande de transports de voyageurs. 1968.

(Studies and research on passenger transport demand. 1968).

Survey commissioned by the Commissariat
Général du Plan d'Equipement et de Productivité.

- Etude de la demande de transport sur l'axe Paris-Rouen-Le Havre. Rapport de synthèse sur l'étude de la sensibilité de la demande de transport régional par rapport aux conditions de transport. 1968.

(Study of transport demand on the Paris-Rouen-Le Havre axis. Summary report on the study of the sensitivity of regional transport demand to transport conditions. 1968).

Study commissioned by the European Economic Community.

2. CREDOC

- Etude sur l'arbitrage entre le coût et la durée du transport dans le choix du mode de transport. Nov. 1966.

(Study on trade-off between journey cost and journey time for purposes of modal choice).

Study commissioned by the Ministère de l'Equipement et du logement, Centre des Affaires Economiques et Internationales (S.A.E.I.).

3. IAURP

François MELLET: "Analyse du choix du mode de transport par les usagers en Région Parisienne".

(Analysis of users' choice of mode of transport in the Paris Area).

in: Cahiers de l'IAURP, vol. 17-18, octobre 1969.

4. Ecole Nationale des Ponts et Chaussées.

COUSQUER Richard: "La valeur du temps dans les déplacements domicile-travail".

(Value of time in journey-to-work trips).

- Cas d'un grand ensemble de Lyon.

(Case study of a multi-storey housing development at Lyon).

Published by the Service des Etudes et Recherches sur la Circulation Routière (now Institut de Recherche des transports), Ministère de l'Equipement et du Logement.

5. CETE d'Aix en Provence.

J. Dürr: Evaluation et sensibilité à certains paramètres de la clientèle d'un métro.
juin 1969.

(Evaluation of an underground railway's clientele and its sensitivity to certain parameters).

6. SEMA

Y. BOULVIN et H. RAYNAUD:

"Recherche sur les comportements en matière de déplacements. Analyse d'entretiens en profondeurs".

(Research on travel behaviour. Analysis of detailed interviews).

Interim report on a research project financed by the Délégation Générale à la Recherche Scientifique et Technique.

7. CERAU: Study in progress, planned for completion in April 1970.

Choix du mode de transport dans l'agglomération marseillaise.

(Modal choice in the Marseilles conurbation).

Study commissioned by the Institut de Recherche des Transports (I.R.T.).

ANNEX B

VALUE OF TIME SAVINGS ON LONG TRIPS - A NOTE ON SOME ADDUCED TENDENCIES.

1. For valuing time savings due to improvements in transport networks we are by definition interested in the value of time at the margin rather than the value of time averaged over the whole journey. These may or may not be the same: if the marginal value is constant for journey times from zero upwards, then the average value is equal to the marginal value. In which case it would not matter whether a particular empirical method measured the marginal value or the average value.

2. If we accept the "opportunity cost to the employer" view of the value of working time, then we can say straight off with some theoretical justification that the value of working time at the margin of a journey is constant irrespective of the journey length (or time) - and is thus the average value. Since we accept a behavioural view of the value of non-working time, we need to establish empirically what happens to the value of time at the margin as journey lengths vary. As with many other questions in this general area, it cannot be answered directly, and few empirical trade-off situations if any have yielded data of a requisite variety and quality to allow existing multi-variate statistical methods to throw up anything of any value.

3. However it is possible to infer some intuitive and qualitative properties of the marginal value from the functional form of some of the mathematical models used - having been derived independently - to describe and predict different aspects of travel behaviour. One such model is the so-called "gravity model" or distribution model, which allocates or distributes trips originating from a particular area between all possible destinations. This model can take many operational forms, but each form contains an algebraic function of the time or cost or other measure of spatial separation between the originating zone and the typical destination. The value of these functions falls as travel time, (say) increases, so the effect is to reduce the propensity to travel to more distant places, other things being equal. Conventionally the function may be a negative power of the travel time t^{-n} or a negative exponential function of the travel time e^{-t} , or the product of the two, or it may be a wholly "empirical" function which takes the form of a vector $\underline{f}$ whose values corresponding to the elements of the travel time vector $\underline{t}$ are derived directly from analysis of traffic survey data.

4. Normally it is of little concern to the traffic engineer which type of function turns out to "fit" his data best; it is of considerable concern to us, since each of the first three alternatives embodies an assumption about the marginal utility - if not the marginal value - of travel time. Basically, the use of a power function implies that changes in travel time are perceived and acted on in relation to the total time of the journey, and that it is ratios of travel times that are important in determining the propensity of people to choose to go to one place rather than another. An exponential function however, implies that it is absolute changes in travel time which influence behaviour, and that it is differences in travel times between different places that determine where people choose to go to.

5. The first implies a marginal value of time which is increasingly proportional to journey length (or time), the second a marginal value of time which is constant. Let us see how this follows. In the trip distribution model, we can say to a first order approximation that T , the amount of traffic making a particular origin-destination journey, is related:

$$T = k. f(t)$$

where t is the journey time for the journey. The effect of changes in travel time on travel behaviour is given by

$$\frac{dT}{T} = \frac{f'(t)}{f(t)} dt$$

which for the power function $f(t) = t^{-n}$ is

$$\frac{dT}{T} = \frac{-nt^{-n-1}}{t^{-n}} dt = \frac{ndt}{t} = nd (\log t)$$

and which for the exponential function $f(t) = e^{-\lambda t}$ is

$$\frac{dT}{T} = \frac{-\lambda e^{-\lambda t}}{e^{-\lambda t}} dt = -\lambda dt$$

So for the power function, not only is T proportional to changes in t effect behaviour, but the value of T is also a logarithm's function of time; in the exponential function, absolute changes in t are important.

Note also that:

$$\text{for the power function } T_1/T_2 = k_1 t_1^{-n} = k_1 \left(\frac{t_1}{t_2} \right)^{-n}$$

while for the exponential function $T_1/T_2 = k_1 e^{-t_1} = k_1 e^{-\frac{-(t_1-t_2)}{k_2}}$

This highlights how under the power function, trips split proportionally between places on the basis of the ratio of travel times; under the exponential function, it is the difference in travel times that is relevant.

6. In practice, it is often found that an exponential function alone best describes trips made wholly within urban areas, implying that the value of time is constant over urban sorts of journey lengths. For inter-urban travel, much less model-fitting has been attempted than for urban travel, but evidence of recent work within the Ministry of Transport suggests that a combined exponential and power function best describes this longer distance travel behaviour. This carries the implication that the value of time can be regarded as constant for shortish journeys (where the power function has little relative effect) but will tend to decrease at the margin as journey lengths increase - though rather less fast than the increase proportion to the journey length, because the power function is not present on its own. The journey length for which the turn down in marginal time value begins to be significant, and the rate at which it then falls, are both dependent on the relative values of λ and n .

$$\begin{aligned} \text{If } f(t) &= e^{-\lambda t} t^{-n} \\ \text{then } f'(t) &= (-\lambda e^{-\lambda t} t^{-n} - n e^{-\lambda t} t^{-n-1}) dt \\ \frac{dT}{T} &= \frac{f'(t)dt}{f(t)} = -\lambda dt - \frac{ndt}{t} = -\left(\lambda + \frac{n}{t}\right) dt \end{aligned}$$

Empirical findings of $\lambda = 0.1$ for urban studies and $n = 2.5$ and $\lambda = .025$ for inter-urban studies give a constant value of time up to about 33 minutes, after which it drops off to about half the value at 100 minutes and settles down to approach $\frac{1}{2}$ of the value as t gets larger and larger. These values of λ , n etc., are quoted as illustration to indicate the broad pattern of movement rather than as authentic values, although they are certainly in the right range.

ANNEX C

VEHICLE TIME SAVINGS

1. The simplest method of evaluating vehicle time savings is to sum over savings resulting from an investment and then dividing this figure for an assumed average utilization rate for vehicles. The resultant number of vehicles may then be valued at an appropriate unit cost; to this amount may be added sums for time (NOT mileage) related maintenance costs and some depot and garaging costs associated with keeping vehicles. This latter item parallels the overheads associated with the employment of labour mentioned above. In this instance, however, it would not be appropriate to include tax items, since they do not represent a measure of the opportunity cost of the capital tied up in the vehicles. Thus the argument here is the converse of that used for wage costs. The distinction arises solely from the fact that taxes on employment have been assumed general while those in vehicles have been assumed specific to vehicles. Where a tax on a factor is general, then its marginal value product must equal payment to it plus tax throughout the economy. Where a tax is specific to an industry, the increment of resources from the taxed to the untaxed industry results only in an increase in output equivalent to the factor payment.

2. The main objection to this method lies in the assumptions of flexibility and vehicle utilization implied; the justification for using it follows precisely the same lines as that used above for similar assumptions for working time, and there is no need to go over the points again here.

3. The theoretical outline sketched in 1 represents an assumption that because of the increased productivity that road improvements allow, the same volume of work will be done with fewer vehicles: the capital and time dependent costs of these vehicles are saved. It is further assumed that these savings are realized immediately. For this to be feasible, a prior assumption must be made that there is at any point in time a proportion of the vehicle fleet about to be replaced, otherwise the saving could not be realized immediately. In many conditions this assumption will be realistic but this will not be true for cars used privately, since individuals replace infrequently and the fact they make journeys quicker is only marginally relevant to these decisions. Hence no allowance for capital savings is appropriate here.

4. Replacement decisions will be effected in a further way through the fact that the existing fleet and the (reduced) level of a new purchase will wear out quicker in terms of time and hence have to be replaced sooner than previously. Thus at the same time as the current investment bill is reduced, the present value of future bills is increased: its estimation will depend on the age structure and assumed life of the vehicle fleet. This calculation is not straightforward, since it depends on being able to distinguish between mileage (or use) dependent depreciation, and time dependent. If depreciation was purely time dependent, then vehicle life would remain unchanged and total utilization go up: and if it were purely mileage dependent then life would reduce pro rata to mileage run. It is an empirical matter which effects predominates.

5. The studies referred to in the main text concerning earners time are all clearly relevant to the problem of estimating vehicle time savings, since they suggest the existence of rigidities and indivisibilities, some of which will apply to vehicles as well as men, so as to prevent a smooth conversion of time savings into vehicle savings. While vehicle time values have been derived in great detail in the United States (see NCCRP Report 33), we are not aware of any research specifically aimed at testing the assumptions upon which the values are based and in particular to resolve some of the difficulties mentioned above, e.g. the correct treatment of depreciation.

SUMMARY OF THE DISCUSSION

I. PROBLEMS OF QUANTITATIVE EVALUATION

The main points raised in the course of the discussion on this topic were as follows:

1. With regard to the use of econometric models for measuring the value of time, the most successful approach seems to be to start with behaviour-explaining models (e.g. modal choice) and, as a next step, to derive time values from them. It seems better to proceed in this way than to reverse the sequence. Even so, two major problems are encountered:

- (a) logical definition of variables to be adopted (time, cost, etc.);
- (b) the variety of methods for dealing with the evaluation of parameters: discriminant analysis, multiple linear regression and probit methods.

It must be pointed out in this connection that the models so far produced have given better results for urban transport than for inter-city transport; in any event, empirical models for explaining behaviour will have to be built on a whole series of assumptions concerning user psychology. This shows how important it is to achieve close co-operation between psychological and econometric approaches in order to arrive at reliable figures for time values. Incidentally, various aspects of the link between motivation surveys and the econometric approach were dealt with at the Third Round Table organised by the E.C.M.T.

2. Econometric models relating to the value of time have indeed been used with some degree of success, but some of the empirical conditions essential for truly correct model analysis are not entirely fulfilled, if at all. This point is dealt with at greater length in the introductory report.

Complementary research methods are accordingly needed. Simulation technique is one such method which very probably gives the most satisfactory results. It is already well familiar in other fields of research and has been found most useful for the analysis of travel behaviour and for the subsequent derivation of time values.

There are also many problems closely bound up with the application of these techniques. For instance, several checks are needed to test whether people involved in a simulation experiment do in fact have the same reactions as in everyday life. As a general rule, it is advisable to begin by testing such methods in areas that are already fairly familiar, such as commuter traffic.

3. Special problems

(a) Size of time savings. Two aspects received special attention:

- (i) Is one saving of five minutes equivalent to five savings of one minute?
- (ii) How big must a time-saving be before it gives a real impression of value, that is, before it is counted as a time-saving?

Interviews can give interesting information on these points, but the basis for testing the truth and accuracy of replies is still uncertain.

The participants in the Round Table took it as a working hypothesis that time-savings should be regarded as linear. In any event, apprehension of time savings pre-supposes a critical threshold, and it is also clear that this threshold will largely depend on the conditions in which time-savings are obtained and on what the people concerned expect from the existing situation at the start.

In this connection, it may be taken for granted that the time-saving thresholds in the two following situations are fairly different: (a) savings obtained by making use of scheduled transport services (e.g. railways) and, (b) techniques involving no pre-determined time-table (private cars). Even so, it seems that, within the first category, a distinction should be made between services which follow a regular tempo in actual practice and those which do not. Roughly speaking, time-savings are usually reckoned in terms of five-minute units for trips exceeding 20 minutes, and in two-minute units for trips lasting under 20 minutes.

Experience generally confirms that time is fairly correctly "perceived" in the case of more or less regular trips, but there is very little awareness of possible alternatives. However, once the regular tempo is broken for any reason, psychological factors very soon affect the perception of time. For instance, the reported delay of a bus very largely depends on weather conditions. It is also found that late starting is keenly felt as a loss of time and that this impression is not entirely dispelled even if the vehicle or aircraft catches up the delay before the end of the journey.

Generally speaking, there is a tendency to over-estimate in-vehicle time (even more so when the vehicle is running late), but walking time tends to be under-estimated. With regard to the value of small time-savings, these can indirectly enable the individual to make re-arrangements which ultimately yield a fairly big saving well in excess of the original gain.

In the case of investment projects, the inter-dependence of various time-savings deserves special attention. Even if the time-saving for part of the project seems somewhat insignificant, it should not be entirely disregarded but rather treated as a component of the total time-saving that will be yielded by complete fulfilment of the project concerned. As the various parts of a general programme of transport investment are nearly always very closely inter-dependent, it would be wrong to overlook time-savings which may seem insignificant if taken singly but the sum total of which may yield considerable benefits. Hence, careful consideration must be given to every stage of a trip from origin to destination, and to all the minor improvements that can be introduced.

(b) Cost estimation.

This problem particularly applies to users of private cars, they being inclined to under-estimate their costs to a considerable degree. The derived values of time are of course sensitive to this factor.

It was judged desirable to distinguish between the following cases:

- (i) For the appraisal of investment projects, real costs (i.e. objective costs) must in all circumstances be taken into account.
- (ii) For the prediction of behaviour (e.g. modal choice) it is advisable to take the values set by users (i.e. the costs they subjectively perceive). Generally speaking, the "subjective" costs shown by motivation surveys are fairly closely in line with the values obtained by statistical analysis of behaviour.

(c) Classification of time-savings

First, a distinction between working time and non-working time seems necessary. Economic theory can be used as a basis for evaluating savings of working time, but not for savings of non-working time. The latter must be appraised by behavioural studies based on a combined econometric/psycho-sociological approach and on a sufficiently wide range of assumptions.

The borderline between working and non-working time is not always easily drawn in actual practice. Many business trips, for instance, fall outside the span of normal working hours, and the question thus arises whether any time saved in such cases is classifiable as working time or leisure time. The reply probably lies in an overall analysis covering activities before and after the journey itself.

(d) Use of absolute or relative values for travel time

Though it is difficult to lay down hard and fast rules, the following choice seems appropriate for representing time savings in econometric models:

- (i) Urban travel: the absolute difference in travel time between alternatives is relevant;
- (ii) Inter-city travel: relative values (travel time ratios) should be used.

(e) Use of marginal and average values

No distinction can be made between these two values with the methods at present available. This means that average values must be used even in cases where marginal values would be the logical choice. However, this handicap is of no consequence in actual practice. Furthermore, in cases where marginal value is constant, it is equal to average value.

(f) Evaluation of factors other than time

The impact of separate factors such as speed, frequency, comfort and accessibility seems very difficult to judge. For instance, lower speed is readily accepted if it saves changing from one vehicle to another.

This being so, it may be asked whether, instead of evaluating time-saving alone, it would not be better to introduce a more general value concept also encompassing the other aspects of travel.

II. SELECTING TIME VALUES

The points raised by participants in this connection, and the authors' comments are set out below:

1. Value of leisure time as compared with working time

It is generally accepted that working time should be valued at the average wage rate together with certain associated costs, but some participants questioned the authors' proposition that leisure time should be valued at 25 per cent of working time. In their view, a substitution ratio of 4 to 1 gave too much weight to working time.

The authors pointed out that this ratio was based on a number of empirical findings and independent studies. The proposition was not based on theoretical considerations. Apart from this, it would be useful to test this ratio periodically as it might be appreciably altered by changes in the way of living.

2. Value of time for groups (households)

The propositions whereby the same value of time should be attributed to all adult members of a family and one-third of the adult rate to children was not basically criticised, but the participants considered that more elaborate studies might bring

out interesting distinctions. Such research should be mainly concerned with psychological and sociological factors; for instance with questions such as these:

- (a) Does a driver make the same decisions when he is alone and when he has passengers? Would he be prepared to pay more for time saved for all his family than for himself alone?
- (b) How does a husband assess the value of time for his wife? Does this appraisal vary with the husband's type of occupation or social group?
- (c) Could it be true that the value of time for a driver is more closely related to the type of journey than to the number of passengers?

As regards the choice of mode for a household, the decisive factor seems to be cost per head. This applies to some extent to business trips: persons travelling alone are inclined to use public transport while those travelling as a group will use the car.

3. Value of walking and waiting time

The participants agreed that walking and waiting time during non-working hours should be valued at a higher rate than in-vehicle time, but the proposition that it should be twice the rate was judged insufficiently precise.

The following points have a bearing on the relationship between these two values:

- (a) Mode of transport.

There is a readier inclination to walk to a railway station than to a bus stop: this is because users can rely more safely on railway timetables and their journeys can therefore be more carefully planned.

- (b) A good deal depends on the proportion of overall travel time that walking/waiting time accounts for.

(c) Various activities (e.g. shopping or reading) may be undertaken to fill in compulsory waiting time and so mitigate the impression that this time is wasted.

- (d) Degree of information.

Users are more readily inclined to walk a longer distance if they are well-informed about the frequency and other aspects of the transport service concerned. Similarly, delays are more patiently accepted when users are promptly and accurately informed about their probable duration.

(e) Differences in environmental conditions.

The conditions under which waiting time is spent are relevant. For instance, waiting at a bus-stop is altogether different from waiting at an airport.

In conclusion, it may be said that an analysis of walking time or waiting time for a given system of transport is of little relevance to other systems. Thus, it would be difficult to apply more or less conventional values to new transport techniques.

4. Value of time according to journey length

The authors of the report assume a value of time invariant with journey length. This proposition is based mainly on empirical evidence for short and medium journeys. However, it would be hazardous to extrapolate this assumption to cover longer journeys.

Some participants accordingly wanted more data concerning long journeys before adopting the authors' hypotheses. Little information is available on this subject, and the few research findings that do exist are too widely open to conflicting interpretations.

5. Time values in the economic appraisal of transport projects

On this point, the Round Table made a clear distinction between the two following elements:

(a) Forecasting of demand (direct use).

Here, observed individual values and estimates of how they may develop during the period concerned must be used. For economic purposes, this means using values based on how people will, in practice, trade-off travel time-savings against cost.

(b) Evaluation of investment plans as a basis for decision-making (planning).

In this case it is necessary to use "social" values of time based on a more or less normative judgement which lies with the political authorities concerned.

With regard to the economic appraisal of investment projects the authors of the introductory report proposed that the value of leisure time should be given the same treatment for all income groups. This was the policy adapted by the United Kingdom Ministry of Transport.

Without explicitly endorsing this view, most participants agreed that, in practice, project appraisals had to be based on judgements of this kind. However, the problem was to move with some consistency from individual values to a "social" value acceptable to the political authorities.

In any event, the participants considered that it was always necessary to rely to some extent on empirical evidence, as failing this the criteria applied would be purely intuitive and so lead to plans which no longer matched the real needs of the community.

Some participants had stronger views on this point and laid particular stress on the hazards of bringing political considerations into a field which should remain strictly scientific. Hence, the aim should be to use objective models with no political bias. Only after calculations on a strictly economic basis should the results be compared with what is politically desirable. It may be appropriate at this stage to introduce politically determined shadow prices to get an idea of the outcome of alternative policies. In any event, the borderline where economic calculations end and political considerations begin must be clearly drawn.

6. Payment for time-savings

As the time-savings made available to users normally follow from capital investment, often on a considerable scale, the question which immediately comes to mind is whether users should pay directly for the benefits thus obtained.

This is mainly a financial issue and the Round Table did not therefore discuss all its implications but it is no less important and the following comments are worthy of note:

(a) In the case of public transport, the possibilities of converting time-savings into actual revenue seem slight. Partial solutions can be envisaged, however, in particular differential pricing (i.e. according to time of day, route and distance).

(b) On the other hand, the possibilities in the case of road investments are distinctly better, and the principle in question is already being applied to some extent since time-savings are paid for by tolls. More generally speaking, payment for a better standard of service (motorways or very fast trains) is becoming increasingly widespread. Hence, a higher price is being asked for "extra service" (the concept underlying classes for coaches on the railways is in fact extended to encompass a whole range of qualitative aspects).

(c) It may be wondered whether the public in general is prepared to pay the full price of the time-saving obtainable from an investment project. In certain cases, the evidence shows that there is far more readiness to do this than may be imagined at first sight. As in many other fields, the importance of the psychological setting is by no means slight.

(d) If account is taken of time-savings, then due regard should logically be paid to the opposite aspect, i.e. time losses. Drivers of various vehicles (e.g. heavy vehicles and caravans) often inflict such losses on other road users. This particularly applies to roads with a high traffic density where any disparate element must inevitably slacken the flow of traffic and build up traffic jams.

(e) How much should the community invest to achieve time-savings?

As this point was outside the frame of reference of the Round Table, it was simply noted that the reply was mainly a matter of political judgement, and that it largely depended on the authorities' willingness to align the "social" value more or less closely with the sum total of individual evaluations of time-savings.

The Round Table being mainly concerned with criteria for the evaluation of time-savings, a more decided judgement on the question of actual payment is a scientific and political issue for investigation at a later stage. It need hardly be said that this is a vital problem since in the absence of actual payment, the economics of time-saving remain purely academic.

III. FURTHER RESEARCH

The discussion on this point falls under two main headings.

1. Research proposed by the authors

The following comments were made on some of the proposals contained in the Introductory Report:

(a) Value of very small savings

As indirect effects can assume as much importance as direct effects, they should be considered together in an overall investment planning context. In other words, careful attention should be given to the inter-dependence of time-savings in relation to several investment projects which are themselves different and independent.

However, some participants were doubtful about the possibility of developing a purely satisfactory methodology to cover a scattered range disparate elements.

(b) Changes in the value of time over the years

It would be useful if analyses in this field could be based on time series. Extrapolations of present time values are hazardous as they have to be built on assumptions as to future behavioural and living patterns.

This being so, time series for the value of time should be drawn up on a strictly scientific basis and should cover, in particular, changes in social structure, income, leisure time, personal taste and mobility.

(c) The other proposals put forward by the authors of the Report (items 1, 4, 5 and 6) were adopted without comment.

2. Research proposed by participants

These proposals may be summarized as follows:

(a) Relationship between the evaluation of time, availability of leisure time and income per head;

(b) Relationship between evaluation of time and choice of locations for home and work;

(c) Difference in the value of time attributed to private and public transport; the feeling of independence which goes with car ownership is particularly relevant in this context;

(d) Use of time values for different planning purposes, and more especially the relationship between individual and collective values.

Some participants doubted whether this matter came within the scope of scientific research. In their view, it was entirely a matter for political judgement.

Two other comments, of a more general order, were made with regard to future research:

(a) Research has so far failed to differentiate sufficiently between social groups, yet these imply differences in occupational and housing mobility, attitude to disutility of travel, etc. This particularly applies to the study of manual workers' evaluation of time.

Evaluation of time-savings for lower income groups is further complicated by the fact that they often benefit from various kinds of reduced fares on social grounds.

It seems that manual workers have been unduly under-represented in the gathering of data for previous research and that the latter has been mainly focused on time-savings in respect of business or leisure trips. However, this comment does not apply to the same degree to every country.

(b) It should always be borne in mind that the evaluation of time-savings also depends on a number of environmental factors. Values obtained in a given region or country cannot therefore be indiscriminately applied to other areas or countries.

To avoid wrong interpretations or unduly general conclusions, it is important to show clearly, for every survey, in which situation and under which circumstances the values of time were obtained.

