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Values of Travel Time Savings in the UK

Report to Department for Transport

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VALUES OF TRAVEL TIME SAVINGS IN THE UK

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1. INTRODUCTION AND OBJECTIVES

Values of time for use in modelling and appraisal are informed by three sets of considerations – evidence, policy, and practicality. The *evidence* may be theoretical or empirical in nature: while in some cases values of travel time savings (VTTS) can be derived on the basis of theoretical reasoning, it is more often the case that theory alone gives no guide to the relevant VTTS, and a mix of theoretical and empirical approaches is required. In relation to *policy*, Governments may choose to apply VTTS in particular ways for the evaluation of public projects. The outstanding example in the UK is the use of a single standard value of non-work time savings in evaluation of public projects, despite an acceptance that VTTS varies with socio-economic characteristics. Finally, with respect to *practicality*, Government must ensure that official procedures are practical and cost-effective for the use to which they will be put.

The current study begins by considering the evidence. As a stepping stone to writing this report, we produced six interim working papers which are referred to at relevant points. A list of these working papers, which are all available as ITS Working Papers, is given in Appendix A.

An earlier version of the summary of the evidence was produced in August 2001, and on the basis of this, Dr Denvil Coombe was commissioned to consider the feasibility of implementing the findings from the evidence. A seminar for experts was held at the Department in December 2001, and Dr Coombe's report has been submitted to the Department*. As a result of that seminar, various issues came to light which have necessitated further investigations of the data, and this Report takes account of these, with the detailed additional work reported in Appendices. In the later chapters of this Report, we make recommendations in relation to policy and practicality, in the light of the revised evidence, and the conclusions from Dr Coombe's work.

The layout of the report is as follows. Chapter 2 provides some background discussion of VTTS with special relation to the UK experience, and describes the main aims of the study. Chapter 3 discusses the VTTS for employers' business travel, including freight transport. Chapter 4 is concerned with the relationship between the VTTS and the sign and size of the time savings. Our preferred approach for the value of non-work time savings is set out for car users in Chapter 5, and in Chapter 6, for public transport users. Then in Chapter 7, we construct a bridge between the empirical results and their use in evaluation. In Chapter 8, we consider, against theory and evidence, the case for the standard value of non-working time in evaluation and for variations in the VTTS by journey length and mode of travel. Finally, in Chapter 9, we make recommendations for revisions to the values in the Transport Economics Note.

*We refer to the Government Department responsible for transport as "The Department".

2. BACKGROUND

An extensive literature exists which discusses revealed preference and stated preference methods for obtaining the value of travel time savings (VTTS) and many hundreds of studies have been undertaken in order to obtain values, particularly for modelling and forecasting work. In addition to the UK, national studies have been carried out in the Netherlands, the Nordic countries and currently New Zealand and Singapore (see eg HCG 1990, Gunn et al, 1999, Algers et al, 1995, Ramjerdi et al, 1997).

2.1 UK History

A brief history of the VTTS in the UK may be a useful background to this report. In the 1960s, early cost benefit analysis work, such as that for the M1 study and the Victoria Line study, utilised the wage rate theory of the valuation of time savings for travel during employers' business, but found no theoretical basis for deriving non-work time values from the wage rate or any other observable data. This led to work which tried to infer values from people's observed travel choice behaviour (RP) or from people's statements of the choices they would make, faced by given combinations of time, cost, comfort and other attributes (SP). Pioneering papers by Beesley (1965), Quarmby (1967), Lee and Dalvi (1969) were written; a useful summary by Harrison and Quarmby (1969) is in Layard (ed) (1972).

Hand in hand with this went the development of the concept of "generalised cost", for which the *locus classicus* is the Department's MAU Note 179 (McIntosh & Quarmby, 1970). With hindsight, this can be seen as an early version of the "indirect utility" specification of discrete choice models, in which different attributes of a given travel alternative are combined (usually in a linear form) with "weights". In this form, the VTTS is the ratio of the weights on time and money.

MAU Note 179 drew a fundamental distinction between the weights used for modelling and those used for evaluation. Conceptually, there is little difficulty with modelling; weights are needed which best reflect the behaviour of the individuals who make up the relevant market, and should be based on the assessed willingness to pay for travel time and other journey attributes. For evaluation, however, other considerations were held to apply.

The willingness to pay to save travel time varies with income, among other things. During the ministerial reign of Barbara Castle at the end of the 1960s, a decision was made that for all publicly funded projects, a single 'equity' value (later renamed 'standard' value) of non-working time would be used to value in-vehicle time savings for all locations, modes, incomes and non-work journey purposes :

> *"The equity value of time is based on the average income of travellers on the journey to work and is updated using the growth in disposable income per head of population.....it is assumed to hold for all individuals on all forms of non-work journeys"* (Nichols, 1975)

Based on the work carried out for the then Ministry of Transport, walking and waiting time was to be valued at twice in-vehicle time, and the standard value was set at 25 per cent of the average gross of tax wage rate. As a result the standard value was assumed to grow proportionately to the forecast growth in income. Appropriate corrections were recommended (MAU Note 179, p 25) to convert to *household* income, so that the value of adult time in the household was assumed to be 19% of Gross household income, assumed over a 2000 hour working year.

This first wave of work on the value of travel time ended in the early 1970s, and the official position was then stable for about a decade.

In the early 1980s, the Department decided that a review of VTTS was necessary. This was in part due to the passage of time, but there was also a concern that the non-working time values were derived predominantly from commuting evidence in towns, while much of the road programme was primarily interurban. In addition, there had been substantial developments in computing capacity and analytical techniques had improved with the development of the discrete choice "paradigm".

At an early stage in this second wave of work, it became clear that despite the interest in exploring choices away from the "traditional" journey-to-work context, it would be very difficult, and expensive, to find suitable locations where genuine choices could be "revealed" and the statistical data properties necessary for successful estimation of VTTS guaranteed. The study therefore recommended that stated preference (SP) methods should be investigated, and on the basis of empirical data developed a sufficient case for compatibility between SP and the conventional revealed preference (RP) approach that official confidence in SP was established. Since then, SP methods have become the "norm" for VTTS estimation, though there is still a tendency to supplement the data collection with RP data, where a suitable context can be found.

The headline outcome of this work, which led to the MVA/ITS/TSU report of 1987 and the official paper which followed (DoT, 1987) was that the Department's philosophy of evaluation, including the standard value of non-working time, was retained intact, but the standard value itself was increased by 58 per cent to 43 per cent of the average hourly earnings of full time adult employees, which was equivalent to 40 per cent of the mileage weighted hourly earnings of commuters. For travel on employers' business, the traditional 'cost saving' approach was retained, with recommended values for categories such as bus and coach drivers, commercial vehicle drivers and car drivers on employers' business. This 1987 paper is the source of the official values used today, rebased for price changes and updated for changes in real incomes – most recently in the Transport Economic Note (DETR, 2001).

In 1994, the Department commissioned a further study of the valuation of travel time savings on UK roads, which was conducted by a consortium of Accent Marketing and Research and the Hague Consulting Group[1] (AHCG). A major international seminar was held in 1996 to discuss the findings of this work (PTRC 1996). The AHCG report was published in 1999 together with several reviews.

It is fair to say that the Department has found it difficult to decide how best to implement the recommendations of the AHCG report and the situation was noted in the 1999 SACTRA report. This is the backdrop to the work which is reported here, the purpose of which is to review the evidence on the valuation of work and non-work travel time savings.

2.2 Sources of evidence

We have considered both theoretical and empirical evidence. The first key source of evidence is the work carried out by AHCG,. We have conducted a substantial reanalysis of this data. We are very grateful to AHCG for making the data available in a timely fashion and in readily usable condition. A brief description of the datasets which we have used is given in Appendix B.

Although the main evidence on values of time is that gathered specially for official studies, there are many studies for public and private sector clients which yield estimates of VTTS.

[1] The Hague Consulting Group are now known as Rand Europe

The second source of evidence we have used is based on a set of data assembled from these studies, which we refer to as the "Meta-Analysis Dataset". This is usefully complementary to the AHCG dataset both because it provides an independent check on the pattern of AHCG results and also because it provides evidence on topics not covered by AHCG, such as VTTS for public transport and time series evidence on the growth in the value of time over time.

The Key Features of this Meta-Analysis Dataset are described in Appendix C. Two separate meta-analysis exercises have been conducted. The main exercise was concerned with values of in-vehicle time, walk time, wait time and headway, and the maximum level of disaggregation of the values collected was according to journey purpose, mode and distance. A supplementary exercise, focussing solely on in-vehicle time, was conducted with the specific purpose of examining cross-sectional variations in the value of time with income.

3. TRAVEL TIME IN EMPLOYERS' BUSINESS

In this chapter, we deal with a number of issues. First we consider the relevant economic principles, then their application to professional transport such as the bus and coach and freight transport sectors. Finally, the complex issue of values of time for employees travelling in the course of business – so-called briefcase travellers – is considered.

3.1 Principles

There are two main approaches to the valuation of travel time savings in employers' business. The first of these relies predominantly on theoretical argument, and is known as the 'cost saving' or 'wage rate' approach. Employers are assumed to hire labour to the point at which their gross wage costs including labour related overheads are equal to the marginal value product which the labour yields. Then, a travel time saving during the course of work permits *either* an increment of output value equal to the wage rate of the worker *or* release of that labour into the market place where it can be re-hired at the going wage rate. Either way, the value of the time saving is equal to the wage rate including labour-related overheads.

Many authors such as Harrison (1974) have pointed out that this result rests on a set of assumptions including

- *competitive conditions in the goods and labour markets;*
- no indivisibilities in the use of time for production, so every minute equally valuable;
- all released time goes into work, not leisure
- travel time is 0% productive in terms of work
- the employee's disutility of travel during working hours is equal to their disutility of working.

It is evidently the case that in particular situations, one or more of these conditions will not hold. However, there is a reasonable basis for arguing that on average, and taking a long-run view, these effects are largely self-cancelling. The issue, therefore, is whether taking account of some or all of these points would yield a robust improvement on the cost saving approach. The Department has considered this from time to time, and asked AHCG to look at this again.

It is worth noting before proceeding that using the cost saving approach in practice involves calculating the appropriate average gross wage either for all travellers on employers' business or for relevant sub-categories. This requires knowledge of the pattern of use of the roads and transport network for employers' business purposes, and needs to be reviewed from time to time.

The alternative approach, due to Hensher (1977), investigates the willingness to pay for travel time savings by allowing for some of the factors listed above. The interests of both employer and employee are considered. This approach, though there are variants, may be summarised in the equation

$$VBTT = \underbrace{[(1 - r - pq)\ MP + MPF]}_{\textit{employer value}} + \underbrace{[(1 - r)\ VW + rVL]}_{\textit{employee value}}$$

where VBTT = value of savings in business travel time
MP = marginal product of labour
MPF = extra output due to reduced (travel) fatigue
VW = value to employee of work time at the workplace relative to travel time
VL = value to employee of leisure time relative to travel time
r = proportion of travel time saved used for leisure

p = proportion of travel time saved at the expense of work done while travelling

q = relative productivity of work done while travelling relative to at workplace

To apply the Hensher formula, each of these items needs to be quantified. In practice, Hensher (1977) omitted MPF from his calculations, no doubt because of the difficulty of obtaining suitable data, and this term has generally been ignored. The terms r, p, q are *in principle* measurable from survey observations, though they present practical difficulties, as we shall discuss. VL is the individual's private VTTS, which can be obtained from the standard methodology for non-working time valuation: VW is more difficult, relating to the relative disutility, in money terms, of work and travel (NB *ignoring* any marginal payment for work). Finally, a number of alternatives are available for MP, but most commonly it is assumed equal to the gross wage rate plus a mark-up for overheads, to reflect what the employer actually has to pay to obtain an additional time unit of work.

There is clearly a category of employers' business travel in which, broadly speaking, the work being done during employers' business time actually consists of travelling: this applies, for example, to service engineers, delivery people, public transport drivers, lorry drivers etc.. More accurately, perhaps, one should say that the characteristic of these workers is that their job involves either them or their entrusted "cargo" being away from the main business premises. These people may not be 'travelling' all the time, but they are 'out and about', and if travel conditions change to enable them to travel further in a given time, they will become more productive.

In the case of drivers *per se*, although it could be argued that travel time *is* fully productive, the implication of "p" in the above formula relates to work potentially doable outside the travel context: hence we can assume that no work (other than driving) is undertaken during travel, so that p = 0. Similarly, VW = 0, since there is no difference between travel and working for this category of worker.

In the absence of indivisibilities, if each of these people can achieve their previous travel distance in one hour less each week, then the employer gains an extra hour's productive work from each of them. If there are indivisibilities present, for example such that a bus driver previously fully employed cannot fit in an extra trip in the one hour, then the threshold argument (see Fowkes, 1999) says that the overall result is just the same as if there were no indivisibilities. This is because the presence of indivisibilities will mean that each employee will have a bit of spare unusable time to begin with, for example like the bus driver without sufficient time to complete a further trip. The amount of this spare time will be uniformly distributed, between zero and the amount of time necessary to undertake a further piece of work. If a piece of work takes two hours, then the extra one hour will be useless to half of the employees, while the remaining employees will now be able to work 2 hours longer. On average therefore, each employee has gained one hour of productive work, and none of the travel time saved is used for leisure (r = 0).

Hence, in this special case where:

r = 0, p = 0, VW=0, MPF = 0 and MP = w, the gross wage rate

the "Hensher" equation simplifies to the cost saving approach.

The case of the travelling salesman or service engineer is only marginally different. In this case, the productive activity is predominantly at a remote destination, and cannot be carried out while travelling, implying p = 0. The same arguments about indivisibilities etc. apply here, so that it is reasonable to assume that travel time savings can be used for additional work (r = 0). The only issue relates to VW – in other words, whether the employee would rather be carrying out his productive activity or travelling. On balance, it does not seem unreasonable to assume that VW = 0.

The practical issue, which we return to below, arises for those who travel in the course of work whose work activity is not 'driving' nor constrained to be at a remote location: the classic example is the "briefcase" traveller. For all other categories, principally bus and coach drivers and commercial vehicle drivers, the "wage rate plus" approach seems an acceptable practical approach.

In attempting to obtain "direct" estimates of VTTS from vehicle operators, there is a danger of confounding two sources of money saving relating to reduced travel times – those related to the cost of the employee (which is what we want), and those relating to vehicle operating cost. In making comparisons of different results, it is important to keep this in mind

In the latest TEN, Working Values of Time in pence per hour are provided for a number of "driver" categories: these are in average 1998 values and prices, based on average wage rates from the 1998 New Earnings Survey, factored up by a factor of 1.241 to reflect overheads, and are thus in line with the theoretical discussion above.

Converting to end-1994 values, for comparison with AHCG results, we allow for a growth in real GDP per head of 8.9% and 12.3% inflation, giving an overall deflator of 1.223. We use the "perceived" values from the TEN table:

Category	TEN VTTS converted to end 1994 p/min
Car driver	23.8
LGV occupant (driver or passenger)	10.0
OGV occupant	10.0
PSV driver	9.1

The question of relevance is then whether the AHCG empirical data and analysis has something to contribute to the discussion of working time values. In addition to the topic of "business" travellers to which we return below, SP surveys were carried out for Coach & Bus Operators, and Freight Operators. We discuss these in turn.

3.2 Coaches and Buses

For Coach and Bus Operators, AHCG sampled 10 Scheduled Bus Operators, 9 Scheduled Coach Operators, and 28 Chartered Coach Operators: the aim was to contact the "Key Decision Maker regarding routeing" – specifically *not* the driver himself. In addition to collecting considerable information about the mode of operation, fleet composition etc., the respondent was presented with 2 SP experiments, one relating to "within-route" options where "total transport time" and "total transport costs" were traded, along with two other attributes relating to information and unexpected delay, and the other a choice between an untolled and a tolled route, with transport costs otherwise constant, but transport time varying and, on the tolled route only, some information provision.

From the interview transcripts provided by AHCG it is clear that the "Total Transport Costs" are meant to represent the cost of operating the service for a one-way journey, specifically "including drivers wages, fuel etc." On this basis, it is far from clear what the trade-off between "total transport time" and "total transport costs" implies, since *all* time-related costs should have been converted into money terms.

For the first experiment, AHCG report values of "about 50 p/min for Scheduled Coaches, 33 p/min for "Motorway Charters", 17 p/min for Scheduled Buses and 0 [actually negative] for

Trunk Road Charters" (p 235). It appears that the Charter segment has been split on the basis of response to the "type of road used most extensively" for the service in question, with approximately 40% assigned to Trunk roads. Bearing in mind that the estimations have not been corrected for repeated observations, none of these results carries a high level of statistical significance.

In the case of Experiment 2, respondents were asked to identify an alternative route and to estimate the total cost (including wages) and time: these values are then used as the basis for the variations in the SP variables. Once again it is hard to interpret the trade-off actually being made: for example, the costs are only varied in respect of the toll, but the times on both routes vary independently, without any impact on wage costs. On grounds of practicality, Experiment 2 was not given to Scheduled Bus operators.

Two models are presented, one which excludes the subset who always rejected the tolled route (possible policy response bias): in terms of VTTS, the differences are small, and using the results which exclude the subset noted above, the values are about 58 p/min for Scheduled Coaches, 24 p/min for "Motorway Charters", and 20 p/min for Trunk Road Charters. Only in the case of Motorway Charters is a high level of significance reported.

In drawing conclusions, AHCG note the following:

*For **coach**, the study was designed to offer a new insight into factors affecting operators' valuations of travel time by interviewing the operators themselves, differing from the COBA approach which looked instead at the VOTs for driver and passengers. As with freight, the direct approach to the operators, as taken in this survey, has been judged to yield the appropriate VOTs for forecasting: for evaluation, however, we would recommend retaining the COBA approach, rather than adding on passengers utility change from the time savings/gains to the operator's VOT. This difference is due to the expectation that the operator's VOT will include the expected fare increase/decrease that could be charged for a faster/slower service, which will in turn be some fraction of the passengers' utility change from the time savings/loss. Simply adding the two would then result in double counting.* [p 295]

In our judgment, it is highly unlikely that in responding to the SP tasks, the operators have been able to take into account the assumed elasticity of demand to travel time variations and the potential for recouping this through the farebox! More generally, we have concerns about the whole context of the tradeoffs. Assuming that they are intended to represent both wage costs and operating costs, we might expect the element for operating costs, based on the formula in TEN, to contribute about 50p/min for coach (assuming an average speed of 80 kph) and around 21p/min for Scheduled Bus (assuming a running speed of 20 kph). Note that these are in 1998 values, so for comparison might be reduced by 20%.

At these speeds, therefore, the 'implied' "full" cost per minute in 1994 values is about 50 pence for scheduled coach and about 25 pence for scheduled bus. The coach values check out quite well with the AHCG scheduled coach results but the AHCG bus and charter values seem on the low side. We think that the AHCG survey data is interesting, but that the conventional TEN approach of accounting separately for the driver's time using the cost saving approach, the vehicle operating cost effects, and the value of (mainly) non-working time for the passengers, has inherent appeal both for forecasting and for evaluation.

3.3 Commercial Vehicles

Turning now to the corresponding freight surveys, essentially similar methodology was used. AHCG sampled 165 Hauliers (of whom 118 were classified as HGV) and 105 "Own Account" Operators (of whom 48 were classified as HGV). Both the identification of the "Key Decision Maker" and the presentation of the SP experiments followed the lines of the Coach surveys.

In this case the interview transcripts make it clear that the "Transport Costs" are meant to represent the "typical cost for a shipment", excluding loading, unloading and handling costs. It appears that this should therefore also include driver's wages, fuel etc. Once again, therefore, it is far from clear what the tradeoff between "total transport time" and "total transport costs" implies.

For the first experiment, AHCG report "VOTs for the Hire and Reward segments are about 45p/min and for the Own Account segments about 35p/min, with almost no differences between LGV and HGV" (p 232). The level of statistical significance is reasonable. We have some reservations about the credibility of the time/cost trade-offs offered in this experiment since we think that routes with big time/cost trade offs are quite rare in the UK. (Portsmouth and Southampton to various destinations is one example).

The second experiment involves choosing a toll to use the quicker (current) route against a slower free alternative. This is believable, but causes a different problem, an anti-toll bias. Values are around 20p/min except HGV own account which is 33p/min. However, 25 per cent of the sample refused to trade time for money and the results therefore depend on the plausibility of the responses of this group. The models excluding the subset who always rejected the tolled route produce generally similar VoTs, *except* for HGV Own Account, where the value rises to 59 p/min.

As with the coach SP, respondents were asked to identify an alternative route and to estimate the total cost (including wages) and time: these values are then used as the basis for the variations in the SP variables. Once again it is hard to interpret the tradeoff actually being made: for example, the costs are only varied in respect of the toll, but the times on both routes vary independently, without any impact on wage costs.

In contrast to the Coach surveys, the two experiments lead to results which are significantly different. Apart from the HGV Own Account group, which are more or less the same between the two experiments, but increase strongly (as noted) when the "non-traders" are removed, the experiment 2 values tend to be about half the experiment 1 values. This might be expected on the basis of a toll response bias, but it was not found with the Coach SP.

As with the coach surveys, we have concerns about the whole context of the tradeoffs. Assuming that they are intended to represent both wage costs and operating costs, we might expect (assuming an average speed of 50 Kph) to add about 9 p/min for LGV operating costs and between 20 (OGV1) and 35 (OGV2) p/min for HGVs: these are in 1998 values, so for comparison might be reduced by 20%.

Very roughly, we can present the figures as follows, for comparison with the adjusted TEN "full cost" values (assuming average 50 kph).

	LGV H&R	LGV OA	HGV H&R	HGV OA
Expt 1	43.5	35.5	47.1	35.5
TEN adjusted	17.5	17.5	26.7–39.2	26.7–39.2
Expt 2 (excl non-traders)	15.1	17.7	20.5	59.3

In line with the arguments used elsewhere in this report, AHCG favour the use of results which are not based on tolls. Accordingly, they recommend the use of the values from Experiment 1 quoted above. Other work, some of it recent work for the Highways Agency, is reported in the working paper. However much of this work is aiming at the value of reducing unexpected delays rather than the value of a pure 'anticipated' time saving. It is difficult to make secure deductions about the latter from evidence on the former.

While the Experiment 2 LGV figures are consistent with the TEN values, all the AHCG Experiment 1 figures apart from the HGV Own Account are well in excess of the "wage rate plus" values. The lack of difference between LGV and HGV is difficult to accept, given the much higher operating costs for the latter.

It is worth noting that deriving reliable values of time savings for freight transport from willingness to pay based approaches is a notoriously difficult task.

- the industry is heterogeneous and there is a problem of finding a suitable sampling frame from which to ensure a representative sample is taken;
- the respondent, who might be a transport manager, is unlikely to have a comprehensive perspective of the impact of time savings on the overall value to the logistics chain; this is particularly true of respondents in the Hire and Reward sector
- there are difficulties in representing designs and choices which are relevant and credible to the respondents; some researchers have sought to overcome this problem by using adaptive SP methods
- ideally we would like to separate out the value of a unit time saving or loss which is fully understood and anticipated in advance by the firm (such as a decision to impose a legal maximum speed limit of 90 kph) from the value of changes in unexpected delays (policy actions which reduce travel time variability). In practical SP experiments, this can be problematic.

On balance, we do not think the empirical evidence is sufficiently strong to warrant moving away from the traditional COBA/TEN approach to valuing "pure" time savings. We note that the TEN currently assumes a vehicle occupancy of unity for commercial vehicles. We recommend a small study be undertaken to establish the acceptability of this assumption.

3.4 "Briefcase" Travellers

For these people it is clearly an empirical question whether r and p in the Hensher formula are sufficiently different from zero to be worth calculating. To date, the UK authorities have not been convinced of this. A particular problem is how to pose the survey questions to obtain reliable answers.

In an earlier discussion, Fowkes *et al* (1986a) made a number of observations, based on surveys of business travellers intercepted travelling on East Coast Main Line trains, or via employers in Newcastle.

For VW, Fowkes et al could see no reliable way of estimation. However, as it was felt that the effect could not be large, they set VW = 0, i.e. business travellers were assumed to be on average indifferent between travelling (working or not) and working in the office. This hardly seems satisfactory from a theoretical point of view, but might not be far wrong on average.

For p, the proportion of travel time savings which is at the expense of work done whilst travelling, Fowkes et al felt that those who do work while travelling generally work for a sufficiently short time that realistic travel time savings would have no impact. So while the proportion of total travel time spent working has empirically been found to be greater than zero for groups of business travellers, giving the value of p used by Hensher, Fowkes et al felt that this should be called p*, with true p lying between zero and p*. Estimated values of p* ranged from 0.03 for car to 0.21 for rail.

For q, Fowkes et al followed previous practice by asking how long was worked on a particular trip, and how long that work would have taken in the office. They state that, due to the expected overreporting of work done, it is to be expected that q will be biased upwards, but really it is a second bias effect affecting q that is the problem. It is not that a lot of work was done while travelling, it is more the claim that it was no less productive per minute as work in the office. For car the reported average value of q was above unity, and it is hard not to imagine that as an overestimate. For air the average was 0.98 and for rail 0.95.

For r, Fowkes et al rejected the use of the proportion of total travel time which occurs in leisure time. Firstly it was felt that for day trips starting and ending at home, where there is sufficient work to be done at the destination, travel time savings are likely to result in more time spent at the destination, rather than a later start from home or an earlier arrival back (though this is complicated by public transport schedules). Secondly, business travellers may be able to substitute travel out of normal work hours for work time on another day. Accordingly, Hensher's value was denoted r*, and the true value of r taken to lie between zero and r*. Values of r* found varied from 0.32 for car to 0.42 for rail and air.

All this implies that the Hensher formula will be some weighted average of MP and the private VoT, VL. Since VL<MP, the formula will in general give lower values than the wage rate approach. On plausible assumptions, VTTS for car might be 80-90 per cent of the wage rate, for rail and air perhaps 65-75 per cent. However, it seems that employers' willingness to pay for time savings is *greater* than the gross wage rate (perhaps MPF >0, or additional time at the destination is particularly valuable) so that the final VTTS for business travel is not very different from the gross wage (Fowkes et al, 1986).

Having discussed the formula in general, now we consider how AHGG implemented it.

In order to estimate values corresponding to the Fowkes *et al* parameters (l-r*), p* and q, AHCG asked car travellers the following questions:

> *Q20 Suppose that the business trip that you were making had taken 15 minutes longer as a result of congestion on the roads. Would that extra time have been paid by your employer, or would it have come mostly out of your own time [or a combination of both]?*
>
> The 'combination' replies were counted as 50%, the 'employer's time' as 100%, and 'mostly own time' as 0% (despite the 'mostly'). On average, AHCG found '(l-r*)' to be 0.537. However, the question has no meaning for the 22% who were self employed. Those not self employed reported '(l-r*)' on average as 0.64 (or r* = 0.36). The slightly higher figure of 0.655 was obtained for travellers whose employer was paying the travel costs. This result is consistent with the r* value of 0.32 for car found by Fowkes et al.

Q21 Did you use any of the time during that trip to do work which you otherwise would have done elsewhere; for example preparing for a meeting, conversations on a portable telephone, etc? If so, about how much time?

Given that total travel time is known, this question allows us to estimate p*, the proportion of travel time spent working. AHCG found that 22.2% of respondents did do some work, the average proportion for these people being 0.195. Hence p* = 0.222 (0.195) = 0.043. The Fowkes et al car value for p*, was 0.033, but this applied to long distance only, in which case the AHCG value rises to 0.052. Perhaps this reflects the increasing use of mobile phones, laptops etc., or perhaps 'mental' preparation was included thereby changing the definition compared to the earlier study.

Q22 Approximately how long would that same work have taken you if you had done it at your office or at your home?

This question is clearly an attempt at finding q, the relative productivity of work done while travelling compared to in the office. The mention of 'or at your home' is a complication however, since it is quite possible to imagine the office being the most productive environment per minute work, followed by 'in car', with 'at home' being the least productive. In any event, values found were close to unity, averaging 1.02. Ignoring journeys of less than 30 minute reduces that to 1.01. Fowkes et al found q values of 0.96 and 1.07 in their two samples of car business travellers, averaging 1.01, thereby agreeing (rather by fluke) with the AHCG long distance car figure. The agreed figure is, however contrary to the expectation that q is significantly less than one. How to proceed from this point is not clear. The simplest approach is to say that there are no grounds for taking q to be any value other than 1.00. Another approach has been to replace q values above unity by unity, on grounds of plausibility, and then recompute the average. Attempts to do this can lead to big changes in q, though the effect on VTTS is not large.

All this suggests that the true value of pq is very little different from zero, and the main attention therefore turns to r.

The AHCG study gives the value of travel time savings on employers' business as

$$\text{VTTS} = \text{MP}\,(1 - r - pq) + \text{VP}$$

Compared to the "Hensher" equation, MPF is dropped, and it is assumed that VP - the "employee value" in the "Hensher" equation given earlier - can be taken as the Business Traveller's (private) VTTS. This implies that in responding to the SP tradeoff questions, Business travellers take into account whether time increases or reductions will be transferred to/from leisure or work. According to Gunn (2002), "Exploratory work was done to check for biases in cases where employees might pay, both by stressing a non-reimbursement condition[2] prior to asking for the trade-off, and by checking for the impact of any re-imbursement on the derived values."

In the case of those who answered that time increases would come out of their own time to Question 20 above, ie r* = 1, we may assume that the expressed estimate of VP is equivalent to VL. The question then is: will those who give values of r* = 0 provide estimates of VP equivalent to VW (with an intermediate value for those who give r* = 0.5)? We find this *a priori* most unlikely, *particularly* in the light of the reimbursement condition. If Business respondents are encouraged to think that cost changes whether positive or negative will be borne by them personally, are they not likely to think the same for time changes? Note also

[2] The instructions preceding the first Stated Preference experiment were: "If you did not actually pay for the journey yourself, please assume that you would receive a fixed amount of reimbursement equal to the current journey cost, so that any additional or saved costs would go to you."

that Question 20 relates to time increases being paid for, rather than whether they would shorten the amount of time spent working. Hence, we incline towards the view that the SP is likely to provide a value of VL, irrespective of the value of r*

We note that the AHCG version of the equation is also used in Algers et al (1995), but with a slightly different interpretation:

> "In this study, the value of time to the employee was not differentiated depending on whether the time saved would be spent at work or on leisure, and it was thus implicitly assumed that the private VOT (VP) is the same in both cases, or that VW equals VL."

Setting VW equal to VL implies that the marginal utility to the employee of time in work is assessed equal to that spent in leisure. We feel that this is incorrect ; for most business travellers, VW cannot be assumed to equal VL, since travellers will not be indifferent between spending time working and leisure time. Although we understand that the equivalence was assumed because it was unclear whether the saved time would be transferred to leisure or working, we think it is more plausible to assume that VW, as defined, equals zero.

At face value, therefore, allowing for the "near zero" value of pq, this might suggest the simpler formula:

$$VTTS = (1-r).MP + r.VL$$

On our interpretation, a value of VL, the private value of time for Business travellers is available from AHCG, and for those travelling on their "own time and money" is reported as 6.7 p/min[3]. In order to calculate the final outcome, AHCG required an average wage rate for their business sample, which they estimated as 30.9 p/min. Their explanation of this is as follows (p 254):

> *This assumes that the annual household income (taken as the midpoint for the survey category) is divided by 1800 hours per year, and then adjusted for the number of workers in the household (because the business traveller generally earns the bulk of the household income, 2 workers is assumed to equal 1.5 equivalent 'work years' and 3 or more workers to equal 2.0 'work years). Finally, a factor of 1.4 is applied to account for extra wage-related costs.*

There are several assumptions involved here, which taken together make the final figure highly unreliable. Our overall view is that the Hensher formula approach is data hungry, and that none of the various parameters r, p and q are at all easy to estimate with confidence. AHCG have made a fair attempt, but their basis for imputing the MP values is weak. Therefore we cannot recommend adoption of the approach taken and values derived in the AHCG report.

There remains the question of what should be done about the possibility that business travel time savings may be used for leisure purposes (r>0). There would appear to be two significant groups of interest: those who can take time off in lieu for travel time outside of normal working hours, and those who accept some out of hours travel as a condition of the job.

In the former case, any time saved for travel time reductions will either result in additional time spent at work directly, or indirectly due to less time taken off in lieu. Such arrangements

[3] Note that this figure applies to only 253 out of the sample of 1442 Business travellers: the income distribution for the subset is to some extent more concentrated in the lower part of the range.

may only work imperfectly, but we feel that the gain to the employers will be near enough the gross wage rate.

In the latter case, *if* we assume that the labour market is working correctly, then it must be the case that remuneration packages for this group reflect that there is a significant amount of out of hours travel which cannot be set against time taken off in lieu. If there are travel time savings resulting in an hour saved, then some of that may result in extra work completed and some may reduce the amount of travel undertaken out of hours. To analyse this, it will suffice to consider the two extreme cases: all in work hours, all outside work hours.

When all travel is during working hours, it is clear that the benefit to the employer is most simply taken to be equal to the gross wage rate. Note that, particularly in the context of long distance day trips, having three hours at the destination instead of two could be especially valuable, e.g. three productive hours in a ten hour working day instead of two. In the second case, where the time at destination is held constant but the journey starts later and/or ends later, the employee receives the immediate benefit. For day trips there can be a considerable benefit, since extra time in bed in the early morning is particularly highly valued (according to the Fowkes et al sample), and presumably time saved late in the day may also be highly valued. In this context, we are attracted by a flexible wage assumption rather than the rigid wage assumption underpinning the Hensher formula. That is, given these improvements in the conditions of work, it is reasonable to assume that profit maximising employers will wish to take them into account when deciding aspects of the remuneration package. Our view is that the simplest assumption to make is that if employee A is spending one hour less on company duties, the employer will be able to pay that employee one hour's wage less, all else equal.

It has been suggested in discussion (Gunn (2002) that this requires an ability to forecast the way in which wage rates would alter to reflect changes in the onerousness of travel. However, the argument above does not relate to wage rates as such, but to the total remuneration. Salaries can fall if working hours are reduced without any implication for the wage rate.

To summarise our conclusions for the valuation of time savings for employers' business trips:

- for professional drivers, there is a strong justification in principle for retaining the 'cost saving' approach;
- there is a great deal of uncertainty about the 'true' values of the parameters in the Hensher model such as r, q and p, in spite of the effort put into devising suitable questions;
- there is also doubt, in any case, about whether changes in the onerous nature of working conditions, including travel time on employers' business, are not anyway in the medium term reflected in the total remuneration;
- given these uncertainties, and given that alternative assumptions give results either side of the Department's current value, we see no strong case for abandoning the cost saving approach for valuing savings in travel time for briefcase travellers;
- the Department should validate empirically its assumption that the vehicle occupancy for goods vehicles is unity, possibly via a special question on the CSRGT, and should keep under review the average gross wage rates and wage-related overheads of travellers on employers' business.

4. SIZE AND SIGN OF TIME SAVINGS

The conventional UK approach has been to use standard values per minute regardless of the sign and size of the saving. This has attracted criticism from those who argue that small time savings should be valued at a lower unit value than standard (Welch and Williams, 1997). This is an important practical issue for road appraisal, since if "small" is defined as, say, less than 5 minutes, most time savings on most schemes would fall in that category.

Anticipating issues of practicality, it must be conceded that any attempt to introduce sign and size variation (more generally, non-linearity with respect to time changes) into the appraisal process is fraught with difficulties, for reasons which have been well rehearsed, relating to essential concepts such as additivity and reversibility within the Cost Benefit appraisal. Nonetheless, this in itself is no reason not to attempt to see whether such variation exists.

The AHCG study set out to examine this fully, and found that, "For any level of variation around the original journey time, gains (savings) are valued less than losses. For non-work related journeys, a time saving of five minutes has negligible value". However, AHCG did not recommend that values for appraisal should be differentiated by size and sign. We have reanalysed the AHCG data to see whether further light can be shed on the two findings above.

4.1 Sign of Time Savings

From first principles, one might expect an indifference map of the form shown in Figure 1. Starting from the origin, in quadrant 4 every unit cost increase requires increasing amounts of time saving to justify it as the money budget constraint binds tighter. In quadrant 2, every unit time increase requires increasing amounts of money to compensate as the time constraint binds tighter. While the expected curvature is clear, the scale of the diagram is unspecified. A reasonable conjecture is that the curves might approach linearity for small changes in cost and time, though empirical evidence could refute this.

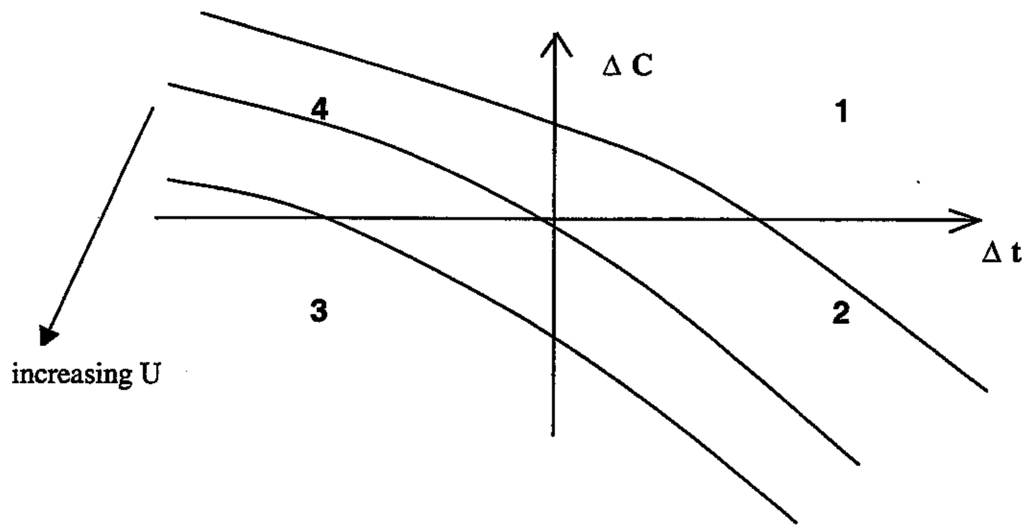
Note that the theoretical form of the indifference curve requires the sign of the second derivative $\frac{\partial^2 U_k}{\partial t^2}$ to be non-positive, and this is incompatible with any implications that small time savings are valued at a lower unit rate. Nonetheless, the theoretical form, of course, assumes that (utility maximising) behaviour is reassessed in the light of any changes in travel conditions, and in the short term this may not be the case.

The main AHCG stated preference experiment (see Appendix B) offered a series of pairwise comparisons where the two options were characterised solely in terms of changes in time and money. These involved the following types of trade-off:

- A choice between an option which was slower than the current journey and an option which was more expensive, other things equal (quadrant 1).
- A choice between an option reflecting the current situation and an option which was slower but cheaper than the current situation (quadrant 2).
- A choice between an option which was quicker than the current journey and one which was cheaper, other things equal (quadrant 3).
- A choice between an option reflecting the current situation and an option which was quicker but more expensive than the current situation (quadrant 4).

The options were specified as changes to the current situation. Across all the different designs, nine levels of time variation were used: time savings and losses of 5, 10, 15 and 20 minutes and a 3 minute time saving.

Figure 1 - The standard indifference map



In what follows we provide an abbreviated description of our investigations. More detail is available in ITS Working Paper WP561, and for most of the models mentioned here, details of the coefficients and model fit are given in Appendix E of this Report.

We began by reproducing the basic model results [Model 4-1] set out on page 162 of AHCG's final report. This model can be written:

$$U_{ikj} = \beta_c . c_{ikj} + \beta_t . t_{ikj} \qquad \text{(M1)}$$

where: i relates to an individual journey
k relates to a design "treatment" – ie a single SP pairwise choice
j relates to pairwise option A or B within treatment k

As is standard in Discrete Choice analysis, we work in terms of a "utility formulation". Since increased cost and time convey *dis*utility, we expect the coefficients to be negative. In its simplest linear form, as given here, utility is directly compatible with "generalised cost", except that for the latter the coefficients are set to be positive, so that it is in fact a measure of disutility, The "value of time" is calculated straightforwardly as the ratio of the marginal utilities of time and cost, thus in this linear case, VTTS = β_t/β_c.

In AHCG the model is estimated with a tree structure and the cost coefficient constrained to equal 1. This allows the value of time and the associated t-statistic to be a direct output of the model. We have dropped the tree structure and coefficients are freely estimated for time and cost changes. All our models have been estimated using GAUSS software (Aptech Systems, Inc, Maple Valley, WA 1996).

As shown in Table 1, this specification of the model yields the same level of fit, values of time and t-statistics as those reported by AHCG. Thus we can have confidence that both the data and the method of analysis are compatible.

Table 1: M1 Base Models [= AHCG Model 4-1]

	Business	Commute	Other
Time	-0.0780 (26.30)	-0.0824 (14.19)	-0.0545 (15.31)
Cost	-0.0075 (24.51)	-0.0163 (19.74)	-0.0122 (25.36)
value of time (p/min)	10.4	5.1	4.5
Average LL	-0.649687	-0.636065	-0.632679
No. Obs	9557	4737	8038

All t-statistics are given relative to zero. As is the case with AHCG, we have not in this Report carried out any adjustment on the standard errors to allow for the "repeated measurements" problem (though AHCG report some later work using Jackknife techniques). Thus we should have some caution in interpreting the t-statistics and possibly the log-likelihood ratios as well: we can expect the level of significance to be generally somewhat overstated.

Investigations of this model (M1) suggested that the data would support a non-linear utility specification implying variation in VTTS with the sign and size of the time change. There are various ways in which non-linearity could be reflected. The basic AHCG approach was to allow for different coefficients on time and cost according to the sign of Δt and Δc. In fact, AHCG do not report the results of such a model, but move on immediately from the basic model (M1) to one which includes other terms as well (AHCG Model 4-2), chiefly due to size effects. However, we have estimated this model (M5[4]). Because each combination of positive and negative values of Δt and Δc implies a different "quadrant", it is possible to calculate the implied variation in VTTS for each quadrant, and these are reported in Table 2 for each of the three journey purposes. It can be seen that the values obtained in quadrants 1 and 3 are broadly similar; however in quadrants 2 and 4 they are spectacularly different (ratio 4.6, 7.7, 8.4 for the three purposes).

Table 2: Re-Analysis of the AHCG Data (1994 pence per minute)

	Quadrant 4	**Quadrant 1**
Business	4.76	9.01
Commuting	1.50	4.63
Other	1.34	4.55
	Quadrant 3	**Quadrant 2**
Business	11.52	21.80
Commuting	3.75	11.59
Other	3.29	11.18

While the comparison between quadrants 2 and 4 appears to support the AHCG conclusion that losses are valued significantly more highly than gains, we have doubts about the validity of this interpretation. In the AHCG survey design, respondents were first asked to give details of the journey being made at the time of recruitment. They were then offered various time/cost choices and asked to state their preferences. For the offers which fall in quadrants 1 and 3, the respondent's journey is used to frame the choices offered, but is not directly included in the set of choices offered. However, for the offers which fall in quadrants 2 and 4,respondents were offered a choice between their existing time and cost and a faster more expensive alternative(quadrant 4) or a slower cheaper journey (quadrant 2). Previous exploratory analysis (Bates, 1999) had indicated that AHCG's findings with respect to sign

[4] The details of the model are given in Table 8 of ITS WP561

could be explained by the presence of an "inertia" effect. In this context, inertia is a systematic preference for the current situation, and in the AHCG design this is confined to choices relating to quadrants 2 and 4. If there is an inertia effect of this form, we would expect the values of time in quadrant 2 to be inflated since respondents will be less prepared to suffer a time loss in return for a cost saving. In quadrant 4, the inertia effect would lead to a lower willingness to pay than otherwise.

It is convenient to refer to the dummy variable which signifies that an option (in quadrants 2 or 4) coincides with the current journey as "inertia". The presence of true inertia in transport behaviour is well-attested: however, the explanation has usually been advanced in terms of the cost of acquiring information about alternatives, or, slightly differently, the uncertainty surrounding the performance of the alternative. In principle, neither of these reasons should apply to SP where the information about the alternatives is provided directly and without qualifications (though there remains the possibility that the respondent may not *believe* it!). In addition, the alternatives presented have no *inherent* characteristics (as might be the case, for example, with different modes), and therefore there is no reason to postulate any "brand loyalty". In this case, therefore, it is more difficult to conceive that a true inertia effect is present.

However, for an SP respondent, choosing the current situation in a choice context may be a safe option, and one which avoids having to make a careful assessment. There is also the possibility that people may tend to believe more that they will get the costs than that they will get the benefits! If a respondent is adequately satisfied with his current journey, he can avoid the effort of assessing the tradeoffs in Quadrants 2 and 4 by selecting the current journey. Taken at face value, this will therefore in itself imply low values of time for time savings and high values of time for time losses, unless the possibility is allowed for. In the case of tradeoffs in quadrants 1 and 3, there is no obvious way in which one of the options can be regarded as "special".

If the effect in Model (M5) relates genuinely to the sign of the cost and time changes, then the same results should be obtained whether we confine the data to quadrants 1 and 3, on the one hand, or quadrants 2 and 4, on the other. We therefore estimate a partitioned version of Model (M5) for these two subsets of the data. The results were striking: confining the data to quadrants 1 and 3 produced no evidence of an effect due to sign. Moreover, when an inertia term was introduced into the estimated utility functions for the data in quadrants 2 and 4, it was found to be highly significant and no significant differences between the values of gains and losses remained. On this basis we pooled the data again, but included the inertia term for all observations relating to quadrants 2 and 4. We refer to the corresponding model as (M1I).

As Table 3 shows, the overall fit[5] of the model with inertia (M1I) is far better than that which differentiates the values by sign (M5), despite the former containing one less parameter. We therefore do not accept the AHCG conclusion that the VTTS should be differentiated by *sign*.

Table 3: Comparison of Model Fit (LL per observation)

Model	**(M1) [linear]**	**(M5) [sign effect]**	**(M1I) [linear+inertia]**	No. of observations
no. of parameters	**2**	**4**	3	
Business	-0.649687	-0.626621	-0.613180	9557
Commuting	-0.636065	-0.603173	-0.593923	4737
Other	-0.632679	-0.600531	-0.588771	8038

5 More details of the models are given in ITS WP561

We note that an inertia effect was also apparent in the findings of Dillen and Algers (1998) who used a similar design. We have also conducted some analysis on the Tyne crossing route choice SP data set collected in the first British national value of time study (MVA et al., 1987) and one collected in the AHCG study. In neither case is there evidence to support the VTTS varying by sign.

Hence, as set out in WP561, we do not believe that the AHCG conclusions on variation by *sign* are safe, and within the likely range of variation, we do not believe that there is any empirical basis for distinguishing gains or losses.

4.2 Size of Time Change

Having introduced inertia terms to account for sign effects, we conducted further re-analysis of the AHCG data to examine the size effect. There are different ways in which this can be demonstrated, but we are in no doubt at all from the resulting models that, as AHCG found, the unit values of 'small' time changes come out very different from 'large'.

In investigating what the data tells us about small time changes, it will be sensible to correct, as far as possible, for the journey covariates. This is particularly the case since the smaller changes (3 and 5 minutes) tend to be presented in relation to the shorter journeys (See Appendix B on the design). It is convenient for the analysis of small time changes if we can confine the effect of the journey covariates to the **cost** coefficient: in fact, this turns out to be the preferred model specification (Model 6d).

We began by creating dummy variables for each time change, thus allowing us to estimate the utility for each of the values Δt = (–20, –15, –10, –5, –3, +5, +10, +15, +20). Note that this is close to the final specification adopted by AHCG (ignoring the inertia effects) except that they dropped the term corresponding with Δt = –3, thus presumably forcing it to have a zero valuation.

The findings (Model M7I[6]) are given in Table 4. For changes of 10 minutes or greater, values of time of around 5 pence per minute are found for non-work purposes. For changes of less than 10 minutes, the values are found to be close to zero, or even negative. Although our model specification is different, these findings are not essentially in disagreement with those reported by AHCG.

Table 4: Values of Time by Size of Time Change (p/min)

Δt	Commute	Other	Business
-20	6.15	6.59	12.46
-15	7.61	6.67	11.34
-10	6.99	5.05	12.12
-5	3.82	-1.53	8.50
-3	-5.18	-13.87	-3.11
+5	-2.85	-11.16	-5.66
+10	3.63	1.12	6.24
+15	5.66	5.88	8.82
+20	8.23	5.50	9.95

[6] More details of the model estimation are given in ITS WP 561

A number of tests were conducted to attempt to identify the likely causes of this pattern of results. On the face of it, it is possible to hypothesize a number of reasons as to why these results are occurring: they could be related to

- problems with the analysis
- problems with the design
- problems in responding to the SP tasks

The implied negative values of time are, taken at face value, simply illogical. However, it is critical to note that the design does not offer respondents any opportunity to *display* a negative value of time – e.g. by choosing a time increase rather than a cost decrease. Hence, if negative values are derived, this would seem to be an outcome of the model specification, and need not imply that the *data* is illogical. To see why we are obtaining these model results, we need to go back to the data.

In practice, we do not expect all respondents to evince the same value of time, and there will be a distribution. The proportion choosing the cost saving should rise as the cost saving increases. We therefore examined all the tradeoffs in Quadrants 1 and 3. Apart from minor variations, the data for each purpose confirmed that:

- for a given value of Δt, the propensity to choose the lower cost option increased as the cost difference increased; and
- for a given value of Δc, the propensity to choose the lower cost option decreased as the time difference increased

This is precisely what one would require on grounds of general rationality.

In a prior review of the AHCG study, Fowkes and Wardman (1999) had raised some concerns about the adequacy of the SP design. We therefore subjected the designs to testing using synthetic data and found it to be able to recover a large range of values of time remarkably well. We are confident that the results being obtained are *not* artefacts of the design.

We also used the mixed logit model of Revelt and Train (1998) to examine random taste variation but although the specification of a lognormal distribution for the time coefficient removed the negative values of time, the broad pattern of results for small time changes remained.

The phenomenon of apparent negative values is discussed at length in Working Paper 561. The explanation is technical and concerns the assumptions of the logit model in situations where large proportions of respondents refuse to trade time for money in the SP at any of the rates offered. This explanation suggests that the apparent negative values of time are *not* a true feature of the data, and that a model form is required which does not allow the value of time to go negative.

The most consistent model which we could develop to explain the data involved a "tapering" function (M8), whereby time changes offered in the SP exercise below a "threshold" of 11 minutes were progressively reduced (as if respondents perceived that the actual time change would be smaller). In place of including the presented time change Δt in the model specification, we substituted a modified value $\Delta\tau$, where[7]:

$$\Delta\tau = \text{Sign}(\Delta t) * \{ |\Delta t| . [|\Delta t| \geq \theta] + \theta.(|\Delta t|/\theta)^m . [|\Delta t| < \theta] \}$$

[7] Here and elsewhere, the square brackets represent logical (Boolean) variables defined on the enclosed condition

where θ is the threshold value (estimated at 11 minutes), and m > 1 an estimated "tapering" parameter. The rate of "tapering" was highest for Other purpose travel, and lowest for Business travel. Note that when m = 1, $\Delta\tau = \Delta t$. The results for this model are given in Table 5:

Table 5: M8 models with "perceived" time coefficient (θ = 11)

	Business	Commute	Other
Time ("perceived")	-0.090624 (28.21)	-0. 105646 (14.09)	-0. 086387 (20.52)
m	3.149952 (7.19)	4.435129 (4.42)	8.202311 (7.45)
Cost	-0.009843 (22.06)	-0.016677 (18.77)	-0.01710 (27.71)
Cost Covariate CΔc	0.00000171 (6.76)	0.00000261 (3.29)	0.00000345 (9.98)
Inertia	0. 82229 (24.84)	0. 891382 (18.20)	0.964581 (25. 09)
Average LL	-0. 604423	-0. 582373	-0. 563342
No. Obs	9557	4737	8038

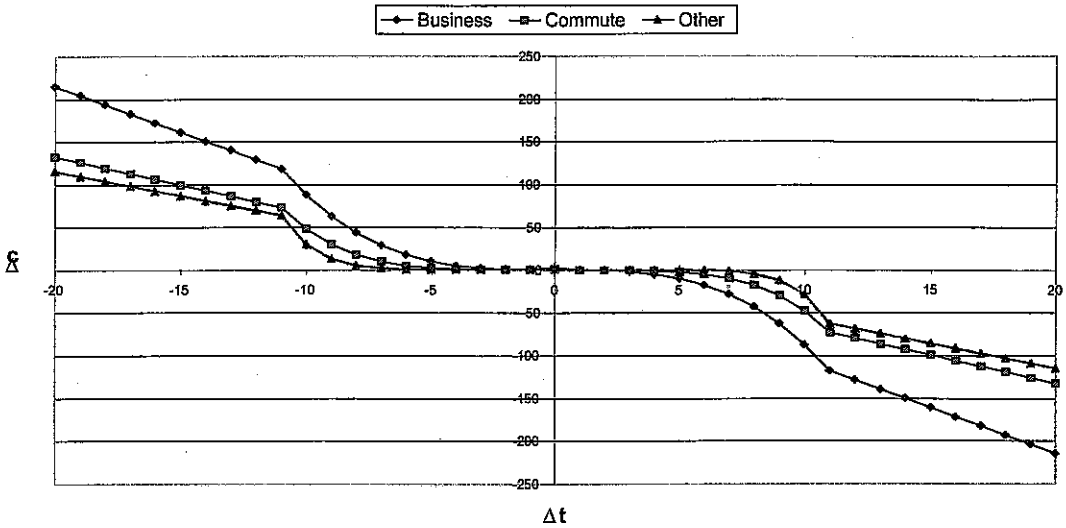
If we transform to indifference curves, we obtain the pattern shown in Figure 2. While these curves now respect the theoretical condition on the first derivatives, thus avoiding implications of negative values of time, they clearly do not respect the conditions on the second derivatives. It should be noted that the symmetry results from the constraints imposed by the model form, where there is assumed to be no variation by *sign*.

In Table 6 we set out the statistics for overall model fit as relates to the size effect. Although our preferred model (M8) is not the best fit to the data, it is considerably more parsimonious in terms of parameters *and* avoids illogical negative values of time, which we have shown are inconsistent with the data.

Table 6: Comparison of Model Fit (LL per observation)

Model	**(M6d) [no size effect]**	**(M7I) [dummies]**	**AHCG Sign & Size[4-2]**	**(M8) [threshold]**	No. of observations
no. of parameters	**4**	**12**	**14**	**6**	
Business	-0.609129	-0.600748	-0.6058	-0. 604423	9557
Commuting	-0.591140	-0.577071	-0.5755	-0. 582373	4737
Other	-0.578161	-0.553108	-0.5622	-0. 563342	8038

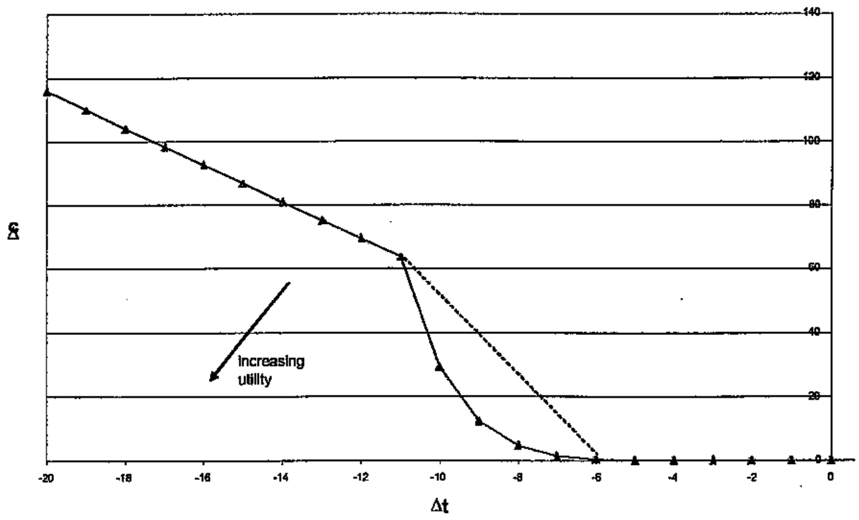
Figure 2: Indifference Curves with Perception Effect



Although the data strongly indicates that a lower unit utility attaches to small time changes (whether positive or negative), we feel it would be unwise to take these results at face value. In the first place, the results are inconsistent with the theoretical expectations on the shape of the indifference curve, at least when allowance is made for adjustments beyond the immediate short term. Moreover, it implies extremely high marginal values of time as the threshold of 11 minutes is approached.

We can illustrate this with respect to the implied indifference curve in Quadrant 4 (reduced time, increased cost) for Other travellers as shown in Figure 1 (using Model M8 calculated at the mean journey cost for the sample). In effect, we have the position where, *on average*, a traveller is prepared to pay virtually nothing for a time saving of up to about 6 minutes, but is prepared to pay 64p to save 11 minutes and 69p to save 12 minutes. This implies inconsistent "trading" according to the slope of the indifference curve between time and money within the estimated range of ± 11 minutes around the current journey time, suggesting short term lack of adjustment (this is similar to the argument adduced by AHCG).

Figure 3: Illustration using Implied Indifference Curves



The inconsistency is associated with a violation of the convexity of preferences: according to this, if the average traveller is indifferent between say a time saving of 6 minutes with zero cost and a time saving of 11 minutes costing 64p, then we should be able to find some intermediate point along the dashed line joining these two points (e.g. a saving of 8.5 minutes costing 32p) which would make him at least as well off. In fact, the indifference curve lies *below* the dashed line, suggesting that he would be worse off at any intermediate point along the dashed line.

Effectively, the data is telling us that for time changes between 0 and 6 minutes, the value of time is more or less zero, for a *further* change of 5 minutes the marginal value of time is on average 12.8 p/min, and thereafter it reverts to about 5 p/min.

In general, the following kinds of explanation may be considered:

(a) The data reflects real perception and preferences. People are willing to trade at a lower rate for small changes than for large. This would lead to a recommendation (at least for modelling) of lower unit values for 5 mins or less than for 10 (or, perhaps, 11) mins or more.

(b) The data relating to small time changes as presented in SP is unreliable. People's perception of the problem is defective, there is a failure of belief, and they refuse to trade at a plausible rate. This may be because they believe such time savings would not actually come to pass or are minor alongside day-to-day variation in car journey times.

(c) Alternatively, people may take the SP offer at face value, but perceive themselves when responding to SP questions as operating in a short-run context with slack time buffers and scheduling constraints so that small time savings are perceived to be useless and small losses can be accommodated within the schedule. The longer term adjustment opportunities offered by 5 minutes each way per day on the commute are too complex for the respondent to consider and value. But this does not mean they are worthless. Fowkes (1999) has demonstrated that if there is a threshold below which a time saving has no value, or its value is reduced because of an inability to reschedule, then there must be a uniform distribution of such amounts of time across individuals from zero up to the threshold. It is further demonstrated that a given small time saving in that range will move exactly the right proportion of recipients over the threshold, thereby gaining a time saving equal to the size of the threshold. The result is that the outcome is the same as valuing all time savings at the same unit value.

Our evidence is essentially silent on which of these explanations is correct. In our view, AHCG have a made a major effort to investigate the value of small time changes, as requested by the Department. Explanation (a) cannot be ruled out on the grounds of faulty research design, incorrect analysis, or irrational respondents. Nevertheless, our preference is for a mixture of explanation (b) and (c). On balance, we feel that the lower values for the small time savings arise because of the artificial nature of SP exercises, and the large imaginative leap the respondent is required to make to answer the question in a long-term rather than an immediate term manner. Our judgement is therefore to reject the values associated with small time savings.

Although such a decision is clearly controversial, it should be contrasted with an alternative position which might have been revealed. Suppose, contrary to the actual evidence, that we had found that travellers were (on average) willing to pay nothing for time savings up to 10 minutes, but had a marginal value of time of 5p/min thereafter. In this case, we could still use the Fowkes argument as above, and we would still have a violation of convexity, though to a much weaker extent. However, to assume that 10 minutes is worth 50p when respondents have valued 11 minutes at 5p would involve ignoring the data to a much greater extent than we are proposing here. Essentially, our case is based on the unreasonable high marginal values of time manifested between 5 minutes and 11 minutes.

It follows from this that we do not think the evidence can be used to support the use for modelling of very low or zero VTTS for small time changes as proposed by AHCG. We note the fundamental effect a zero VTTS would have on much modelling work, since time could no longer be justified as the dominant (or sole) component of generalised cost.

As far as evaluation is concerned, AHCG proposed using average values *across all the data* for evaluation (rather than reduced or zero values for small time savings). Our approach differs from that in that our "perception" mechanism effectively reduces the weight given to observations with time changes in the range $\pm$ 11 minutes around the current journey time. Given the time changes actually offered in the AHCG designs, this means that our results are dominated by those with gains or losses of 15 or 20 minutes. This has the further implication that the values from our model are higher on this account than the AHCG averages since, effectively, they are the values associated with the larger time changes (i.e. greater than 10 minutes).

It has been put to us that what we are effectively doing is "censoring" the data by discarding all observations relating to time changes below 11 minutes (the estimated "threshold" value for the "perception function"). In Appendix D we report some investigations into the effect on the value of time from **actually** dropping the observations according to different criteria. We show that dropping all observations where the change in time is less than 11 minutes would deliver substantially higher values of time than our preferred model. In fact, when using the perception function, the contribution of the "small time changes" (5 minutes or less) to the estimation is actually to raise the values of time to some extent (10-20%). The values which we are recommending, using the perception function, are broadly in line with an approach without the perception function which drops observations where the time change is *five* minutes or less.

We are aware, of course, of the long-standing "lay" reaction that small time savings have little or no value. Although we do not accept this, since we consider that it involves the same short term lack of adjustment assumptions, we understand the scepticism about implying that 3600 persons saving 1 second is equivalent to one person saving an hour. It would probably be helpful to display the *distribution* of time savings, to see how dependent the overall benefits were. Additionally (an argument which needs to be debated further), there must be questions about the statistical confidence which can be attached to a modelled saving of one second as opposed to one of, say, 10 minutes..

4.3 Conclusions

We believe that the AHCG conclusion relating to significant differences in valuation according to the sign of both time and cost changes is invalid, due to a model specification error. This in turn relates to that part of the SP design which allowed direct comparisons with the "current journey". Although in our view it would be better not to include such comparisons, it is possible to make an appropriate allowance for them in the model specification. When this is done, the "sign effect" effectively vanishes.

This does not mean that the idea that gains are less valued than losses is inherently implausible: what it does mean is that over the range of changes examined in the AHCG study, which would certainly cover the vast majority of highway schemes, there is no significant evidence of an effect.

With regard to the "size" effect, there is no doubt that the data strongly indicates that a lower unit utility attaches to small time changes (whether positive or negative). There is nothing apparently illogical in the data or the design which could have contributed spuriously to such an outcome, nor is it an artefact of the model specification.

There must be some doubt, however, as to whether Stated Preference is a suitable vehicle for carrying out the investigation of responses to small time changes. Consequently, any recommendations in this area (both for modelling and evaluation) must rely on a mixture of theory interpretation and pragmatism. It will be important to examine critically any other evidence especially RP data which can be brought to bear, as well as the question of what is actually to be defined as "small" in the context of time changes.

In the circumstances, our considered view is that the correct approach, both for evaluation and for forecasting models, is to reject the hypothesis of a low or zero value of small time changes and to base the values of time on the implied rate of tradeoff between time and money for the larger time changes. This avoids the difficulty of a high marginal value of time below the threshold of 11 minutes. As Appendix D demonstrates, the resulting implied values of time are broadly consistent with what would have been obtained if all observations relating to time changes of 5 minutes or less had been dropped. We emphasise, however, that we have preferred to use a model form which provides a good explanation to *all* the data, and then to interpret the results carefully.

5. AHCG DATA: NON-WORKING TIME VALUES FOR CAR USERS

5.1 General findings relating to variation

Introduction

In deriving recommended values of time, we take the view that in the case of Car Users, we have a purpose-designed sample in the AHCG data, which offers us the best prospects for analysing cross-sectional variation. Our general approach, therefore, is to make as much use of the AHCG data as possible. In the light of the conclusions of the previous chapter, however, the results will be different from those actually reported by AHCG, since we are making use of a different model specification which ignores sign effects and applies the "perception" model to deal with size effects.

Apart from this, our method of analysis has been essentially compatible with that used by AHCG: the SP choices are analysed according to Discrete Choice Modelling principles, using a binary logit model with a specified utility function relating to the design variables Δc and Δt (the change in journey cost and journey time from the current position).

While the analysis in the previous Chapter was directly aimed at dealing with sign and size effects, we now put these aside and deal with variations in VTTS due to characteristics of the journey or the traveller. We have generally confirmed the AHCG result that there is considerable variation in the values of time across the sample.

This makes it somewhat difficult to present the results in a concise way. We can estimate "representative" values, dependent on selected values of other variables, and we can indicate the chief sources of variation. Alternatively, we can use the "sample enumeration" method developed by AHCG, which involves estimating the value of time for each individual in the sample, and then weighting the values for all, or subsets, of the data. However, to be valid, this requires that the sample is adequately representative of the population of travellers.

As we discuss later in this Chapter, the sample is not representative with respect to the key factor of journey length. There is therefore a need to reconcile with some nationally representative sample such as the NTS, and this is discussed in Chapter 7.

From now on, given our proposed treatment of Business values, we confine ourselves to Commuting and Other purposes, and do not report any results for the Business sample (though these are available).

The chief sources of variation are found to be a) income and b) factors related to journey length. In both cases a positive relationship is found. While a number of other effects are found, and are briefly reviewed towards the end of this Section, we have generally treated them as secondary, and we concentrate here on income and journey length.

The effect with income is expected on theoretical grounds: indeed, some relationship whereby value of time increases with income has been found in all major value of time studies. While it is less widely reported, it has often been found that VTTS for long distance trips are substantially higher than those for short distance trips: this was true, for example, of both the Swedish and Norwegian studies.

Journey Length

There are a number of possible reasons why the VTTS might vary with journey length. Since the VTTS is the ratio of the marginal utilities of time and money, the effect could be the outcome of variations in either or both of these utilities. While such variations could be related to distance *per se*, they can also be expected to be affected by the absolute time and money "costs" of the journey. Since we can expect both time and money to increase in line with distance, this would bring about an association of VTTS with distance.

On theoretical grounds, based on the expected shape of the indifference curves (see WP561), we would expect the marginal *dis*utilities of both time and cost to increase as both time and cost increased, because of *budget effects* ($\frac{\partial^2 U_k}{\partial t^2}$ and $\frac{\partial^2 U_k}{\partial c^2} \leq 0$). In itself, this implies nothing for the value of time. If the value of time is to increase, this implies that the marginal disutility of time increases faster than the marginal disutility of money.

There are at least three reasons to expect that this might indeed be the case. The marginal disutility of travel time may increase with journey length as fatigue, boredom and discomfort set in. Secondly, time constraints may typically bind more tightly than money budget constraints. Within the rhythm of the day, travel time on longer journeys eats into the time available at the destination, so that the opportunity cost of time spent travelling can be expected to be greater on that account for longer journeys. Thirdly, the mix of journey purposes also varies with journey length; activities associated with longer journeys must be relatively highly valued to justify the travel time and cost involved in undertaking them.

A counter-argument is that short distance trips, being concentrated in urban areas, are more likely to be affected by congestion which can be expected to provide a stimulus to higher values.

An alternative view, which is *not* in line with traditional economic theory, is that consumers are less perturbed by an increase of a given amount when it is relative to a larger amount: we refer to this as the *a relative effect.* While economic theory assumes that a £1 increase conveys the same disutility wherever it occurs (because of its opportunity value), it is plausible that consumers' response may be different according to whether the original cost is £1 or £1000. (Tversky and Kahneman, 1991). The same argument could be used for time changes. (We note in passing that while the relative argument is behaviourally plausible, its implications for evaluation need to be considered carefully).

On this basis, the marginal disutilities should *decline* as the distance increases ($\frac{\partial^2 U_k}{\partial t^2}$ and $\frac{\partial^2 U_k}{\partial c^2} \geq 0$). Once again, in itself, this implies nothing for the value of time. If the value of time is to increase, this implies that the marginal disutility of time declines more slowly than the marginal disutility of money.

This discussion shows that some indication of the nature of the effect can be given by the sign of the second derivative of the utility function. In WP561 we presented results for a number of alternative model formulations, but we did not explicitly examine them from this point of view.

Of the possible measures of impedance, the journey length is not recorded in the AHCG data, so we can deduce nothing directly about the variation of VTTS with distance. However, respondents were asked to give the total journey time and the total cost. Hence, we can investigate the variation of VTTS with total time and cost.

Model Investigations

With a view to obtaining some clarification about the nature of the journey length effect, we have removed from the data set a number of observations that were potentially suspect in terms of their relationship between reported time and cost (see Appendix E) on the grounds that these "outliers" could exert undue influence on the estimation. It turns out, however, that there is no evidence of such an effect. Hence, while we have presented the results based on the reduced data set, it may be seen from the corresponding results in Appendix E that no significantly different conclusions would have been reached had we stayed with the original analysis. Accordingly, we conclude that the results are robust.

In model M6a, we obtain the following for the marginal utilities of time and cost:

	Commute	Other
$\partial U/\partial t =$	$-0.08289 + 0.000119\,T$	$-0.04582 - 0.000081\,T$
	(9.64) (1.28)	(8.16) (2.51)
$\partial U/\partial c =$	$-0.01911 + 0.00000523\,C$	$-0.01777 + 0.0000043\,C$
	(17.66) (4.15)	(23.35) (9.12)

Thus there is a significant effect whereby the marginal disutility of cost (i.e. the negative of $\partial U/\partial c$) *falls* with increasing journey cost – indicating a relative effect rather than the theoretically expected budget effect. For time, the effect is less strong: the marginal disutility of time falls for Commute but the effect is not significant and it *rises* for other (though the effect is only just significant taking into account the effect of 'repeated measurements' in the estimation of standard errors. So, taking the ratio of the marginal disutilities, we find that VTTS increases with longer journeys, but not for the theoretically expected reason.

In model M6b, we investigate whether *both* marginal utilities should be functions of journey time. The overall model fit worsens, and we obtain the following results:

	Commute	Other
$\partial U/\partial t =$	$-0.08148 + 0.000109\,T$	$-0.04313 - 0.000093\,T$
	(9.20) (1.08)	(7.03) (2.45)
$\partial U/\partial c =$	$-0.0195 + 0.00004454\,T$	$-0.01703 + 0.00002774\,T$
	(15.98) (3.52)	(19.98) (6.13)

Apart from the fact that the change in marginal utility of cost is less well explained by journey time than by journey cost, this confirms the general pattern in Model M6a.

If we assume a *constant* marginal utility of cost, then Model M6e does suggest a more significant *increase* in the marginal disutility of time as journey time increases – consistent with the budget effect. In terms of overall model fit, however, this is a worse result. Moreover, a model [M6d] which assumes a constant marginal utility of *time*, while allowing the marginal utility of cost to change with journey cost, fits almost as well as the first model M6a, as shown in the Table below in terms of mean log-likelihood per observation.

Table 7: Comparison of model specifications

	Commute		Other	
MODEL	Mean LL	wrt M6a	Mean LL	wrt M6a
M6a	–0.590784		–0.575021	
M6d	–0.590959	–0.000175	–0.575436	–0.000415
M6b	–0.591462	–0.000678	–0.578287	–0.003266
M6e	–0.592994	–0.002210	–0.580663	–0.005642

On balance, therefore, this suggests that a) the effect is largely due to reduced sensitivity to cost changes as the overall journey cost increases; and b) that a model which assumes *constant* marginal utility of time does not perform significantly worse than one which allows for some variation with journey time. Our conclusion is that an appropriate model formulation is to allow the disutility of a change in cost to vary with the absolute cost of the journey, and that the consequence is that VTTS rises with journey cost.

Note in passing that the Dutch National Model has used a formulation for utility which replaces the money cost variable C by ln (a + C), where a (> 0) is, effectively, a constant of calibration, and generally small. Hence, if β is the coefficient on "ln cost", $\partial U/\partial c = \beta/(a + C)$: *this also is a declining function of C (in disutility terms), in line with the effect found here.* However, in WP561 we showed that applying the "ln cost" formulation to the AHCG data produced a markedly worse fit: primarily this appeared to be because the logarithmic function effectively transforms the *change* in cost (Δc) as well.

As noted earlier, the 'relative' effect whereby a given cost increase conveys less disutility when the base cost is large is not in line with general economic theory. Indeed, according to neoclassical microeconomics it is irrational, since it implies that the value of an extra pound depends on where it is saved. However, there is evidence that people may not behave according to the theory: they are less averse to spending an extra pound when they are already prepared to spend a large amount for a particular commodity, and so they do not view the disutility of an extra pound on a £1 bus fare in the same way as an extra pound on a £50 train fare. While this can be viewed as a form of 'misperception', we do not see it as an essentially short term phenomenon but as one which can be expected to endure. On balance, therefore, we accept it as having behavioural relevance. We return to the implications for evaluation in section 8.2.

A model for both income and journey length (cost) effects

Making further allowance for income variation introduces some complications because of the potential interdependence between income and journey length. Allowing for a pure income effect along the line of:

$$\partial U/\partial c = \beta_{c0} + \beta_{c1}\, C + \beta_{c2}\, Y$$

shows that the marginal disutility falls with increasing income, as expected, while the effect of journey cost remains stable [cf Tables 10b, 11b of Appendix E]. Unfortunately, the detailed variation, and hence the implied elasticities, is sensitive to the model specification.

An alternative specification which performed much better for both purposes involved estimating the elasticity directly, using the following form for the coefficient on Δc:

$$\beta_c \cdot \left(\frac{Inc}{Inc_0}\right)^{\eta_{Inc}} \cdot \left(\frac{C}{C_0}\right)^{\eta_C}$$

where C is the reported total journey cost, and Inc_0, C_0 are arbitrarily defined base or reference values which do not affect the estimation of the elasticities. Although this form does not allow for interaction between cost and income, adding an interaction to the earlier model form was, in fact, insignificant, and the fit was significantly worse than the "elasticity" model..

In this formulation, the marginal utility of cost is a function of both income and journey length/cost. Since we (now) expect it to decline, in absolute terms, with both these variables, the elasticity coefficients will be negative. However, since VTTS is the ratio of the marginal utilities of time and cost, the net outcome is that in VTTS terms, the elasticities with respect to income and journey length are positive.

On this basis, the estimated elasticities to income and cost are:

	Commuting	**Other**
Income η_{Inc}	0.36 (7.58)	0.16 (5.49)
Cost *qua* Distance η_C	0.42 (9.08)	0.31 (11.86)

As the elasticities indicate, the Commuting values are more sensitive both to income and journey length. It is difficult to compare these directly with other estimates, including the income elasticities reported by AHCG (though they also noted that the effect was lower for Other than for Commuting), since, as noted above, calculated elasticities depend both on model formulation and the choice of points used for calculation. Although the assumption of constant elasticity is not necessarily correct, allowing an overall elasticity to be estimated directly is probably the best way to obtain an unbiased value, in our opinion. We note, however, that the values estimated by AHCG for income elasticity were substantially higher: 0.65 for Commuting and 0.35 for Other (AHCG, Table 126).

We investigated whether there was a potential problem of attribution between the income and cost elasticities. However, the correlation between the parameter estimates was low: -0.122 for Commuting and –0.193 for Other.

Other effects on VTTS

We have investigated whether the models for Commuting and Other are significantly different (see Appendix F). Although it turns out that the *average* values (see Chapter 7) are not very different, we conclude that on balance the models are sufficiently different to keep them separate. In any case, the AHCG data contains substantial observations for both purposes.

Having considered the broad implications of purpose, income and distance, we now consider the remaining segmentation results, based on the analysis in WP565. It is clear both from our work and the much more detailed segmentation carried out by AHCG that a large number of apparently significant effects can be identified. Not all the effects are in agreement, and in some cases the effects change substantially according to the model specification. While this is perfectly reasonable, it does place a substantial onus on the model specification, if we are to avoid spurious correlations.

While some of the identified effects accord well with common sense (for example, travellers with cost reimbursement evince higher values of time), others are harder to interpret, particularly when they vary by purpose. There is a general tendency for values of time to fall with age for all purposes, though not generally in a regular way: some of this is associated with lower values for retired persons (though the age effect is also found in Business and Commuting). Females have higher values for Commuting (and Business) but lower for Other.

While the proportion of time spent in congested circumstances had a marked effect on Business travellers' values, the effect for Commuters was barely significant, though it suggested an increase of 40%: no significant effect was found for Other traffic.

Allowing for the impact of free time was generally insignificant, though the coefficients had the expected sign. Only the Other purpose had results approaching significance, one model specification suggesting a 0.3% reduction in VTTS for each additional hour of free time. These are less impressive results than those reported by AHCG: however, the AHCG results still only implied a reduction of between 0.4 and 0.6% (according to purpose) for each additional hour. Moreover, we have some reservations about the values of the variable on the data files.

We may note that the tentative results about free time are not helpful in providing explanation for changes in VTTS *over time*. The cross-sectional income results, combined with those of the temporal analysis in Chapter 6, give some indications about the role of income growth, while the distance effect allows a principled method for comparing results from different samples which may vary widely in terms of average distance.

A significant effect was found in relation to *passengers*. In discussing this, it is necessary to make clear how the data was collected. Travellers were approached at service stations (NB *not* those on motorways) and, after some screening questions, asked if they would be willing to participate in a self-completion SP, relating to the journey they were making. For this purpose, they were asked whether they were the driver or the passenger (i.e. at the time of travel), and the questionnaire was marked accordingly. A separate record was kept as to whether a questionnaire had been given a) only to the driver, b) only to the passenger, c) to both driver and passenger.

What we do not know is whether, for example, the person identified as the passenger was always a passenger (e.g. because they had no driving licence) or merely a passenger for that journey. If they had no driving experience, it is not easy in general to see how they could respond to the questions involving the cost of the journey and variations therein. By contrast, if they had driving experience, these issues should not be a problem, but we could have some concern as to whether the "passengers" have really responded as passengers rather than as drivers.

For these reasons, we are not completely convinced that those VTTS results that can be estimated for passengers as opposed to drivers genuinely refer to the distinction required. In spite of this, for both Commuting and Other purposes, a consistent effect was found whereby passengers' VTTS was around 20-25% lower than that of drivers (see Appendix E). The result for Commuters was not significant, but this can be explained by the small sample of passengers of this purpose, which in itself is not unreasonable, given that the great majority of car commuters travel alone.

Overall, our feelings are that these segmentation results are generally indicative of the richness of the data. However, for the most part they do not display sufficient consistency or strength to imply a modification of the headline results, with the exception of age/retired status and passengers. The results on congested travel are indicative, and broadly (but weakly) support previous results, while the results on reimbursement are convincing but difficult to implement.

Conclusions

As a result of these investigations, and bearing in mind the practical requirements, we believe that the chief variation in VTTS is that related to income and journey length, the latter primarily a reflection of decreased cost sensitivity. We also propose to keep the Commuting purpose separate from Other leisure purposes, though the actual values turn out not to be very different. There is some evidence supporting lower values for passengers, and although we have some reservations about the data, the results appear reasonable.

5.2 Correcting for Representativity

As noted, the AHCG dataset contains no information about journey distance. This would not in itself be a problem if the sample was reasonably representative of all car travellers. In this section we show that this is not the case.

Section 4.4 of the AHCG Report compares the journey duration for the sample with data from the 1992/94 NTS: for Commuting 58% of the sample has a duration greater than 25 minutes, compared with only 27% in NTS: the corresponding figures for Other are 57% and 16%. Although it both notes and provides an explanation for the substantial over-sampling of longer distance journeys, no correction is proposed or carried out.

NTS data is more often classified by distance: for example, from the 1992/94 survey, only 20% of all car driver trips were greater than 10 miles, and this included trips for employers' business, where the proportion of longer trips is significantly higher than for other purposes.

If there was no reason to believe that VTTS varied with journey length, the non-representative nature of the AHCG data in this respect would not be of great concern. However, as noted in the previous section, we have specifically identified a relationship with the cost of the journey, which will be strongly correlated with distance. Unless we always operate with values of time segmented by journey length, we will overestimate the average VTTS if we use the AHCG-based results unweighted because of the higher than representative mean trip length.

In order to attain a suitably weighted average VTTS, we need an appropriate trip length distribution. The most obvious source is the NTS. Although in principle NTS trips can be analysed either by journey time or distance, almost all the published information relates to the distribution by distance. There is no NTS information on costs for car driver journeys, and it was cost, rather than time, which was shown above to be the best explanatory variable for variations in VTTS with journey length.

For this reason, we have considered it essential to construct a "bridge" between the AHCG reported costs and journey distance. Although this is not a straightforward task, we need both to correct for representativity *and* to find a way of applying the preferred model in relation to data sets which do not contain the relevant information on cost.

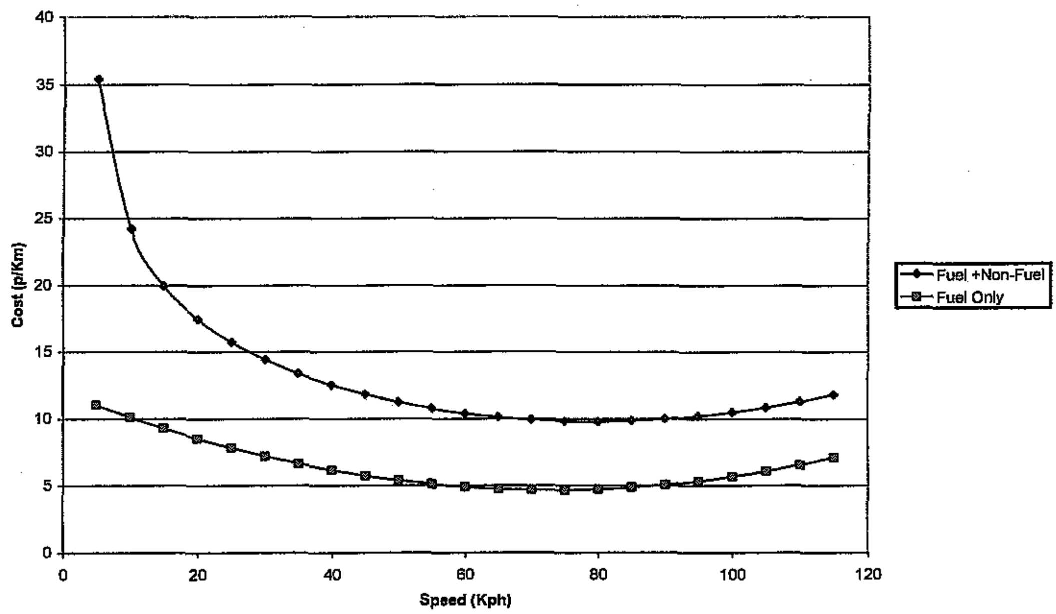
In the seminar conducted in December 2001, it was strongly represented that distance itself cannot be an appropriate explanatory variable for the variation in VTTS. We have no difficulty in accepting this in principle: it is however more difficult to decide actually what the effect is. The model results presented earlier suggest that for a given current journey cost, changes in cost incur less unit disutility the higher the current cost. While this is plausible, its implications for modelling say mode choice are not clear. Are we to assume that the assessment of cost differences can only be made relative to the cost of the current mode? We have already shown that using a utility function with a declining function of *absolute* cost fits the data poorly.

A possible explanation may be that the cost of a journey acts in some sense as a "framing" device in carrying out comparisons between alternatives: people expect a long journey to be more expensive than a short journey, and react differently to given changes in cost. . We believe that this is an important issue which remains currently unclear.

5.3 Dealing with "Journey length"

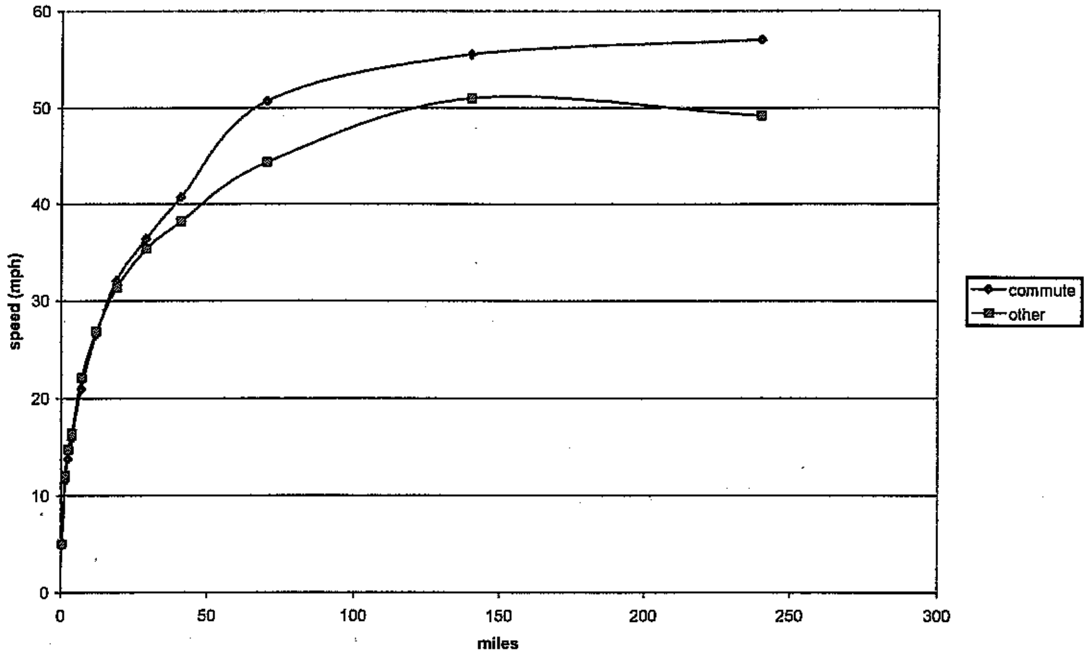
In forging the "bridge" between distance and cost, we have made extensive use of the Department's methodology on vehicle operating cost, as presented in the recent Transport Economic Note (TEN). According to the 1998 TEN relationships, the cost per distance increases in the following way:

Figure 4: TEN 1998 Petrol Car Operating Costs



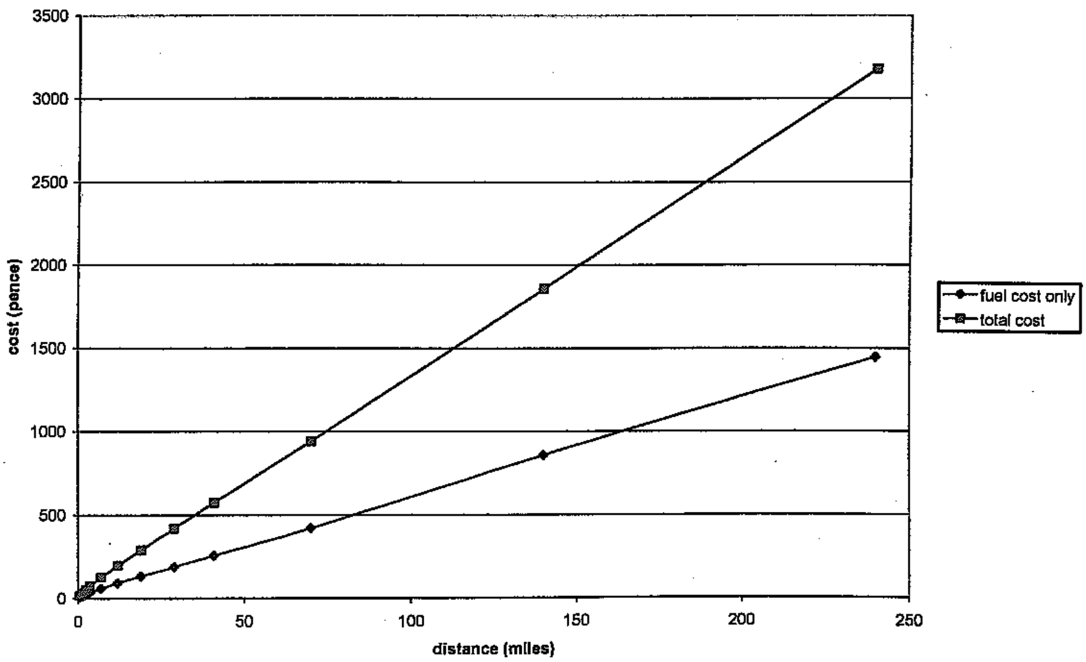
In addition to the TEN relationships, the Department has provided us with NTS tabulations for the period 1995/2000, relating to a) purpose (Commuting, Other leisure), b) income, c) distance and d) (mechanised) mode (car driver, car passenger, bus, rail). This indicates that for car drivers average speeds tend to increase with journey length, as shown below:

Figure 5: Average speed by journey length



Putting these together, we might expect an average relationship between cost and distance of the following type:

Figure 6: Estimated TEN journey cost by distance (1984 prices)



In other words, we have a relationship close to linear, though it is steeper for short distances. Hence, treating cost as a linear multiplier of distance is not at serious variance with known relationships. This means that the derived elasticity of VTTS with respect to journey cost can be interpreted as a distance elasticity. There remains the question, however, of whether the cost should be confined to fuel, or include all elements of operating cost.

In the AHCG survey, the instructions given to respondents for reporting journey costs were: "Please give an estimate for the one-way leg, including out-of-pocket costs only, i.e. petrol, parking and any tolls, if applicable". This does not seem particularly clear, but might incline us to think that fuel costs only is appropriate, given that parking and toll costs are likely to be rare.

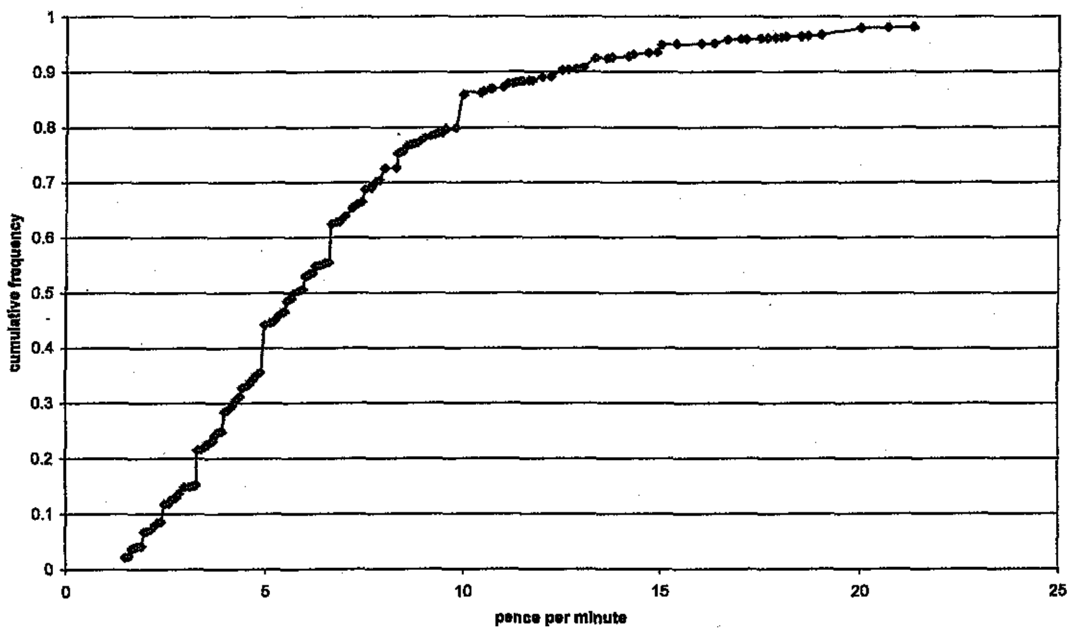
With this in mind, we carried out a careful investigation of the AHCG data relating to reported costs *and* travel times. In addition to the time for the whole journey, respondents were also asked to provide the amount of time spent on each of motorways, trunk roads, and other principal roads. The following data was discarded:

- cases where journey cost = not recorded or zero;
- cases where at least one of time "components" (road types) = not recorded;
- cases where journey time is > 5 minutes *less* than sum of components.

(note that since some of the journey may be on other road types – e.g. B roads – it is not required that the sum of the components equals the total time).

We then examined the implied values of the ratio of journey cost to journey time for the remaining sample. Although reported values range from 0.33 p/min to 133.33 p/min, dropping the top and bottom 2% of the distribution reduces the range to [1.5, 21.33]. The cumulative distribution is plotted in the figure below:

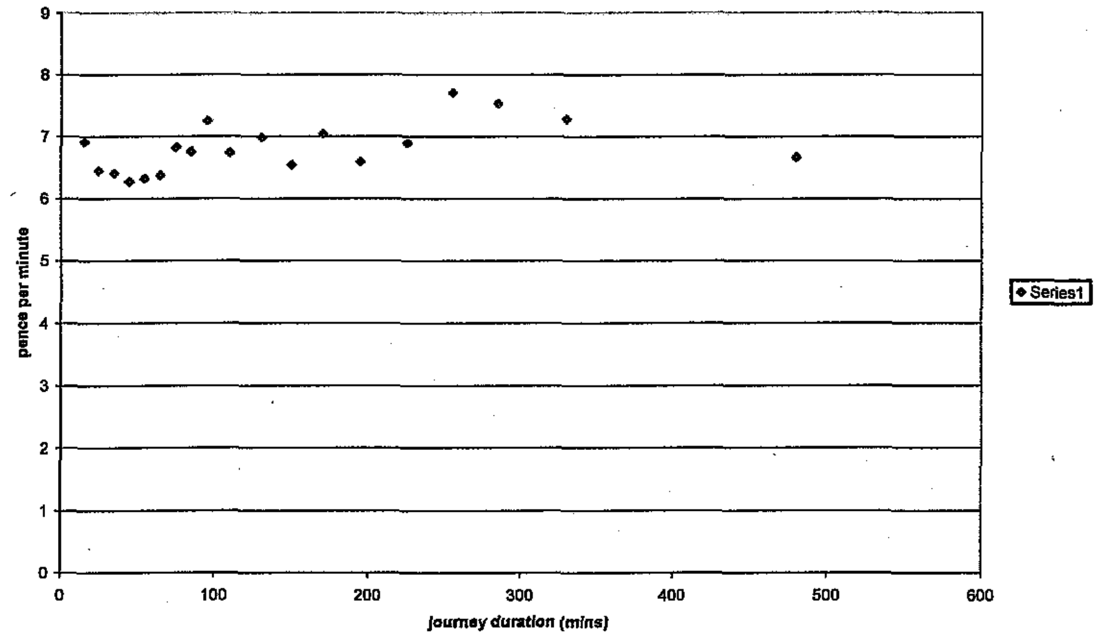
Figure 7: Distribution of cost/time from 2% to 98%



It can be seen that there are "spurts" in the graph demonstrating the concentration of ratios at the values 2.5, 3.33, 4, 5, 6.67, 10, suggesting a rough and ready approach to the cost estimation, often based on the *time*.

Since one might expect longer journeys to have higher speeds, there could be a trend relating to the journey duration:. However, after confining the data to the 96% of the distribution, as above, the average cost/time ratios at different "journey lengths" were as plotted below, and revealed no such trend:

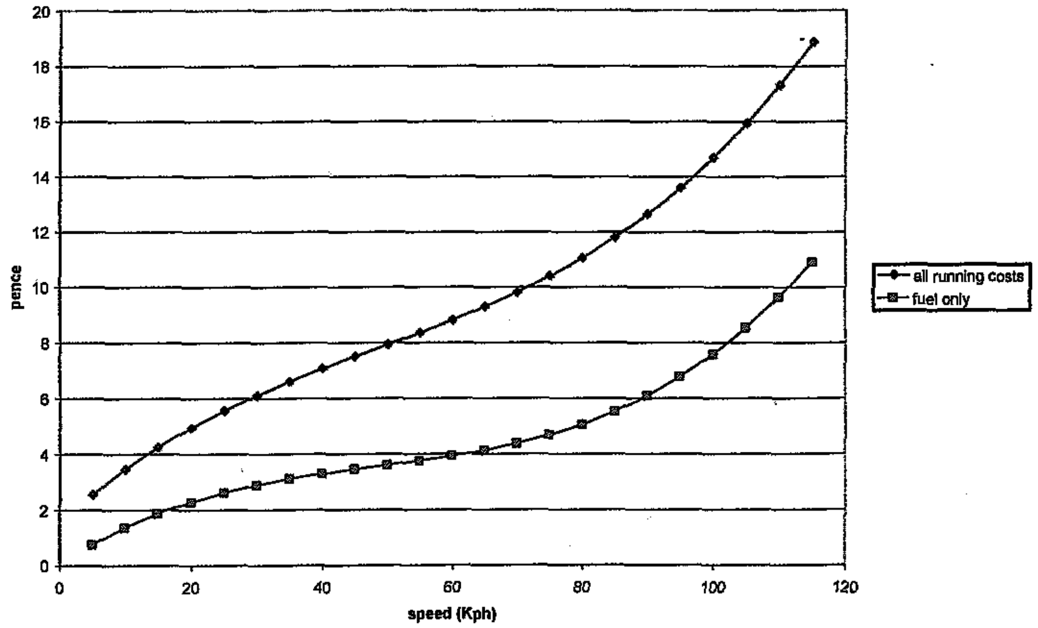
Figure 8: Ratio of costs to time



We can then use the TEN operating cost formulae to see what kinds of ratios of cost to time are implied, correcting for changes in prices back to 1994. The average 1994 pump price was 54p. For non-fuel, we have followed the TEN recommendation and not adjusted in real terms – the inflation factor is 1.123.

Hence we can generate the TEN cost *per minute* at different speeds: this is plotted, for fuel and total costs, below:

Figure 9: Petrol car: costs per minute (1994 prices)



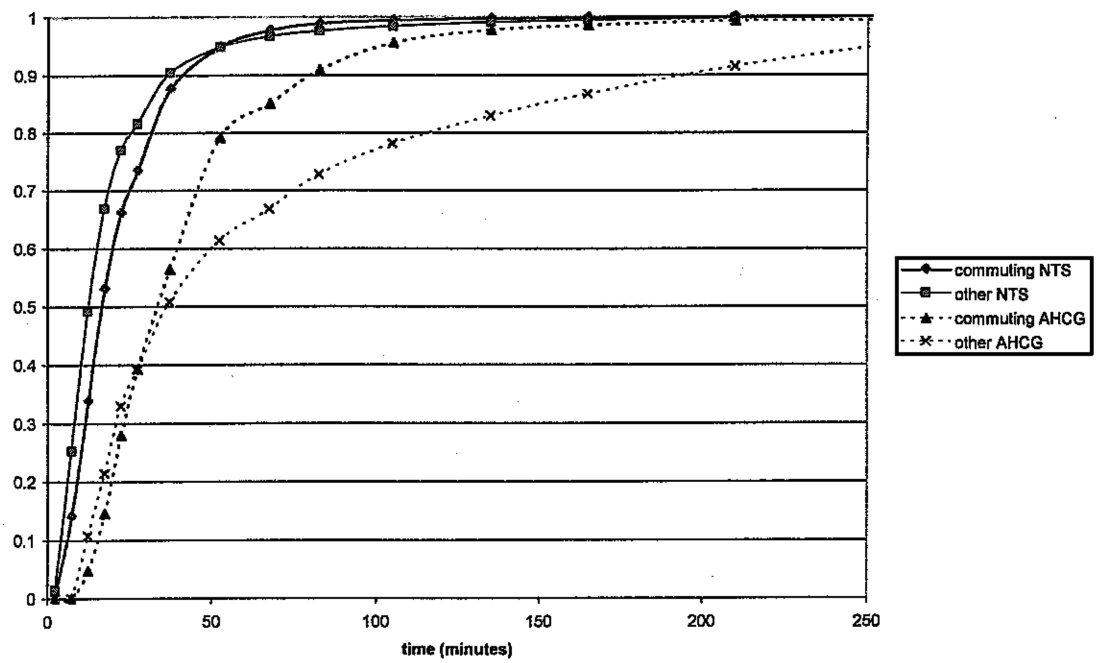
Since it seems unlikely that any actual journeys will have an average speed outside the range [30, 90], the official (TEN) average range of cost per minute is [2.9, 6.1] pence for fuel only, and [6.1, 12.6] pence for all costs. This suggests that it is certainly not unreasonable to remove the possible effect of extreme values by restricting the AHCG data to the 96% range of [1.5, 21.33]: this is substantially wider than the likely true range. It is shown in Appendix E that censoring the data in this way has no significant effect on the general results.

The TEN "model" suggests about 6p/mile fuel, and 13.2p/mile all operating costs (1994 prices). On average, the AHCG cost data is more compatible with all costs rather than fuel alone: however, there is considerable variation. The average AHCG cost per *minute* is around 7p: in fuel cost terms, this corresponds with an average speed of 98 Kph, while in terms of all cost, it corresponds with 40 Kph. The NTS data suggests that the average speed for all car driver journeys is 43 Kph.

While any average assumptions made here can be criticised, our view is that it would be reasonable to assume that the AHCG respondents were in fact estimating total journey cost as opposed to fuel cost only: hence we work with 13.2 p/mile (8.25 p/Km). This allows us to convert the AHCG data on reported journey cost to a distance.

If, after confining the AHCG data to the 96% range given above, we compare the cumulative distributions of journeys by journey time with the corresponding samples from the 1995/2000 NTS, we see the substantial bias towards longer duration journeys in the AHCG sample, as shown in Figure 10. The bias is very strong for Other purpose, though for Commuting it is less pronounced, and arises largely because the shortest quarter of car commuting trips in the NTS – c. 10 minutes and less – are underrepresented in AHCG.

Figure 10: Cumulative frequency of journeys by journey time



Given the relationship between VTTS and journey length (via the cost variable), it is clear that in recommending any average values it will be important to correct the AHCG sample for representativity. This is discussed in Chapter 7.

5.4 The recommended model

As a result of these deliberations, we choose our recommended model for application. The model varies by journey purpose, and allows for the variation in value of time through the mechanism of the cost coefficient being sensitive both to income and journey length, the latter represented by reported cost, though in application we will convert this to distance using the assumed cost of 8.25 p/Km.

We have considered whether to include the passenger effect. On balance, our inclination is against it (as will be further discussed in Chapter 7): however, for the sake of completeness, we here report alternative models with and without a distinction between drivers and passengers.

All models incorporate the "inertia" effect and the "tapering" effect as discussed in the previous Chapter. The estimation data has been restricted to those records which satisfy the conditions set out in the previous Section, though as Appendix E shows, this does not result in significant changes to the model results. Compared with the estimation set used by AHCG and reported in our earlier WPs, the Commuting sample has been reduced by just over 3% and the Other sample by just over 4%.

Table 8: Model A: no distinction between drivers and passengers

	Commute	Other
$\Delta\tau$ β_τ	-0.10098040 (-15.07)	-0.08291784 (-19.33)
M	2.14015281 (6.02)	7.06711097 (6.63)
Theta	11.0 (fixed)	11.0 (fixed)
Δc β_c	-0.02472923 (-14.84)	-0.02227485 (-18.51)
Inertia	0.89235685 (17.65)	0.95544259 (24.08)
Income Elasticity η_{Inc}	0.35877551 (7.58)	0.15680538 (5.49)
Distance Elasticity η_C	0.42130442 (9.08)	0.31472703 (11.86)
Mean LL	-0.567479	-0.555104
No. Obs	4583.00	7689.00

The formula for the value of time is given as:

$$\text{VTTS} = [\beta_\tau/\beta_c].\left(\frac{Inc}{Inc_0}\right)^{\eta_{Inc}}.\left(\frac{C}{C_0}\right)^{\eta_C},$$

where Inc is household income in £'000 pa and C is journey cost in pence (both in 1994 prices), and Inc_0 and C_0 take the fixed values 35 and 100 respectively. Illustrative values using this formula are given in Chapter 7.

Table 9: Model B: separate values for drivers and passengers

	Commute	Other
$\Delta\tau$ β_τ	-0.10151343 (-15.04)	-0.08580795 (-19.12)
Passenger. $\Delta\tau$	0.01943503 (0.67)	0.02036531 (2.35)
M	2.13376453 (6.06)	7.00643755 (6.65)
Theta	11.0 (fixed)	11.0 (fixed)
Δc β_c	-0.02484929 (-14.85)	-0.02241235 (-18.55)
Inertia	0.89227441 (17.65)	0.95415958 (24.04)
Income Elasticity η_{Inc}	0.35594946 (7.50)	0.15591207 (5.46)
Distance Elasticity η_C	0.42489123 (9.13)	0.31783203 (11.97)
Mean LL	-0.567430	-0.554745
No. Obs	4583.00	7689.00

For drivers the value of time formula is as above. For passengers, the "Passenger. $\Delta\tau$" needs to be added to the base time coefficient β_τ: as noted earlier, this results in a reduction of 20-25% for passengers.

Approximately 11% of the Other sample were described as passengers: for Commuters the proportion was only 2%. Corresponding figures from NTS 1995/2000 are 40% and 17% respectively, so that passengers are substantially underrepresented in the AHCG sample.

6. META-ANALYSIS

Whereas for the 1987 value of time report, the official studies were the only contemporary source of evidence on the VTTS, there are now many studies which yield estimate of VTTS. Though not purpose-designed, the meta-analysis permits conclusions from the AHCG data to be compared with a much wider dataset. In addition, the meta-analysis dataset allows us to conduct some analysis of changes in the VTTS over time and to extend the conclusions to cover public transport.

In addition to the money values of time in the Database, information has been collected on a range of factors which might explain variations in the valuations. These include the year and quarter of data collection and associated income and retail price indices, sample size, journey distance, type of data upon which the model was estimated, journey purpose, choice context, user type, mode valued, numeraire, location, the omission of non traders and use of logic checks, the means of presenting an SP exercise and the number of attributes in it, the mean level of the attributes and the purpose of the study. It is assumed that the variation in the values which cannot be explained by the above key variables is randomly distributed across the sample.

The variables for which we have information are either continuous or categorical. The form of model used to explain variations in the monetary values (V) takes the form:

$$V = \tau.\exp\left(\sum_{j=1}^{p}\sum_{k=1}^{q-1}\beta_{jk}z_{jk}\right)\prod_{i=1}^{n}x_i^{\alpha_i} \qquad (1)$$

where there are p categorical variables (Z_{jk}) each having q categories, and n continuous variables (X_i). We specify q-1 dummy variables for a categorical variable of q levels and their coefficient estimates are interpreted relative to the arbitrarily omitted level. A logarithmic transformation of equation 1 allows the estimation of the parameters by ordinary least squares.

The α_i coefficients are interpreted as elasticities, denoting the proportionate effect on the value V of a proportionate change in X_i. The exponential of β_{jk} denotes the proportionate effect of level k of categorical variable j on the value V relative to its omitted level.

6.1 Results for car journeys

For comparability with the analysis reported in section 5.1, we here restrict the discussion of the meta-analysis findings to those relating solely to car drivers' valuations of car in-vehicle time (IVT)[8]. The valuation of public transport IVT, by both car users and public transport users, is dealt with in section 6.2. The key findings of the meta-analysis are that significant influences were obtained from:

- Distance
- GDP
- Journey Purpose
- The numeraire used to derive the money value of time
- Whether the value relates to travellers in London or the South East.

[8] In this chapter we refer to IVT rather than VTTS because we wish to consider the relativity between IVT and walking, waiting etc. for public transport trips.

We here provide a summary of our findings: more detailed discussion of the results is contained in Working Paper 564.

Our study obtained a distance elasticity of 0.184 for all modes except car, and a higher elasticity of 0.259 for car travel. We take the latter to indicate that the marginal disutility of travel by car increases at a faster rate than for other modes[9]. In addition, inter-urban trips were found to be 29% more highly valued than urban trips over and above the pure distance effect.

The distance elasticity will unfortunately include income effects to the extent to which those with higher incomes travel farther and have higher VTTS. However, the evidence obtained from re-analysis of the AHCG data and presented in section 5.1 indicates that trip length does not vary greatly with income whilst the cross-sectional income elasticity, in line with other evidence, is not high. We therefore conclude that any confounding effect from income is minimal. There will also be SP design specific effects if the VTTS estimate depends on the size of time variation offered and larger time variations are offered for longer distance journeys. The evidence obtained from re-analysis of the AHCG data and reported in section 4.2 confirms that this is a possibility.

We expect that as individuals become wealthier, they will become less sensitive to cost variations. This reduction in the marginal utility of money will increase the value of time. There is a mass of convincing evidence, both from Britain and elsewhere, that the value of time is higher for those with larger incomes. However, there are reasons, discussed in section 6.8, why the cross-sectional income elasticity may differ from the time series income elasticity.

In contrast with the mass of empirical evidence, the meta-analysis provides a time series elasticity. However, since GDP (or some other measure of economic wellbeing) and time are highly correlated, we cannot estimate reliable effects to each. We have therefore specified a GDP term, which will discern both income and time trend effects, and its elasticity was estimated to be 0.72 for the entire sample and 0.82 for the sample of solely IVT values. This elasticity did not vary by mode.

For the record, we found business trips to be valued 163% more highly than leisure trips. However, some of the employers' business values will entirely or in large part reflect the employee's valuation and hence will understate the employer's willingness to pay for time savings.

Commuting trips were found to have values which are 11% higher than leisure trips, presumably because of the more difficult and frustrating driving conditions in the peak and the greater constraints on arrival times and on available time. However, income differences between commuters and leisure travellers could also have influenced these results.

We might expect the value of time to vary according to the cost numeraire used in its calculation. For example, if petrol costs are not treated as a marginal cost, or are paid by others such as the employer, the cost coefficient will be lower and the value of time will be higher than it would otherwise be. On the other hand, protest responses against toll or road user charges will lead the value of time to be lower than it otherwise would be. In this study, we found that values of time based upon a toll numeraire were 19% lower than all other numeraires.

[9] This is largely rail since most longer distance observations related to rail and car.

Finally, it was found that values obtained from travellers in London and the South East were 16% higher. In part, this will be because of more congested driving conditions, but the higher incomes in the South East may have contributed to the finding.

We conclude this section by providing the relevant parts of the estimated model relevant to calculating car users' values of time for car travel and using the model to provide illustrative values for a range of situations.

The formula for obtaining estimates of car users' monetary values of car time (V), in 1994 quarter 4 prices, is:

$$V = GDP^{0.723} D^{0.259} e^{-4.800+0.258\,Inter+0.968\,EB+0.100\,Comm+0.147\,LSE}$$

GDP denotes gross domestic product per capita, and the value for 1994 quarter 4 is 3019. D denotes distance in miles and Inter represents inter-urban trips. EB and Comm denote employers' business trips and commuting respectively, and LSE represents values for London and the South East.

Terms not in the above equation but which were estimated in our model reported in Working Paper 564 are those that we feel should not be allowed to influence the value of time. For example, the toll numeraire effect is not included since we regard its coefficient estimate to be a reflection of protest response rather than a genuine effect on the value of IVT.

Table 10 provides illustrative values of IVT in 1994 quarter 4 prices for three journey purposes and different distances. The relatively small difference between commuting and leisure trips is apparent as is the relatively strong distance effect.

Table 10: Illustrative Car Users' Values of Car IVT (1994 Quarter 4)

Purpose	Distance	
Comm	2 miles	3.6
	10 miles	5.4
	25 miles	6.9
Leis	2 miles	3.2
	10 miles	4.9
	50 miles	9.6
	200 miles	13.8
EB	2 miles	8.5
	10 miles	12.9
	50 miles	25.3
	200 miles	36.3

6.2 Results for public transport journeys in-vehicle time

We here summarise our findings based on meta-analysis relating to:

- Public transport users' values of time
- Car Users' values of public transport time

Section 6.1 summarised the meta-analysis findings relating to car users' values of car time. However, the analysis also indicates how car users value time on other modes, and this is reported here. The public transport users are largely made up of rail and bus users, with some underground users, air users and combined users of various modes. The latter are obtained from studies which did not distinguish by user type.

For some attributes, such as GDP, journey purpose, whether the journey was inter-urban and whether the value related to journeys in the South East, their effects on public transport users' values of IVT were not significantly different from their effects on car users' values. However, there were some important differences.

A noticeable difference is that the distance elasticity of 0.259 for car travel time is higher than the distance elasticity of 0.184 which relates to the public transport modes. At least for longer journeys, the data is dominated by values of time relating to rail and car and we conclude that, because of fatigue and comfort related factors, it is reasonable that there is an incremental effect on the distance elasticity relating to car.

Another important and plausible finding is that, largely as expected, there is variation in the value of time by mode user type. The variations by user type seem to be in line with expected differences in incomes across modes.

Air users have by far the highest values, even after allowing for distance and journey purpose effects, although the correlation between air users and business travel and air users and long distance within our sample may mean that the air users values do contain purpose and distance effects.

The next highest values are for underground users, although we are here unable to distinguish between user type and mode. Whilst it can be expected that the high values for these users will be due to their relatively high incomes, a further contributory factor might be the at times unpleasant travelling conditions on the underground. Note, however, that we found that there was an additional strong incremental effect apparent for those commuting on the underground.

Rail users have slightly higher values than car users, presumably due to an income effect, and not surprisingly the lowest values of time are for bus users. We tested a whole range of interactions between user type and other attributes, including journey purpose, distance and GDP but, apart from the incremental effect for underground commuters, no statistically significant effects were apparent.

In addition to differences between user types, we were also able to discern differences in the value of IVT according to the mode to which the value relates, at least amongst the sample of car drivers for whom we have the most observations and also a good spread of valuations across modes. Car users value time spent on bus most highly, presumably reflecting the perceptions of lower comfort and inferior travelling conditions, and value train travel time least. However, the differences are not large and the relationship between the values for the different modes is moderated by the larger distance elasticity for car travel.

We have been able to detect differences in VTTS according to both user type and the mode to which the value relates. Of the two effects, the former is clearly the stronger.

We conclude this section by providing the formulae for deriving values of IVT for the main user types in our sample of car, rail, underground and bus and for the three modes of car, bus and rail for car users. We then provide illustrative values of IVT, in 1994 quarter 4 prices, for a range of situations. For completeness and to enable comparisons to be made, we also repeat the formula for car users' values of car IVT and the illustrative values previously reported in Table 10.

The VTTS for Car Users' relating to car IVT is:

$$V = GDP^{0.723} D^{0.259} e^{-4.800+0.258\,Inter+0.968\,EB+0.100\,Comm+0.147\,LSE}$$

For all other modes, the distance elasticity falls to 0.184. The formula for Car Users' values of rail and bus is:

$$V = GDP^{0.723} D^{0.184} e^{-4.800+0.258\,Inter+0.968\,EB+0.100\,Comm+0.147\,LSE+0.335\,Bus}$$

For public transport users, the value of IVT for the same user type and mode is:

$$V = GDP^{0.723} D^{0.184} . e^{-4.800+0.258\,Inter+0.968\,EB+0.100\,Comm+0.147\,LSE-0.379\,Bus+0.255\,Rail+0.103\,UG+0.52\,Comm.UG}$$

This formula provides the values of rail IVT for rail users, bus IVT for bus users and underground IVT for underground users. Modifiers as to how different users value different modes would have to be obtained from the evidence relating to car users.

Illustrative values of IVT are provided in Table 11 for commuting and leisure trips for a range of distances. These relate to car users' values of car, rail and bus IVT along with the IVT values of bus for bus users, rail for rail users and underground for underground users. The variations by distance and purpose are apparent as are the influence of user type and mode type. Comparison of the values by the different combinations of user type and mode demonstrates that the user type effect is generally stronger than the mode effect, although this can be reversed for longer journeys where the higher distance elasticity for car travel has a stronger bearing.

Table 11: Illustrative Absolute Values of IVT (1994 Quarter 4)

Used		BUS	UG	RAIL	CAR	CAR	CAR
Valued		BUS	UG	RAIL	RAIL	BUS	CAR
Comm	2 miles	2.3	7.3	4.4	3.4	4.7	3.6
	10 miles	3.1	9.8	5.9	4.6	6.4	5.4
	25 miles	3.7	11.7	7.0	5.4	7.5	6.9
Leis	2 miles	2.1	3.9	4.0	3.1	4.3	3.2
	10 miles	2.8	5.3	5.3	4.1	5.8	4.9
	50 miles	4.9	n/a	9.3	7.2	10.0	9.6
	200 miles	6.3	n/a	12.0	9.3	12.9	13.8

6.3 Results for public transport journeys out of vehicle time

The out-of-vehicle values that we have addressed in this study are walk time, wait time and headway. Values of these attributes were obtained for car users as well as public transport users.

The meta-analysis model examined variations in these attribute values simultaneously with variations in values of IVT. Whilst all the values were pooled into a single model, allowance was made for different impacts from the explanatory variables, such as user type, purpose, GDP and distance, on the different valuations. A distinction was retained where it was empirically supported.

As far as the money values of walk time, wait time and headway are concerned, they were influenced by the level of GDP, journey purpose, journey distance, user type, the type of data used in estimation, the mean level that the variable took, whether the value was estimated to travellers in London and the South East and a number of other less important factors which are considered in more detail in Working Paper 564.

The effects of GDP, journey purpose, whether the value was for a London or South East traveller and whether the journey was inter-urban on the values of walk, wait and headway were the same as on the value of IVT. They had been allowed to have a different effect but there was no statistical support for such a distinction.

The distance elasticities were somewhat different than for IVT. The distance elasticity for headway was slightly negative. We do not find it surprising that the importance of headway diminishes with distance. Not only do travellers plan longer distance journeys in more detail, they do not expect frequency to be as high for longer distances.

The distance elasticity for walk and wait time is 0.111. This is lower than the 0.256 for car IVT and 0.184 for other modes' IVT. A lower value is to be expected if the marginal disutility of IVT is more sensitive to distance than are the marginal disutilities of walk and wait time, although the other distance effects discussed in section 5.1 could be expected to operate on the values of walk and wait time as well as the value of IVT.

Car users were the most averse to walking and waiting followed by rail/underground users with bus users having the lowest values. In part there is an income effect at work here but we might also expect car users to be more averse to walking and waiting. However, for headway it is rail/underground users who have the highest values followed by car users with bus users again having the lowest values.

Very strong effects were apparent on the values of walk and wait time from the type of data used in estimation. When the value was obtained from RP data, it was 46% higher for walk time and 143% higher for wait time. If we take RP based evidence as more reliable, these findings overturn previous recommendations that the time valuations of walk and wait time are less than two (Wardman, 2001).

The values of walk and wait time were found to vary with the levels that they take. The elasticity for walk time was 0.271 and for wait time it was 0.157. This dependency of the values of walk and wait time on levels of walk and wait time is not unreasonable. It is consistent with diminishing marginal utility of savings in walk and wait time whilst walking trips are observed to fall off strongly as journey distance increases and small amounts of waiting time are accepted as inevitable. In addition, the absolute levels of the elasticities seem plausible.

The usual means of recommending values of out-of-vehicle time is to specify them relative to the value of IVT. Indeed, recommending values of walk and wait time that are twice the value of IVT is a widespread convention and a feature of the Department's official recommendations.

In contrast with current official recommendations, our findings indicate that the IVT valuations of walk and wait time are not constant, but will vary with distance, user type, journey purpose and the levels that walk and wait time take. Nor will the value of headway be a constant. Hence providing a single recommendation from our findings is not sensible.

Instead, we provide formulae which can be used to derive IVT valuations of walk, wait and headway and some illustrative valuations for a range of situations.

Values of walk time, wait time and headway in equivalent units of IVT are obtained as the ratio of the money values of walk, wait and headway and the money value of IVT.

The formulae presented below are for IVT values of walk time, wait time and headway. The numerator walk, wait and headway values relate to a car, bus or rail user and the denominator relates to the equivalent users' value of IVT for that mode. Hence a 'Car User Car IVT' value of walk time is the ratio of car users' money values of walk time and car users' money values of car IVT.

The formulae for the IVT values of walk time, wait time and headway for car users, bus users and rail users are given in Tables 12, 13 and 14. WK and WT denote the amounts of walk and wait time in minutes and RP indicates that the value was obtained from an RP model.

Table 12: Formulae for IVT Values of Walk Time

IVT VALUE OF WALK TIME FORMULAE	
Car User Car IVT	$WK^{0.271}D^{-0.148}e^{0.379RP + 0.315}$
Bus User Bus IVT	$WK^{0.271}D^{-0.073}e^{0.379RP}$
Rail User Rail IVT	$WK^{0.271}D^{-0.073}e^{0.379RP - 0.266}$

Table 13: Formulae for IVT Values of Wait Time

IVT VALUE OF WAIT TIME FORMULAE	
Car User Car IVT	$WT^{0.157}D^{-0.148}e^{0.886RP + 0.410}$
Bus User Bus IVT	$WT^{0.157}D^{-0.073}e^{0.886RP}$
Rail User Rail IVT	$WT^{0.157}D^{-0.073}e^{0.886RP - 0.022}$

Table 14: Formulae for IVT Values of Headway

IVT VALUE OF HEADWAY FORMULAE	
Car User Car IVT	$D^{-0.272}e^{0.211*EB - 0.152}$
Bus User Bus IVT	$D^{-0.197}e^{0.211*EB - 0.237}$
Rail User Rail IVT	$D^{-0.197}e^{0.211*EB - 0.116}$

The formulae above are straightforward to apply, and we have used them to obtain the illustrative IVT valuations of walk time, wait time and headway for a range of circumstances that are reported in Tables 15 and 16.

The IVT values of walk and wait time vary considerably across the different situations, with the wait time values exceeding the walk time values. The latter appear to centre around the conventional value of two, but the former are generally somewhat higher than this. The IVT values of headway are all less than one and vary across a large range.

Table 15: Implied Weights for Walk and Wait Time

WALK WAIT	DIST	CAR USER		BUS USER		RAIL USER	
		Walk	Wait	Walk	Wait	Walk	Wait
2	2 miles	2.18	3.68	1.68	2.57	1.28	2.51
5		2.79	4.25	2.15	2.97	1.65	2.90
10		3.37	4.73	2.59	3.31	1.99	3.24
20		4.07	5.28	3.13	3.69	2.40	3.61
2	10 miles	1.72	2.90	1.49	2.29	1.14	2.24
5		2.20	3.35	1.91	2.64	1.46	2.58
10		2.66	3.73	2.30	2.94	1.77	2.88
20		3.21	4.16	2.78	3.28	2.13	3.21
2	50 miles	1.35	2.28	1.32	2.03	1.02	1.99
5		1.74	2.64	1.70	2.35	1.30	2.30
10		2.09	2.94	2.05	2.62	1.57	2.56
20		2.53	3.28	2.47	2.92	1.90	2.85
2	200 miles	1.10	1.86	1.20	1.84	0.92	1.80
5		1.41	2.15	1.53	2.12	1.18	2.07
10		1.71	2.39	1.85	2.36	1.42	2.31
20		2.06	2.67	2.23	2.64	1.71	2.58

Note: The walk and wait column denotes the levels of these variables and the distance column indicates the length of the overall journey in miles. In all cases, the weight is in units of the value of IVT for the user type and mode in question.

Table 16: Implied Weights for Headway

DIST	PURPOSE	CAR CAR	BUS BUS	RAIL RAIL
2	EB	0.88	0.85	0.96
2	Non EB	0.71	0.69	0.78
10	EB	0.57	0.62	0.70
10	Non EB	0.46	0.50	0.57
50	EB	0.37	0.45	0.51
50	Non EB	0.30	0.37	0.41
200	EB	0.25	0.34	0.39
200	Non EB	0.20	0.28	0.31

6.4 Summary of Findings for Public Transport Values

We have developed robust models from the meta-analysis which allow values of IVT to be obtained for public transport users alongside car users and which distinguish between user type and mode valued. This enables public transport values to be obtained relative to car users' values of car IVT. We have also conducted a detailed analysis of values of walk time, wait time and headway, and these can be expressed relative to the value of IVT, as is conventionally the case, and according to user type and mode valued. The various formulae to enable these values to be calculated have been provided in the text.

Section 6.1 dealt with car users' values of car IVT and we here summarise only the additional findings relating to public transport users' values of IVT and the values of walk, wait and headway. The key findings are:

- A number of explanatory variables have the same proportional effect on public transport users' values of time as car users' values. These include the key variables of GDP and journey purpose, for which plausible effects on the values of IVT were obtained. We return to the issue of the GDP elasticity below.
- A number of explanatory variables have the same proportional effect on walk, wait and headway values as on the IVT values. These again include GDP and journey purpose.
- Strong distance effects were obtained for all values. These indicated that car values increase with distance at a faster rate than for public transport values of IVT which in turn had a larger elasticity than walk and wait time. The distance elasticity for headway was found to be slightly negative.
- Many studies have discerned variations in values of IVT by user type and mode, although a clear distinction between the two sources of variation is not always made. We have found the values of IVT to vary strongly according to user type, with air users having the highest values, followed by underground users, rail users and car users, and bus users having the lowest values. The variations according to mode tend to be less strong, and are influenced by the different distance elasticity for car travel, but the general pattern is that bus travel has a higher disutility than car travel which in turn has a higher disutility than rail travel.
- A review of previous studies, covering both British and international evidence, raised doubts surrounding the widely used convention for valuing walk and wait time. In particular, there is evidence that wait time is more highly valued than walk time, and its value might exceed twice the value of IVT, although valuing walk time at twice IVT seems more justified. However, there appeared to be a conflict, particularly in the British evidence, between the higher values in the earlier largely RP based studies and the lower values in the more recent and largely SP based studies. In addition, the weights attached to walk and wait time may well vary across different situations, and in part this may have contributed to the different results apparent across studies. These expectations were largely confirmed in our empirical analysis. The values of walk and wait time are higher when obtained from RP data and vary with the respective amounts of walk and wait time and with journey length. The IVT valuations of walk time and wait time vary considerably, with the former appearing to be distributed around the conventional weight of two but the latter being somewhat higher.
- The values of walk and wait time according to user type follow a similar pattern to the values of IVT. Car users tended to have the highest values, followed by rail and underground users with bus users having the lowest values.
- The IVT valuation of headway is less than one and varies considerably according to journey purpose, mode and particularly distance.

6.5 Changes over time – theoretical considerations

We here summarise our evidence, drawn from a number of sources, relating to how the VTTS might vary over time. This condenses the material contained in Working Paper 566. We firstly consider why the VTTS will vary over time and then outline the approaches that can be used to address this issue. We then describe the various results we have obtained and provide a summary assessment of them.

The most widely held convention relating to the adjustment of recommended values of time over time is that they should be linked proportionately to growth in some measure of income. No consideration is given to possible changes in the value of time for other reasons. Even disregarding the latter issue, there is no reason from a theoretical standpoint why the income elasticity for private travel should be unity since it is a matter of personal preference how an individual or household allocates additional income to purchase time savings. In contrast, and as is clear from chapter 3, the case for a close link between the value of time and income is much stronger for business travel.

Official recommendations in Britain, as elsewhere, increase the value of non-work travel time over time in line with growth in income. The Department's Transport Economics Note specifies that both work and non-work time values should be increased in line with real GDP per head.

Beesley (1978) pointed out various sources of variation in the value of time over time and, on the basis of the uncertainty as to even the direction in which the values might vary, he argued in favour of a zero trend value. The first British national value of time study (MVA et al., 1987) claimed that a constant real value of time was on theoretical grounds "equally logical and defensible" as the convention of linking the value of time to income growth. However, it was recognised that there did seem to have been an increase in the value of time over time. It was concluded that, "We do not feel able, therefore, in the absence of any specific work on this topic within our programme, and given the existence of plausible arguments in contrary directions, to come to any firm conclusions. The matter must remain on the agenda for further investigation".

The money value of time for non-work travel is the ratio of the marginal utility of time and the marginal utility of money. The former is made up of components attributable to the disutility of time spent travelling and to the opportunity cost of travel time.

At the outset, we recognise that theory can give no precise guidance on how the value of time varies over time. We can, however, look to theory for guidance on the likely direction of change in the value of time over time as well as for assistance in model specification and interpretation. We here concentrate on how an individual's value of time might vary over time, as opposed to how the value of time in the travelling population as a whole might vary. The latter is additionally influenced by variations in its socio-economic composition.

We expect that income will grow over time and that travellers will become less sensitive to variations in money costs as their income increases. This reduction in the marginal utility of money will mean that the value of time increases with income. However, there is no reason to expect that the value of time varies in direct proportion with income. All that we can reasonably conclude is that since time savings are not an inferior good the income elasticity is expected to be positive[10].

[10] We suspect that what is regarded to be a plausible range in which the income elasticity is expected to lie will vary somewhat across observers.

The inter-temporal value of time will also be influenced by trends in the disutility of travel and the opportunity cost of travel, issues which tend to be ignored in official recommendations.

The disutility of travel will fall over time as quality, comfort and facilities improve. Cars have become more comfortable over time and there have been improvements to in-car entertainment and environment. Public transport modes have also become more comfortable, with improvements in attributes such as interior decor, seating, ride quality and, in some instances, better on-board facilities and services.

There might however be offsetting effects in certain circumstances. For example, urban car driving conditions are worsening whilst problems of crowding have heightened on some rail services into major conurbations. These would act to increase the disutility of time spent travelling. The incidence of 'road rage' as symptomatic of generally reduced levels of patience may indicate an exogenous increase in the value of time over time.

On balance though, given the continual improvement in vehicle quality and available facilities, we feel that changes in the disutility of travel will operate to reduce the value of time over time.

As the quantity and quality of leisure time activities increase, and there becomes more effective competition between these activities, the opportunity cost of time spent travelling can be expected to increase. However, offsetting this will be the trend towards fewer working hours so that time constraints are reduced. In addition, the opportunity to use travel time productively can be expected to impact on the value of time, and in this respect the advent and widespread ownership and use of mobile phones and the possibility to use laptop computers on some modes may have had a significant downward influence on the value of time. Future developments may further increase the quality and quantity of useful activities which can be undertaken while travelling.

As far as the marginal utility of money is concerned, we expect income growth over time to lead to increases in the VTTS, although theory gives no guidance on what the elasticity might be. On the other hand, whilst the effect on the marginal utility of time of changes in the disutility of travel and the opportunity cost of travel time over time is, strictly speaking, indeterminate, our interpretation of likely future changes leads us to conclude that it is more likely that there will be a reduction in the VTTS due to falling marginal disutility of travel time. The overall trend over time in VTTS will be the combination of the two effects.

6.6 Changes over time – evidence and findings

If we wish to conduct research to determine how the VTTS varies over time, there are a number of different approaches that can be adopted.

An approach that achieves a close degree of control over the conditions of comparison, and which can provide evidence on both the effect of income on the value of time and variations due to changes in the marginal utility of time, is to repeat a study using the same SP design, survey method, means of presentation and choice context, with respondents selected to ensure that differences in the socio-economic, demographic, cultural and trip characteristics of the two samples are minimised.

Controlled comparisons of this form are quite clearly practical, but few have been conducted. Instead, reliance is more commonly placed on purely cross-sectional evidence derived from a study conducted at a particular point in time. The income elasticity derived across decision makers might then be taken as the best estimate of how the value of time varies over time with income growth. The study might also provide evidence on how the marginal utility of time will vary over time, according to such factors as the amount of free time, productive use of travel time and certain types of travel condition, but it is unlikely to be able to provide a complete picture of such possible variations. A further drawback of this approach is that it assumes that relationships that apply across the population will also apply over time.

These approaches ignore the large amount of empirical evidence relating to the VTTS which can provide estimates of how the value of time varies over time. Meta-analysis aims to draw together the findings from separate studies and to develop a quantitative relationship to explain variations in the values. Some of the variation across studies will be due to inter-temporal variation in the value of time.

The contribution that analysis of this form could make to understanding how the VTTS varies over time has long been recognised:

> *Surveys and analyses of the values of travel times have typically been based on individual cross-sectional analysis and not repeated over time. Nonetheless, the conclusions derived from such analyses are generally assumed to apply to the future as well as the past. The attention that has been given to the problem of improving cross-sectional estimates has not been accompanied by concomitant attention to analyses of changes in the value of travel time savings over time. As repeated cross-sections of behaviour become available from transport studies, some attention could perhaps be given to investigating and explaining shifts in the implied values of time and their relationship to changes in income.* McKnight (1982, p21)

However, as far as we are aware, this method has not previously been conducted on the scale of that reported here.

An attraction of this approach is that not only is it based on a large number of values of time obtained from many studies but it is also based on many different time periods rather than just two. With regard to the analysis of inter-temporal variations in the value of time, there are three basic forms that the meta-analysis could take.

The first and most general approach is that the study could collect values of time from different studies which included disaggregations by income group as well as other variables such as purpose and mode. This would allow analysis of both cross-sectional and time series variations in the value of time. Secondly, a special case of the above approach, and one that will yield far more data given that many studies do not perform income segmentations, is to collect information on values of time without any income segmentations and to rely solely on inter-temporal variations. The resulting elasticity would contain the combined effects of changes in the marginal utilities of time and money. Finally, the most straightforward approach would be to collate evidence on the cross-sectional variations in the value of time according to income that are apparent within studies. If comparisons were only made across values obtained within studies, the need to explain the influence of other factors such as mode and purpose is avoided since they will not vary within any comparison.

6.7 Results

In this study, we have used the second and third of the meta-analysis approaches outlined above along with an opportunity to analyse two comparable SP data sets obtained at different points in time. We have also reviewed cross-sectional evidence obtained from a number of other national value of time studies. The results from each of these aspects of our study are summarised in turn.

Time Series Meta-Analysis

Our previous meta-analysis (Wardman, 2001) reported an elasticity to GDP of 0.51 but the 95% confidence interval of ±118% does not allow us to place a great deal of confidence in it. This was attributed to the clustering of the values around the years 1988 and 1994 during which time a recession limited the amount of variation in income levels.

We have added a considerable amount of new evidence to the data set, increasing the sample size and obtaining more variation, both of which are expected to lead to a more precise GDP elasticity estimate. The process increased the number of IVT values by 33% to 719 and the number of walk, wait and headway values by 28% to 448. The combined 1167 observations were obtained from 171 studies.

As a result of the extra data, the variance of the GDP per capita measure increased fourfold with the expected beneficial effects on the precision with which its elasticity is estimated. Separate models were estimated to the values of walk, wait, headway and IVT combined and just to the IVT data. The estimated GDP per capita elasticities and 95% confidence intervals were:

- 0.723 (±43%) for all data
- 0.823 (±40%) for IVT data

The model which contained all the data did not find any significant difference between the GDP elasticities for IVT and for the other attributes.

Cross-Sectional Meta-Analysis

There is a wealth of evidence that there is a positive influence from income on the VTTS across individuals and this is rather conclusive in its indication of a cross-sectional elasticity far less than one. Modifiers to the value of time according to household income group estimated in the final phase of the first British value of time study are reported in Table 17.

Table 17: Value of Time Modifiers: Household Income

Household Income	Urban Bus	Urban Car Commute	Urban Car Leisure	Inter Urban Car	Inter Urban Rail	Inter Urban Coach
<5000	1.00	1.00	1.00	1.00	1.00	1.00
5-10000	1.00	1.16	1.11	1.00	1.49	1.10
10-15000	1.10	1.23	1.11	1.05	1.45	1.10
15-20000	1.18	1.23	1.31	1.34	1.94	1.30
20000+	1.18	1.23	1.31	1.34	1.94	1.30

The first British national value of time study (MVA et al., 1987; p122) concluded that, "...... we have clearly demonstrated the existence of an income relationship, which has never been done before with any conviction" and that "the value of time as a proportion of income is a decreasing function of income, rather than a constant as has hitherto been assumed". The second British study (Hague Consulting Group and Accent, 1999; p31) concluded that, "The findings of this study, supporting those reported in The Netherlands, are that VoT is indeed related to income, but the relationship is not one of proportionality. Rather, income elasticities of around 0.5 have been found".

In addition to the findings of the two British national value of time studies, a number of other studies have reported income segmented value of time estimates. Including all the British evidence of which we are aware, we have amassed 157 values of IVT segmented by income from 20 studies.

We have examined how the values varied with income by developing a regression model which explains variations in the value of time (expressed as ratios of two values) in terms of variations in income (expressed as ratios of mean income levels). Other key factors, such as mode, purpose and distance, were the same for each value being compared. The 157 values yielded 137 independent ratios. Since the logarithm of the value of time ratios was regressed upon the logarithm of the mean income ratio, the coefficient estimate is the income elasticity.

Over all the studies, the income elasticity was 0.578. However, a dummy variable indicated that an income elasticity based on individual rather than household would be greater than one. This reflects the results of the North Kent RP study (Fowkes, 1986b) which obtained the most impressive segmentation of values of time by income that we are aware of. The results for the separate models estimated by income band are reproduced in Table 18. The implied income elasticity between the lowest and highest income groups is 1.05 for the value of IVT. Corresponding income elasticities for the values of walk and wait time were 1.30 and 0.80 respectively.

Table 18: North Kent RP Model: Individual Income Segmentations

Band	Mean Income	Value of IVT	Value of Walk	Value of Wait
1,2	5259	2.15	1.99	4.82
2,3	6946	2.24	1.85	5.99
3,4	9037	2.54	1.87	6.22
4,5	10759	2.79	1.47	7.51
5,6	12683	4.78	2.66	12.04
6,7	16011	7.38	9.79	11.35
7,8	19844	8.66	11.11	13.91

Review Material

We reviewed national value of time studies recently conducted in Sweden, Norway and Finland and two conducted in the Netherlands. The overwhelming evidence is that there is cross-sectional variation in the value of time according to income but that the elasticity is far less than one.

Two of these studies have also tackled the issue of whether to segment the value of time according to household or individual income. These were the Swedish national value of time study (Algers et al., 1996) and the Norwegian study (Ramjerdi et al., 1997).

Regarding cross-sectional variations in the value of time with income, Algers et al. (1996) concluded that, "The relationship between income and VoT is, as in many other studies, positive but fairly weak" and "It also seems as if the relationship with income is more pronounced if individual income is used". If the lowest income group is disregarded and the remainder are grouped into two halves, the value of time income elasticities are 0.46 for single person households, 0.07 to 0.24 for two person households with and without children when household income is used and 0.23 to 0.42 when individual income is used. The Norwegian study obtained similar findings.

Repeat Study

Comparable studies repeated at two points in time provide a means of examining how both the marginal utilities of time and money vary. The pioneering work in this area has been conducted on SP data collected in the 1997 and 1988 Dutch value of time studies (Gunn et al., 1998).. Models were estimated to the two data sets, accounting for factors which influence the marginal utility of time and the marginal utility of money and explicitly including allowance for trend effects on the marginal utility of time.

It was found that there was a trend decline in the value of time. This was attributed to mobile phones, laptops and the introduction of a 36 hour working week in the Netherlands. This negative time trend was sufficient to offset value of time growth due to income such that the real value of time is broadly constant.

Such an exercise was repeated in this study, based around the Tyne Crossing route choice SP data collected in 1985 as part of the first British value of time study and in 1994 as part of the second British study.

A joint model was estimated to the two data sets for commuting and leisure. The results from the leisure model are not entirely satisfactory, implying a negative time trend of over 50% of the value of time in 1985. The nominal values of time in the 1994 study for leisure travel were actually lower than those estimated in the 1985 study. It seems to us that the 1985 values are out of line, being too high and indeed higher than the commuting values for that year.

With regard to the joint commuting model, there was some evidence of a negative time trend of between 10 and 30% of the original values, depending upon the elasticity that is associated with the income variations. The results for the commuting model are much more in line with the Netherlands evidence.

Although essentially the same design was used in the two studies, with the toll and petrol costs increased in line with inflation, it must be borne in mind that the two SP exercises were not as comparable as might be wished. The differences were:

- The 1985 study used cards to present the SP exercises whilst the 1994 study used a pen and paper method. Our meta analysis indicates that the latter leads to lower values of time.
- The 1994 study specified a screenline and the SP exercise was related to travel from this point whereas the 1985 study paid more attention to screening in only those whose whole journey could be reasonably represented by the route choice exercise designed.
- The 1985 study recruited travellers at the Bridge whereas the 1994 contacted potential travellers by other means.
- There is clear evidence of more noise in the 1994 data.

6.8 Summary of Findings with Respect to Inter-Temporal Variations

For the purpose of estimating the growth in the VTTS over time, we place greatest confidence in the results based on the time-series based meta-analysis. This is because it is based on a large data set, yielding plausible estimates, and because it provides direct evidence on how the value of time varies over time. However, the main point to note is that what we have termed the GDP elasticity includes the combined effects of variations in both the marginal utilities of time and money.

The estimated elasticity, in the range 0.72 to 0.82 might be broadly consistent with an intertemporal income elasticity of around unity and a negative time trend. Using such a range to predict future changes in the value of time requires the assumption that any downward trend in the marginal disutility of travel time is maintained into the future.

As far as the cross-sectional income elasticity is concerned, the balance of evidence supports an income elasticity of around 0.5 to 0.6. (Note that such a value is significantly higher than the results from our reanalysis of the AHCG data). . Taken at face value, this cross-sectional income elasticity is only consistent with the meta-analysis GDP elasticity if there has been a positive trend in the value of time, and the empirical evidence does not support this. However, we have less faith in the cross-sectional evidence for a number of reasons.

Firstly, inspection of the quite large body of empirical evidence would reveal that variations in the cost coefficients with income group tend not to be the most spectacularly impressive of results. To quote one of the authors, "In the author's experience, market segmentation has seldom led to significant differences in valuations. When fine distinctions are made, for example, along the income scale, inconsistencies normally appear which result in a coarsening of the scale until an acceptable pattern is found. The process whereby this is achieved is not usually reported to the client!" (Bates, 1994).

Secondly, the treatment of income within studies yielding value of time estimates is often quite cavalier, having advanced little since early studies which established that it was feasible to collect such data at least for a reasonable proportion of the sample. Household income prior to deductions is collected, but often there is little consideration of how this is allocated amongst household members, what the impact of household size is and what the appropriate deductions are to arrive at disposable income. We have cited evidence which suggests that cross-sectional income elasticities based on individual income are more consistent with the time series meta-analysis evidence than are the elasticities based on household income.

Finally, cross-sectional elasticities are not necessarily appropriate to variations in the value of time over time. It may be that some of those with higher incomes have an inherently different attitude towards money, which is precisely why they have become richer. They might even be more sensitive to changes in money than those with less income. This would have a serious dampening effect on the relationship between the value of time and income at the cross-sectional level, but such a cross-sectional relationship need not apply to the same individual over time. There is also the issue of self-selectivity. MVA et al. (1987, p122) state that, " .... In as far as there does exist a relationship between values of time and income, there is a possibility that the evidence from within-mode SP experiments will underestimate the slope of the relationship". Almost all the cross-sectional evidence has come from within-mode SP experiments. The argument is based around inter-personal taste variation, self-selectivity and choice based sampling. Let us suppose that over the population as a whole, the value of time does increase with income. Amongst bus users, we would expect to find relatively low incomes. Those with higher incomes ought to have a value of time that is sufficient to make them choose car, and thus those high income travellers remaining with bus are those who have below average values of time for their income. The relationship between the value of time and income will then be dampened. Similarly, a car sample may well include some low income users who have high values of time and have as a result of this chosen to buy and use a car. There may be some high income travellers who have not selected rail because they have relatively low values of time. These will again dampen the estimated impact of income on the value of time.

7. RECOMMENDED MODELS - TOWARDS A SYNTHESIS

7.1 Introduction and Methodology

In this Chapter, we attempt to pull the results together and to compare with official practice. There are a number of steps involved.

We begin by assessing the general level of agreement between the AHCG-based and Meta-Analysis models for car journeys (Section 7.2). However, to compare the *absolute* levels, as opposed to relativities, it is necessary to face up to the problems of obtaining suitably averaged values across relevant dimensions such as income and journey length. This requires a fairly substantial analysis (Section 7.3) in which we have to make judgments about the temporal stability of the models, the use that can be made of the representative sample of journeys obtained from NTS data, and accounting for modal variation.

Based on what we consider to be reasonable procedures, we construct average non-business values of time for Commuting and Other journeys (Section 7.4). On balance, we take the view that the values should **not** be modally differentiated, though this is based on the relative weakness of the empirical evidence, rather than as a matter of principle. We also provide some evidence that the observed variation in modal values of time by Mode User is primarily due to variations in income and journey length in the sample of modal journeys.

From this basis, we go on (Section 7.5) to compare the outcome with current Official Procedures, which derive essentially from the 1985 Study. Taking all the results together, the final Section 7.6 draws out the general conclusions.

7.2 Car journeys – comparing our results from the AHCG-based and Meta-Analysis models

The starting point is to compare the elasticity properties of the two sets of results. The distance elasticity is estimated at 0.26 in the meta-analysis model and at (on average) 0.37 in our model of the AHCG data. Given the range of distances to which these elasticities are applied, these numbers are rather different. However, the difference is reduced somewhat when the inter-urban dummy in the meta-analysis is omitted. As noted in Chapter 6, the formula for the value of time of car users was estimated as:

$$V = GDP^{0.723} D^{0.259} e^{-4.800+0.258\,Inter+0.968\,EB+0.100\,Comm+0.147\,LSE}$$

When we re-estimated the meta-analysis model leaving out the dummy variables relating to Interurban movements and journeys in London and the South-East, we obtained the revised formula for car users:

$$GDP^{0.776} D^{0.324} e^{-5.650+0.088\,Comm}$$

It can be seen that the distance elasticity has increased, adjusting for the previous contribution of the Interurban dummy.

As far as income is concerned, the two datasets are not really able to measure the same thing: the Meta-Analysis essentially provides a time-series analysis, with an elasticity of 0.72 to GDP per head, while the AHCG data implies a cross-sectional elasticity of 0.16 for Other and 0.36 for Commuting, both with respect to *household* income. Note that we have investigated the impact of income when the AHCG sample is segmented by household size, to see whether the apparently low elasticities were associated with the specification of the income variable: however, this did not reveal any clear conclusion.

Both AHCG and the Meta-Analysis imply that values of time are similar for Commuting and Other, but that Commuting is slightly higher than Other.

Thus, in terms of the key effects, there is a reasonable level of agreement, though we cannot compare the cross-sectional income elasticities. Comparing the absolute values is more difficult, because of the number of factors involved, even in the relatively simple models that have been derived. In the next section we discuss an approach to this problem.

7.3 Producing average values - dealing with representativity

We noted earlier that the dependency of the VTTS formula on a number of variables caused difficulty in presenting summary or average values. The AHCG solution to this problem was to rely on the well-established "Sample Enumeration" procedure, whereby a value can be calculated for each observation in the sample, and these values can then be appropriately averaged.

In our earlier work we followed the same principles, with the exception that, because we were not allowing for variation by sign and size, we were able to estimate values for each *respondent*. By contrast, the AHCG sample enumeration implicitly assumed that the options offered in the SP survey design were somehow representative, in order to take account of size and sign effects.

The method of sample enumeration was developed to avoid the problems of so-called "aggregation bias". Since most model relationships are non-linear, applying estimated models directly to the sample means of the relevant variables (like income, journey length) can lead to substantial bias, compared with what would be obtained by applying the model for each observation in the sample (possibly re-weighted for representativity) and then taking the average over the sample.

We noted in Section 5.2 that the AHCG data was not representative with respect to journey length, so that if we were to use sample enumeration, we would need to carry out a re-weighting. However, the DfT was able to provide us with tabulations from NTS for the six years 1995/2000 giving information on the distribution of all the variables of interest (that is, income, distance, purpose and mode). This allows us to consider applying the chosen model **directly** to the NTS data, thereby dealing with the problem of representativity.

The NTS data available to us contains household income in 21 bands, and journey distance in 12 bands, thus giving 252 "cells", though some of these are, of course, empty or sparsely populated. In income terms this is considerably more detail than is available in the AHCG sample (which only distinguished 7 categories), and in terms of journey distance our view is that the level of differentiation is sufficient for the purpose. In addition, by working in this way, we automatically take care of the significant positive interaction between income and journey distance. Hence, rather than apply sample enumeration, as is conventional, at the level of the individual observation, we can estimate the value of time separately for each cell in the NTS matrix.

There remain, nonetheless, a number of issues to be considered, in particular:

model stability - treatment of income growth
modal variation
weighting - (trip vs distance)

We now discuss these issues in turn.

Temporal Stability

The preferred model relates to end-1994, whereas our "representative" data relates to the period 1995-2000. Thus some income growth will have occurred (on average, three years[11]), and we can also expect a trend to increasing distance. Effectively, we have therefore to take a view on the stability of the model over time. From the previous Chapter, it will have been seen that there is generally a shortage of empirical evidence in this area.

In the circumstances, we will set out a base position, and investigate its implications carefully. With relatively little effort, the assumptions can be revisited and the impacts tested.

We will make the starting assumption that apart from corrections for the price level in which income is measured (and the conversion of AHCG cost to distance along the lines set out in Chapter 5), the models can be applied to data for years other than the one in which the underlying data was collected (end-1994): in other words, we assume temporal stability of the VTTS relationships. We will consider the impact of this at a later stage.

The average RPI value for the last quarter of 1994 is 145.5, while the value for December 1997 (end of the first three years in NTS) is 160.0: hence the correction for inflation is 1.100. Hence our formula for VTTS from the AHCG-based model becomes:

$$1.1\ [\beta_\tau/\beta_c].\left(\frac{Inc'}{Inc'_0}\right)^{\eta_{Inc}}\left(\frac{D}{D_0}\right)^{\eta_C}$$

where *Inc'* represents the NTS household income in £'000 pa, Inc'_0 is set to the value 35*1.1, D is the NTS distance (in *miles*), and D_0 is the conversion of the £1.00 AHCG cost to distance at an assumed cost of 8.25 p/Km (13.2 p/mile), so that D_0 = 7.58 miles. Since the NTS income data is banded, it was necessary to assume an appropriate representative value for each band: these are given in Table 19 below:

Table 19: NTS income ranges, and assumed midpoints

inc ≥ £K	0	1	2	3	4	5	6	7	8	9	10
and											
< £K	1	2	3	4	5	6	7	8	9	10	12.5
assumed											
midpt	0.85	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	11.25
inc ≥ £K	12.5	15	17.5	20	25	30	35	40	50	75	7
and											
< £K	15	17.5	20	25	30	35	40	50	75	∞	
assumed											
midpt	13.75	16.25	18.75	22.5	27.5	32.5	37.5	45	62.5	93.75	

Although the meta-analysis does not allow us to take into account the cross-sectional income variation, we can still allow for the distance effect, and apply the model to the NTS distance distribution. For this purpose we use the modified model for car users' VTTS reported in

[11] The average annual rate of growth of GDP per head between 1994 and 2000 was 2.4%. However, because of a fall in average household size (approximately 0.5% per annum), this translates into a lower growth in **household** income.

Section 7.2, omitting the dummy variables relating to Interurban movements and journeys in London and the South-East, and adjust by the factor of 1.1 to allow for the change in price level:

$$1.1 * GDP^{0.776} D^{0.324} e^{-5.650+0.088\,Comm}$$

where the value for end 1997 GDP is 3252.

Variation by Mode

In the previous Chapter we showed that there was evidence that values of time for a given traveller depended on the mode used, and in Chapter 5 we noted that there was evidence to suggest that drivers' VTTS was higher than that of passengers.

From a theoretical perspective, why might average modal values of time vary? There are several reasons, and it is important to distinguish them.

(i) the income and socio-economic characteristics of travellers might vary systematically by mode. Low income users with low average VTTS might gravitate to mode A while high income users with high average VTTS might tend to choose mode B;

(ii) the composition of trips and purposes might vary systematically by mode. Mode A might have a strong market share in short distance trips, while mode B might be stronger at longer distances (see chapter 6);

(iii) a cross-section of people with given income and socio characteristics making a given trip will have a distribution of values of time (and individual values may vary according to the constraints faced). People with low VTTS for that trip will self-select into relatively low cost/high time modes and vice versa;

Point (iv) aside, from a theoretical prospective, individuals have the <u>same</u> VTTS for a given trip regardless of mode used. We would therefore favour an approach which picks up (i) - (iii) through the income, socio characteristics and trip and purpose characteristics of the traffic modelled to the various sub-markets. The outturn average VTTS by mode is the product of the characteristics of the slice of the market attracted to that mode which in turn depends on the positioning of that mode in terms of the cost, time and quality attributes offered.

However, variations in modal quality (point (iv) above) might give rise to genuine differences in VTTS by mode. Time spent on mode A might be less pleasant or more tedious than on mode B. It is therefore interesting to separate out empirically effects due to point (iv) from effects due to points (i) – (iii). In doing this we rely on the analysis presented in chapter 6.

Table 7 from chapter 6 gave modal VTTS results from the meta-analysis on two bases - User Type (i.e. current mode) and Mode Valued. While in most cases the current mode was also the mode valued, in the case of car users, it had proved possible to obtain their values for different modes[12]. These values are given in the last three columns of the Table.

Hence, within the table, there are two separate types of comparison which can inform the discussion on mode-specific values of time.

[12] Note that the data set contained other instances of valuations for alternative modes, but the samples were not sufficient to yield significant effects for the meta-analysis.

Valuation of Time on Different Modes by the Same Set of Individuals

Firstly, for the same group of individuals ('car users') in our dataset, there are some apparent differences between their valuation of car, bus and rail time savings. Table 20 extracts the car users' valuations of bus and rail time savings and presents them as a % of their car time value.

Table 20: Car users' VTTS by Mode

Trip Purpose and Distance		Car Users		
		$VTTS_{car}$,	$VTTS_{rail}$,	$VTTS_{bus}$,
		pence per minute	as % of $VTTS_{car}$	as % of $VTTS_{car}$
Commute	2 miles	3.6	94	131
	10 miles	5.4	85	119
	25 miles	6.9	78	109
Leisure	2 miles	3.2	97	134
	10 miles	4.9	84	118
	50 miles	9.6	75	104
	200 miles	13.8	67	93

Overall, car users' valuation of bus time savings exceeds their valuation of car time savings: in other words, they find bus travel more onerous, per minute, than car travel. In the case of 10 mile commuting trips, for example, the value of bus time is 6.4 against 5.4 for car time (a ratio of 1.19:1). By contrast rail time savings appear to be valued below car time savings: 4.6 for a 10 mile rail commute against 5.4 for car (a ratio of 0.85:1).

Within this general pattern, there are some interesting variations and consistencies:

- The ratio of car : bus : rail appears fairly stable between commuting and leisure purposes;
- However, that ratio varies substantially with distance: the reason being that there is estimated to be a greater disutility effect due to distance for car driver than for other modes, presumably reflecting fatigue etc. Consequently,
- for very short distances (2 miles), rail time appears to be valued almost as highly as car (94/97%) and bus time is valued roughly 30% higher;
- as distance increases towards 50 miles, the premium on bus time falls towards zero (and becomes negative by 200 miles) whilst the value of rail time falls substantially to 75% of the car value.

Summary

For individuals who are current **car users**, making commuting or leisure trips up to 100 miles:

$$VTTS_{rail} < VTTS_{car} < VTTS_{bus}$$

We interpret these variations in VTTS by mode as caused by variations in the valuation of comfort, cleanliness, information and other modal characteristics.

However, the statistical significance of the findings is a problem: at a 95% confidence level, the difference between the bus and the car time values is of marginal significance (the t-statistic on the difference is 1.78). Other corroborating evidence would be needed to support a modal VTTS from a scientific point of view.

Secondly, Table 9 allowed us to explore whether individuals in the different 'user types' have different valuations for the same kind of travel time savings. In Table 21 we draw some comparisons for bus and rail.

Table 21: Different Users' VTTS for Bus and Rail Time

Trip Purpose and Distance		Bus Time Savings		Rail Time Savings	
		Car Users' Valuation, pence per minute (a)	Bus Users' Valuation, pence per minute (b)	Car Users' Valuation, pence per minute (c)	Rail Users' Valuation, pence per minute (d)
Commute	2 miles	4.7	2.3	3.4	4.4
	10 miles	6.4	3.1	4.6	5.9
	25 miles	7.5	3.7	5.4	7.0
Leisure	2 miles	4.3	2.1	3.1	4.0
	10 miles	5.8	2.8	4.1	5.3
	50 miles	10.0	4.9	7.2	9.3
	200 miles	12.9	6.3	9.3	12.0

Since the values do not relate to the car driver mode, the distance effect, as estimated, is consistent between the different user groups. The Bus users' valuation of the Bus mode is 49% of the Car users' valuation, while the Rail users' valuation of the Rail mode is 129% of the Car users' valuation.

It is noteworthy that these results are essentially the opposite of the presumed "comfort" effect. Whereas for car users, bus time savings were of the highest value and rail of the lowest, when we investigate the average values of the users of each mode, it is the bus users who have the lowest, and the rail users the highest. Possible reasons include:

- income difference between 'bus users' as a group , 'car users' as a group, and 'rail users' as a group, which would tend to influence their valuations of the same saving (through differences in the marginal utility of income);
- different preferences with respect to time savings and levels of comfort (etc) which have led individuals to self-select towards particular modes, leaving the modal aggregate VTTS to reflect differences between the two groups of individuals.

As we argue further in the next Chapter, we believe that there is a strong case *in principle* for allowing values to vary by mode, in so far as this reflects variations in comfort, effort etc.

In spite of this, the empirical evidence for the variation in VTTS, while generally according with intuition, is not particularly strong. In the first place, therefore, we propose to ignore it, and assume that the car driver models reported at the end of Chapter 5 can be considered applicable, at least as a convenient approximation, to *all* (mechanised) modes in respect of in-vehicle time.

Because the modal shares do vary by both income and distance, as Figures 11 and 12, which give the proportion of all journeys in the NTS 1995-2000 data that are by car, indicate, it will be necessary to check how sensitive the outcomes are to this assumption. We discuss this at the end of this Section.

Figure 11: Modal share variation by income (NTS 1995/2000)

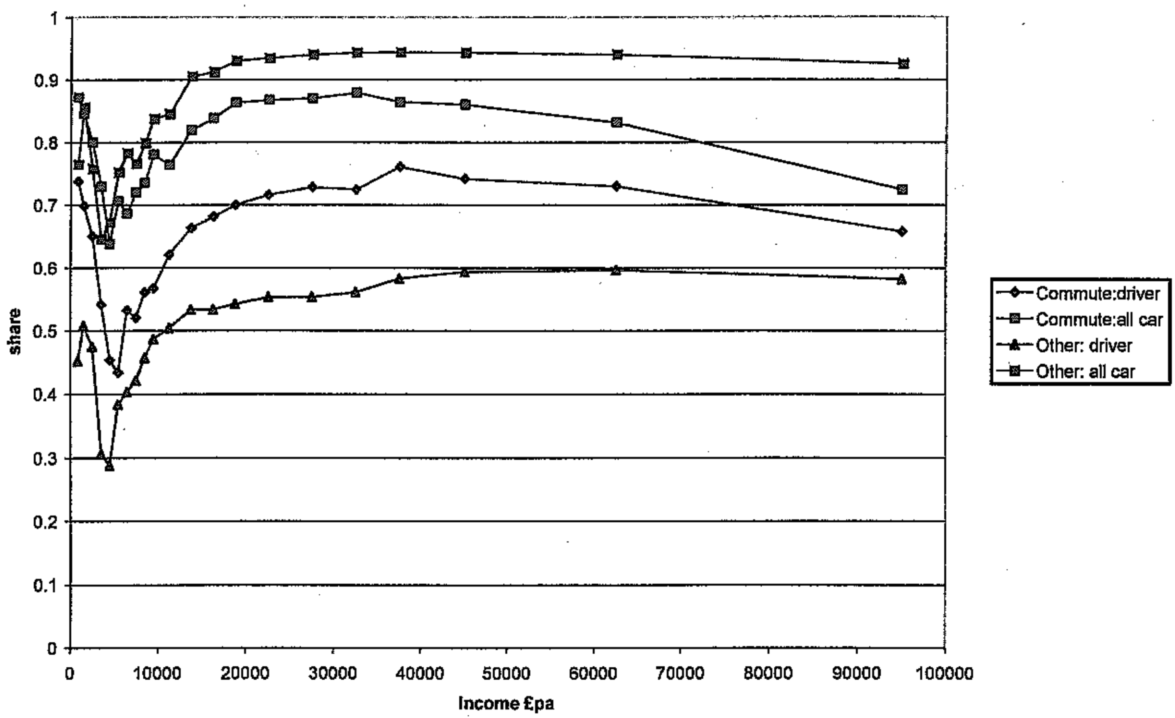
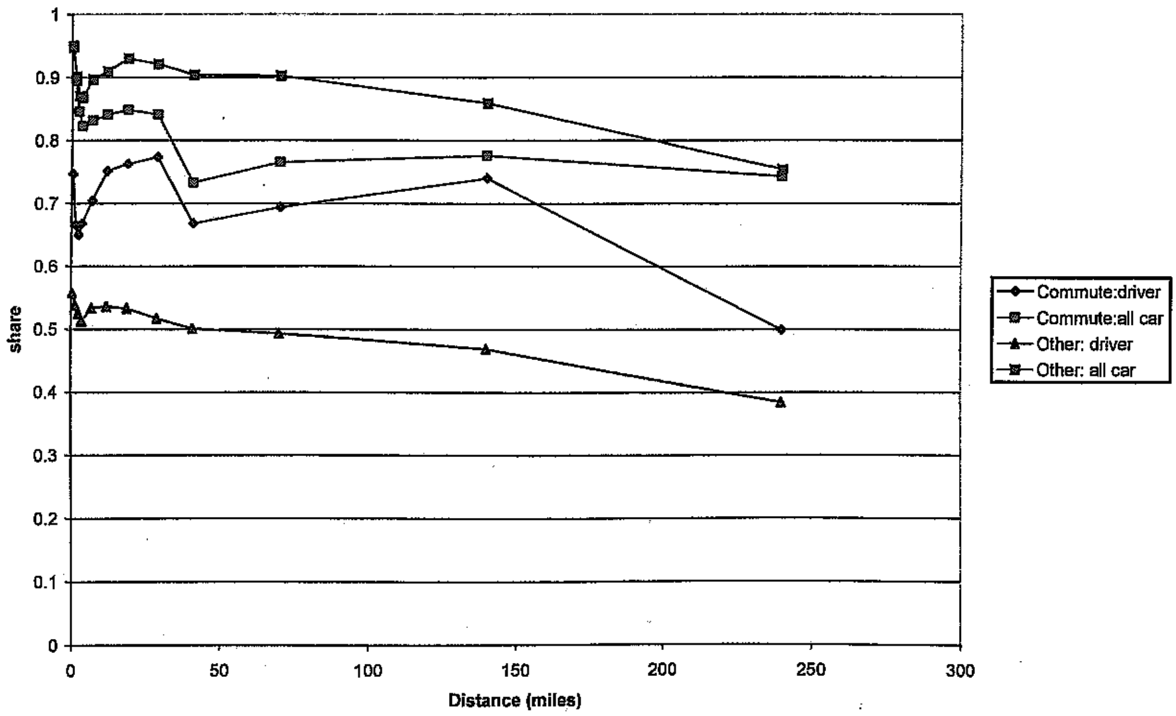


Figure 12: Modal share variation by distance (NTS 1995/2000)



Mileage- or trip-based weights

The final question is how we should calculate the sample average. Suppose individuals j have different values of time v_j and travel time t_j. In applying an average value of time $\bar{v}$, say, it would seem sensible to attempt to ensure that

$$\bar{v} \Sigma_j t_j = \Sigma_j v_j t_j$$

so that the value of the total time disutility is correct. Hence a travel time-weighted value of time (assuming that there are differences in v_j within the population) appears intuitively reasonable, and preferable to a trip-weighted value.

In practice, in the past the Department's conventional approach to weighting has been to carry it out on a *mileage* basis. The main instance relates to working values of time, where the value is assumed to be proportional to the wage rate (or income per hour). For each chosen category, the mileage weighted average wage rate can be calculated, and hence the value of time derived. The standard approach is to use NTS data for journeys subdivided by income and journey length, as well as other parameters of interest (e.g. mode). Since journey duration is also available, the averaging could, in principle, be time-weighted.

However, at least within mode, there is likely to be a reasonable correlation between time and distance, and hence a mileage-weighted average appears an acceptable approach, and preferable to a trip-weighted value.

In the case of non-working time, the identified variation may cover a large range of variables, though in the 1985 UK study it was relatively limited. The same principles apply in respect of weighting, though it is not known exactly what level of variation was used in implementing the earlier results (obviously if *no* variation is taken into account, then the weighting is not required).

The fact that, in broad terms, journey length has been identified as a factor tending to increase values of time might suggest that by using a distance-weighting, there is an element of double-counting. It is certainly the case that a distance-weighted average will be higher than a trip-weighted average, and this will be demonstrated below. However, if the main aim is accepted of allowing time savings to be aggregated in a way which coincides with the total "value" reflected in individual values of time, the fact that values of time are positively correlated with "distance" does not affect the argument. Essentially, a distance-weighting is preferable to a trip-weighting.

7.4 Application of the recommended models

On this basis, we now proceed to apply the models, adjusted as described, to the NTS distribution by income and distance, across all mechanised modes, separately for Commuters and Others. For the AHCG-based model, we derive the results in Tables 22 and 23 – all results in pence per minute (end 1997 prices).

Although the recommended averaging procedure is mileage-based, we have also calculated it on a trip-weighted basis. This results in the following:

	Trip-weighted	Mileage-weighted
Commuting	3.95	6.58
Other	3.25	5.88

We may compare these with some of the results derived directly from the AHCG estimation data: of course, since this is end-1994, we should certainly correct for the inflation factor of 1.1, though there is no simple way of allowing for any changes in the income and distance distribution. The simplest linear models reported in Table 1 (Chapter 4), implying a single value of time, gave values of 5.05 for Commute and 4.47 for Other, which become 5.56 and 4.92 respectively after adjusting for the price level. The AHCG Sample enumeration results for *Drivers*, based on their final recommended model, are 5.4 for Commute and 4.4 for Other (Tables 111, 112): these become 5.94 and 4.84 respectively after adjusting for the price level.

Our reweighted values are therefore somewhat higher than AHCG's, though they make some allowance for changes in income and distance. On the other hand, there is fairly good agreement on the relativity between Commuting and Other.

Table 22

Commuter

	Journey Distance (miles)											
	Under 1	1 to 2	2 to 3	3 to 5	5 to10	10 to 15	15 to 25	25 to35	35 to 50	50 to100	100 to 200	200and over
av dist	0.4	1.4	2.4	3.6	7	12	19	29	41	70	140	240
Income £'000 per annum												
< 1	0.33	0.56	0.70	0.84	1.11	1.39	1.68	2.01	2.33	2.92	3.91	4.90
1 to 2	0.41	0.69	0.86	1.02	1.36	1.70	2.06	2.47	2.86	3.58	4.79	6.01
2 to 3	0.49	0.83	1.04	1.23	1.63	2.04	2.48	2.96	3.43	4.30	5.75	7.22
3 to 4	0.55	0.93	1.17	1.39	1.84	2.31	2.80	3.34	3.87	4.85	6.49	8.15
4 to 5	0.60	1.02	1.28	1.52	2.01	2.52	3.06	3.66	4.23	5.31	7.10	8.92
5 to 6	0.65	1.10	1.38	1.63	2.16	2.71	3.29	3.93	4.55	5.70	7.63	9.58
6 to 7	0.69	1.16	1.46	1.73	2.29	2.88	3.49	4.18	4.83	6.05	8.11	10.17
7 to 8	0.72	1.23	1.54	1.83	2.42	3.03	3.68	4.40	5.09	6.37	8.53	10.71
8 to 9	0.76	1.28	1.61	1.91	2.53	3.17	3.85	4.60	5.32	6.66	8.93	11.20
9 to 10	0.79	1.33	1.67	1.99	2.63	3.30	4.00	4.79	5.54	6.94	9.29	11.66
10 to 12.5	0.84	1.42	1.78	2.11	2.79	3.51	4.25	5.08	5.88	7.37	9.87	12.39
12.5 to 15	0.90	1.52	1.91	2.27	3.00	3.77	4.57	5.46	6.32	7.92	10.61	13.31
15 to 17.5	0.95	1.62	2.03	2.41	3.19	4.00	4.85	5.80	6.71	8.41	11.26	14.13
17.5 to 20	1.00	1.70	2.14	2.54	3.36	4.21	5.11	6.11	7.07	8.85	11.85	14.88
20 to 25	1.07	1.82	2.28	2.71	3.58	4.50	5.46	6.52	7.54	9.45	12.66	15.88
25 to 30	1.15	1.95	2.45	2.91	3.85	4.83	5.86	7.01	8.11	10.16	13.60	17.07
30 to 35	1.22	2.07	2.60	3.09	4.09	5.13	6.23	7.44	8.61	10.78	14.44	18.12
35 to 40	1.29	2.18	2.74	3.25	4.30	5.40	6.55	7.83	9.06	11.35	15.20	19.08
40 to 50	1.38	2.33	2.93	3.47	4.59	5.76	7.00	8.36	9.67	12.12	16.23	20.37
50 to 75	1.55	2.62	3.29	3.91	5.17	6.49	7.87	9.41	10.88	13.63	18.26	22.91
>=75	1.79	3.03	3.81	4.52	5.98	7.50	9.10	10.88	12.59	15.77	21.12	26.50

Table 23

Other

	Journey Distance (miles)											
	Under 1	1 to 2	2 to 3	3 to 5	5 to10	10 to 15	15 to 25	25 to35	35 to 50	50 to100	100 to 200	200and over
av dist	0.4	1.4	2.4	3.6	7	12	19	29	41	70	140	240
Income £'000 per annum												
< 1	0.89	1.32	1.57	1.78	2.20	2.60	3.01	3.44	3.83	4.53	5.64	6.68
1 to 2	0.98	1.45	1.71	1.95	2.40	2.84	3.29	3.76	4.19	4.96	6.16	7.30
2 to 3	1.06	1.57	1.86	2.11	2.60	3.08	3.56	4.07	4.54	5.37	6.68	7.91
3 to 4	1.11	1.65	1.96	2.22	2.74	3.25	3.75	4.29	4.78	5.66	7.04	8.34
4 to 5	1.16	1.72	2.04	2.31	2.85	3.38	3.91	4.46	4.97	5.89	7.32	8.68
5 to 6	1.20	1.77	2.10	2.39	2.94	3.49	4.03	4.60	5.13	6.08	7.56	8.95
6 to 7	1.23	1.82	2.16	2.45	3.02	3.58	4.14	4.73	5.27	6.24	7.76	9.19
7 to 8	1.26	1.86	2.21	2.51	3.09	3.66	4.23	4.83	5.39	6.38	7.93	9.40
8 to 9	1.28	1.90	2.25	2.56	3.15	3.73	4.31	4.93	5.50	6.50	8.09	9.59
9 to 10	1.30	1.93	2.29	2.60	3.21	3.80	4.39	5.02	5.59	6.62	8.23	9.75
10 to 12.5	1.34	1.98	2.35	2.67	3.29	3.90	4.51	5.15	5.74	6.80	8.45	10.02
12.5 to 15	1.38	2.05	2.43	2.76	3.40	4.03	4.65	5.32	5.93	7.01	8.72	10.34
15 to 17.5	1.42	2.10	2.49	2.83	3.49	4.13	4.78	5.46	6.08	7.20	8.96	10.61
17.5 to 20	1.45	2.15	2.55	2.89	3.57	4.23	4.88	5.58	6.22	7.36	9.16	10.85
20 to 25	1.49	2.21	2.62	2.98	3.67	4.35	5.03	5.74	6.40	7.58	9.42	11.17
25 to 30	1.54	2.28	2.70	3.07	3.79	4.49	5.19	5.93	6.61	7.82	9.73	11.52
30 to 35	1.58	2.34	2.78	3.15	3.89	4.61	5.32	6.08	6.78	8.03	9.98	11.83
35 to 40	1.62	2.40	2.84	3.23	3.98	4.71	5.45	6.22	6.94	8.21	10.21	12.10
40 to 50	1.66	2.47	2.92	3.32	4.09	4.85	5.60	6.40	7.14	8.45	10.51	12.45
50 to 75	1.75	2.60	3.08	3.50	4.31	5.11	5.90	6.74	7.52	8.89	11.06	13.11
>=75	1.87	2.77	3.28	3.72	4.59	5.44	6.29	7.18	8.01	9.48	11.79	13.97

Applying the **meta-analysis model** to the NTS distance distribution (as noted earlier, the model does not allow us to take into account the cross-sectional income variation) results in the following:

	Trip-weighted	Mileage-weighted
Commuting	4.16	5.93
Other	3.44	6.20

Note that in the meta-analysis results the mileage-weighted value for Other is in fact higher than that for Commuting, despite the base values being lower. This is due a) to the higher number of long distance trips, and b) to the fact that the meta analysis does not allow for the cross-sectional income effect present in the AHCG model.

In line with the application of the AHCG-based model, these values are weighted by trips for *all* modes. However, the higher distance elasticity in the Meta-Analysis only relates to the car mode. We have therefore tested the effect of restricting the NTS sample weights a) to the car mode only, and b) to car drivers only. It turns out that the changes to the average VTTS are very small, as can be seen in Appendix G, reflecting the fact that car is the dominant mode (84% of all commuting journeys are made by car, and 90% of all non-commuting).

Both AHCG and the Meta-Analysis imply similar values of time for Commuting and Other: in general, Commuting is slightly higher than Other, though, as noted, the mileage weighted values for the Meta-analysis are in fact higher for Other. The four mileage-weighted values for end-1997 are all in the range [5.88, 6.58] pence/min (1997 prices), while the trip-weighted values are in the range [3.25, 4.16].

Overall, the level of agreement is encouraging, given the coarseness of the assumptions that have had to be made. We may conclude that, apart from some disagreement about the level of differential between Commuting and Other VTTS, the two data sets are telling substantially the same story about the distance effect and the general absolute level of VTTS.

It is also of interest to see whether, running our preferred AHCG-based model, some of the empirical variation in outturn value of time by mode can be accounted for by the different income and distance composition of trips on the various modes. The NTS data available to us distinguishes four groups of mode:

Car Driver
Car Passenger
Bus and Coach
Rail and Underground

The averages presented above are taken for all modes combined. Table 24 shows the outcome if the calculations are restricted to particular modes. Note that the model for VTTS is not changed, only the weights used to obtain the average.

Ta'ble 24: Values of time by purpose and mode

	Trip-weighted	Mileage-weighted
Commuting		
All modes	3.95	6.58
Car Driver & Passenger	3.90	6.41
Car Driver	4.03	6.52
Bus & Coach	2.92	4.02
Rail & Underground	6.02	8.70
Other		
All modes	3.25	5.88
Car Driver & Passenger	3.28	5.83
Car Driver	3.27	5.79
Bus & Coach	2.74	4.82
Rail & Underground	4.73	7.91

It is noteworthy that the same pattern by mode user is found as in the Meta-Analysis work. Bus & Coach values are substantially lower than car values (38% lower for Commuters and 17% lower for Other, using the mileage-weighted results), while Rail & Underground are substantially higher (33% higher for Commuters and 37% higher for Other). Thus, this is indicative that the difference is due to variations in the income and distance distributions, rather than the modes per se.

However, while this effect has usually been considered to be due to income, further analysis of the impact does not bear this out. If we artificially turn off the distance effect in the model, the mode relativities are much reduced. Again using the mileage-based results, Bus & Coach values are only 12% (Commuting) and 10% (Other) lower than the comparable car value, while Rail & Underground values are only 9% (Commuting) and 1% (Other) higher than car. This suggests that the distance effect is, if anything, more important than income in bringing about the observed variation by mode user.

7.5 Car journeys – comparing absolute values with Official Procedures

We now need to consider how these results relate to the Department's current practice, which is based on the methodology derived from the 1985 study. There are two aspects to consider: the average values of time, and the growth rate of the value of time over time. The official procedures adopt a single average value of travel time savings for all non-work purposes, and growing over time at the same rate as the growth of GDP per head (that is, with a constant unit income elasticity). Our findings bear on each of these aspects.

The Average Value of non-working time

The COBA 1988 recommendations are based on the 1985 study figures. From this benchmark, as AHCG have described, we can make alternative assumptions about the income elasticity over time. Adjusting to 1994, as given in AHCG Table 132, the implied official values, which apply to both purposes, are 6.2 p/min with "full" adjustment for income growth (i.e. assuming an income elasticity of 1). If *no* adjustment were made for income growth, the value would fall to 5.6 p/min.

In the Department's latest Transport Economics Note, a 1998 value for non-working time (all modes) of 7.5 p/min is recommended. As noted earlier, the appropriate factor for inflation and real income growth between 1994 and 1998 is 1.223, giving a comparable 1994 figure of 6.2 p/min. This is thus compatible with the 1988 figure, as it should be.

Making a small correction for income growth and price changes over the first 6 months of 1998 (2.16% for inflation and 1.08% for real income) reduces the official figure to 7.3 p/min as at end-1997. If we assumed no income growth from the 1988 benchmark, the official value for 1998 would be updated to 6.3 p/min, and reducing this for 6 months' inflation gives an alternative end-1997 value of 6.2 p/min for non-business travel.

These can now be compared with the values just calculated from the AHCG and Meta-Analysis models. The Table below sets out the various values.

	Commuting	Other Leisure
TEN official method	7.3	
TEN no income adjustment	6.2	
AHCG-based model (mileage)	6.6	5.9
Meta model (mileage)	5.9	6.2

VTTS (p/min) at end 1997 prices and values

There are a number of comments to be made. In the first place there is no implication that the official average value is seriously out of line with the available evidence from the AHCG study and the meta-analysis. The official values are in the right ballpark. Having said that, it is certainly the case that both the AHCG and the meta-analysis produce values nearer to the TEN values *without* income adjustment. Of course there are a number of possible explanations of this, but a possible interpretation might be as follows.

Our inclination, for reasons already given, is to prefer the AHCG-based values, at least for car drivers. For Commuters, the value is intermediate between the no income and the full income estimates from TEN. We take that as some indication that an intermediate income "elasticity" would be appropriate. Bearing in mind that the implied AHCG-based income elasticity is lower than the meta-analysis value, there is still possible room for some further income effect between end-1994 and end-1997: however, this would not increase the AHCG-based values by more than 3%.

It is probably also the case that the conclusions of the 1985 study were dominated by the Commuting purpose, and it could be argued that a more careful treatment of Other leisure purposes, as has been done in the AHCG study, confirms that these have a VTTS about 10% lower than that for Commuting.

Growth over time

In terms of the implications for growth in the value of time over time, these comparisons cannot be considered conclusive. In Section 6.5 we considered the limited further evidence available, and based on the meta-analysis data set suggested on balance a temporal elasticity with respect to GDP of 0.72 (± 43%) for all data and 0.82 (±40%) for in-vehicle time data. However, this analysis was not able to take into account the *temporal* effect of distance. Over time, there has been a tendency to longer journeys (associated in particular with more car ownership). Over the period covered by the meta-analysis (1963-2000), TSGB2001 indicates (Table 9.1) that total distance travelled by mechanised modes (including cycle, but excluding walk) has increased by 2.3% pa, and allowing for the population growth of 0.29%pa gives a distance per head growth of 2.0% pa.

Allowing for the effect of increases in trip length over time adds a small amount (+0.03 to +0.08) to the above elasticities. However, the proportion of this journey length effect which is due to GDP growth, as apposed to other trends such as the following real cost of motoring, is not clear. Any chosen intertemporal elasticity is likely to be a mixture of a 'pure' income effect and other trends over time which cannot easily be separated.

We conclude that the evidence as a whole tends to support an intertemporal elasticity for non-working time of somewhat less than unity, probably in the range of 0.5 to 1.

7.6 The recommended model – summary and conclusions

In this chapter, we have analysed the causes of variation in the values of time using the AHCG data and the meta-analysis of past studies. From our reanalysis of the AHCG data, the principal findings are as follows:-

- the chief sources of variation in VTTS for car users are income and factors relating to journey length.
- the VTTS for commuting is somewhat higher than for other non-work purposes, but the differences are not great.
- VTTS are lower for retired persons, other things equal.
- the results for other determinants do not display sufficient consistency and strength to justify modifying the headline results, with the possible exception of passengers, whose VTTS appears to be about 20% lower than that of drivers.

The key results of the meta-analysis, as they relate to car travel, are that the VTTS varies with distance, income (GDP), journey purpose, the numeraire used to derive the value of time, and a London and South East factor.

Comparing the results of the two studies, we find

- fairly similar values of time for Commuting and Other; in both cases Commuting is slightly higher than Other for a given distance or cost.
- distance elasticities of 0.26 (0.32 if the interurban dummy is dropped) in the meta-analysis and (on average) 0.37 in the AHCG, so a reasonable correspondence.
- no directly comparable results on income. The AHCG results imply a cross-sectional income elasticity of 0.16 for other and 0.37 for commuting, both with respect to <u>household</u> income. The Meta-Analysis provides a time series elasticity of 0.72 to GDP per head.
- comparing the VTTS from the sources is not straightforward, but on reasonable assumptions, there is a fair degree of similarity in the level and pattern of VTTS in the AHCG and meta-analysis data.
- On balance, our inclination is to accept the AHCG model as temporally stable, but with a further adjustment to allow for a higher temporal income elasticity.

Comparing our results with official values, we conclude that:

- the official average value is not seriously out of line with the available evidence from the AHCG study and the meta-analysis. In relation to the headline average VTTS, we incline towards;
- revising the 1997 Commuting mileage – weighted VTTS downwards by 10 per cent to 6.6 pence/minute;
- differentiating the Commuting and Other purpose value, with the mileage-weighted Other value 10 per cent below the Commuting value;
- using an intertemporal elasticity below unity to reflect both income and distance effects as incomes grow.

Comparing values of time by mode:

- for people who are currently car users, their VTTS on rail is less than on car which in turn is less than on bus. We interpret these variations as caused by mode quality attributes such as comfort cleanliness, and information. We consider that in principle, such values should be included in generalised cost modelling and evaluation. However, the statistical significance of the findings is currently a problem, and further evidence is required;

- other differences in the outcome VTTS by mode are due to differences in the mix of income and journey distances which the modes cater for rather than to innate modal characteristics.

8. USING VALUES OF TIME -PRACTICALITIES AND PRINCIPLES

It is one thing to say what the evidence is for the variation of the VTTS with respect to economic, social and trip characteristics. It is another to make recommendations for the application of this evidence in modelling and appraisal practice. There may be reasons of principle for overriding or moderating what the evidence says. Also, there may be relevant practical issues – considerations of data collection, cost-effectiveness, auditing and control of the appraisal process impinge on what can be recommended. Recommended practice may need to vary according to the circumstances – good practice in the context of a very significant scheme or policy intervention may differ from what is required for routine scheme appraisal or comparison between scheme options. Decision contexts such as tolling or pricing may place particular requirements on the analysis. In this chapter, we consider how best to make the bridge from the results to their application in practical appraisal work.

8.1 Practicalities

In the previous Chapter, we presented a case for recognising variations in the value of travel time savings by journey and for segmenting the analysis according to distance, income and retired status. Variations in value of time by mode which are due to mode quality differentials should ideally be handled by attribute specific values of quality. If practice falls short of that, then such differentials might be represented via modal values of time.

The Department hosted a seminar in December 2001, attended by 36 invited delegates from consultants, Government and academia. The seminar had two purposes – first to expose to a professional audience the key findings of the work, and to receive feedback, and secondly to consider the practical feasibility of implementing the recommendations. In order to do the latter, Dr Denvil Coombe was appointed as facilitator, and eight consultants were commissioned to give their view. Dr Coombe reported his findings to the Department, and his conclusions, with which we concur, are set out in Appendix H. These bear on implications for both modelling and evaluation; indeed the general conclusion is that greater segmentation of values of time has more practical implications for modelling than for evaluation.

We can summarise Dr Coombe's conclusions along the following lines. In terms of modelling practicality, he saw no major issues of principle, but noted that there could be substantial data requirements (particularly for income variation), and that the implied additional segmentation could lead to "very substantial" increases in model run times. The related data issues also affected the statistical reliability of the segmentation, assuming that substantial increases in sample size were probably not realistic. One way to alleviate this would be for the Department to make default information available, both about the proportions of travel in different segments and the associated variation in values of time.

In regard to forecasting issues, it was noted that both the distribution of income and the partly related distribution of the value of time appeared to be very difficult to forecast. If modal values of time were adopted to reflect comfort/quality aspects, that would require assumptions to be made about comfort/quality by mode for future year reference cases. It was also noted that there were some quite fundamental dilemmas involving the way in which changes in generalised cost parameters are handled in spatially-detailed multi-modal models which are, as yet, unresolved.

Overall, he considered that:

- as a matter of principle, segmentation by value of time is preferable to segmentation by crow-fly distance or income;

- models which include segmentation on non-work purposes by the value of time are practical now, although the increased run times is an issue to consider; and
- this kind of approach is most needed where changes in significant money charges are being considered – road tolls, congestion charges, parking charges and public transport fares; but
- the derivation of suitable local values of time needs care and external validation to avoid intentional or unintentional bias; and although
- no special issues of practicality arise with the appraisal;
- forecasting the change in the distribution of the value of non-working time over time is not straightforward.
- Variations in the value of in-vehicle time to account for differences in comfort/quality can be accommodated.

On this basis, it seems to us that there is some case for considering the possible use in modelling of values of time varying at least with income and distance. On general grounds of practicality, we think it wise to restrict the variation to three groupings for each variable, leading to 9 cells in all. In determining how the boundaries should be drawn, we have borne in mind the following considerations:

a) we should respect the existing boundaries of the NTS tables;
b) we should partition the two variables so that approximately 1/3 of the sample falls into each grouping;
c) the grouping should be the same for both purposes.

We must also note that the outcome will be different according to whether we consider the sample basis to be trips or distance. In line with the decision to use mileage weights, we incline towards distance, but in so doing there is a danger that the number of trips found in the highest distance band will be very small. Accordingly, we have made some compromise. Note that the average distance is about 8.5 miles, and nearly 60% of all trips are less than 5 miles.

A proposed grouping is therefore shown in the following table, which also indicates the total percentage of trips and distance found in each cell according to the NTS 1995/2000 data:

Table 25: Travel proportions by income and distance band (all modes combined)

Distance	Below 5 miles	5 – 25 miles	Above 25 miles
Income			
Below £17,500 p.a.	% trips: 21.5 % distance: 5.5	% trips: 11.1 % distance: 12.6	% trips: 1.5 % distance: 10.1
£17,500 – £35,000	% trips: 22.6 % distance: 5.8	% trips: 13.8 % distance: 16.2	% trips: 2.4 % distance: 16.5
Above £35,000 p.a.	% trips: 14.1 % distance: 3.7	% trips: 10.5 % distance: 12.7	% trips: 2.4 % distance: 17.0

On this basis, the mileage weighted VTTS for the cells are as follows (p/min - end 1997 values and prices):

Table 26: Implied Values of time by income and distance band

Distance	Below 5 miles		5 – 25 miles		Above 25 miles	
Income						
Below £17,500 p.a.	Commuting	1.88	Commuting	3.30	Commuting	7.17
	Other	2.31	Other	3.67	Other	7.12
£17,500 – £35,000	Commuting	2.57	Commuting	4.75	Commuting	10.13
	Other	2.75	Other	4.37	Other	8.71
Above £35,000 p.a.	Commuting	3.32	Commuting	6.25	Commuting	13.23
	Other	3.09	Other	4.93	Other	9.85

8.2 Questions of Evaluation

We now turn away from modelling issues, and consider questions relating to evaluation. There are a number of important questions, which are dealt with in the following sections.

In the first place, we need to consider the possibility of using different modal values. We have already argued that this could be justified when the differences relate to *comfort* effects.

Secondly, we need to discuss the propriety of incorporating the empirical evidence on the variation of values of time with distance in the Cost-Benefit analysis.

Finally, we return to the much-discussed issue of the "standard" or "equity" value of time, and attempt to negotiate a way forward.

As a result of this discussion, we are able to put forward our general recommendations in Chapter 9.

8.3 Values of time by mode

In chapters 6 and 7, we reviewed the evidence on the variations in the value of travel time by mode and by activity (walking, waiting, riding) within mode. Here, we formulate our conclusions and recommendations based on that evidence.

For working time, it is conventional in UK transport appraisal to differentiate value of travel time savings by mode. This follows from the marginal product of labour (MPL) theory and the associated empirical evidence which shows that business users of certain modes (especially air) tend to have relatively high MPL while business users of other modes have a relatively low MPL. For example, in the Transport Economics Note (TEN), the appraisal value of working time savings in bus travel is 44% of the value in rail travel. The MPL theory and alternatives were reviewed in Chapter 3 above, and the recommendation is to continue with the MPL approach. This section raises some further issues which are relevant to applying the TEN values for working time in cases where there is switching between modes. However, the main focus of this section is on non-working time.

It should be noted that although the Standard Appraisal Value is the recommended approach, there has been a long-standing tradition of single mode appraisal involving different rules, and often locally chosen values of time. However, the movement towards an integrated approach across modes, implicit in the Guidance on Methodology for Multi-Modal Studies, makes it important to regularise the treatment.

The primary theme of this section is to explore the differences in willingness to pay by mode. It then addresses the question "is there a case, in the light of the theoretical and empirical evidence, for modally differentiated values of non-working time?"

If values are taken direct from existing *users* of each mode (as in the Bus-Bus, Underground-Underground, Rail-Rail and Car-Car columns of Table 22), then inconsistencies will arise in the CBA because bus time benefits will be valued in accordance with the average income level of bus users, whilst car benefits will be valued in accordance with the average income level of car users. On this basis, "switchers" between modes will be treated anomalously.

A further complication is that 'modal average' preferences are unlikely to remain stable over time: switchers will be moving in and out of modes in response to changing conditions (including the project being appraised). Fixing 'modal average' preferences actually risks fossilizing existing low valuations of bus journey time, for example, rather than allowing values to increase as individuals with higher values move into the mode. Note that the same problem exists, in principle, for business values.

Counteracting this is the observation that in many cases, the amount of mode switch will be small compared with the number of existing users: to the extent that is true, the preferences of existing users will dominate the benefit calculation, not the preferences of switchers. This is an empirical issue, which remains unresolved at this time.

However, the logical way forward is to allow explicitly for the different income composition of the travelling population, with appropriately differentiated values of time, in such a way that the *mean* values for the current users of each mode exhibit the variation shown in Table 23 above.

In a context where we expect a non-negligible amount of mode transfer, our view is that on grounds of consistency we need to address the underlying reasons for the 'self-selectivity' type of variation, of which income is probably the most important. However, we have also shown that on theoretical grounds we could allow the same individual to have different modal values of time, providing that these were essentially reflecting variations in comfort and convenience.

If such variations were incorporated into CBA, then the NPV and BCR of public transport / mixed mode projects would be affected. For example, suppose we consider the effect of a 10 minute improvement in both bus and car modes, other things being equal. Suppose numbers of users are T_b by bus and T_c by car before, and T'_b and T'_c after. Then the total benefit is given by:

$$\tfrac{1}{2}\,[(T_b + T'_b).v_b\,(10) + (T_c + T'_c).v_c\,(10)]$$

where v_b is the value of bus time savings;
v_c is the value of car time savings.

There will be positive benefits on both modes. Some switch to bus will occur. If, as in Table 21, $v_b > v_c$, then the social benefit per unit of time saved will be greater on the bus mode than on car. It is important to note that we are not assuming that the valuations v_b, v_c are specific to current users, but that they are specific to the use of particular modes.

It is worth trying to dispel the possible misapprehension that differentiated values of time by mode could lead to perverse results, such as disbenefits following (rational) modal switch by individuals following a PT improvement. Appendix J shows that this is not the case.

Summary of Conclusions and Recommendations – Modal Values

Considering the results of the analysis so far and the discussion above, we conclude that:

- There is some evidence that individuals value non-working time savings on the bus mode more highly than for car, and these in turn more highly than travel time savings by rail, other things being equal.
- This appears to be true equally for commuting and leisure.
- We interpret these differences as reflecting differences in comfort, cleanliness, information and other characteristics of spending time on each mode. In principle, we think it is consistent with UK public sector appraisal conventions to move towards a differentiated 'value of time' by mode, insofar as they reflect users' valuations of these differences.
- Evidence also indicates that when aggregating across individuals to the level of 'user types', a reverse pattern is found. Bus users have the lowest value of time savings, followed by car and rail. This pattern is likely to be due to some combination of income differences between the 'user types' and self-selectivity - individuals migrating to modes whose characteristics suit their own.
- Self-selectivity suggests that there is a danger in 'fixing' values to modes based on the sample of current users: over time we might expect (and indeed want) average modal values to change, as a result of individuals with different preferences changing mode. We think that the correct approach is to make the underlying income differences explicit in both modelling and appraisal.
- Although we see no theoretical objections to allowing modal values of time to vary *for the same individual* to reflect comfort etc. valuations in transport appraisal, we think that more work is needed to identify statistically robust modal values.
- We also think that work is justified to *define, quantify* and *value* the modal characteristics involved. There are two reasons for going this extra step:

(i) At present it is not clear, for example, what the comfort effect (or the comfort value) is, nor how this fits into the wider set of modal attributes which influence people's perceptions of each mode. What we have is a general residual term which includes people's preferences for an average example of a particular mode. If appraisal is to be transparent, it would be advantageous to be able to say: "this project yields benefits to transport users in terms of increased travel comfort, information, and so on, which are quantified and valued in the appraisal".

(ii) A major part of current policy is targeted at improving the quality of particular modes (specifically bus and rail). If we do not explicitly value the characteristics of modes (quality of information, comfort and so on), then we will not be in a position to value improvements in modes. We will only have a poorly understood 'modal value' which become obsolete as soon as modal quality starts to improve.

8.4 Values of time with distance

There is considerable evidence that the willingness to pay for travel time savings increases with journey length. This evidence includes both the AHCG data and the meta-analysis. Taking the two sources of evidence together, an elasticity of the VTTS to distance of around 0.3 is found.

For purposes of behavioural modelling, we believe such a result should be accepted. This is to say, we expect to find that, all else equal, long distance travellers facing a given route choice between a faster tolled section of route and a slower untolled alternative will have a higher propensity to choose the tolled option than shorter distance travellers facing the same choice. This could perhaps be tested in the context of the BNRR/M6Toll.

We have discussed the possible explanations of a positive relationship between VTTS and distance in section 5.1 above. From an economic theory point of view, the most appealing explanation would be that both the marginal disutilities of time and cost increase with journey length due to budget relationships. Mathematically we expect $\frac{\partial^2 U}{\partial T^2}$ and $\frac{\partial^2 U}{\partial C^2}$ both to be negative. If the first of these is more negative than the second VTTS (the ratio between them) rises with journey length. If we had found this to be the case we would have had no hesitation in recommending VTTS suitably differentiated by distance in evaluation.

However, the AHCG data provides no support for a negative value of $\frac{\partial^2 U}{\partial T^2}$ and provides strong support for a *positive* value of $\frac{\partial^2 U}{\partial C^2}$. The analysis strongly suggests that the increase in VTTS is due to this 'relative' effect, which can be interpreted as "the disutility of spending an additional £ is less when the overall price is larger". This contradicts economic rationality, since £1 = £1 regardless of how it is acquired or saved. However, it has behavioural plausibility and is confirmed in other analyses (e.g Dutch National Model, Heathrow Surface Access Model).

The meta-analysis data also shows a positive relationship between VTTS and journey length but does not enable us to distinguish the reason for it. One notable feature of the meta analysis results is the higher elasticity with distance for car vis a vis non-car modes. This differential effect might be interpreted as an effort or fatigue effect associated with the task of car driving.

Given this, the question we face is whether the evidence supports variations in VTTS with journey length in economic evaluation. The practical options are

- to rely on the evidence as a whole including the meta analysis to accept a distance elasticity – say +0.3 – as being relevant for evaluation and to implement that using a few distance bands.
- to use the best estimates of the income and distance elasticities to compute the average values of time, but not to differentiate VTTS by distance in evaluation.

We have considered the merits of the two options set out above, and our view is that it is a close call. In favour of the first option is the argument of consistency between values used in modelling and values used in evaluation. More fundamentally, behaviouralists would support the use of behavioural values in evaluation without investigating too closely the rationality or otherwise of consumer choices. As against this, we attach considerable weight, in the evaluation context, to consistency with neoclassical microeconomics which is the foundation of cost-benefit analysis. We do not feel comfortable about basing a recommendation on a phenomenon – falling marginal disutility of cost as cost rises – which is inconsistent with theory. On balance therefore, we recommend the second option.

The implication is that the variation by distance given in Table 24 could be used for modelling, but we do not recommend it for appraisal. We present the recommended values, by income only, in Chapter 9.

8.5 The standard value of non-working time

The standard value of non-working time has been a feature of UK appraisal practice since the 1960s. It has been regarded as a fixed feature of the scene, and was not reviewed in the 1980s work on the valuation of time. The standard value is a concept which relates primarily to benefit evaluation rather than to modelling. There are two arguments for using a standard value.

- That, in principle, the same values for non-working time savings on all locations and modes should be applied, irrespective of the willingness to pay of the particular group of consumers who get the benefits;
- That using a single standard value is a practical procedure to follow given the difficulty of acquiring relevant market information (incomes etc.) on which case-specific values would need to be based.

Robert Sugden's 1999 paper for the Department called for an end to the use of the standard value of non-working time on the grounds that it is "incompatible with the logic of CBA". This is an important recommendation from a wide-ranging paper, most parts of which are accepted by both us and the Department. It is useful to set out the argument in a formal way.

Consider cost-benefit analysis as a form of applied welfare economics in which social welfare(W) is defined as being some function of the utility, U, enjoyed by members of society i.e.,

$$W = W(U_1, U_2 \ldots U_q) \quad (1)$$

where there are q individuals or homogenous groups in society.

Utility is gained by consuming goods and services and this is constrained by incomes, prices, and time available for consumption. So,

$$W = W[U_1(Y_1, P_1 T) \ldots\ldots U_q(Y_q, P_1 T)] \quad (2)$$

Consider a change in a particular travel opportunity whereby both time and cost change, by Δt and Δc. This results in a change in utilities ΔU_q for each q and hence a change in overall welfare ΔW, given by

$$\Delta W = \Sigma_q \frac{\partial W}{\partial U_q} \Delta U_q = \Sigma_q \Omega_q \Delta U_q \quad (3)$$

where Ω_q are the relative weights attached to the utility of the different groups q.
For small changes, it is acceptable to linearise the utility function so that,

$$\Delta U_q = \alpha_q \Delta t + \lambda_q \Delta c \quad (4)$$

(and of course the value of time $V_q = \alpha_q / \lambda_q$)

Hence combining (3) and (4),

$$\Delta W = \Sigma_q \Omega_q (\alpha_q \Delta t + \lambda_q \Delta c) \quad (5)$$

Note in passing that this implies that the values of time V_q are a separate matter from the set of social weights to use, Ω_q. *Although in practice these have been run together*, there is no reason in principle to do so. Moreover, the choice of welfare weights should come as a matter of cross-sectoral Government policy, whereas the value of travel time savings will be a transport specific matter. There are therefore attractions in keeping them separate, and this is consistent with the approach taken in the draft Green Book. (Treasury 2002).

Now, let us consider some interesting cases. Suppose we assume that $\Omega_q = 1/\lambda_q$. Then we are assuming that a unit change in income bears equally on all q. Then the social benefit is given as the sum of individual willingness to pay for benefits.

$$\Delta W = \Sigma_q \ (V_q \Delta t + \Delta c) \qquad (6)$$

This is the Harberger approach to cost-benefit analysis – unweighted adding up of willingness to pay. Arguments for this are of the following kind:

- It is what happens with normal market commodities in a commercial appraisal context, and in particular, it is how revenues and costs are typically treated in transport appraisal;
- If the existing income distribution is considered optimal, it is the optimal social weighting scheme;
- Even if the existing income distribution is not considered optimal, it is not the business of transport policy to put it right.

These are the arguments of those who see cost-benefit analysis as an analogue to commercial appraisal, but accounting for external effects and consumer surplus as well as producer surplus. But there are some difficulties concerning the treatment of safety and environmental impact within such a framework. The third argument is particularly weak, since if the income distribution is sub-optimal, it is possible for public policy to take account of this at sector level without explicitly trying to correct the income distribution. Policy dimensions such as 'social exclusion' make sense in this context.

In the wtp approach, $\Omega_q = 1/\lambda_q$ where λ_q is the marginal utility of income for group q. Since we know that this declines with income, it follows that wtp weights in favour of the richer q. Reflections such as this have led to the exposition by Galvez and Jara-Diaz (1998). This argues that the most attractive option is to set the Ω_q factors equal to each other (e.g. unity) so that individuals' utility is weighted equally. Relative to the willingness to pay approach this rescales the benefits towards the lower income groups.

One possible way of implementing the Galvez and Jara-Diaz model is to standardise on time rather than income. In other words, assume that a small change in travel time bears equally heavily on utility terms on all groups q. Then the benefit is given as the sum of individual time equivalences and is in time units.

$$\Delta W = \Sigma_q \ (\Delta t + 1/V_q \ \Delta c) \qquad (7)$$

To convert this to money units for the CBA, we require a single value of time V which can be considered equivalent to the standard value. So then, in money terms,

$$\Delta W = \Sigma_q \ (V \Delta t + \frac{V}{V_q} \ \Delta c) \qquad (8)$$

Here we are effectively saying that time savings/losses are equally weighted among the different q but that costs are differentially weighted by the ratio of the standard value to the individual or group value V_q.

Suppose for a moment that the cost term Δc is zero. This may be roughly considered to be the case under which the equity value was originally conceived – time saving from road investment without direct payment. The individual values of time V_q do not enter the evaluation formula (except indirectly since V is a weighted average of V_q), and the equity argument is directly reliant on the assumption that time savings are equally weighted for all q.

In our view, this could easily be a poor assumption, though not so poor as assuming that cost savings are equally weighted for all q. Tastes could easily vary across q. People on higher incomes might tend to work more hours so that their marginal utility of non-work time might be higher. The old argument that "we all have twenty four hours a day available" is too general to provide a rigorous defence of the single standard value of time.

Also, there is another difficulty. British appraisal practice has been to use neither (6) nor (8). Rather, it has used a mixture,

$$\Delta W = \Sigma_q (V \Delta t + \Delta c)$$

So, comparing with (6), time savings are rescaled by the ratio of V/V_q, but cost savings are not rescaled. This is inconsistent and has led to criticism. As Pearce and Nash point out,

"This inconsistency could lead to misallocation of resources; for example a scheme which gives the poor time savings at an increased money cost of travel could be selected in circumstances in which they would rather forgo the time savings for the sake of cheaper travel". (Pearce and Nash, 1981, p 182). A similar example, but from the opposite end of the income spectrum is given by Sugden (1999), para 7.2.

From the perspective of principle, therefore, we conclude that:

- The standard value of non-working time is an incomplete approach to social weighting and introduces problems of inconsistency between time and costs;
- Specifically, the relativities between time and costs are different in modelling and evaluation, and this introduces problems where users are paying for benefits through fares or charges;
- The standard value relies on the strong assumption of equal marginal utility of time across groups;

In principle, then, we believe that appraisal should:

- Discover the willingness to pay for all the costs and benefits accruing to all relevant social groups q;
- Use those values consistently in modelling and evaluation;
- Re-weight the costs and benefits according to some social weighting scheme which is common across sectors.

The weighting scheme should apply consistently across all impacts (time, money, safety risk, environment...). There is no particular reason to expect that the outcome would be a social value of time which is equal for all q. We therefore conclude that the argument of principle for the standard value of time falls.
However, we regard a full distributive weighting approach to appraisal as very ambitious for most practical transport applications. We can mention the following difficulties:

- Obtaining the relevant data on the pattern of usage by income and social group q at the scheme level;
- Defining the final incidence of costs and benefits to groups q – especially difficult for working time and revenue effects;

- Treating the non-monetised elements in the appraisal consistently with the monetised ones within the social weighting scheme;
- Agreeing the set of social weights.

Suppose that, for these reasons, implementing a full social weighting scheme in the transport sector proves to be challenging. Then, on pragmatic grounds we would recommend falling back on the use of a set of standard values of non-working time for most scheme appraisal work. We regard this, in the absence of a social weighting approach, as a second best which is a practical approach in an appraisal regime which contains many standard parameters. We believe this conclusion is consistent with the approach to appraisal taken in the Green Book.

However, because we are relying on pragmatism rather than principle, we accept that there are circumstances where the disadvantages of using the standard value outweigh the advantages. These are primarily quasi-commercial appraisals such as rail investment, toll roads, and major policy initiatives such as road user charging. It is in these applications that the problems of inconsistency in modelling and evaluation are most serious.

8.6 Recommendations for appraisal

The approach to appraisal taken in the Green Book can be seen as an ideal to which practical work might aspire. It involves two steps:-

- an evaluation in which the behavioural values of time and cost are carried through directly, assuming consistency between the values used for modelling and those used for evaluation. These would be reported in the Transport Economic Efficiency analysis.
- the use of a set of social or welfare weights to re-weight the efficiency benefits.

We consider that the use of social weights in transport appraisal will inevitably be limited. We see no possibility of undertaking a distributive analysis of the user benefits for employers' business trips and freight traffic because we see no practical way of identifying the pattern of <u>final</u> beneficiaries. However, we do think there are better prospects when considering commuting trips and other non-work purposes.

The first step towards this more extended form of analysis would be to undertake the entire evaluation in income quintiles so that the pattern of benefits across income and social groupings would be displayed. A subsequent step would be to apply social weightings to the time and money benefits so as to arrive at a social evaluation.

In coming to our recommendations for changes in appraisal practice, it is necessary to bear in mind considerations of principle and of practice. In relation to principle, some of our recommendations are contingent on progress being made in the transport sector towards a distributive analysis of the kind proposed in the Green Book. We note that many appraisal institutions around the world such as the World Bank have found distributive analysis an onerous and data hungry procedure, and we are not very optimistic about the prospects.

In any case, we think it is inconceivable that the Department will wish in practice to apply the approach outlined above in all the decision contexts which exist, in grounds of feasibility and cost-effectiveness. We think that the Department should consider moving to a more varied set of appraisal options as set out below.

<u>Level 1 – routine appraisal work</u>

For much routine appraisal work, including the evaluation of small to medium sized schemes and particularly for the choice between scheme options, there is a great deal to be said for a relatively simple standard values approach to both modelling and evaluation. Much appraisal work should in practice continue to rely on standard values of the kind set out in the TEN. The benefits of a standard approach outweigh the costs of creating and auditing special values for every context. Revised standard values are therefore recommended in chapter 9.

Level 2 – major schemes and strategies

We have found that the value of non-work travel time savings varies with a number of factors such as income, journey length and retired status. For strategic *modelling* including major schemes such as motorway widening, we recommend the use of a more differentiated set of behavioural values than for Level one. Use of scheme-specific data on income, journey length, retired status etc would need to be authorised on the basis that the local data would be auditable. A set of default values and relationships could be derived from our recommended model. On the *evaluation* side, we have established above the issues of principle and practice which are at stake. In principle, we recommend moving away from the single average value of time to a set of income-related values. However, implementing this recommendation requires progress to be made in the treatment of distributional effects. Ideally, we would like to see a full distributive analysis, but, as noted, this is likely to be challenging. In the absence of substantial progress in this direction, we feel that the following is the minimum acceptable:

- in the first place, a Level 1 approach should still be carried out, as a benchmark
- any Level 2 disaggregation by income should present the distribution of benefits separately for the three income levels distinguished
- as far as practical, the distributional implications of any increase in the overall benefits consequent on the move from Level 1 values to Level 2 values should be clearly indicated

Level 3 – special applications

There are various situations for which standard behavioural values are not considered adequate for modelling, and it is necessary to segment the market into various sub-components with different willingness to pay characteristics. Classic examples are contexts which involve varying mixes of time and cost in the choice set – toll roads, cordon pricing, LRT v buses – where such market segmentation is essential. In such cases, it will be likely that bespoke Stated Preference exercises will be conducted in order to elicit context specific values. This is already done for modelling purposes and for the commercial evaluation of projects. Again, subject to auditability and to verification against the standard values, we would be willing to recommend the use of these values in evaluation as well as in modelling. On balance, we think the advantages of using behavioural values throughout the appraisal in cases where a significant proportion of consumer surplus is being converted into producer surplus through tolls or charges outweigh the disadvantages of inconsistency in the appraisal of free versus tolled facilities. Clearly the balance of advantage is context – dependent, and we would expect the Department and its agencies to give advice and guidance to consultants. For Level 3 evaluations, both the Level 2 and Level 1 results should be presented as benchmarks.

9. SUMMARY OF MAIN CONCLUSIONS AND RECOMMENDED VALUES

With regard to employers' business and freight transport:

R1 for professional drivers such as bus and freight transport drivers and attendants, the cost saving approach should be retained.

R2 for other travellers on employers' business such as 'briefcase travellers', there remains a great deal of uncertainty regarding the true values of the factors in the Hensher Model and about the labour market assumptions which are relevant when working conditions change. Given this, there is no strong case for abandoning the cost saving approach to valuing savings in travel time on employers' business.

R3 we recommend that because of the importance of working time savings in the total, the income characteristics of travellers on employers' business, the occupancy rates of vehicles and other inputs which affect the recommended values should be kept under review.

The rest of our recommendations relate to non–working time. There is evidence that values of travel time savings vary with income, journey length, journey purpose, mode, driver/passenger, and retired status.

R4 there is no sound basis for differentiating values of travel time savings in terms of their sign or size either for car or public transport applications;

R5 for *journey purpose*, the evidence is that the value of travel time savings for Other purposes is 10 per cent below that for Commuting. This is a fairly robust conclusion; it is for the Department to decide whether this is worth implementing in the various evaluation contexts. In the values given below, we assume that it is worth doing so;

R6 for *mode*, we are only interested in variations in the valuation of travel time savings due to innate modal quality differences. There is evidence that for car users, VTTS on bus is higher than that for car, which in turn is higher than that for rail. However, it is not statistically robust, and we think it will be more useful if related to specific attributes such as comfort, cleanliness, information etc. For the moment we do not recommend differentiating VTTS by mode. We do offer
further evidence on out of vehicle time – walk, wait and headway. We recommend that wait time values should be increased to two and a half times in-vehicle time with walk time values remaining at twice in-vehicle time;

R7 the results from our analysis of the AHCG data suggest the value of travel time savings for passengers is on average some 20 per cent below that for drivers. However, for reasons given in the Section 5.1, we are not completely convinced of the validity of this result and do not recommend its implementation;

R8 the results show that the value of travel time savings for retired persons is significantly lower, by the order of 25 per cent, all else equal, than for economically active persons. Following the 1987 Report which found a similar result, the Department issued a number of 'socio economic status' modifiers to the standard value of time. Our impression is that these have rarely been used in practical appraisal work. The issue is essentially whether and in what circumstances data on the retired proportion can be obtained for network modelling and evaluation work. We emphasise that the values given below are averages which include the retired in the calculations;

R9 we find that the valuation of travel time savings varies significantly with income and with journey length, and recommend that this variation should be reflected in behavioural modelling work. However, from an evaluation perspective, we have some reservations about the consistency of the results with microeconomic theory. On balance we are inclined against *differentiating* VTTS by journey length on this evidence. Accordingly, we recommend using the best estimates of the income and distance elasticities to compute the average values of time, but not to differentiate by distance in evaluation. This is a priority for further work, since variations by distance could affect the relative worth of schemes significantly.

R10 the evidence as a whole tends to support intertemporal elasticities for non-working time of somewhat less than unity, probably in the range +0.5 to +1. We recommend a move from the current unit value to a value of +0.8, and that this should be used to uprate the values below from end 1997 to current values.

R11 we think it would be consistent with the recommendations of the Green Book to adopt a degree of flexibility in the valuation of travel time savings in evaluation and we suggest that the single standard value might be replaced by a three-level approach.

R12 for level 1 appraisals, we recommend that the VTTS by income band recommended in R13 below should be weighted using a standard distribution of incomes and journey lengths. Using NTS 1995-2000 data, this gives the following average VTTS (mileage-weighted) at end 1997 prices for all non-business trips and all mechanised modes:-

		pence/min
Commuting	All modes	6.6
Other	All modes	5.9

Compared with the values currently in use, these represent a 10 per cent fall in the Commuting value and a 20 per cent fall in the Other value at the base year (1997).

R13 For level 2 appraisals we recommend that more detailed account should be taken of the variation in VTTS by income band. Applying the coefficients in our preferred model to the pattern of incomes and journey length in the NTS 1995 – 2000, we derive the following weighted average VTTS by income band, again at end 1997 prices and values:-

Income Band	**Commuting**	**(p/min)**	**Other**
Below £17,500 pa	3.6		4.6
£17,500 – 35,000 pa	5.9		5.9
Above £35,000 pa	8.6		7.1

R14 For level 3 appraisals such as the evaluation of toll roads, user charging schemes, metros and other 'user pays' facilities, the Department would rely on specific market research exercises. However, we strongly recommend that these be explicitly benchmarked against more general evidence, including the level 2 values above and other data from this study, and that they be subject to quality control.

We recommend further targeted research on the following issues:-

- variation in the marginal utility of time and cost with respect to the levels of time and cost, so as to provide a more secure foundation for variable VTTS with journey length. A mixture of RP, SP and experimental economics approaches may be useful;
- values of the non-time attributes of travel (comfort, security, information etc.). In principle we would like to see these introduced into mainstream cost-benefit analysis especially of public transport. Such values will need to be based securely against values of time;
- variations in VTTS between driver/passenger and for larger groups. We have found in this piece of work that larger groups should probably be assigned lower VTTS per person than solo drivers;
- the value of savings in congested time and in changes in reliability are increasingly important issues not considered in this report.

We believe that each of the above could significantly affect the relative worth of different policies and projects and therefore merit pursuing further. More generally, VTTS remains a key parameter in transport modelling and appraisal, and its relationship with journey purpose, journey length and income, both cross-sectionally and particularly over time, need to be regularly revisited through review work, meta analysis and further bespoke studies.

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APPENDIX A
WORKING PAPERS

1. J. Bates and G. Whelan, Size and Sign of Time Savings, ITS Working Paper 561, December 2001.

2. A.S. Fowkes, Principles of Valuing Business Travel Time Savings, ITS Working Paper 562, December 2001.

3. A.S. Fowkes, Value of Time for Road Commercial Vehicles, ITS Working Paper 563, December 2001.

4. M. Wardman, Public Transport Values of Time, ITS Working Paper 564, December 2001.

5. G. Whelan and J. Bates, Values of Time by Market Segment, ITS Working Paper 565, December 2001.

6. M. Wardman, Intertemporal Variations in the Value of Time, ITS Working Paper 566, December 2001.

APPENDIX B
THE AHCG DATA SET

A number of different datasets are provided by AHCG. In our re-analysis we have concentrated entirely on Experiment 1, which is the main source of the AHCG findings.

The Experiment 1 Design

There are 12 separate questionnaires, relating to the traffic conditions (M U T) x the length of the journey (A B C D). The distribution is as follows:

	Motorway	Urban[13]	Trunk
A	5–25 mins (Q1)	5–15 mins (Q5)	5–25 mins (Q9)
B	26–50 mins (Q2)	16–25 mins (Q6)	26–50 mins (Q10)
C	51–75 mins (Q3)	26–40 mins (Q7)	51–75 mins (Q11)
D	75+ mins (Q4)	41+ mins (Q8)	75+ mins (Q12)

It should be noted that these times do *not* relate to the whole journey. Rather, according to the recruitment questionnaire, potential respondents were asked which road type (Motorway, Urban, Trunk) was used for the longest distance during the journey, and then were asked how long they spent driving *on that road type*. In general, the total journey time T was considerably greater than the ranges given above would indicate.

The design is conceived around the following ideas:

- each questionnaire has 8 pairwise comparisons, based on the variables time and cost, in all cases defined relative to the current journey, thus Δt, Δc where Δt, Δc are defined relative to the current journey (T,C), so that $\Delta t = t - T$ etc. ; each of Δt, Δc is set to zero in *one* of the alternatives to be compared;
- there are eight "boundary values of time", measured as $\Delta c/\Delta t$ - in pence per minute these are: 1, 2, 3.5, 5, 7, 10, 15, 25. Minor variations occur, presumably to deal with rounding
- there are four "types" of pairwise comparison, according to the quadrants in Figure A1:

1$\Delta t > 0, \Delta c > 0$
2$\Delta t > 0, \Delta c < 0$
3$\Delta t < 0, \Delta c < 0$
4$\Delta t < 0, \Delta c > 0$

The types can be illustrated graphically in the diagram below: the slope of the line represents the (negative) boundary VoT (Bvot): in the case of types 2 and 4, the current journey will be chosen if actual VoT > Bvot (type 2) or < Bvot (type 4); for types 1 and 3 the point on the Δt axis will be chosen if actual VoT < Bvot (type 1) or > Bvot (type 3).

[13] The earlier review by Bates noted that the values for experiment 1 were identical between UA and UB, so that there were only 11 distinct sets of choices. This turns out to be an error, based on an erroneous copy of the questionnaire. We are satisfied that the correct values were used, both at the time of interview and in the analysis.

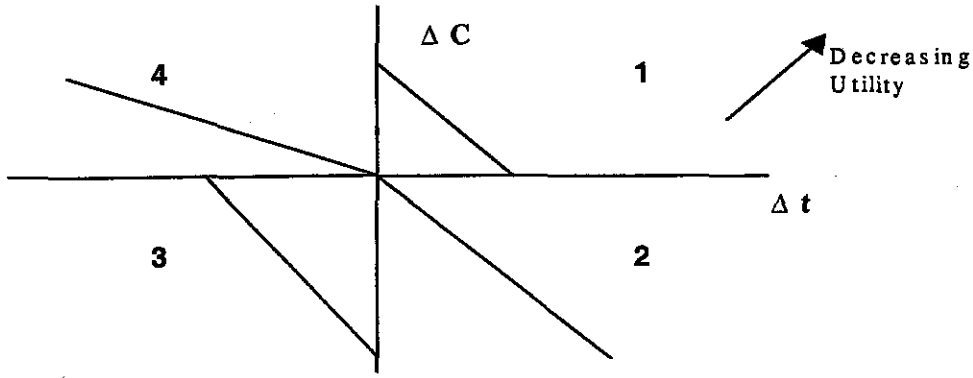


Figure B1: Types of Pairwise Comparison in SP Design (Experiment 1)

Each "type" is represented twice among the eight comparisons, once with a "low" boundary VoT (≤ 5), and once with a "high" boundary VoT (> 5 p/min)

The design is simple in concept, allowing a satisfactory range of boundary values and the possibility, in principle, of testing the variation in coefficients with gains or losses on either time or cost variable. The ability to estimate the effect of different *sizes* of saving/loss is dependent on the actual *values* used in the design: here there are some constraints imposed by the current journey, since the changes need to be seen as reasonable.

There is a minor problem in the implementation of one of the questionnaires, which appears to be a printing error. In questionnaire MC, the fourth pairwise comparison is in fact a dominant choice: option A should always be preferred. Interestingly, the data on response (Appendix H of the HCG/Accent Report) does not entirely confirm this to be the case: option A was chosen by 167 out of 193 respondents. Since comparison type 2 only occurs *once* in the MC set, it may be deduced that the cost for alternative A was meant to be *10p higher* than the current rather than lower. We have confirmed that the coding of the data reflects this error – i.e. it gives the values actually presented rather than the intended values.

In addition, it is strange that in this set (MC) the 2nd highest boundary vot is 22.5 p/min (comparison 1) rather than the 15 p/min that is used in all the other questionnaires. It is suggested that the time reduction for alternative B should have been 15 rather than 10 minutes.

As far as the range of Δt and ΔC are concerned, the actual values used are as follows:

For Δt we have:

Value	No.of occurrences
-20	4
-15	6
-10	15
-5	16
-3	8
+5	12
+10	22
+15	7
+20	6

NB: the "number of occurrences" relates to the number of occasions the value occurs over the 12x8 = 96 different pair-wise comparisons: in practice, these will be weighted in different ways as the 12 questionnaires are distributed among the sample. However, the information makes it clear that a limited number of absolute time changes has been investigated.

For ΔC the number of options is much greater: the 96 comparisons are reasonably distributed over the range (−300,+300), and the majority are in the range (−100,+100). All values are rounded to 5p.

The discussion about boundary values above shows that the design is generally capable of distinguishing a sensible range of VoT's both over the whole experiment *and* within each of the four "types". It is also of interest to see how well distributed the boundary values are over the *size* of Δt. The table below summarises the boundary values as they apply to each value of Δt (some values may occur more than once):

Δt	boundary values (p/min)
−20	1, 3.5
−15	(−1), 7, 15
−10	1, 2, 3.5, 5, 7, 10, 15, 22.5, 25
− 5	1, 2, 4, 5, 7, 10, 15, 25
− 3	1.67, 5, 10, 25
+ 5	2, 5, 10, 25
+10	1, 2, 3.5, 5, 7, 10, 15, 25
+15	1, 3.33, 7
+20	1, 3.5, 7, 15

This shows that within the Δt range (−10,+10), the full range of boundary values (1,25) applies, though the number of values for Δt = −3 and +5 is more restricted. Outside the range (−10,+10), the coverage is less good, particularly at the higher end of the boundary vot spectrum. These observations aside, the power of the design is well distributed across the central values of Δt.

Of the 9 possible values of Δt, only four different values are presented in any given questionnaire. The distribution is as follows:

Questionnaire codes	Base time range	Δt values
UA	5-15 mins	−3,−5,+5,+10
UB	15-25 mins	−3,−5,+5,+15
MA,TA	5-25 mins	−3,−5,+5,+10
UC	26-40 mins	−5,−10,+10,+15
UD	> 40 mins	−5,−15,+10,+20
MB,TB	26-50 mins	−5,−10,+5,+10
MC,TC	51-75 mins	−10,−15,+10,+15
MD,TD	> 75 mins	−10,−20,+10,+20

For understandable reasons, there is a correlation between the values presented and the base time, in order to avoid unrealistic changes. There appears to be sufficient commonality of values across the experiments to allow separate values to be estimated for each Δt value: nonetheless, it needs to be borne in mind that no respondent has explicitly traded between all 9 possibilities.

The SP presented the alternatives *relative* to the current journey: thus, for example, choices were offered of the kind:

Option A: Time as now; Cost 20p lower than now
Option B: Time 10 mins shorter than now; Cost as now

The data was analysed in three separate subsets according to the journey purpose – Business, Commuting, Other. Somewhat more information about the exact purpose was available.

APPENDIX C
META-ANALYSIS DATA SETS

What is termed meta-analysis involves the analysis of variations in a large number of values of time drawn from different studies. Our analysis is restricted to the evidence provided by disaggregate modelling exercises conducted in Great Britain. We here briefly describe the main characteristics of the two data sets used.

The main exercise was concerned with values of IVT, walk time, wait time and headway. The maximum level of disaggregation of the values collected was according to journey purpose, mode and distance. Thus from any one study, multiple values were collected where separate values had been reported by mode, journey purpose or distance. Values of time segmented by, say, income group, location, travel constraints, gender or age group, were not collected.

A supplementary exercise was conducted with the specific purpose of examining cross-sectional variations in the value of time with income. It focused solely on values of IVT which were segmented according to income category.

Key Features of the Main Meta-Analysis Data Set

The main exercise obtained 1167 valuations of IVT, walk, wait and headway from 171 studies. These ranged from the initial British empirical study of Beesley (1965) through to studies which reported their findings in the final quarter of 2000.

The purpose of the main meta-analysis was to examine the valuations of IVT, walk time, wait time and headway. Information was collected on a range of variables which could be used to explain variations in these values across studies. These included journey purpose, distance, GDP and household disposable income, mode used and the mode to which the value relates, the form of the cost numeraire, whether the value was obtained from an RP or SP model, region and choice context.

Table C1 shows the distribution of the values across mode used and the attribute to which the value relates. Not surprisingly, given the importance of IVT in travel decision making and in transport scheme appraisal, values of IVT form by far the largest category (62%). However, we have collected large samples of the values of the other attributes.

Table C1: Mode Used and Attribute Characteristics

	Car	Bus	Rail	UG	PT	Car&PT	Other	Total
IVT	294	70	175	23	30	60	67	719 (62%)
Walk	109	39	15	0	15	31	19	228 (19%)
Wait	4	11	4	11	12	8	11	61 (5%)
Headway	69	32	17	14	4	10	13	159 (14%)
Total	476 (41%)	152 (13%)	211 (18%)	48 (4%)	61 (5%)	109 (9%)	110 (9%)	1167

As far as mode used is concerned, some studies do not produce values relating to a single user type, but cover combined public transport (PT) modes, such as rail and bus, or car and one of the public transport modes (Car&PT). The Other category includes combinations of several modes and also air travellers.

Car users form the largest category of user type. In part this is due to the dominance of car travel but it also reflects the large number of studies whose objective was to determine abstraction from car as a means of estimating demand for new or improved public transport services or else whose purpose was to examine the extent to which reliance on car travel could be reduced for congestion or environmental reasons.

The large number of rail valuations reflects the rail industries early adoption of the SP method and its commitment to the use of market research to underpin its pricing, service quality and investment decisions.

Other important dimensions are journey purpose, distance and inter-temporal features. The distribution of values according to journey purpose and distance is given in Table C2 both for the IVT values separately and for all the values. Although most values relate to urban trips, a good spread of values by distance has been obtained. With regard to journey purpose, the other category reflects values where the study made no distinction by journey purpose or else a single value was estimated to more than one purpose. Again we have achieved a good spread of values across journey purposes. As expected, commuting trips tend to be shorter distance and business trips longer distance.

Table C2: Values by Journey Purpose and Distance

	IVT					ALL				
Miles	Comm	Leis	EB	Other		Comm	Leis	EB	Other	
-10	129	125	11	129	394 (55%)	262	232	15	225	734 (63%)
11-30	26	23	13	23	85 (12%)	36	28	18	38	120 (10%)
30-100	26	52	36	22	136 (19%)	36	76	48	23	183 (16%)
100+	7	39	49	9	104 (15%)	9	47	58	16	130 (11%)
	188 (26%)	239 (33%)	109 (15%)	183 (25%)	719	343 (29%)	383 (33%)	139 (12%)	302 (26%)	1167

The years in which the data were collected are depicted by Table C3. Although the vast majority of the values have been estimated since 1986, there is a large range which provides a firm basis for examining how the values vary over time.

Table C3: Years of Data Collection

Year	IVT		All	
Year	Studies	Values	Studies	Values
63-70	8 (5%)	25 (3%)	8 (5%)	45 (4%)
71-75	2 (1%)	3 (1%)	2 (1%)	11 (1%)
76-80	1 (1%)	3 (1%)	1 (1%)	3 (1%)
81-85	12 (7%)	46 (6%)	12 (7%)	64 (5%)
86-90	40 (23%)	163 (23%)	40 (23%)	255 (22%)
91-95	67 (40%)	294 (41%)	68 (40%)	525 (45%)
96-00	39 (23%)	185 (26%)	40 (23%)	264 (23%)

Other notable characteristics of the data are that 91% of the IVT values and 90% of all the values were obtained from SP models whilst 62% of the values of IVT were obtained from mode choice contexts, 6% from route choice contexts and 32% from abstract choice contexts. The values have been obtained from disaggregate studies conducted for any purpose and not just from specific value of time studies. 11% of the values of IVT were obtained from studies which were specifically concerned with estimating the value of IVT, 56% were obtained from studies whose main objective was demand forecasting whilst the remaining 34% were obtained from studies which were concerned with valuation but not specifically the value of IVT.

Key Features of the Supplementary Meta-Analysis Data Set

Data was collected from 20 studies which reported segmentations of the value of IVT by income group to support analysis of cross-sectional variations in the value of IVT with income. The studies yielded 157 values of time by income group.

In addition to the value of time and details of the income category, other information was collected relating to journey purpose, mode of travel, distance and whether the model had segmented just the cost coefficient by income or whether both the cost and time coefficient were segmented. These latter variables allow analysis of whether the cross-sectional income elasticity varies across different circumstances. In all but one study, the income category was gross household income.

APPENDIX D
SENSITIVITY OF VALUES OF TIME TO OMITTING OBSERVATIONS RELATING TO SMALL TIME CHANGES

The most parsimonious original model that we developed allowed the cost coefficient to vary with both cost and income according to an "elasticity" formulation. Because of this, we have to make clear for what values of cost and income we are quoting values of time: *all VoT's in this Appendix relate to an income of £35,000 p.a. and a journey cost of £1.00.*

For the model developed on the earlier data set, the key results are as follows:

	Commuting	Other
Observations	4737	8038
Value of time	4.23	3.73
Mean likelihood	-0.568078	-0.556706

In our most recent work, we have slightly reduced the data set to remove possible outliers in terms of journey time and cost (see Chapter 5 of the main text). The corresponding results are:

	Commuting	Other
Observations	4583	7689
Value of time	4.08	3.72
Mean likelihood	-0.567479	-0.555104

The impact is generally small.

We now remove from the estimation all those cases where the change in time is 5 minutes or less, while keeping the "perception function" fixed, with the following results:

	Commuting	Other
Observations	1841	4079
Value of time	4.41	4.61
Mean likelihood	-0.587879	-0.575641

Clearly, this has removed a substantial part of the data, and the model fit is also significantly worse. However, the value of time has *increased.*

If, using the same data set, we drop the "perception function" formulation, we obtain:

	Commuting	Other
Observations	1841	4079
Value of time	4.05	3.47
Mean likelihood	-0.58896	-0.581687

The model fit is worse again, but the values of time have dropped back to the earlier levels.

Finally, we consider the effect of excluding the observations relating to changes of 10 minutes as well: the results are now based entirely on those where changes in travel time of 15 minutes or more was offered. Since the perception function is only effective for changes below 11 minutes, it plays no part in the estimation.

	Commuting	Other
Observations	375	1370
Value of time	6.96	4.98
Mean likelihood	-0.569783	-0.596604

These values of time have increased by around 50%.

The general conclusions are thus that the model which we are recommending is *not* equivalent to a censoring of all observations where the change in time is less than 11 minutes: such an approach would deliver substantially higher values of time. Moreover, when using the perception function, the contribution of the "small time changes" (5 minutes or less) to the estimation is actually to raise the values of time to some extent (10-20%). The values which we are recommending, using the perception function, are broadly in line with an approach which drops the perception function and censors all observations where the time change is *five* minutes or less.

The key data which our approach relies on was given in Table 27 of WP561, which showed the proportion choosing the lower cost option when the time changes were small. Faced with a choice between an increased journey time of 5 minutes and an increased cost of 10 pence, 49% of Commuters and 66% of Others were not prepared to accept the extra cost, while slightly lower proportions (45% and 52% respectively) were not prepared to forego a gift of 10 pence in return for a gain of 5 minutes.

As the table below (from Appendix C of WP561) shows, these proportions fall appreciably when both the time and cost changes are doubled (thus maintaining the same tradeoff between money and time). This leads to the inconvenient property that the average valuation per minute of the additional five minutes over and above the first five minutes is substantially higher than the average valuation over the entire ten minutes. The "perception function" is one way of smoothing out this effect.

Estimation sample proportions choosing lower cost option (Quadrants 1 & 3).

Δt	Δc	proportion choosing lower cost	
		Commuting	Other
-5	-10	0.45	0.52
-10	-20	0.37	0.35
+5	10	0.49	0.66
+10	20	0.33	0.48

APPENDIX E
SUPPLEMENTARY ANALYSIS OF AHCG DATA

The main aim of this appendix is to present a set of model re-runs on a subset of the original data. However, it also provides a useful place to record some of the original model runs which have been described in more detail in ITS Working Papers 561 and 565. The results for the Business sample are not recorded here, since they have not ultimately been used: however, for the original data they are reported in the two Working Papers cited above.

The main data set corresponds precisely with that used by AHCG for model estimation, and in the following paired Tables, Part (a) shows a selection of the estimated models using this data. In view of the concerns about the effect of journey length described in Chapter 5, it was considered prudent to remove additional observations from the main data set according to the following criteria:

- where journey cost =-1 or zero
- where a journey time component =-1
- where journey time is >5 minutes less than the sum of road-type components
- where the reported cost per minute fell outside of the range 1.5 to 21.33

A selection of models were then re-estimated to see if the conclusions on the role of time and cost are supported on the reduced data set. Part (b) of the paired tables below shows the results using the reduced dataset.

Table E1a: Model M1 [= AHCG 4-1]

Coefficient	Commute	Other
Time	-0.08242 (14.19)	-0.05445 (15.31)
Cost	-0.01632 (19.74)	-0.01219 (25.36)
Mean LL	-0.636065	-0.632679
No.Obs.	4737	8038

Table E1b: Model M1 (Reduced dataset)

Coefficient	Commute	Other
Time	-0.08033690 (-13.63)	-0.05484724 (-15.05)
Cost	-0.01647370 (-19.46)	-0.01247094 (-25.04)
Mean LL	-0.635006	-0.630446
No.Obs.	4583	7689

Table E2a: Model M2

Coefficient	Commute	Other
Time	-0.08762 (10.90)	-0.04455 (8.73)
Cost	-0.01825 (18.37)	-0.01595 (23.67)
Time (quad) [t^2]	0.00003184 (0.71)	-0.0000524 (3.50)
Cost (quad) [c^2]	0.000001882 (3.53)	0.000001515 (7.83)
Mean LL	-0.6341131	-0.623004
No.Obs.	4737	8038

Table E2b: Model M2 (Reduced dataset)

Coefficient	Commute	Other
Time	-0.08434713 (-10.22)	-0.04785891 (-8.91)
Cost	-0.01831847 (-18.04)	-0.01682652 (-23.31)
Time (quad) [t^2]	0.00002324 (0.50)	-0.00004137 (-2.61)
Cost (quad) [c^2]	0.00000185 (3.28)	0.00000183 (8.31)
Mean LL	-0.633082	-0.619585
No. Obs.	4583	7689

Table E3a: Model M2a Quadratic on Incremental Time and Cost

	Commute	Other
Time (Δ)t	-0.0903 (14.72)	-0.0668 (17.55)
Cost (Δ)c	-0.0202 (20.59)	-0.0154 (25.67)
Time (quad) [Δt^2]	-0.0025319 (7.76)	-0.00173329 (10.53)
Cost (quad) [Δc^2]	-0.00004754 (10.68)	-0.00002547 (12.17)
Mean LL	-0.615510	-0.614007
No. Obs	4737	8038

Table E3b: Model M2a Quadratic on Incremental Time and Cost (Reduced dataset)

	Commute	Other
Time (Δ)t	-0.08878305 (-14.23)	-0.06732103 (-17.25)
Cost (Δ)c	-0.02050489 (-20.30)	-0.01566242 (-25.34)
Time (quad) [Δt^2]	-0.00247830 (-7.49)	-0.00175262 (-10.43)
Cost (quad) [Δc^2]	-0.00004907 (-10.67)	-0.00002517 (-11.67)
Mean LL	-0.614342	-0.612150
No. Obs	4583	7689

Table E4a: Model M2b Quad on Incremental Time and Cost with Time and Cost Covariates

	Commute	Other
Time (Δ)t	-0.0961 (11.49)	-0.0560 (10.60)
Cost (Δ)c	-0.0217 (19.44)	-0.0191 (25.22)
Time (quad) [Δt^2]	-0.00250379 (7.54)	-0.00183171 (10.76)
Cost (quad) [Δc^2]	-0.00004413 (9.73)	-0.00002208 (11.31)
Time Covariate [TΔt]	0.00009432 (1.03)	-0.00009288 (3.04)
Cost Covariate [CΔc]	0.00000359 (2.79)	0.00000367 (8.22)
Mean LL	-0.614272	-0.604248
No. Obs	4737	8038

Table E4b: Model M2b Quad on Incremental Time and Cost with Time and Cost Covariates (Reduced dataset)

	Commute	Other
Time (Δ)t	-0.09165370 (-10.71)	-0.05865445 (-10.60)
Cost (Δ)c	-0.02161538 (-19.18)	-0.01985033 (-24.80)
Time (quad) [Δt^2]	-0.00247510 (-7.34)	-0.00182951 (-10.51)
Cost (quad) [Δc^2]	-0.00004558 (-9.62)	-0.00002124 (-10.67)
Time Covariate [TΔt]	0.00004867 (0.51)	-0.00007563 (-2.33)
Cost Covariate [CΔc]	0.00000289 (2.23)	0.00000431 (8.43)
Mean LL	-0.613387	-0.601365
No. Obs	4583	7689.00

Table E5a: Model M6a Covariates For Time and Cost with Inertia

	Commute	**Other**
Time	-0.0859 (10.26)	-0.0415 (7.77)
Cost	-0.0190 (18.05)	-0.0168 (23.63)
Time Covariate TΔt	0.00013635 (1.51)	-0.00010833 (3.56)
Cost Covariate CΔc	0.00000529 (4.47)	0.00000354 (8.55)
Inertia	0.9091 (18.88)	0.9492 (25.33)
Mean LL	-0.590903	-0.577363
No. Obs	4737	8038

Table E5b: Model M6a Covariates For Time and Cost with Inertia (Reduced dataset)

	Commute	**Other**
Time	-0.08289360 (-9.64)	-0.04581517 (-8.16)
Cost	-0.01911334 (-17.66)	-0.01776737 (-23.35)
Time Covariate TΔt	0.00011917 (1.28)	-0.00008095 (-2.51)
Cost Covariate CΔc	0.00000523 (4.15)	0.00000430 (9.12)
Inertia	0.89980682 (18.39)	0.93565056 (24.40)
Mean LL	-0.590784	-0.575021
No. Obs	4583	7689

Table E6a: Model M6b Time Covariates on Time and Cost with Inertia

	Commute	Other
Time	-0.0838 (9.61)	-0.0420 (7.00)
Cost	-0.0192 (16.05)	-0.0164 (20.01)
Time Covariate TΔt	0.00011927 (1.19)	-0.00009689 (2.60)
Cost Covariate TΔc	0.00004349 (3.49)	0.00002580 (5.84)
Inertia	0.9084 (18.87)	0.9456 (25.27)
Mean LL	-0.591882	-0.579991
No. Obs	4737	8038

Table E6b: Model M6b Time Covariates on Time and Cost with Inertia (Reduced dataset)

	Commute	Other
Time	-0.08147943 (-9.20)	-0.04313235 (-7.03)
Cost	-0.01951090 (-15.88)	-0.01702623 (-19.98)
Time Covariate TΔt	0.00010911 (1.08)	-0.00009257 (-2.45)
Cost Covariate TΔc	0.00004454 (3.52)	0.00002774 (6.13)
Inertia	0.89979460 (18.39)	0.93294355 (24.39)
Mean LL	-0.591462	-0.578287
No. Obs	4583	7689

Table E7a: Model M6c Time Covariates on Cost Effect Only with Inertia

	Commute	Other
Time	-0.0763 (12.72)	-0.0544 (14.74)
Cost	-0.0185 (18.16)	-0.0176 (25.16)
Time Covariate TΔc	0.00003263 (4.08)	0.00003439 (11.68)
Inertia	0.9125 (19.01)	0.9363 (25.16)
Mean LL	-0.592029	-0.580421
No. Obs	4737	8038

Table E7b: Model M6c Time Covariates on Cost Effect Only with Inertia (Reduced dataset)

	Commute	Other
Time	-0.07457484 (-12.25)	-0.05510573 (-14.59)
Cost	-0.01885274 (-18.00)	-0.01816064 (-24.99)
Time Covariate TΔc	0.00003449 (4.22)	0.00003600 (11.91)
Inertia	0.90354911 (18.52)	0.92411423 (24.29)
Mean LL	4583	-0.578684
No. Obs	-0.591588	7689.00

Table E8a: Model M6d Cost Covariates on Cost Effect Only with Inertia

	Commute	Other
Time	-0.0772 (12.83)	-0.0544 (14.93)
Cost	-0.0185 (18.93)	-0.0176 (26.03)
Cost Covariate CΔc	0.00000414 (4.63)	0.00000439 (12.66)
Inertia	0.9134 (19.00)	0.9388 (25.17)
Mean LL	-0.591140	-0.578161
No. Obs	4737	8038

Table E8b: Model M6d Cost Covariates on Cost Effect Only with Inertia (Reduced dataset)

	Commute	Other
Time	-0.07522995 (-12.33)	-0.05629847 (-14.81)
Cost	-0.01859768 (-18.72)	-0.01849854 (-26.02)
Cost Covariate CΔc	0.00000415 (4.52)	0.00000503 (13.36)
Inertia	0.90379474 (18.51)	0.92815095 (24.30)
Mean LL	-0.590959	-0.575436
No. Obs	4583	7689.00

Table E9a: Model M6e Time Covariates on Time Effect Only with Inertia

	Commute	Other
Time	-0.0655 (8.99)	-0.0208 (4.40)
Cost	-0.0163 (19.41)	-0.0128 (25.74)
Time Covariate TΔt	-0.00016670 (2.36)	-0.00026024 (10.17)
Inertia	0.9178 (19.12)	0.9596 (25.73)
Mean LL	-0.593330	-0.582053
No. Obs	4737	8038

Table E9b: Model M6e Time Covariates on Time Effect Only with Inertia (Reduced dataset)

	Commute	Other
Time	-0.06258738 (-8.48)	-0.02034500 (-4.20)
Cost	-0.01648826 (-19.17)	-0.01309984 (-25.44)
Time Covariate TΔt	-0.00018301 (-2.57)	-0.00026706 (-10.23)
Inertia	0.90946085 (18.64)	0.94740698 (24.86)
Mean LL	-0.592994	-0.580663
No. Obs	4583.00	7689.00

Table E10a: M8 Preferred Base models with "perceived" time coefficient (θ = 11)

	Commute	Other
Time ("perceived") $\Delta\tau$	-0. 105646 (14.09)	-0. 086387 (20.52)
M	4.435129 (4.42)	8.202311 (7.45)
Cost	-0.016677 (18.77)	-0.01710 (27.71)
Cost Covariate $C\Delta c$	0.00000261 (3.29)	0.00000345 (9.98)
Inertia	0. 891382 (18.20)	0.964581 (25. 09)
Mean LL	-0. 582373	-0. 563342
No. Obs	4737	8038

Table E10b: M8 Preferred Base models with "perceived" time coefficient (θ = 11) (Reduced dataset)

	Commute	Other
Time ("perceived") $\Delta\tau$	-0.10492934 (-13.67)	-0.08663042 (-20.14)
M	4.65050291 (4.46)	8.13339431 (7.28)
Cost	-0.01680689 (-18.86)	-0.01779500 (-27.52)
Cost Covariate $C\Delta c/10000$	0.02518706 (3.16)	0.03936341 (10.45)
Inertia	0.88464046 (17.78)	0.95462388 (24.26)
Mean LL	-0.581887	-0.560830
No. Obs	4583	7689

Table E11a: Preferred Base Base Models with Income Group Co-variates

	Commute	Other
$\Delta\tau$	-0.10612858 (14.47)	-0.08711295 (20.58)
M	3.81217866 (4.01)	8.03239107 (7.44)
Theta	11.0 (fixed)	11.0 (fixed)
Δc	-0.02636637 (8.08)	-0.02006585 (19.48)
Inertia	0.90448704 (18.24)	0.97376061 (25.18)
$\Delta c.C/10000$	0.03127249 (3.50)	0.03304387 (9.42)
[Inc 2].Δc	0.00075848 (0.22)	0.00092210 (0.81)
[Inc 3].Δc	0.00773316 (2.35)	0.00222729 (1.92)
[Inc 4].Δc	0.01156933 (3.49)	0.00307729 (2.38)
[Inc 5].Δc	0.01044651 (3.03)	0.00764266 (6.07)
[Inc 6].Δc	0.01773847 (4.65)	0.00643388 (3.72)
[Inc 7].Δc	0.01866342 (5.20)	0.00866309 (6.19)
Observations	4737	8038
Final likelihood	-2712.72	-4488.90

Mean likelihood	-0.572667	-0.558460

Table E11b: Preferred Base Models with Income Group Co-variates (Reduced dataset)

	Commute	Other
$\Delta\tau$	-0.10576260 (-13.82)	-0.08746880 (-20.21)
M	4.16117342 (3.89)	7.98746617 (7.28
Theta	11.0 (fixed)	11.0 (fixed)
Δc	-0.02597705 (-8.01)	-0.02020417 (-19.15)
Inertia	0.89873249 (17.82)	0.96422314 (24.35)
$\Delta c.C/10000$	0.02918309 (3.34)	0.03720395 (9.59)
[Inc 2].Δc	0.00073215 (0.21)	0.00030282 (0.26)
[Inc 3].Δc	0.00718226 (2.18)	0.00128745 (1.05)
[Inc 4].Δc	0.01084389 (3.26)	0.00259597 (1.95)
[Inc 5].Δc	0.01040867 (3.03)	0.00740923 (5.74)
[Inc 6].Δc	0.01773629 (4.61)	0.00581496 (3.26)
[Inc 7].Δc	0.01852174 (5.17)	0.00801322 (5.50)
Mean LL	-0.572202	-0.555962
No. Obs.	4583	7689

Table E12a: Preferred Base Models with Income Group and Income Group*Cost Co-variates

	Commute	Other
$\Delta\tau$	-0.10548599 (14.80)	-0.08729417 (20.57)
M	3.47685946 (4.29)	7.90022459 (7.42)
Theta	11.0 (fixed)	11.0 (fixed)
Δc	-0.03039900 (7.02)	-0.01730675 (13.97)
Inertia	0.90720340 (18.25)	0.97583150 (25.19)
$\Delta c.C/10000$	0.08576244 (2.46)	0.00197654 (0.20)
[Inc 2].Δc	0.00429097 (0.92)	-0.00347192 (2.15)
[Inc 3].Δc	0.01287496 (2.92)	-0.00182912 (1.05)
[Inc 4].Δc	0.01214316 (2.64)	-0.00240781 (1.19)
[Inc 5].Δc	0.01347645 (2.85)	0.00787228 (4.13)
[Inc 6].Δc	0.01079284 (1.79)	0.00428815 (1.46)
[Inc 7].Δc	0.02034263 (3.89)	0.00579015 (2.79)
[Inc 2].$\Delta c.C/10000$	-0.04928925 (1.23)	0.04397773 (3.70)
[Inc 3].$\Delta c.C/10000$	-0.07651769 (2.10)	0.04164615 (3.19)
[Inc 4].$\Delta c.C/10000$	0.00896836 (0.21)	0.05306485 (3.64)
[Inc 5].$\Delta c.C/10000$	-0.03721282 (0.81)	0.00362669 (0.24)
[Inc 6].$\Delta c.C/10000$	0.29665614 (2.17)	0.02647882 (1.40)
[Inc 7].$\Delta c.C/10000$	-0.01014736 (0.16)	0.03180129 (2.13)
Observations	4737.	8038.
Final likelihood	-2698.81	-4474.89
Mean likelihood	-0.569730	-0.556716

Table E12b: Preferred Base Models with Income Group and Income Group*Cost Co-variates (Reduced dataset)

	Commute	Other
$\Delta\tau$	-0.10419794 (-14.21)	-0.08772618 (-20.21)
M	3.66068682 (4.03)	7.96174839 (7.28)
Theta	11.0 (fixed)	11.0 (fixed)
Δc	-0.03008952 (-6.97)	-0.01884990 (-13.24)
Inertia	0.90014168 (17.80)	0.96415372 (24.33)
Δc.C/10000	0.08500349 (2.44)	0.01959228 (1.43)
[Inc 2].Δc	0.00364780 (0.79)	-0.00231120 (-1.30)
[Inc 3].Δc	0.01258607 (2.85)	-0.00002555 (-0.01)
[Inc 4].Δc	0.01121848 (2.43)	-0.00107053 (-0.50)
[Inc 5].Δc	0.01346907 (2.85)	0.00923393 (4.53)
[Inc 6].Δc	0.00875537 (1.29)	0.00543411 (1.77)
[Inc 7].Δc	0.02013292 (3.85)	0.00725424 (3.30)
[Inc 2].Δc.C/10000	-0.03753644 (-0.95)	0.02752316 (1.80)
[Inc 3].Δc.C/10000	-0.08188237 (-2.21)	0.01700989 (0.99)
[Inc 4].Δc.C/10000	0.01210854 (0.28)	0.03613751 (2.07)
[Inc 5].Δc.C/10000	-0.03758123 (-0.82)	-0.01178484 (-0.66)
[Inc 6].Δc.C/10000	0.39118882 (2.14)	0.01059430 (0.50)
[Inc 7].Δc.C/10000	-0.00877970 (-0.14)	0.01236806 (0.70)
Mean LL	-0.568979	-0.555057
No. Obs	4583	7689.00

Table E13a: Preferred Base Models with Income and Income*Cost Co-variates

	Commute	Other
$\Delta\tau$	-0.10654543 (14.43)	-0.08717604 (20.61)
M	3.89331958 (4.00)	8.03403697 (7.46)
Theta	11.0 (fixed)	11.0 (fixed)
Δc	-0.02583073 (13.81)	-0.02107306 (21.03)
Inertia	0.90467384 (18.26)	0.97335445 (25.19)
Δc C/10000	-0.00688166 (0.31)	0.03010628 (4.98)
Income.Δc	0.00025105 (5.03)	0.00014679 (5.14)
Income.Δc.C/10000	0.00140301 (1.87)	0.00009572 (0.51)
Observations	4737.	8038.
Final likelihood	-2716.16	-4492.28
Mean likelihood	-0.573393	-0.558881

Table E13b: Preferred Base Models with Income and Income*Cost Co-variates (Reduced dataset)

	Commute	Other
$\Delta\tau$	-0.10600962 (-13.80)	-0.08736918 (-20.21)
M	4.22604861 (3.93)	7.96948549 (7.28)
Theta	11.0 (fixed)	11.0 (fixed)
Δc	-0.02521554 (-14.38)	-0.02209388 (-21.61)
Inertia	0.89846004 (17.83)	0.96269945 (24.33)
Δc C/10000	0.00043306 (0.02)	0.04170669 (6.26)
Income.Δc	0.00022844 (5.04)	0.00015716 (5.99)
Income.Δc.C/10000	0.00104787 (1.49)	-0.00017005 (-0.95)
Mean LL	-0.573041	-0.556666
No. Obs	4583.00	7689.00

Table E14a: Elasticity Models

	Commute	Other
$\Delta\tau$	-0.10329483 (15.61)	-0.08241236 (19.64)
M	2.09391119 (6.37)	6.96901854 (6.72)
Theta	11.0 (fixed)	11.0 (fixed)
Δc	-0.02441488 (15.12)	-0.02208297 (18.60)
Inertia	0.90018351 (18.10)	0.96634915 (24.92)
Income Elasticity	-0.36636803 (7.80)	-0.15725053 (5.58)
Distance Elasticity	-0.40946336 (9.29)	-0.31718139 (12.16)
Observations	4737	8038
Final likelihood	-2690.98	-4474.80
Mean likelihood	-0.568078	-0.556706

Table E14b: Elasticity Models (Reduced dataset)

	Commute	Other
$\Delta\tau$	-0.10098040 (-15.07)	-0.08291784 (-19.33)
M	2.14015281 (6.02)	7.06711097 (6.63)
Theta	11.0 (fixed)	11.0 (fixed)
Δc	-0.02472923 (-14.84)	-0.02227485 (-18.51)
Inertia	0.89235685 (17.65)	0.95544259 (24.08)
Income Elasticity	-0.35877551 (-7.58)	-0.15680538 (-5.49)
Distance Elasticity	-0.42130442 (-9.08)	-0.31472703 (-11.86)
Mean LL	-0.567479	-0.555104
No. Obs	4583	7689

Table E15a: Base Models with 'Passenger' Co-variates

	Commute	Other
□□	-0.10609782 (-14.10)	-0.08918268 (-20.20)
M	4.39669627 (4.43)	8.13959918 (7.51)
Theta	11.0000000 (fixed)	11.0000000 (fixed)
Δc	-0.01673165 (-18.69)	-0.01714032 (-27.73)
Inertia	0.89110680 (18.20)	0.96336218 (25.05)
Δc.C/10000	0.02703946 (3.30)	0.03477317 (10.03)
[Passenger].Δτ	0.02114047 (0.67)	0.01967549 (2.23)
Mean LL	-0.582327	-0.563034
No. Obs	4737	8038

Table E15b: Base Models with 'Passenger' Co-variates (Reduced dataset)

	Commute	Other
□□	-0.10530576 (-13.67)	-0.08948089 (-19.81)
M	4.61756120 (4.46)	8.08974998 (7.34)
Theta	11.0 (fixed)	11.0 (fixed)
Δc	-0.01685013 (-18.79)	-0.01784392 (-27.54)
Inertia	0.88440760 (17.77)	0.95337053 (24.21)
Δc.C/10000	0.02593408 (3.17)	0.03976270 (10.52)
[Passenger].Δτ	0.01745750 (0.55)	0.01954785 (2.20)
Mean LL	-0.581855	-0.560516
No. Obs	4583	7689

APPENDIX F
DIFFERENCES BETWEEN COMMUTING AND OTHER

In the main analysis we have kept the Commuting and Other samples separate, and there is clearly sufficient data and difference of coefficients to justify this treatment. Nevertheless, the differences in VoT are not especially large, and there is therefore some value in considering a pooled data set, while allowing for possible variations.

The combined model produces a VoT of 4.08: the distance elasticity has fallen, while the income elasticity is in between the estimates for the two separate purposes. Compared with the separate models, the log-likelihood has fallen by 27.9 points.

	Commute	Other	Combined
$\Delta\tau$	-0.10098	-0.082918	-0.086344
Δc	-0.024729	-0.022275	-0.021142
Income Elasticity	-0.358773	-0.156806	-0.222585
Distance Elasticity	-0.421305	-0.314727	-0.307487
Observations	4583	7689	12272
Final likelihood	-2600.76	-4268.19	-6896.82
VoT	4.08	3.72	4.08

Investigations to see whether a difference in VoT could be found, and whether it resided mainly in the cost or time coefficient, concluded that the time coefficients were significantly different, and the cost coefficients were not. This preferred model is shown below: in the second model the first time coefficient relates to Commuting and the second to Other.

	Combined	Combined
$\Delta\tau$	-0.086344	-0.108653 / -0.079302
Δc	-0.021142	-0.022044
Income Elasticity	-0.222585	-0.207496
Distance Elasticity	-0.307487	-0.33088
Observations	12272	12272
Final likelihood	-6896.82	-6886.53
VoT	4.08	4.93 / 3.60

This has increased the log-likelihood by 10 points, and has magnified the difference between the commuting and other values of time (Commuting is now 37% higher). Some of this is likely to be due to the "averaging" of the perception function, which for Other was much steeper than for commuting.

Since these results are indicative, but raise some problems, it seems best to continue to separate the two purposes. A more comprehensive analysis is set out in the Annex to this Appendix.

ANNEX TO APPENDIX F

Tables F1 and F2 show new elasticity models for commuters and other traffic respectively. A new base model is calibrated on a censored dataset (see Appendix E)

- Model 1 shows the elasticity model where small time changes are omitted (|Δt| is 5 minutes or under), while fixing the m and theta (perception) coefficients.
- Model 2 shows a repeat of Model 1 without perception formulation (theta=0, m=1).
- Model 3 shows a repeat of Model 2, further dropping all cases where |Δt| is 10 minutes or under

Table F1: Commuting Elasticity Models

	New Base	Model 1	Model 2	Model 3
$\Delta\tau$	-0.10098028 (-15.07)	-0.09157338 (-12.26)	-0.08604907 (-12.17)	-0.08596690 (-7.53)
M	2.14016040 (6.02)	2.14016040 (Fixed)	1.0 (Fixed)	1.0 (Fixed)
Theta	11.0 (Fixed)	11.0 (Fixed)	0.0 (Fixed)	0.0 (Fixed)
Δc	-0.02472920 (-14.84)	-0.02077288 (-9.55)	-0.02123821 (-9.57)	-0.01234485 (-3.79)
Inertia	0.89235711 (17.65)	0.91533156 (11.22)	0.90795276 (11.14)	0.92699543 (5.22)
Income Elasticity	-0.35877286 (-7.58)	-0.34834642 (-5.34)	-0.34536295 (-5.31)	-0.20804479 (-1.56)
Distance Elasticity	-0.42130502 (-9.08)	-0.34373634 (-5.59)	-0.35958761 (-5.86)	-0.09872048 (-0.86)
Observations	4583	1841	1841	375
Final likelihood	-2600.76	-1082.29	-1084.28	-213.67
Mean likelihood	-0.567479	-0.587879	-0.588960	-0.569783

Table F2: 'Other' Elasticity Models

	New Base	Model 1	Model 2	Model 3
$\Delta\tau$	-0.08291787 (-19.33)	-0.07430024 (-16.74)	-0.06223869 (-15.60)	-0.07040395 (-12.79)
M	7.06710553 (6.63)	7.06710553 (Fixed)	1.0 (Fixed)	1.0 (Fixed)
Theta	11.0 (Fixed)	11.0 (Fixed)	0.0 (Fixed)	0.0 (Fixed)
Δc	-0.02227485 (-18.51)	-0.01610565 (-11.34)	-0.01795949 (-11.38)	-0.01414651 (-6.70)
Inertia	0.95544248 (24.08)	0.93824542 (17.49)	0.89302107 (16.84)	0.83394686 (8.94)
Income Elasticity	-0.15680613 (-5.49)	-0.21489450 (-5.96)	-0.21136199 (-5.91)	-0.22151781 (-4.18)
Distance Elasticity	-0.31472687 (-11.86)	-0.22500002 (-6.30)	-0.27799765 (-7.93)	-0.20933437 (-3.78)
Observations	7689	4079	4079	1370
Final likelihood	-4268.19	-2348.04	-2372.70	-817.35
Mean likelihood	-0.55510	-0.575641	-0.58168	-0.596604

Table F3 shows a set of models calibrated on a combined commuting and other traffic.

Model 4 shows a separate coefficient on perceived time ($\Delta\tau$ for commuters and other traffic. These coefficients are significantly different from each other (t-statistic of 4.48).
Model 5 shows a separate coefficient on cost for commuters and other traffic. These coefficients are not significantly different from each other (t-statistic of 1.79).
Model 6 shows separate coefficients on time and cost for commuters and other traffic. The time coefficients are significantly different (t-statistic of 3.61) from each other and the cost coefficients are not significantly different (t-statistic of 0.06) from each other.

Table F3: Combined Commuting and 'Other' Elasticity Models

	New Base	Model 4	Model 5	Model 6
Δτ (both)	-0.08634439 (-23.26)	n.a	-0.08689512 (-23.31)	n.a
Δτ (commute)	n.a	-0.10865341 (-16.94)	n.a	-0.10838815 (-15.04)
Δτ(other)	n.a	-0.07930172 (-19.88)	n.a	-0.07941134 (-18.84)
M	5.17491657 (7.20)	5.22298956 (6.94)	5.25024579 (7.21)	5.22834869 (6.92)
Theta	11.0 (Fixed)	11.0 (Fixed)	11.0 (Fixed)	11.0 (Fixed)
Δç(both)	-0.02114225 (-24.20)	-0.02204423 (-23.89)	n.a	n.a
Δç(commute)	n.a	n.a	-0.02015037 (-21.77)	-0.02199452 (-19.83)
Δç(other)	n.a	n.a	-0.02281782 (-20.56)	-0.02209358 (-19.92)
Inertia	0.93273513 (29.93)	0.92934082 (29.76)	0.93232578 (29.90)	0.92937991 (29.75)
Income Elasticity	-0.22258471 (-9.33)	-0.20749597 (-8.62)	-0.20137963 (-8.10)	-0.20691941 (-8.24)
Distance Elasticity	-0.30748691 (-13.64)	-0.33087983 (-14.29)	-0.32441787 (-14.03)	-0.33120699 (-14.09)
Observations	12272	12272	12272	12272
Final likelihood	-6896.82	-6886.53	-6893.14	-6886.53
Mean likelihood	-0.561996	-0.561158	-0.561697	-0.561158

Table F4 show the specification for models 1 to 3 estimated to a joint commute/other dataset. The new base model is taken as model 4.

Model 7 shows the same specification as Model 1.
Model 8 shows the same specification as Model 2.
Model 9 shows the same specification as Model 3.

Table F4: Combined Commuting and 'Other' Elasticity Models

	New Base (Model 4)	Model 7	Model 8	Model 9
Δτ(both)	n.a	n.a	n.a.	n.a
Δτ(commute)	-0.10865341 (-16.94)	-0.09548934 (-14.63)	-0.07998263 (-14.63)	-0.08424104 (-10.36)
Δτ (other)	-0.07930172 (-19.88)	-0.07391970 (-18.19)	-0.06394029 (-17.40)	-0.07123162 (-13.83)
M	5.22298956 (6.94)	5.22298956 (Fixed)	1.0 (Fixed)	1.0 (Fixed)
Theta	11.0 (Fixed)	11.0 (Fixed)	0.0 (Fixed)	0.0 (Fixed)
Δç(both)	-0.02204423 (-23.89)	-0.01754626 (-14.88)	-0.01912727 (-14.92)	-0.01374300 (-7.80)
Δç(commute)	n.a	n.a	n.a	n.a
Δç(other)	n.a	n.a	n.a	n.a
Inertia	0.92934082 (29.76)	0.92688201 (20.72)	0.89577486 (20.16)	0.85699527 (10.40)
Income Elasticity	-0.20749597 (-8.62)	-0.23468073 (-7.63)	-0.23024348 (-7.54)	-0.22197666 (-4.57)
Distance Elasticity	-0.33087983 (-14.29)	-0.25854923 (-8.63)	-0.30380141 (-10.24)	-0.18978334 (-3.89)
Observations	12272	5920	5920	1745
Final likelihood	-6886.53	-3436.40	-3460.56	-1031.54
Mean likelihood	-0.561158	-0.580473	-0.584553	-0.591143

APPENDIX G
SENSITIVITY OF AVERAGE VTTS TO MODES USED FOR WEIGHTING

In this Appendix we provide some results from changing the modal composition of the NTS sample used to weight the data. The same vot model is being used throughout, making no distinction by mode (incl driver/passenger). It would of course be possible to use the model which distinguishes driver and passenger, but this has not been done here.

The different results merely reflect the NTS data which is used to calculate the average.

[AHCG based model]

all modes

	Trip-weighted	Mileage-weighted
Commuting	3.95	6.58
Other	3.25	5.88

all car

	Trip-weighted	Mileage-weighted
Commuting	3.90	6.41
Other	3.28	5.83

drivers only

	Trip-weighted	Mileage-weighted
Commuting	4.03	6.52
Other	3.27	5.79

[Meta Analysis Model]

all modes

	Trip-weighted	Mileage-weighted
Commuting	4.16	5.93
Other	3.44	6.20

all car

	Trip-weighted	Mileage-weighted
Commuting	4.13	5.86
Other	3.43	6.12

drivers only

	Trip-weighted	Mileage-weighted
Commuting	4.21	5.91
Other	3.41	6.01

Generally, there is virtually no effect from the change of "base" for weighting. Note, however, that the mileage-weighted values from the Meta-analysis are higher for Other than for Commuting. This is because the cross-sectional income effect is ignored in this model..

APPENDIX H
CONCLUSIONS OF DR COOMBE'S REPORT ON PRACTICALITIES

"Modelling issues"

My conclusions about the practicality of including variations in the value of time more extensively in current models are as follows.

- allowing for variations in the value of time by journey length and/or income will require further segmentation of the demand.
- while segmentation by crow-fly distance is straightforward, segmentation by income is not. In some circumstances, the available data on income distribution may be quite misleading if assumed to apply to the movements under study.
- an easier alternative is to segment the car non-work matrix into a number of equal segments and assign a mean value of time to each so that, taken together, the mean values represent the distribution of the value of time. This is common practice in toll road studies and accords with the advice given by the DTLR for the appraisal of charging proposals.
- the implication of adopting any of these approaches is that model run times will increase substantially, especially the run times of the road traffic assignment models. If segmentation by both crow-fly distance and income was required, the impacts on computing times could be very substantial. Faster computers will make it easier to accommodate the longer run times, but we should not forget that there may be other model enhancements which may make better use of any increased computing power.
- increased demand segmentation will mean that the Department ought to disaggregate its elasticity values published in DMRB Volume 12.2.2, for consistency.
- adoption of locally determined values of time could lead to some inconsistencies between studies and models in the treatment of trips which are common to both areas.
- it is straightforward to allow variations in the value of time by mode in conventional models based on generalised cost or time. If the values by mode also vary by purpose, segmentation and treatment of the demand by purpose would be required.

Data issues

My conclusions about the data issues associated with changes to the treatment of the value of time are that:

- while segmentation of demand by crow-fly distance will not affect the statistical quality of the resulting matrices, segmentation by income or value of time will reduce the reliability of the cell values in the new matrices;
- it is practical to determine variations in the value of time by distance and income, and variations in the value of time between modes, and local distributions of the values of time, through the use of stated preference experiments, but quality and consistency between studies would be a real concern; and
- it is possible to envisage an approach by which the Department could exert some control over quality, in which the Department:
    - publishes national relationships between the value of time and distance;
    - publishes more formally its national distribution of the value of time; and
    - provides some indicators which vary by region which can be used to modify these two relationships.

My concerns about the widespread use of stated preference experiments to determine local values of time are that:

- the expertise required to conduct stated preference experiments properly may not always be available;
- stated preference experiments are open to abuse by promoters with a case to enhance; and
- some considerable resource would be required by the Department to 'police' the derivation of local values.

Appraisal issues

My conclusions about appraisal issues associated with changes to the treatment of the value of time are that:

- it is feasible to use increased numbers of demand segments and associated matrices of the elements of generalised cost in TEE appraisal conducted using TUBA (no amendment of the software would be necessary), although users may be concerned about the increased complexity and there may be more scope for errors to be made;
- the scope for bias, either intentional or unintentional, to creep into appraisals which are based on entirely locally-determined values of time is considerable and would require a substantial effort on the part of the Department if it were to attempt any degree of rigorous monitoring and audit of appraisals; and
- the correct extraction of costs for appraisal remains an over-riding and under-appreciated concern.
-

Forecasting issues

My conclusions about the forecasting issues associated with changes to the treatment of the value of time are that:

- no forecasting issues arise with segmentation by crow-fly distance;
- changes in distribution of income over time appear to be very difficult to forecast;
- changes in the distribution of the value of time over time also appears to be very difficult to forecast;
- adoption of modal values of time to reflect comfort/quality aspects will require assumptions to be made about comfort/quality by mode for future year reference cases; and
- there are some quite fundamental dilemmas involving the way in which changes in generalised cost parameters are handled in spatially-detailed multi-modal models which are, as yet, unresolved.

Overall conclusions

My overall reactions to the propositions I was asked to consider are as follows:

- as a matter of principle, segmentation by value of time is preferable to segmentation by crow-fly distance or income;
- models which include segmentation on non-work purposes by the value of time are practical now, although the increased run times is an issue to consider; and
- this kind of approach is most needed where changes in significant money charges are being considered – road tolls, congestion charges, parking charges and public transport fares; but
- the derivation of suitable local values of time needs care and external validation to avoid intentional or unintentional bias; and although

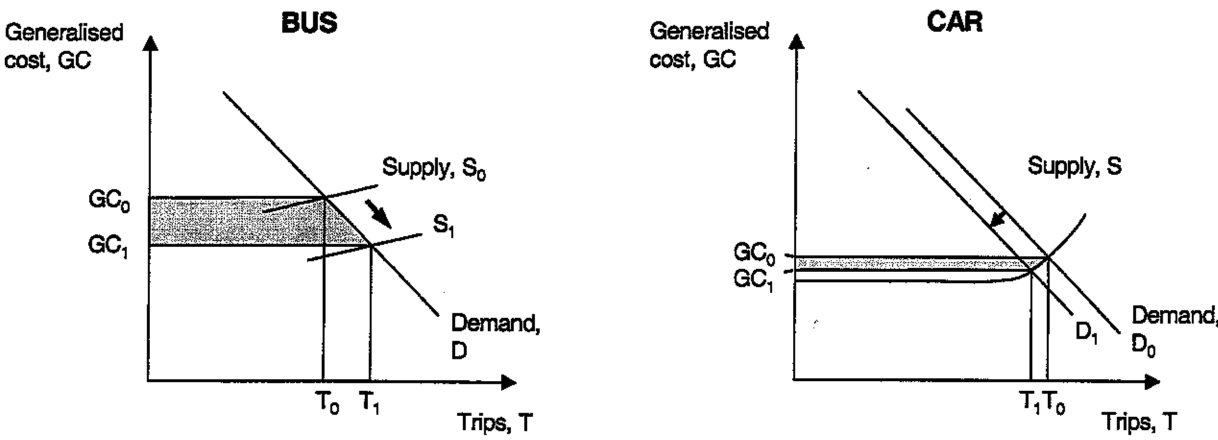
- no special issues of practicality arise with the appraisal;
- forecasting the change in the distribution of the value of non-working time over time is *not straightforward.*

Variations in the value of in-vehicle time to account for differences in comfort/quality can be accommodated".

APPENDIX J
USING MODAL VALUES IN APPRAISAL

Consider a case where there are two modes available, car and bus. The project reduces bus time by Δt, which attracts some travel from car, leading in turn to some reduction in congestion.

Figure 13 User Benefits with simultaneous cost changes



Using the standard GOMMMS/TUBA algebra (DETR, 2000), user time benefits are calculated as:

$$\frac{1}{2}\sum_{ijm}\left(T_{ijm}^{0}+T_{ijm}^{1}\right)\left(G_{ijm}^{0}-G_{ijm}^{1}\right)$$

where $G_{ijm}^{s}=v_m t_{ijm}^{s}+c_{ijm}^{s}$

superscript s indicates the scenario (0=do-minimum; 1= do-something);
T_{ijm} is the number of trips between zones i and j by mode m;
G_{ijm} is the generalised cost of travel between zones i and j by mode m;
t_{ijm} is the travel time between zones i and j by mode m;
c_{ijm} is the money cost between zones i and j by mode m;
v_m is the value of travel time savings (VTTS), to which the subscript m has been added to indicate modally-differentiated values.

It can be seen from the function above that using a different v for each mode cannot affect the sign of the benefits *on that mode*. The project as described leads to a benefit to bus users (valued using the bus VTTS) and a benefit to car users (valued using the car VTTS). The usual algebra implies that those who switch from car to bus get half the benefit on the car mode and half the benefit on the bus mode.

Note also that if we improved *both* modes simultaneously by Δt, we would expect some shift to mode m, since the time improvement counts for more on mode m: this seems logical.

As another example, assuming that $[v_{Bus}/v_{Car}] > 1$, suppose that we improve the quality of the bus so that after the scheme is introduced $[v'_{Bus}/v_{Car}] = 1$. This improvement will attract new custom, and if t_{Bus} is the bus travel time, the implied benefit in money terms is t_m [VoT_{Bus} – vot_{car}] > 0. Once again, the valuation of benefits is consistent with the demand response.