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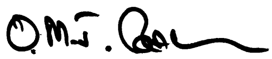
Signature	

FOREWORD

This is one of a series of papers prepared under DETR contract PPAD9/65/79, 'Revising The Values of Work and Non-Work Time Used for Transport Appraisal and Modelling'.

The views expressed in these papers are those of the authors and do not necessarily reflect the views of the DETR (now DTLR).

Working Papers 561-566 were originally prepared in May 2001 and formed the basis for Working Paper 567 which reports on the evidence and was prepared in August 2001. Working Papers 568 and 569 on policy and practicality were written subsequently.

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Working Papers

561 Size and Sign of Time Savings
562 Principles of Valuing Business Travel Time Savings
563 Values of Time for Road Commercial Vehicles
564 Public Transport Values of Time
565 Variations in the Value of Time by Market Segment
566 Intertemporal Variations in the Value of Time
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568 The Standard Value of Non-Working Time and Other Policy Issues (provisional)
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1 INTRODUCTION

The conventional approach in the U.K. has been to value all travel time changes at a constant rate regardless of their size or direction. This 'constant unit value' approach was supported by the 1980-86 UK DoT Value of Time Study (MVA/ITS/TSU, 1987). However, there has always remained a vocal body of opinion critical of this approach (see Welch and Williams, 1997, for references and discussion). Some of the main objections have been the following:

i. small amounts of time are less useful than large amounts;

ii. small time savings (or losses) might not be noticed by travellers and any that are not noticed cannot be valued by those affected and so should not be valued by society;

iii. small time savings are said to often account for a large proportion of scheme benefits, so that small errors in measurement might mean that the scheme is really of no benefit to anyone;

iv. allowing small time savings to have 'full' value is said to inflate the measured total of benefits and so lead to schemes (often road schemes) being wrongly found to have sufficient net benefit to justify implementation;

v. time savings are less highly valued than are time losses, according to surveys, and so should have a lower unit value when evaluating schemes.

Both aspects relate to the possible non-constancy of the value of time for a given journey made for a given purpose (clearly, it is much less controversial, and indeed standard practice, to allow for variation by purpose and traveller type).

The practical difficulties are twofold. On the one hand, it is difficult to overcome the lay reaction that small time savings have little or no value, as well as the feeling that losses are more important than gains. On the other hand, if these points have any empirical relevance, they cause major problems for the cost-benefit calculus, as losses and gains will not cancel out, and time savings cannot be directly aggregated.

Although they do not recommend that values differentiated by size and sign should be used **for appraisal**, the HCG/Accent (1999) Report (AHCG) notes that [p 259]

> For any level of variation around the original journey time, gains (savings) are valued less than losses. For non-work related journeys, a time savings of five minutes has negligible value.

A recent paper by Gunn (2001) notes that corroborative results are available from a re-analysis of the 1988 Dutch value of Time study.

For reasons which will be carefully rehearsed in this paper, we do not believe that the conclusion on the differences between gains and losses is safe. This is based on an extensive re-analysis of the AHCG data. We have found it harder to reach a conclusion on the issue of small time savings, we agree with AHCG that their data undoubtedly implies a lower valuation: we have some concerns, nonetheless, as to the interpretation which should be placed on this.

2 PRELIMINARIES

2.1 The data

AHCG have helpfully provided us with the original documented datasets, which we have accessed without difficulty. In this report, we have concentrated entirely on Experiment 1, which is the main source of the AHCG findings. Table 1 describes the data.

Table 1: The Data Sets

	Observations Before Processing	Observations After Processing
Business (B1.DAT)	11427	9557
Commuting (C1.DAT)	6031	4737
Other (O1.DAT)	10399	8038

For each data set, observations were rejected by AHCG in their analysis according to the following conditions:

- if total journey cost <10 pence
- if total journey time <10 minutes
- if total journey cost < absolute value of cost change (A) in SP design
- if total journey time < absolute value of time change (A) in SP design
- if total journey cost < absolute value of cost change (B) in SP design
- if total journey time < absolute value of time change (B) in SP design
- if time on motorway/total journey time is negative (sic)
- if time on trunk roads/ total journey time is negative (sic)

We have not queried the basis for these exclusions, though we consider them generally sensible, and we have also shown for a number of models that the overall results do not appear to be greatly affected by different approaches to exclusions.

2.2 The Basic Model

Confining our analysis to the data set after exclusions, we have reproduced 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

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 are estimated using GAUSS software (Aptech Systems, Inc, Maple Valley, WA 1996).

As shown in Table 2, 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 2: 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.

2.3 Non-Linear Formulations

Both the sign and size issues impact on the linearity of the model, although their effect is different. We note, of course, that there are other factors (which we refer to as "co-variates") related to the journey and the traveller which will impact on the value of time: in general, these are not our concern here. However, because within the AHCG design the size of time and cost changes is sensibly related to the time and cost of the current journey, we have in many places estimated the effect of these "journey co-variates". Further analysis of co-variates is the subject of a later part of the study.

We therefore investigated three straightforward alternatives to the linear model M1:

(quadratic) $U_{ikj} = \beta_c . c_{ikj} + \beta_{c2} . c_{ikj}^2 + \beta_t . t_{ikj} + \beta_{t2} . t_{ikj}^2$ (M2)

(power) $U_{ikj} = \beta_c . c_{ikj}^{\delta} + \beta_t . t_{ikj}^{\gamma}$ (M3)

(log cost) $U_{ikj} = \beta_c . \ln(c_{ikj}) + \beta_t . t_{ikj}$ (M4)

Once we move to a non-linear formulation, the value of time is not constant, and we need to make assumptions about the values which we assume for the time and cost elements. In doing this, we generally make use of the mean times and costs for the current journeys over the sample of interest, as given in Table 3 below. Note that this is a different convention from the "reference journey" used by AHCG (p 171), which takes 30 minutes and costs £2, and is the same for all purposes.

Table 3: Mean current journey time and cost for estimation sample

	Business	Commute	Other
Time (minutes)	99.7	46.1	81.7
Cost (pence)	822.9	301.5	623.4

The results for the 3 models (M2, M3, M4) are presented in Tables 4a-c: Model M1 is repeated for purposes of comparison.

Table 4a: Non-Linear Utility Specifications (Business Travel)

Coefficient	**Linear (M1)**	**Quadratic (M2)**	**Power (M3)**	**Ln Cost (M4)**
Time	-0.07797 (26.30)	-0.06799 (15.61)	-0.03632 (4.56)	-0.0439 (19.72)
Cost	-0.00754 (24.51)	-0.00911 (20.64)	-0.04403 (3.89)	-1.5732 (16.42)
Time (quad) [t^2]		-0.000046 (3.42)		
Cost (quad) [c^2]		0.000000588 (4.36)		
Time (power) [γ]			1.14473 (29.76)	
Cost (power) [δ]			0.78060 (23.51)	
VOT (at mean)	10.33 (36.61)	9.47 (?)	10.27 (?)	23.0 (?)
Mean LL	-0.649687	-0.646347	-0.643674	-0.667525
No.Obs.	9557	9557	9557	9557
Algorithm	Newton	Newton	BHHH	Newton

Table 4b: Non-Linear Utility Specifications (Commuting)

Coefficient	**Linear (M1)**	**Quadratic (M2)**	**Power (M3)**	**Ln Cost (M4)**
Time	-0.08242 (14.19)	-0.08762 (10.90)	-0.05647 (3.28)	-0.04066 (8.52)
Cost	-0.01632 (19.74)	-0.01825 (18.37)	-0.10127 (3.58)	-1.89321 (15.80)
Time (quad) [t^2]		0.00003184 (0.71)		
Cost (quad) [c^2]		0.000001882 (3.53)		
Time (power) [γ]			1.09328 (18.08)	
Cost (power) [δ]			0.73871 (17.19)	
VOT(at mean)	5.05 (21.24)	4.95 (?)	5.06 (?)	6.48 (?)
Mean LL	-0.636065	-0.6341131	-0.629175	-0.657660
No.Obs.	4737	4737	4737	4737
Algorithm	Newton	Newton	BHHH	Newton

Table 4c: Non-Linear Utility Specifications (Other)

Coefficient	**Linear (M1)**	**Quadratic (M2)**	**Power (M3)**	**Ln Cost (M4)**
Time	-0.05445 (15.31)	-0.04455 (8.73)	-0.02891 (3.30)	-0.01325 (4.71)
Cost	-0.01219 (25.36)	-0.01595 (23.67)	-0.13087 (4.86)	-2.24621 (20.44)
Time (quad) [t^2]		0.0000524 (3.50)		
Cost (quad) [c^2]		0.000001515 (7.83)		
Time (power) [γ]			1.13422 (21.53)	
Cost (power) [δ]			0.69658 (25.64)	
VOT(at mean)	4.47 (22.20)	3.78 (?)	4.58 (?)	3.68 (?)
Mean LL	-0.632679	-0.623004	-0.618773	-0.652490
No.Obs.	8038	8038	8038	8038
Algorithm	Newton	Newton	BHHH	Newton

For all three data sets the power function model yields the best fit, followed by the quadratic, linear and the logarithmic specifications. This suggests that there are significant non-linear effects with regard to journey time and cost. The estimated coefficients for the power and quadratic specifications show that respondents with higher journey times and costs have higher values of time, as was established by AHCG. This is also true for the logarithmic specification of the model, but the logarithmic specification of cost does not generate an improvement in fit.

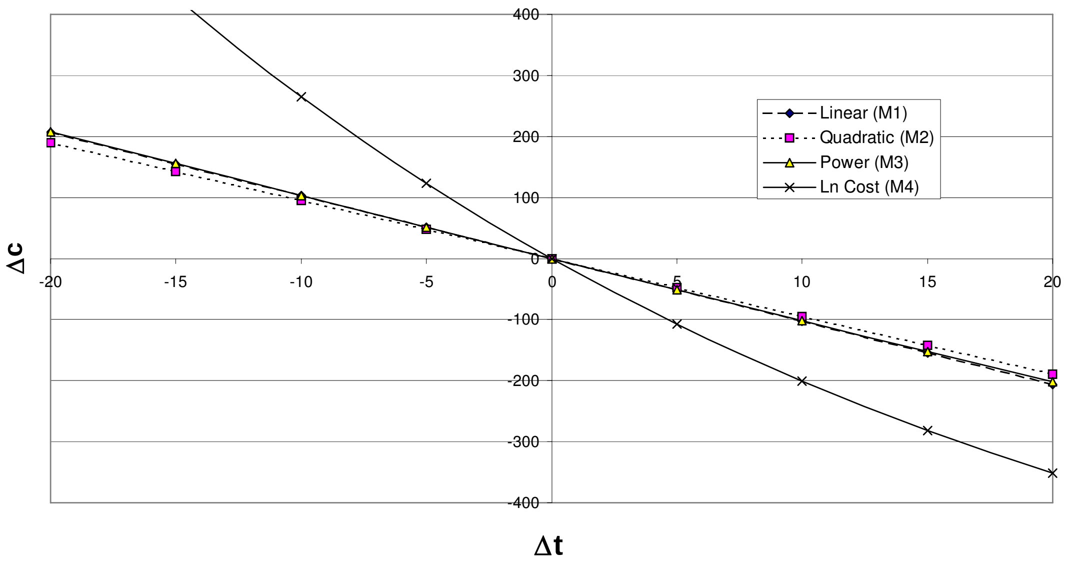
Note that this is contrary to what we might expect, based on the conclusions of Gunn (2001), where he provides strong evidence from Revealed Preference analysis for a "log-cost" utility specification, particularly in the case of mode and destination choice models. Further models were specified in which Time and Cost, and Time alone, were specified in logarithmic form but neither led to an improvement in fit over the linear specification, as shown in Table 5.

Table 5: Average log-likelihood with logarithmic transformations

	Business	Commute	Other
Linear	-0.649687	-0.636065	-0.632679
Ln Cost	-0.667525	-0.657660	-0.652490
Ln Time	-0.685138	-0.656170	-0.647576
Ln Cost Ln Time	-0.679975	-0.660995	-0.653165

We can plot the implied indifference curves for these formulations, around the average current journey.

Figure 1: Indifference Curves for Business Non-Linear formulations



However, although we have based the models on the implied actual time and costs associated with the different SP options, this is not, in fact, how the data was presented to the respondents. All the variations in time and cost in the SP experiment are described as changes to the current journey, in other words as Δt and Δc. If T_i and C_i are the time and cost values for the current journeys, then the models reported above have been estimated using:

$t_{ikj} = T_i + \Delta t_{ikj}$; $c_{ikj} = C_i + \Delta c_{ikj}$

For a linear model, this is immaterial, since we can develop (M1) as

$$U_{ikj} = \beta_c.c_{ikj} + \beta_t.t_{ikj}$$
$$= \beta_c.(C_i + \Delta c_{ikj}) + \beta_t.(T_i + \Delta t_{ikj})$$
$$= [\beta_c.C_i + \beta_t.T_i] + \beta_c.\Delta c_{ikj} + \beta_t.\Delta t_{ikj} \qquad \text{(M1')}$$

Since the term in square brackets is the same for all options faced by individual i, it has no impact on the utility formulation, so that the "absolute" and "incremental" utility specifications are the same model (M1).

When we move to the quadratic formulation, however, this is no longer the case. If we develop (M2) in the same way, we obtain:

$$U_{ikj} = [\beta_c.C_i + \beta_{c2}.\ C_i^2 + \beta_t.T_i + \beta_{t2}.\ T_i^{\ 2}]$$

$$+ \beta_c.\ \Delta c_{ikj} + \beta_{c2}.(\Delta c_{ikj})^2 + 2.\beta_{c2}.C_i\ .\Delta c_{ikj} + \beta_t.\ \Delta t_{ikj} + \beta_{t2}.(\ \Delta t_{ikj})^2 + 2.\beta_{t2}.T_i\ .\Delta t_{ikj} \quad \text{(M2')}$$

Although once again the square bracket term can be dropped, what remains is not the same as an equivalent quadratic "incremental" form, which would be:

$$U_{ikj} = \beta_c.\ \Delta c_{ikj} + \beta_{c2}.(\Delta c_{ikj})^2 + \beta_t.\ \Delta t_{ikj} + \beta_{t2}.(\ \Delta t_{ikj})^2 \qquad \text{(M2a)}$$

This is therefore a **different** model. Moreover, while (M2) is seen to have "cross-product" terms of the form T.Δt, etc, these are effectively **constrained** to have the coefficient $2.\beta_{t2}$ etc, implying that there is yet another quadratic variant without this constraint:

$$U_{ikj} = \beta_c.\ \Delta c_{ikj} + \beta_{c2}.(\Delta c_{ikj})^2 + \beta_{c3}.C_i\ .\Delta c_{ikj} + \beta_t.\ \Delta t_{ikj} + \beta_{t2}.(\Delta t_{ikj})^2 + \beta_{t3}.T_i\ .\Delta t_{ikj} \qquad \text{(M2b)}$$

Fitting the incremental Model (M2a) produces a very different result, as shown in Table 6:

Table 6: M2a Quadratic on Incremental Time and Cost

	Business	Commute	Other
Time (Δ)t	-0.0842 (27.57)	-0.0903 (14.72)	-0.0668 (17.55)
Cost (Δ)c	-0.0086 (25.32)	-0.0202 (20.59)	-0.0154 (25.67)
Time (quad) [Δt^2]	-0.001363 (10.55)	-0.0025319 (7.76)	-0.00173329 (10.53)
Cost (quad) [Δc^2]	-0.00001022 (10.74)	-0.00004754 (10.68)	-0.00002547 (12.17)
Average LL	-0.637375	-0.615510	-0.614007
No. Obs	9557	4737	8038

For all purposes, the LL increases significantly and it can be shown that the model demonstrates much more curvature, as shown by the increased magnitude of the quadratic terms. Effectively we have decoupled the variation **within** the experiment from that associated with the journey details. This is demonstrated by Model (M2b) in Table 7, in which the quadratic terms are virtually unchanged, but the basic variation in value of time with current cost and time is allowed for.

Table 7: M2b Quadratic on Incremental Time and Cost with Time and Cost Covariates

	Business	Commute	Other
Time (Δ)t	-0.0787 (17.49)	-0.0961 (11.49)	-0.0560 (10.60)
Cost (Δ)c	-0.0108 (22.42)	-0.0217 (19.44)	-0.0191 (25.22)
Time (quad) [Δt^2]	-0.00134930 (10.31)	-0.00250379 (7.54)	-0.00183171 (10.76)
Cost (quad) [Δc^2]	-0.00001043 (10.84)	-0.00004413 (9.73)	-0.00002208 (11.31)
Time Covariate [TΔt]	-0.00005191 (1.92)	-0.00009432 (1.03)	-0.00009288 (3.04)
Cost Covariate [CΔc]	-0.00000178 (6.06)	-0.00000359 (2.79)	0.00000367 (8.22)
Average LL	-0.633499	-0.614272	-0.604248
No. Obs	9557	4737	8038

From this we learn two things. Firstly, there is a serious danger of confounding the effects of design variations and the journey detail covariates. Secondly, **after** allowing for the general impact of longer (and more expensive) journeys on the value of time, there does appear to be significant curvature (non-linearity) with respect to the options in the design.

To investigate this further, it is important to understand the SP design in rather more detail, as well as developing an econometric theory for non-linearity. These are the tasks for the following sections.

It may be noted that one consequence of the "incremental" specification is to restrict the number of testable model forms. Since the increments (both for cost and time) are negative as well as positive, it is not possible to use either the logarithmic or power forms in testing non-linearity within the design[1]. We will therefore have to rely largely on the quadratic formulation in what follows. This has some disadvantages, since there is considerable correlation between the linear and quadratic terms.

3 THE DEVELOPMENT OF THE UTILITY FORMULATION FOR VALUE OF TIME ESTIMATION

3.1 Theoretical Considerations

The method of valuing "non-market commodities" (ie, in this context, aspects of travel which cannot be directly traded for money) is firmly based on the concept of "willingness to pay". With a given budget, and given prices, the consumer arranges his expenditure so as to obtain maximum utility U*. If then an improvement is made without charge, the consumer's utility will increase. The willingness to pay for such an improvement (the "Compensating Variation") may be defined as the amount of money P which, subtracted from the consumer's budget B, brings him back precisely to his original level of utility U*. In other words, he should be **indifferent** between not having the improvement, and having it at a cost of P.

Figure 1 shows the outcome for the Business model. It is readily seen that, apart from the Ln Cost form (which has the "wrong" curvature[1]), the "curves" are more or less linear over the range of time changes [–20,+20]: in this example, the power curve is in fact not distinguishable from the Linear. This strongly suggests that the variations in model form are essentially picking up the differences associated with the co-variates relating to the current journey time and cost.

[1] The only possibility is to incorporate dummies to indicate the sign, and use the absolute values in the non-linear transformation. However, this **obliges** us to make an allowance for the direction of change in the model specification.

If ψ is the indirect utility function, as a function of the budget and the travel time (assuming other arguments remain fixed), we may write this as:

$$\psi(B,T) = \psi(B-P,T + \Delta t)$$

where T is the base journey time, and Δt (here assumed negative) is the change in travel time.

This is the definition of the valuation P of the change in travel time Δt, and the aim of any empirical methodology should be to allow P to be estimated.

A rather narrow definition of "Willingness to pay" might imply that this requires contexts where travellers are given the choice of paying more money in order to reduce their travel time. However, the term willingness to pay (WtP) is often used in opposition to the term "willingness to accept" (WtA), and in so-called Contingent Valuation studies both methods are used, with the commonly experienced empirical result that WtP values are **lower** than WtA values.

It is helpful to put this into the general framework of tradeoffs between money and time, as shown in Figure 2.

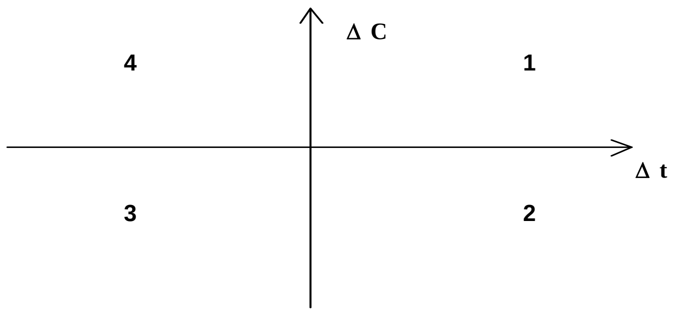


Figure 2: Tradeoffs between cost and time around current journey

It is assumed that the traveller is currently located at the origin of this graph. Any choice which he is required to make relating to changes in cost and time can be expressed as differences relative to the current journey. Thus if $\Delta C > 0$ for a given option, then that option costs more than the current journey.

The economic theory of time allocation derives primarily from the goods leisure tradeoff within the theory of the labour market. The standard analysis is indicated in Figure 3, whereby individuals are assumed to have an indifference between different quantities of money and leisure time, with the shape shown. As leisure time is reduced, individuals become more reluctant to give up additional leisure time to work unless they are compensated by a higher wage rate (implying a rationale for "overtime" rates). Conversely, at low incomes and large amounts of "leisure" (not necessarily voluntary!), individuals will be willing to accept work (ie reduce leisure time) in return for relatively low wage rates.

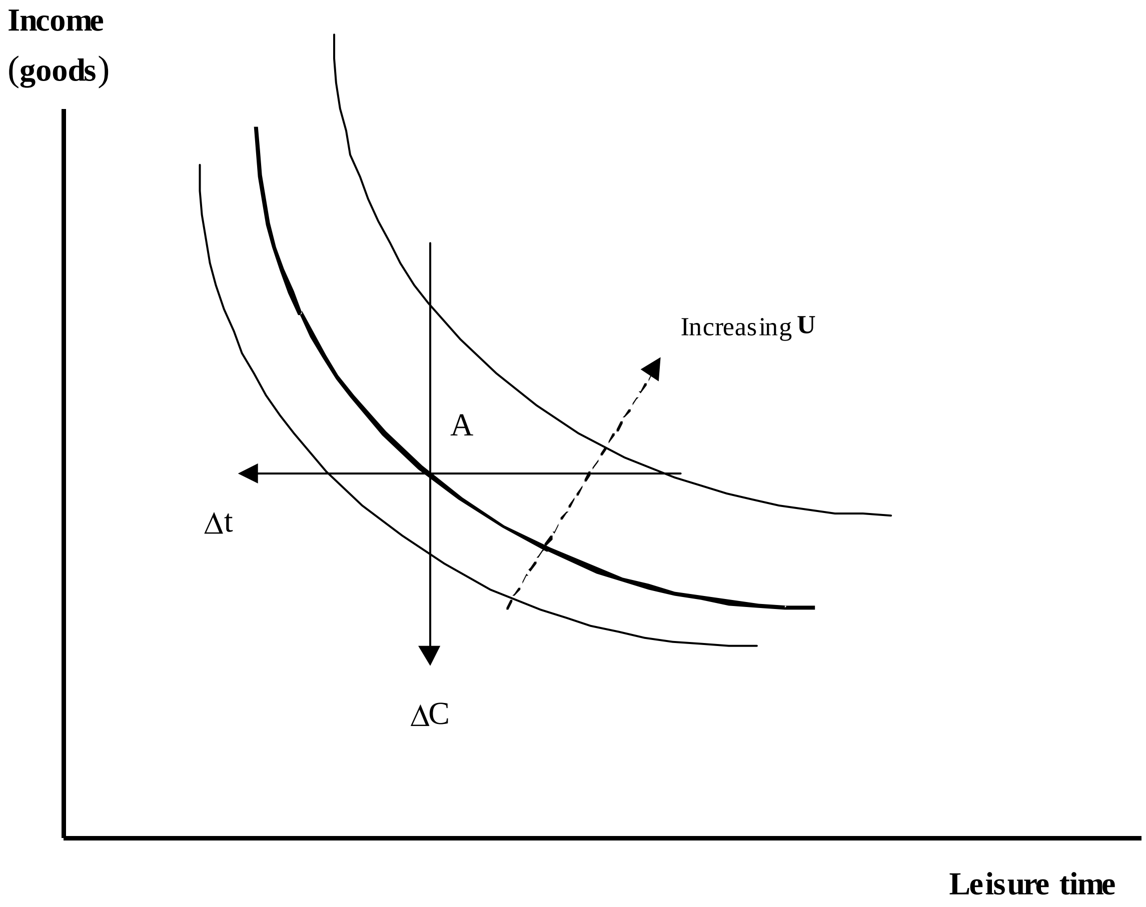


Figure 3: Tradeoff between income and leisure

From the transport point of view, we are interested in how the balance is affected by changes in the cost and time of **travel**. For a given current position A in Figure 3, we can re-interpret the figure in transport terms to produce the shape illustrated in Figure 4, in respect of an individual trip. An increase in travel cost acts in the opposite direction to an increase in income, and an increase in travel time acts in the opposite direction to an increase in leisure time. Hence, the figure is (more or less) inverted. Clearly the indifference curve through the origin must be entirely in the NW and SE quadrants, in which the changes in time and cost are of opposite sign.

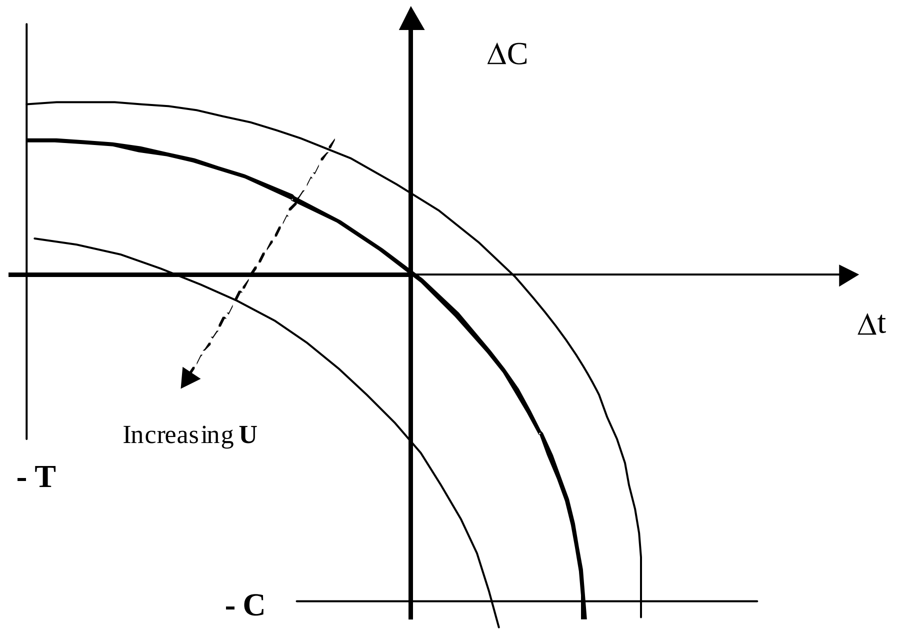


Figure 4: Tradeoff between cost and time for given trip

For an individual making a specified journey with cost C and time T, the basic requirement of the analysis is to deliver a family of indifference curves U(c,t) = k. The value of time at any point c,t can be found by:

a determining on which indifference curve (c,t) lies (ie the value of k)
b along this curve (ie holding k constant), taking the ratio of marginal utilities:

$$v = \left(\frac{\partial U_k}{\partial t} / \frac{\partial U_k}{\partial c}\right)$$

This is related to the fundamental differential equation along the indifference curve:

$$dU_k = \frac{\partial U_k}{\partial t}.dt + \frac{\partial U_k}{\partial c}.dc = 0$$

Hence the slope dc/dt along the indifference curve is given by $-\frac{\partial U_k}{\partial t} / \frac{\partial U_k}{\partial c}$. The (negative) slope of the indifference curve thus gives the "value of time" (tradeoff, or marginal rate of substitution, between time and cost). To remain at the same utility level, an increase in cost must be matched by a decrease in time, and *vice versa*. This allows a time loss or gain to be valued along the lines set out above.

3.1 Conditions on non-linear forms

The direction of the curvature should be clear. From a given base, the greater the cost increase ($\Delta c > 0$), the greater the relative compensating reduction in time must be, leading to a fall in the value of time (flatter curve), as the (money) budget constraint begins to bind. Likewise, the greater the time increase ($\Delta t > 0$), the greater the relative compensating reduction in money must be, leading to an increase in the value of time (steeper curve), as the "time budget" constraint begins to bind.

If non-linearity exists, then the value of time, which is the tangent to the indifference curve, will fall as cost increases and time decreases, and conversely. In other words, it must have the shape shown in Figure 4. Any departure from this will be inconsistent with economic theory. There is thus a good case for imposing such a form on the analysis.

For an individual, the question thus turns on the functional form of marginal utility with respect to money and time. On general theoretical grounds we expect

a both $\frac{\partial U_k}{\partial t}$ and $\frac{\partial U_k}{\partial c} < 0$

b both $\frac{\partial^2 U_k}{\partial t^2}$ and $\frac{\partial^2 U_k}{\partial c^2} \leq 0$

The condition on the second derivatives reflects both the "satiety" axiom (in reverse!) and the constraints on the overall time and money budgets.

If both second derivatives are zero, then the value of time is constant, and the indifference curve **at that level** is a straight line. In practice it is unreasonable to expect either derivative to be zero: however, what is at issue is the change in the marginal utilities over the range of (c,t), both in the SP experiment, **and** in an appraisal.

The simplest form of allowing for this theoretical variation is to use a form

$$\frac{\partial U_k}{\partial t} = -\varphi - \zeta/(X-t) \quad \text{where X is some "travel (time) budget"; } \varphi, \zeta > 0$$

Integrating, $U_k = -\varphi\, t + \zeta \ln (X-t)$ + terms in other variables. We can deal with costs in a corresponding way, to obtain $U_k = -\lambda\, c + \xi \ln (Y-c) + \ldots$, where Y can either be total income, or some "travel (money) budget".

Unfortunately, unless we know the budgets X and Y this is not much help! One possibility is to try to estimate them, or make an assumption about their distribution, and this could be given further consideration. Alternatively, we can expand terms of the form ln (Y–c) as follows:

$$\ln (Y-c) = \ln Y + \ln (1-c/Y) \approx \ln Y - c/Y - ½ (c/Y)^2 \ldots\ldots$$

Since (for a single individual) Y is a constant (as is X), and we are only interested in relative utilities, we can re-write the effective utility function as:

$$U_k = -\varphi\, t - \zeta\, [t/X + ½ (t/X)^2 \ldots\ldots] - \lambda\, c - \xi\, [c/Y + ½ (c/Y)^2 \ldots\ldots] + \ldots$$

Collecting terms and re-defining the coefficients,

$$U_k = [-\varphi - \zeta/X]\, t - [\, ½\, \zeta\, /X^2\,]\, t^2 \,......\, [-\lambda - \xi/Y]\, c - [\, ½\, \xi\, /Y^2\,]\, c^2 ......\, +....$$

$$= -\varphi'\, t - \zeta'\, t^2\ -\lambda'\, c - \xi'\, c^2\ +....$$

The quadratic coefficients ζ' and ξ' will need to be significantly different from 0 to justify a departure from linearity. The original conditions on the positive signs of (φ, ζ, λ, ξ) to satisfy the 2nd order conditions imply that the transformed coefficients (φ', ζ', λ', ξ') must also all be positive.

Since both the linear and quadratic coefficients, in the transformed version for estimation, are functions of the travel time and cost budgets, we can expect that variations in these coefficients across the sample will be found corresponding to different budgets. This can be examined in the later co-variate analysis.

Note that although the curvature as shown in Figure 4 has intuitive validity, the **scale** is not clear. That is, while we expect the slope to increase (in negative terms) as Δt increases, we have no immediate expectations as to what size of increase in Δt is required to lead to a **significant** change in slope. As we discuss below, we might expect little departure from linearity for the majority of changes in cost or time that can be realistically associated with a journey.

While there are no theoretical bounds to the functions in Figure 4, in practice we can assume that the curves are only defined for positive costs and times: this means that we can ignore cases where $\Delta c < -C$ and $\Delta t < -T$, if C and T are the current cost and time of the trip. We note that the rules developed by AHCG for rejecting observations in their analysis mean that data which does not meet this condition has already been excluded.

4 BRIEF DESCRIPTION OF THE EXPERIMENT 1 DESIGN

Note: More detail is given in Appendix A. Here we concentrate on those aspects which are of most relevance to the subsequent analysis.

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	**U**rban	**T**runk
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)

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; 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 2:

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

Taken all in all, only 10 possible values of Δt are presented (−20, −15, −10, − 5, − 3, 0, +5, +10, +15, +20), and only four different non-zero values are presented in any given questionnaire. The range of cost changes is considerably wider.

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 with all 9 possibilities.

5 ANALYSIS OF SIGN EFFECTS

5.1 Introduction

In the first place we concentrate on the effects of the sign of the change, and we turn to the question of the size effects later. Note, however, that any non-linearity effects that are found will have an impact *per se*, since if the theoretically expected curvature is found, then the value of time will fall as time savings increase, and rise as time losses increase. Note, in this respect, that while small time losses would then be worth less (per minute) than large time losses, small time gains would be worth **more** than large time gains.

We noted earlier that the significance of the quadratic terms depended strongly on the utility formulation. The basic model (M2), which appears to be in line with the theory set out above, produced a quadratic cost coefficient of the wrong sign: however, this appears to be due to confounding with the current journey covariates. When this effect was removed, either by modelling on the differences (M2a) or by explicitly allowing for the covariate impact (M2b), significant quadratic coefficients of the theoretically correct sign were obtained, and, on the face of it, a substantial non-linearity was indicated.

5.2 The AHCG Specification of Sign Effects

There are various ways in which this non-linearity could be reflected in the utility specification. The AHCG approach was to allow for different coefficients on time and cost according to the sign of Δt and Δc. Thus, their implied specification is:

$$U_{ikj} = \beta_{c+}.\Delta c_{ikj}[\Delta c_{ikj}>0] + \beta_{c-}.\Delta c_{ikj}[\Delta c_{ikj}<0] + \beta_{t+}.\Delta t_{ikj}[\Delta t_{ikj}>0] + \beta_{t-}.\Delta t_{ikj}[\Delta t_{ikj}<0] \quad \text{(M5)}$$

where (here and henceforth) a term of the form [*condition*] represents a logical (dummy) variable with the value 1 iff the condition is satisfied, 0 otherwise.

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), with the results given in Table 8:

Table 8: M5 Time and Cost Coefficients varying by Sign

	Business	Commuting	Other
Time(+ve)	-0.1090 (27.6)	-0.1286 (17.8)	-0.0973 (20.4)
Time(-ve)	-0.0576 (17.4)	-0.0416 (5.6)	-0.0286 (6.8)
Cost (+ve)	-0.0121 (28.2)	-0.0278 (20.6)	-0.0214 (26.6)
Cost (-ve)	-0.0050 (13.6)	-0.0111 (12.8)	-0.0087 (16.4)
Mean LL	-0.626621	-0.603173	-0.600502
No. Obs	9557	4737	8039

In terms of LL, this is a noticeable improvement on the quadratic formulations (M2a) and (M2b). The expectation is that the "increase" coefficients should be larger (in absolute size) than the "decrease" coefficients, for both time and cost. In fact, the estimated ratios (increase/decrease) were as follows:

Table 9a: Ratio of "increase" to "decrease" coefficients (Model M5)

	time	**cost**
Business	1.89	2.42
Commuting	3.09	2.50
Other	3.40	2.46

On the face of it, these ratios are extremely high. Moreover, even if we can accept that there may be severe short-term constraints which bring about a difference between the utility of time savings vs time losses, it does not seem credible that similar short term constraints can account for the discontinuity in the cost coefficient. After all, encountering fluctuations in commodity prices and making adjustments for them is a daily event in most people's lives, for the kind of maximum variations being discussed in the design here (± £3).

Translating these figures into the implied variation by value of time for each quadrant gives us:

Table 9b: Implied Values of Time by Quadrant (Model M5)

	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

This implies that the average value of time for a point in quadrant 2 (time loss, cost saving) relative to a point in quadrant 4 (time saving, cost loss) is in the ratio of 4.6, 7.7 and 8.4 for the three purposes respectively.

5.3 Subdividing the data by Quadrant

The four types of tradeoff in the design defined in the previous section each involve a different combination of savings and losses. If the effect 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 are set out in Tables 10a-c for the three purposes[2].

Table 10a: Business Travel Models M5

	all data	quadrants 1+3	quadrants 2+4
Time(+ve)	-0.1090 (27.6)	-0.0613 (9.9)	-0.1641 (20.0)
Time(-ve)	-0.0576 (17.4)	-0.0696 (12.5)	-0.0452 (8.3)
Cost (+ve)	-0.0121 (28.2)	-0.0075 (11.9)	-0.0125 (15.7)
Cost (-ve)	-0.0050 (13.6)	-0.0054 (8.8)	-0.0097 (13.2)
Mean LL	-0.626621	-0.658164	-0.584992
No. Obs	9557	4754	4717

Table 10b: Commuting Travel Models M5

	all data	quadrants 1+3	quadrants 2+4
Time(+ve)	-0.1286 (17.8)	-0.0519 (4.6)	-0.1823 (14.2)
Time(-ve)	-0.0416 (5.6)	-0.0490 (4.1)	-0.0427 (3.0)
Cost (+ve)	-0.0278 (20.6)	-0.0157 (9.3)	-0.0318 (12.4)
Cost (-ve)	-0.0111 (12.8)	-0.0113 (6.9)	-0.0161 (11.2)
Mean LL	-0.603173	-0.645439	-0.548040
No. Obs	4737	2338	2380

Table 10c: Other Travel Models M5

	all data	quadrants 1+3	quadrants 2+4
Time(+ve)	-0.0973 (20.4)	-0.0197 (2.6)	-0.1288 (16.0)
Time(-ve)	-0.0286 (6.8)	-0.0418 (6.2)	-0.0508 (6.0)
Cost (+ve)	-0.0214 (26.6)	-0.0109 (11.3)	-0.0290 (16.6)
Cost (-ve)	-0.0087 (16.4)	-0.0114 (11.0)	-0.0108 (12.5)
Mean LL	-0.600502	-0.627432	-0.555203
No. Obs	8039	3983	4005

The results are striking. If we reproduce Table 9a, but with values for the two subsets, we obtain:

[2] Note that because of the error in the implementation of questionnaire MC (See Appendix A), treatment no. 4 cannot be consistently classified by quadrant: the associated responses have therefore been omitted from the data for the estimation by subset, and as a result the number of observations for the three purposes falls by 86, 19, and 51, respectively. If these are also excluded from the estimation for the full dataset, there is no significant effect.

Table 11: Ratio of "increase" to "decrease" coefficients [subsets based on quadrants]

	time			cost		
	2+4	**1+3**	**all**	**2+4**	**1+3**	**all**
Business	3.63	1.14	1.89	1.29	1.39	2.42
Commuting	4.27	1.06	3.09	1.98	1.39	2.50
Other	2.53	0.47	3.40	2.69	0.96	2.46

It is clear that the ratios for types 1 and 3 are, in fact, close to 1 (though for the Other purpose, both ratios are actually **less** than 1), while those for types 2 and 4 are much higher. If the data was confined to types 1 and 3, it would, on the face of it, be difficult to justify a general hypothesis that, over the range of values presented, positive changes (ie, losses) were perceived as causing relatively more disutility than negative changes (savings), per unit change.

The question which obviously arises is: what is the distinguishing feature of types 2 and 4 which could lead to such different results? One answer occurs immediately: all tradeoffs for these types involve a comparison with the current position (ie for one of the options A, B, **both** Δt and Δc are zero), which is not the case for types 1 and 3.

5.4 The "Inertia" Specification

We therefore added to the utility specification a dummy term (which for convenience we refer to as "inertia") indicating when an option coincided with the current journey. In other words:

$$Itc_{kj} = 1 \text{ iff } \Delta c_{kj} = \Delta t_{kj} = 0; \text{ 0 otherwise}$$

The results of this revised specification (M5I) for types 2 and 4 are given in Table 12.

Table 12: M5I Time and Cost Coefficients varying by Sign, + "Inertia" (Types 2 and 4 only)

	Business	Commuting	Other
Time(+ve)	-0.0713 (7.1)	-0.1013 (6.2)	-0.0500 (4.8)
Time(-ve)	-0.1056 (14.9)	-0.1093 (6.5)	-0.0951 (10.5)
Cost (+ve)	-0.0088 (11.5)	-0.0249 (9.6)	-0.0214 (12.3)
Cost (-ve)	-0.0082 (11.4)	-0.0162 (11.1)	-0.0098 (11.3)
"Inertia"	1.0124 (13.7)	0.7740 (7.4)	0.8577 (11.3)
Mean LL	-0.564192	-0.536629	-0.538778
No. Obs	4717	2380	4005

Again the results are striking: for all three purposes the dummy "inertia" term is highly significant and positive, denoting a dominant tendency to choose the current journey, and there is a marked improvement in the LL. But even more important is the impact on the ratio of the coefficients, shown in Table 13 below:

Table 13: Ratio of "increase" to "decrease" coefficients [subsets based on quadrants]

	time			cost		
	2+4	**2+4 with Inertia**	**1+3**	**2+4**	**2+4 with Inertia**	**1+3**
Business	3.63	0.68	1.14	1.29	1.07	1.39
Commuting	4.27	0.93	1.06	1.98	1.54	1.39
Other	2.53	0.53	0.47	2.69	2.18	0.96

In all cases, the ratios for the (2+4) group **with inertia** are now much closer to those for the (1+3) group. Moreover, the ratios for the time coefficients are all **less** than 1.

The next test is to put the data back together, re-estimate the model including the inertia term (Model M5I) , and then to test the difference between the model and one where we ignore the separate coefficients for increases and decreases, but keep the inertia term (Model M1I). This is set out in Tables 14 a-c for the three purposes.

Table 14a: Business Travel Models M5I, M1I

	M5I	M1I
Time(+ve)	-0.0690 (15.4)	-0.0817 (27.1)
Time(-ve)	-0.0908 (22.7)	
Cost (+ve)	-0.0082 (18.0)	-0.0081 (25.2)
Cost (-ve)	-0.0073 (18.1)	
"Inertia"	0.9031 (16.6)	0.8312 (25.3)
Mean LL	-0.611578	-0.613180
No. Obs	9557	9557

Table 14b: Commuting Travel Models M5I, M1I

	M5I	M1I
Time(+ve)	-0.0779 (9.1)	-0.0755 (12.6)
Time(-ve)	-0.0789 (9.3)	
Cost (+ve)	-0.0195 (13.9)	-0.0163 (19.3)
Cost (-ve)	-0.0144 (14.7)	
"Inertia"	0.8066 (10.0)	0.9113 (19.4)
Mean LL	-0.592345	-0.593923
No. Obs	4737	4737

Table 14c: Other Travel Models M5I, M1I

	M5I	M1I
Time(+ve)	-0.0503 (8.9)	-0.0526 (14.3)
Time(-ve)	-0.0556 (11.9)	
Cost (+ve)	-0.0146 (18.2)	-0.0125 (25.1)
Cost (-ve)	-0.0108 (18.7)	
"Inertia"	0.8540 (14.5)	0.9304 (25.3)
Mean LL	-0.587002	-0.588730
No. Obs	8039	8039

From these results we can note two things. Firstly, we can see how the "increase/decrease" ratios, and the implied values of time, have ended up, once the inertia term is included: this is shown in Table 15.

Table 15a: Ratio of "increase" to "decrease" coefficients (Model M5I)

	time	cost
Business	0.76	1.12
Commuting	0.99	1.35
Other	0.90	1.35

Table 15b: Implied Values of Time by Quadrant (Model M5I)

	Quadrant 4	Quadrant 1
Business	11.07	8.41
Commuting	4.05	3.99
Other	3.81	3.45
	Quadrant 3	**Quadrant 2**
Business	12.44	9.45
Commuting	5.48	5.41
Other	5.15	4.66

These coefficient ratios are now all much closer to 1.0, and it is of some interest that while the cost ratios remain above 1, this is not the case for the time ratios where the outcome is at face value counter-intuitive. Note also that the great disparity in values of time by quadrant has largely disappeared.

Secondly, we can compare the overall model fit, in terms of average Log likelihood, for the models M1I, M5 and M5I – these are given in Table 16.

Table 16: Comparison of Model Fit (LL per observation)

Model	(M5)	(M5I)	(M1I)
no. of parameters	**4**	**5**	**3**
Business	-0.626621	-0.611578	-0.613180
Commuting	-0.603173	-0.592345	-0.593923
Other	-0.600531	-0.587041	-0.588771

This makes it clear that the inertia term with single cost and time coefficients (M1I) produces a far better fit than the "increase/decrease" specification without inertia (M5), despite the former containing one less parameter. Further, given the inertia specification, the additional benefit of allowing the coefficients to vary according to the sign of the change (M5I) is small (and, for the time coefficients, counter-intuitive).

A further test based on the quadratic models with an inertia term (Models (M2aI) and (M2bI)) confirmed these general conclusions, compared with the corresponding versions without the inertia term. The quadratic terms were of much lower significance, and that for time was of the wrong sign, as shown in Tables 17 and 18.

Table 17: M2aI Quadratic on Incremental Time and Cost, with Inertia

	Business	Commute	Other
Time	-0.0795 (25.71)	-0.0813 (13.11)	-0.0538 (13.96)
Cost	-0.0077 (22.66)	-0.0180 (18.54)	-0.0131 (22.88)
$Time^2$	0.00044216 (2.86)	0.00003651 (0.10)	0.0001925 (1.01)
$Cost^2$	-0.00000169 (1.69)	-0.00002460 (5.38)	-0.00001170 (5.62)
Inertia	0.8669 (21.11)	0.8316 (14.86)	0.8859 (20.33)
Average LL	-0.612433	-0.590738	-0.586458
No. Obs	9557	4737	8038

Table 18: M2bI Quadratic on Incremental Time and Cost with Time and Cost Covariates, with Inertia

	Business	Commute	Other
Time	-0.0753 (16.52)	-0.0904 (10.62)	-0.0437 (8.09)
Cost	-0.0101 (20.99)	-0.0200 (17.97)	-0.0173 (23.06)
$Time^2$	0.00050570 (3.23)	-0.00014569 (0.39)	-0.00019810 (0.96)
$Cost^2$	-0.00000174 (1.73)	-0.00001989 (4.36)	-0.00000933 (4.91)
Time Covariate	-0.00004130 (1.51)	0.00013977 (1.52)	-0.00009359 (3.01)
Cost Covariate	0.00000198 (6.74)	0.00000480 (3.75)	0.00000378 (8.70)
Inertia	0.8799 (21.29)	0.8504 (15.11)	0.9142 (20.69)
Average LL	-0.608058	-0.588621	-0.575580
No. Obs	9557	4737	8038

The conclusion of this analysis, therefore, is that there is **no** significant curvature related to the sign of the change, once the inertia term is introduced into the model. At least over the range of time changes presented in the experiment, there is no support for time savings being valued differently from time losses. We emphasise that this conclusion relates to the sign effect: we have not yet considered the issue of **small** time changes. There is, of course, the possibility of confounding the two effects, and we will return to this.

5.5 Discussion of the "Inertia" Term

It has been 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.

As discussed in Appendix A, for any SP pairwise comparison based on Δt and ΔC, the slope of the line joining the two options being compared represents the (negative) "boundary value of time" (Bvot) – this assumes, of course, that there is no additional utility effect relating to one of the options. On this basis, in the case of a tradeoff in quadrant 2 (time loss), the current journey will be chosen if the respondent's actual vot > Bvot , while for a tradeoff in quadrant 4 (time saving), the current journey will be chosen if the respondent's actual vot < Bvot.

Correspondingly, the estimation process will "deduce" these relationships when the current journey is chosen.

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", though the fact that the design compels respondents to choose between a time saving (or loss) against a cost saving (or loss) – as opposed to between two options both involving different combinations of time and cost savings (or losses) – could lead respondents to treat the SP task on an essentially short term basis, reflecting "inertia" caused by existing constraints whose effect will be softened over time. In this case an increase in **either** price or time will tend to be resisted, leading to a short-term indifference curve which is discontinuous at the origin, with the shape suggested in Figure 5. It should not be overlooked that this is reminiscent of the SP "inertia=task-simplifying" explanation. In practice, therefore, it will be difficult to be sure that we are observing **genuine** short term responses.

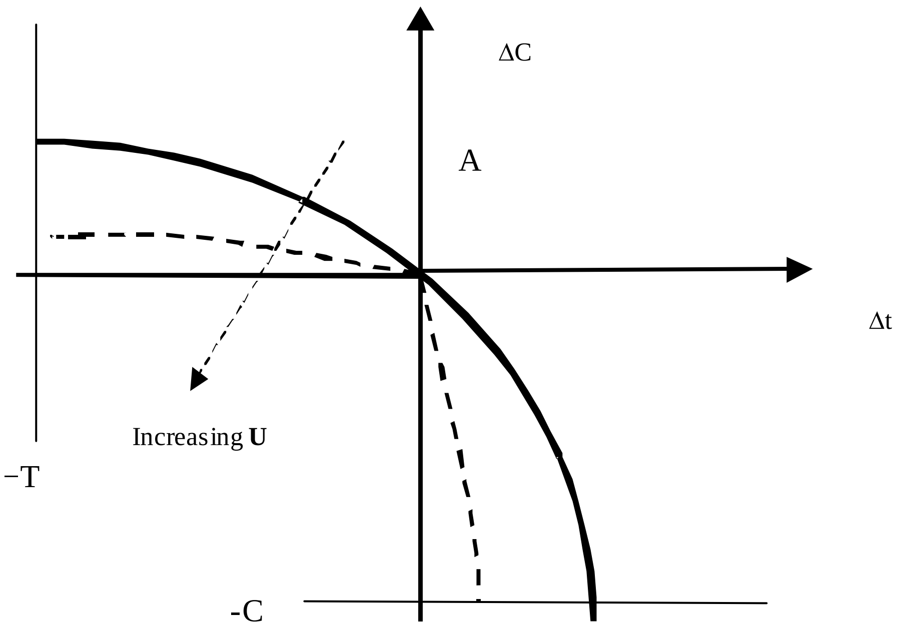


Figure 5: Short term inertia effect

We have carried out further investigations to see whether the "inertia" effect could reside primarily in the time or cost change. This can be done along the following lines:

define $It_{kj} = 1$ if $\Delta t_{kj} = 0$, otherwise 0

define $Ic_{kj} = 1$ if $\Delta c_{kj} = 0$, otherwise 0

The dummy variable used in the analysis so far can be equivalently defined as:

$Itc_{kj} = 1$ if $It_{kj} = 1$ **and** $Ic_{kj} = 1$, otherwise 0

Ideally, we would like to show that the "interaction" coefficient on Itc is highly significant, while the individual time and cost inertia coefficients on It and Ic are not. Unfortunately, the form of the design prevents such analysis. For types 1 and 3, Itc = 0 and Ic = 1–It, while for types 2 and 4, Ic = It = Itc: furthermore, taking the difference of the two options A–B, for types 1 and 3, $\Delta Itc = 0$ and $\Delta Ic + \Delta It = 0$, while for types 2 and 4, $\Delta Ic = \Delta It = \Delta Itc$. Hence, across the whole data set, $\Delta Ic + \Delta It - 2\Delta Itc \equiv 0$: there is thus perfect collinearity and we cannot include all three "inertia" variables. Our investigations reveal that while the overall model fit using Ic and It is slightly better than one using Itc, the differences in the other coefficients are marginal. For the sake of thoroughness, these results are reproduced in Table 19.

Table 19: Alternative Base Model (M1) with Separate Inertia on Time and Cost

	Business	Commute	Other
Time	-0.0817 (27.0)	-0.0757 (12.6)	-0.0525 (14.3)
Cost	-0.0080 (24.9)	-0.0163 (19.3)	-0.0125 (25.0)
Time Inertia	0.3308 (14.7)	0.4256 (13.4)	0.4523 (18.1)
Cost Inertia	0.4998 (22.3)	0.4756 (14.7)	0.4777 (19.2)
Average LL	-0.611577	-0.593835	-0.588736
No. Obs	9557	4737	8038

This is certainly not the first time that "inertia" effects have been suggested in SP analysis. In the Swedish Value of Time study, it appears that **all** the pairwise comparisons were in quadrants 2 and 4. The following extracts are taken from Dillén & Algers (1998):

> The particular way in which the survey was designed – a base alternative resembling the current trip compared with other alternatives – made it easy for the interviewee to adopt a "no change" strategy. It was therefore also quite clear what alternative implied a time gain and a time loss respectively. [p 5]
>
> ...This may, however, produce a certain amount of inertia in favour of the base alternative. The matter was taken into consideration in the original analysis resulting in a significant inertia parameter.. [p 13]

In the Swedish work with the linear model, it appears that the presence or absence of the inertia coefficient does not significantly influence the (average) value of time, though the inertia coefficient is positive and significant. Interestingly, this is entirely compatible with the results here (compare values of time from models (M1) and (M1I)).

In further work on the long-distance travel data, Dillén & Algers investigate whether the inertia effect is different according to the quadrant (2 or 4). They begin by estimating the linear model separately for the two quadrants, without inertia. This produces a value of time for quadrant 2 (time losses) almost twice that for quadrant 4 (time savings). This is compatible with the analysis of the AHCG data, though the effect is less strong.

When they add inertia terms, the values of time for the two quadrants become much more similar: however, the inertia terms are significantly different – that for quadrant 2 is insignificant. Pooling the data but estimating separate inertia terms for the two quadrants restores the significance of both: in terms of equivalent minutes, the quadrant 2 inertia is worth 3.4 minutes and the quadrant 4 13.4 minutes. This pooled model with separate inertia coefficients was the preferred form, and led to an increase in value of time (compared to the single inertia model) of about 16%.

Comparable analysis can be carried out on the AHCG data and is reported in Table 20.

Table 20: Base Model (M1) with Separate Inertia for Q2 and Q4

	Business	Commute	Other
Time	-0.0849 (25.40)	-0.0796 (12.29)	-0.0599 (14.9)
Cost	-0.0079 (24.59)	-0.0157 (18.70)	-0.0120 (24.41)
Q2 Inertia	0.6902 (12.61)	0.7584 (9.72)	0.6645 (11.43)
Q4 Inertia	0.9993 (19.51)	1.0779 (14.15)	1.2507 (20.32)
Average LL	-0.610957	-0.592484	-0.584912
No. Obs	9557	4737	8038

For the business data, in terms of equivalent minutes, the inertia effect is 8.1 minutes for quadrant 2 and 11.8 minutes for quadrant 4. Somewhat higher results apply to the other purposes. The models with separate inertia coefficients are marginally preferred, and lead to a slight increase in value of time compared to the single inertia model. Thus these results are broadly compatible with the Swedish analysis.

Our judgement that there is no evidence of a variation in value of time due to the sign of the time change challenges the conclusions of Gunn (2001), which were based not only on the AHCG data analysed here but also corroborative evidence from the 1988 Dutch Value of Time study data. It turns out, however, that this study had essentially the same kind of design, with corresponding possibilities for “inertia” effects. We postulate, therefore, that if the Dutch data was analysed in the same way, the “sign effect” might vanish there as well.

Some additional evidence can be found from the supplementary AHCG study design for the Tyne crossing experiment (in addition to the replication of the 1985 design): this was similar to Experiment 1 in containing some possibilities for inertia. Preliminary analysis of this data has found significant inertia effects for Commuting, and marginally significant evidence for Leisure, though there is no effect for Business. The effects on the value of time are not marked, but suggest some increase.

6 SMALL TIME CHANGES

6.1 Allowing for Journey Co-variates

In investigating what the data tells us about small time savings, 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) are only presented in relation to the shorter journeys (See Appendix A on the design): although changes of **10** minutes occur in all the questionnaires, it might be argued that this is outside the range of what would typically be implied by “small” time savings.

It is convenient for the analysis of small time changes if we can confine the effect of the journey covariates to the **cost** coefficient, even if this is not the preferred final model specification. With this in mind, we investigate five variants on Model (M1I):

$$U_{ikj} = \beta_c .\ c_{ikj} + \beta_t .\ t_{ikj} + \Omega\ Itc_{kj} \qquad \text{(M1I)}$$

a) cost and time effects:

$$U_{ikj} = (\beta_{c0} + \beta_{c1}\ C_i).\ \Delta c_{ikj} + (\beta_{t0} + \beta_{t1}\ T_i).\ \Delta t_{ikj} + \Omega\ Itc_{kj} \qquad \text{(M6a)}$$

b) time effects on both cost and time coefficients

$$U_{ikj} = (\beta_{c0} + \beta_{c1}\ T_i).\ \Delta c_{ikj} + (\beta_{t0} + \beta_{t1}\ T_i).\ \Delta t_{ikj} + \Omega\ Itc_{kj} \qquad \text{(M6b)}$$

c) time effect on cost coefficient only

$$U_{ikj} = (\beta_{c0} + \beta_{c1}\ T_i).\ \Delta c_{ikj} + \beta_t .\ \Delta t_{ikj} + \Omega\ Itc_{kj} \qquad \text{(M6c)}$$

d) cost effect on cost coefficient only

$$U_{ikj} = (\beta_{c0} + \beta_{c1}\ C_i).\ \Delta c_{ikj} + \beta_t .\ \Delta t_{ikj} + \Omega\ Itc_{kj} \qquad \text{(M6d)}$$

e) time effect on time coefficient only

$$U_{ikj} = \beta_c .\ \Delta c_{ikj} + (\beta_{t0} + \beta_{t1}\ T_i).\ \Delta t_{ikj} + \Omega\ Itc_{kj} \qquad \text{(M6e)}$$

As usual, T and C refer to the actual journey time and cost.

The estimations for these five specifications are set out in Tables 21 a-e.

Table 21a: Covariates For Time and Cost with Inertia

	Business	Commute	Other
Time	-0.0768 (16.92)	-0.0859 (10.26)	-0.0415 (7.77)
Cost	-0.0104 (22.07)	-0.0190 (18.05)	-0.0168 (23.63)
Time Covariate TΔt	-0.00004833 (1.77)	0.00013635 (1.51)	-0.00010833 (3.56)
Cost Covariate CΔc	0.00000188 (6.47)	0.00000529 (4.47)	0.00000354 (8.55)
Inertia	0.8368 (25.38)	0.9091 (18.88)	0.9492 (25.33)
Average LL	-0.608962	-0.590903	-0.577363
No. Obs	9557	4737	8038

Table 21b: Time Covariates on Time and Cost with Inertia

	Business	Commute	Other
Time	-0.0772 (14.28)	-0.0838 (9.61)	-0.0420 (7.00)
Cost	-0.0100 (16.87)	-0.0192 (16.05)	-0.0164 (20.01)
Time Covariate TΔt	-0.00004065 (1.13)	0.00011927 (1.19)	-0.00009689 (2.60)
Cost Covariate TΔc	0.00001344 (3.63)	0.00004349 (3.49)	0.00002580 (5.84)
Inertia	0.8338 (25.34)	0.9084 (18.87)	0.9456 (25.27)
Average LL	-0.610610	-0.591882	-0.579991
No. Obs	9557	4737	8038

Table 21c: Time Covariates on Cost Effect Only with Inertia

	Business	Commute	Other
Time	-0.0823 (27.19)	-0.0763 (12.72)	-0.0544 (14.74)
Cost	-0.0104 (22.00)	-0.0185 (18.16)	-0.0176 (25.16)
Time Covariate TΔc	0.00001661 (6.86)	0.00003263 (4.08)	0.00003439 (11.68)
Inertia	0.8329 (25.32)	0.9125 (19.01)	0.9363 (25.16)
Average LL	-0.610678	-0.592029	-0.580421
No. Obs	9557	4737	8038

Table 21d: Cost Covariates on Cost Effect Only with Inertia

	Business	Commute	Other
Time	-0.0828 (27.29)	-0.0772 (12.83)	-0.0544 (14.93)
Cost	-0.0106 (23.76)	-0.0185 (18.93)	-0.0176 (26.03)
Cost Covariate CΔc	0.00000214 (8.43)	0.00000414 (4.63)	0.00000439 (12.66)
Inertia	0.8360 (25.36)	0.9134 (19.00)	0.9388 (25.17)
Average LL	-0.609129	-0.591140	-0.578161
No. Obs	9557	4737	8038

Table 21e: Time Covariates on Time Effect Only with Inertia

	Business	Commute	Other
Time	-0.0646 (15.64)	-0.0655 (8.99)	-0.0208 (4.40)
Cost	-0.0082 (25.44)	-0.0163 (19.41)	-0.0128 (25.74)
Time Covariate TΔt	-0.00014114 (5.89)	-0.00016670 (2.36)	-0.00026024 (10.17)
Inertia	0.8350 (25.40)	0.9178 (19.12)	0.9596 (25.73)
Average LL	-0.611291	-0.593330	-0.582053
No. Obs	9557	4737	8038

The results indicated that all the specifications were very similar. The theoretically expected form a) performed the best[3], but it was only marginally better than form d), which for all three purposes produced a better fit than all the remaining specifications. Model 6d, which confines the journey length effect to the cost variable, was therefore used as the base for the subsequent analysis.

6.2 Estimating Utilities for Each Time Change

We begin by creating dummy variables for each time change, with the aim of replacing the time term β_t. Δt_{ikj} in M6d by Σ_r β_{tr}. [$\Delta t_{ikj}=R_r$] where the set of values R_r ranges over (–20, –15, –10, –5, –3, +5, +10, +15, +20). Note that this is close to the final specification adopted by AHCG (ignoring further covariate effects) except that they chose to divide the dummy variables by the value of Δt_{ikj}[4] and (for reasons which are unclear) dropped the term corresponding with Δt_{ikj} = –3, thus presumably forcing it to have a zero valuation.

The results are heavily dependent on whether we include the inertia term in the specification, as we would intend on the basis of our earlier analysis. Ideally, we would like to compare the specifications with and without inertia with the AHCG Model 4-2 results, in terms of the implied indifference curves. This is difficult, however, because of the treatment of the sign effect in AHCG's model.

We denote our "dummy variable" specification as:

[3] although the time covariate was not significant for Business and Commuting
[4] This will have no effect on the model specification, but transforms the coefficients directly into values of time

(without inertia) $U_{ikj} = (\beta_{c0} + \beta_{c1} C_i). c_{ikj} + \Sigma_r \beta_{tr}. [\Delta t_{ikj}=R_r]$ (M7)

(with inertia) $U_{ikj} = (\beta_{c0} + \beta_{c1} C_i). c_{ikj} + \Sigma_r \beta_{tr}. [\Delta t_{ikj}=R_r] + \Omega\ Itc_{kj}$ (M7I)

The results of the estimations are given in Tables 22 and 23.

Table 22: Conditioning on Time Change – no inertia (M7)

	Business	Commute	Other
Cost	-0.0096 (20.52)	-0.0166 (17.02)	-0.0149 (21.52)
Cost Covariate CΔc	0.00000156 (6.21)	0.00000227 (3.04)	0.00000264 (7.69)
T-20	1.4856 (17.08)	1.3659 (5.09)	1.0774 (10.49)
T-15	0.8977 (7.94)	1.2659 (4.99)	0.7321 (4.53)
T-10	0.4885 (8.00)	0.6009 (5.51)	0.1673 (2.03)
T-5	-0.1050 (1.73)	-0.1058 (1.38)	-0.4746 (7.00)
T-3	-0.5452 (7.28)	-0.6916 (8.89)	-0.9723 (14.31)
T5	-0.3306 (5.24)	-0.4266 (5.46)	-0.0549 (0.79)
T10	-1.0096 (19.13)	-1.0554 (12.96)	-0.7141 (12.56)
T15	-1.4877 (12.91)	-1.8465 (9.49)	-1.6530 (11.51)
T20	-2.1339 (19.18)	-3.0852 (9.03)	-2.0530 (13.71)
Average LL	-0.628999	-0.603723	-0.582007
No. Obs	9557	4737	8038

Table 23: Conditioning on Time Change – with inertia (M7I)

	Business	Commute	Other
Cost	-0.0096 (19.96)	-0.0164 (16.39)	-0.0141 (20.10)
Cost Covariate CΔc	0.00000158 (6.11)	0.00000204 (2.65)	0.00000249 (7.07)
T-20	2.0777 (22.09)	1.9380 (6.91)	1.6598 (14.91)
T-15	1.4175 (12.32)	1.7980 (7.18)	1.2601 (7.91)
T-10	1.0100 (14.99)	1.1009 (9.43)	0.6361 (7.27)
T-5	0.3543 (5.34)	0.3006 (3.65)	**-0.0963** (1.35)
T-3	**-0.0778** (0.98)	**-0.2449** (2.91)	**-0.5240** (7.25)
T5	**0.2361** (3.39)	**0.2246** (2.52)	**0.7028** (8.77)
T10	-0.5202 (9.04)	-0.5719 (6.35)	-0.1414 (2.18)
T15	-1.1031 (9.32)	-1.3368 (6.78)	-1.1110 (7.59)
T20	-1.6583 (14.39)	-2.5945 (7.44)	-1.3846 (8.88)
Inertia	1.0377 (22.75)	1.0438 (15.52)	1.1208 (20.95)
Average LL	-0.600748	-0.577071	-0.553108
No. Obs	9557	4737	8038

Although these models are not strictly “nested” with AHCG’s 4-2 model, it is of interest to compare the average log-likelihoods, in Table 23.

Table 23: Comparison of Model Fit (LL per observation)

Model	**(M7)**	**(M7I)**	**(AHCG 4-2)**
no. of parameters	**11**	**12**	**15**
Business	-0.628999	-0.600748	-0.6058
Commuting	-0.603723	-0.577071	-0.5755
Other	-0.582007	-0.553108	-0.5622

While AHCG Model 4-2 comfortably outperforms the “without inertia” specification (M7), it gives a worse fit than Model M7I for both Business and Other purposes, and the improvement for Commuting is small given the extra parameters.

For both with and without inertia specifications, the general pattern is clear: on both sides of $\Delta t = 0$, the dummy utility coefficients move in the right direction, becoming smaller (more negative) with increases (losses) and larger (more positive) with time decreases (savings), though not necessarily in a linear manner. However, for all 3 purposes, the specification without inertia (M7) has the wrong sign for both the small time savings (–3,–5), and the specification with inertia has the coefficient for $\Delta t = +5$ of the wrong sign and significant, while that for $\Delta t = -3$ is also of the wrong sign, though not significant for Business. Dummy coefficients with the “wrong sign” are indicated in bold in the Tables.

Of course, we are less interested in the significance of the dummy coefficients *per se* than in the implied **deviations** from the general (linear) utility specification for the time changes. An analysis along these lines for the specification with inertia indicates that the deviation at –10 minutes is not significant, while that at –5 is only significant for Leisure (marginal for Commuting). However, the other deviations appear all to be significant. In other words, time losses of 5 and 10 minutes are less onerous (convey greater utility) than the linear model would imply, while a time gain of 3 minutes conveys less utility than the linear model would imply. A similar analysis for the specification without inertia suggested that all the “small” time changes (–10, –5, –3, +5, +10) appear to be significant, with the exception of that for +10, and the +5 values for Business and Commuting.

These dummy coefficients can be transformed into money terms by dividing by the negative of the effective cost coefficient ($\beta_{c0} + \beta_{c1} C_i$): in order to standardise, we took the average value of the actual journey cost C_i for each of the three purposes, given earlier in Table 3.

These money equivalents represent the money compensation (whether positive or negative) associated with the time change, and can be plotted, as an indifference curve through the origin, against the time savings to which they refer. An instructive pattern emerges (Figure 6a–c). The Figures plot both the “without-” (Table 22) and “with-Inertia” (Table 23) specifications, and, for comparison, a linear (uniform value of time) formulation taken from Table 21d. For all purposes, there is a highly non-linear, and essentially counter-intuitive, pattern in the vicinity of the origin (ie, for small time changes). Points in the 1st and 3rd quadrants denote locally negative values of time (though they may not be significant in all cases).

The most implausible result occurs with the Other purpose, where (using the “with inertia” specification) it is implied that to move from a time **saving** of 3 minutes ($\Delta t = -3$) to a time loss of 5 minutes ($\Delta t = +5$), travellers would on average be prepared to **pay** an extra 97.4 pence! This clearly requires explanation.

6.3 Subdividing the Data by Size of Time Change

There are two issues here, and it is not clear *a priori* how far they are related. The first is whether the value of time is dependent on the size of the time change, and the second is why we are finding counter-intuitive tradeoff behaviour (negative values of time). In order to try to understand this, we began by breaking the data up into three subsets "small, medium, large" based on the (absolute) size of time change in the pairwise comparison, as follows:

“small”	(-3, -5, +5)
“medium”	(-10, +10)
“large”	(remainder)

and estimated separate models for various specifications tested earlier: linear (M1), separate coefficients for increases/decreases (M5), linear with inertia (M1I), and separate coefficients for increases/decreases with inertia (M5I).

For all subsets and combinations thereof, the basic conclusions relating to the “sign” and “inertia” remained valid. We present here merely the comparative log-likelihood values LL – the complete results are given in Appendix B.

Tables 24a–c gives the result for average LL for the three purposes, separately for the three subsets of time changes. The indicator ** means that the ratio of gains to losses is counter-intuitive (ie <1): * means that it is only marginally > 1.

Table 24: Average log-likelihood for different models by purpose and size of time change

a “Large”

	M1	M5	M1I	M5I
Business	-0.6054	-0.5905	-0.5877	-0.5875*
Commuting	-0.6104	**-0.5686**	**-0.5696**	-0.5661
Other	-0.64	-0.6096	-0.6095	-0.607

b “Medium”

	M1	M5	M1I	M5I
Business	-0.6484	-0.6217	-0.6143	-0.6093**
Commuting	-0.6391	-0.6158	-0.6049	-0.5982**
Other	-0.6157	-0.5826	-0.574	-0.5673**

c “Small”

	M1	M5	M1I	M5I
Business	-0.65	-0.6172**	-0.6089	-0.6028**
Commuting	-0.6065	-0.5789**	-0.5702	-0.5691**
Other	-0.5687	-0.5436**	-0.5291	-0.5273**

Encouragingly, the model conclusions for the **sign** effect hold up for each size subset: M1I is better than M5 which is better than M1 (with the exception of Large/ Commuting, where M5 is slightly better than M1I). For Medium and Small, the “expected” relationship between gains and losses becomes counterintuitive in Model 5I, and is always counterintuitive in Model 5 for Small. Values of time are hardly changed by adding the inertia term, but the sign effect vanishes (see Appendix B). This demonstrates that despite the apparent non-uniformity of values of time with the size of the time change, there is no evidence of contamination with the sign effect.

However, the value of time falls consistently as we move through the subsets Large - Medium - Small, and is very low for the Small subset (actually **negative** for the Other purpose, in line with the indifference curve in Figure 6c). The values for the preferred Model 1I of the four tested are given below:

Table 25: Values of time (model M1I) by purpose and size of time change

	Large	Medium	Small
Business	12.12	9.33	2.7
Commuting	7.94	4.79	1.58
Other	7.17	2.38	-2.99

A further variant on the preferred linear model with journey covariates (M6d in Table 21d) is given in Table 26. This splits the data into pairwise choices with “large time savings” (–10 minutes or more), “large time losses” (+10 minutes or more) and small time changes in the range [–5,+5]. Separate time coefficients are estimated for each range.

Table 26: Model with Cost Covariates on Cost, Inertia and 3 way time split

	Business	Commute	Other
Time (Δt ≤ –10)	-0.0953 (25.26)	-0.1011 (11.94)	-0.0721 (15.65)
Time (–10<Δt<10)	-0.0087 (0.98)	0.0068 (0.60)	0.0941 (9.60)
Time (Δt ≥ 10)	-0.0722 (17.27)	-0.0741 (9.83)	-0.0461 (9.16)
Cost	-0.0096 (21.30)	-0.0160 (16.42)	-0.0141 (21.16)
Cost Covariate CΔc	0.00000178 (7.06)	0.00000270 (3.32)	0.00000284 (8.40)
Inertia	0.9135 (23.27)	0.9354 (17.55)	1.0054 (22.89)
Average LL	-0.604069	-0.582888	-0.560486
No. Obs	9557	4737	8038

For all three types of journey purpose, "large" time savings are shown, in fact, to have a **higher** value than "large" time increases: this counter-intuitive result is in line with the earlier findings (see Table 15) when the inertia term is present. The (uncorrected) t-statistics reporting the significance in the difference between time coefficients for large savings and losses are 4.6, 2.7 and 4.3 for business, commuting and "other" traffic respectively.

For small time changes, business and commuting traffic have (effectively) a zero value of time and "other" traffic has a (significant) negative value of time. Note that a corresponding effect was seen in AHCG's Model 4-2 where the Other purpose coefficient on Δt = +5 had the wrong sign, though its significance was marginal.

We are thus finding a strong effect that the value attached to small changes in time is very low, and, in some cases, apparently negative. Although our model specification is different, these findings are not essentially in disagreement with those reported by AHCG.

6.4 Interpretation of Findings relating to Small Time Changes

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

In Section 3 we demonstrated 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. 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. There is also the issue of to what extent small time changes are **perceived** (or, perhaps better, in the context of an SP exercise, taken seriously).

The implied negative values of time are a different matter: taken at face value, they are simply illogical. The fact that we have estimated one negative value of time (apparently significant) plus, from the earlier tables, significant dummy utility coefficients of the wrong sign needs to be very carefully considered in order to arrive at a correct interpretation.

In the first place, it is critical to note that the design does not offer respondents any opportunity to **display** a negative value of time – ie by choosing a time increase rather than a cost decrease[5]. 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.

If we concentrate on the "small time changes", and, for convenience, on the tradeoffs in quadrants 1 and 3, where "inertia" is not an issue, we can see from the design (given in Appendix A) that for each time change Δt, there are a number of possible comparisons across the different questionnaires – sometimes the same comparison occurs in different questionnaires.

Thus, for Δt = –3, we have:

Q1 treatment 6	Δc = –75
Q5 treatment 6	Δc = – 5
Q6 treatment 7	Δc = –30
Q9 treatment 8	Δc = – 5

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. Although there will be differences associated with the respondents facing different questionnaires, because of their base journey conditions, we would generally expect that for "Q1 treatment 6" the proportion choosing the cost saving will be higher than those for "Q5 treatment 6" and "Q9 treatment 8", since in the first case a cost saving of 75 pence is offered, while in the latter cases, the cost saving is only 5 pence – all to be traded against a time saving of 3 minutes.

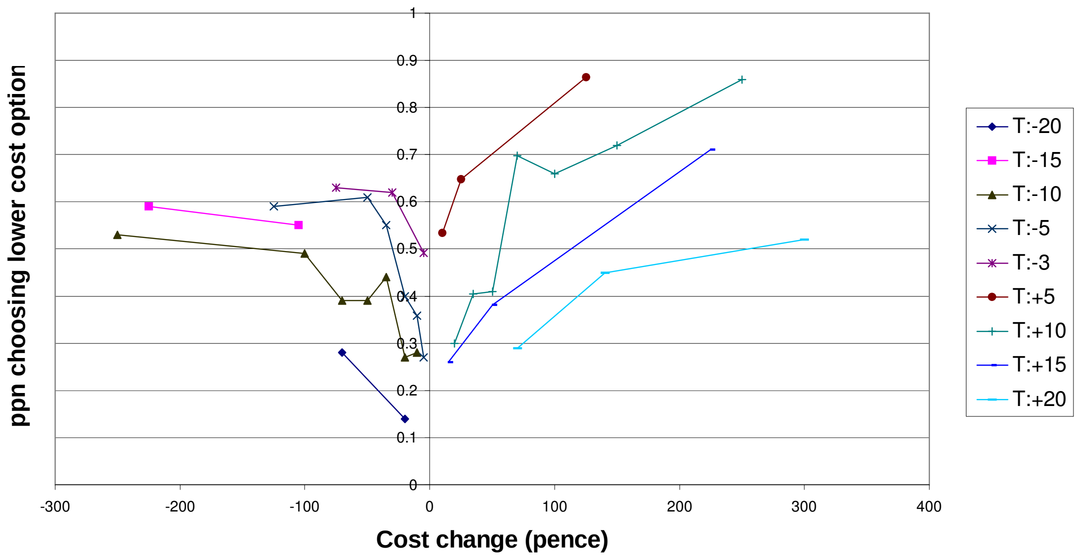
We therefore examined all the tradeoffs in Quadrants 1 and 3. Apart from minor variations, the data for each purpose confirmed that:

> 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, and is illustrated for the Business purpose in Figure 7 (Figures for the other purposes are given in Appendix C). Type 3 tradeoffs (reductions in cost and time) are on the left side, and Type 1 tradeoffs on the right side. Each connected line corresponds to a particular time change (eg Δt = +10), and the vertical axis shows how the proportion choosing the lower cost option changes according to the size of the cost change. For Type 3, the lower cost option is the cost saving itself, while for Type 1 it is the increased time option. This explains the different orientation of the two sides of the Figure.

[5] The only (trivial) exception is that due to the error in the questionnaire relating to one of the treatments (see footnote 3)> However, we have already demonstrated that this has no significant impact on the analysis.

Figure 7: Business Travel - aggregate choices in raw data



In spite of the general rationality displayed by this data, the general level of those choosing the cost saving is high, even when the cost saving is small. As an illustration, we present in Table 27 the results for "small" time changes (as defined previously) – note that observations have been combined across questionnaires when the tradeoffs are identical.

For example, this shows that for Business travellers, 27% would prefer a reduction of 5 **pence** in the journey cost to a reduction of 5 minutes in the time, and this proportion rises to 59% who would prefer a reduction of £1.25 rather than 5 minutes. It is the values at the low end of the cost savings that are most difficult to accept – ie that more than a quarter of business travellers value a 5 minute saving at less than 1 p/min.

Table 27: estimation sample proportions choosing lower cost option (Quadrants 1 & 3)

Δt	Δc	proportion choosing lower cost		
		Business	Commuting	Other
-5	-5	0.27	0.19	0.45
-5	-10	0.36	0.45	0.52
-5	-20	0.40	0.39	0.50
-5	-35	0.55	0.68	0.71
-5	-50	0.61	0.66	0.65
-5	-125	0.59	0.73	0.84
-3	-5	0.49	0.56	0.59
-3	-30	0.62	0.79	0.86
-3	-75	0.63	0.79	0.90
+5	10	0.53	0.49	0.66
+5	25	0.65	0.69	0.78
+5	125	0.86	0.93	0.92

In examining this further, it is convenient to reproduce the form of “dummy variable” analysis reported in Table 23 etc. leaving out the “inertia” cases (types 2 and 4). These results are given in Table 28 below:

Table 28: Conditioning on Time (types 1 and 3 only)

	Business	Commute	Other
Cost	-0.0081 (12.36)	-0.0144 (9.89)	-0.0139 (13.12)
Cost Covariate CΔc	0.139E-05 (4.05)	0.153E-05 (1.42)	0.307E-05 (6.30)
T-20	1.6396 (12.61)	1.3936 (3.60)	1.1751 (7.91)
T-15	0.7922 (4.76)	1.6745 (4.50)	0.8903 (3.64)
T-10	0.9212 (10.45)	0.8281 (5.34)	0.5309 (4.63)
T-5	0.3181 (3.93)	0.1876 (1.90)	-0.2384 (2.79)
T-3	-0.0195 (0.20)	-0.2798 (2.77)	-0.4454 (5.26)
T5	0.3707 (3.77)	0.1833 (1.44)	0.7439 (5.79)
T10	-0.3937 (5.47)	-0.2929 (2.53)	-0.0315 (0.37)
T15	-0.9319 (6.69)	-0.9737 (3.96)	-0.9239 (5.06)
T20	-1.4356 (9.52)	-2.5415 (5.42)	-1.0568 (4.73)
Average LL	-0.646311	-0.630568	-0.592166
No. Obs	4754	2338	3983

While not identical, these results are generally very close to those given in Table 23 for the whole sample, with the inclusion of the inertia term, as can be seen from Figures 8a-c which plot both the Table 23 results and those from Table 28 as indifference curves.

Figure 8a: Business Indifference Curves

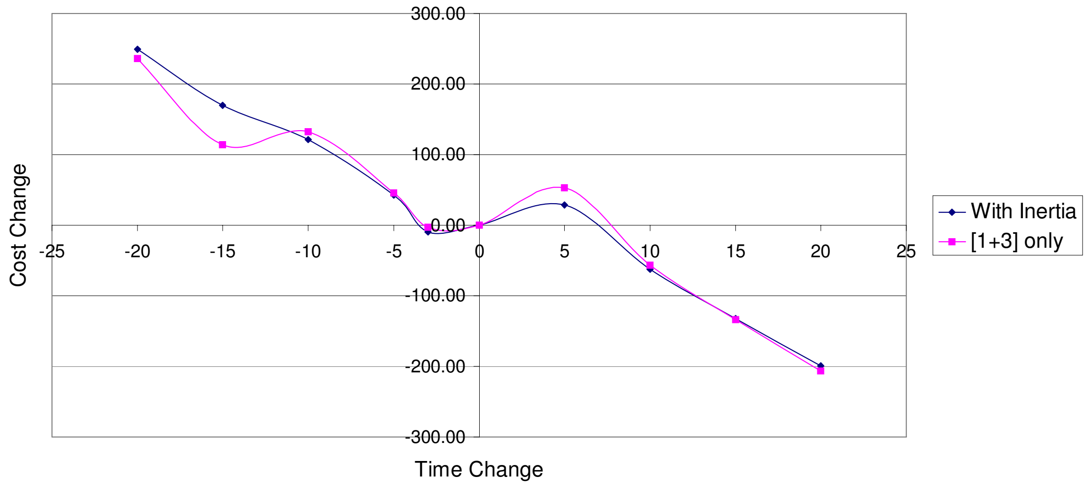


Figure 8b: Commuting Indifference Curves

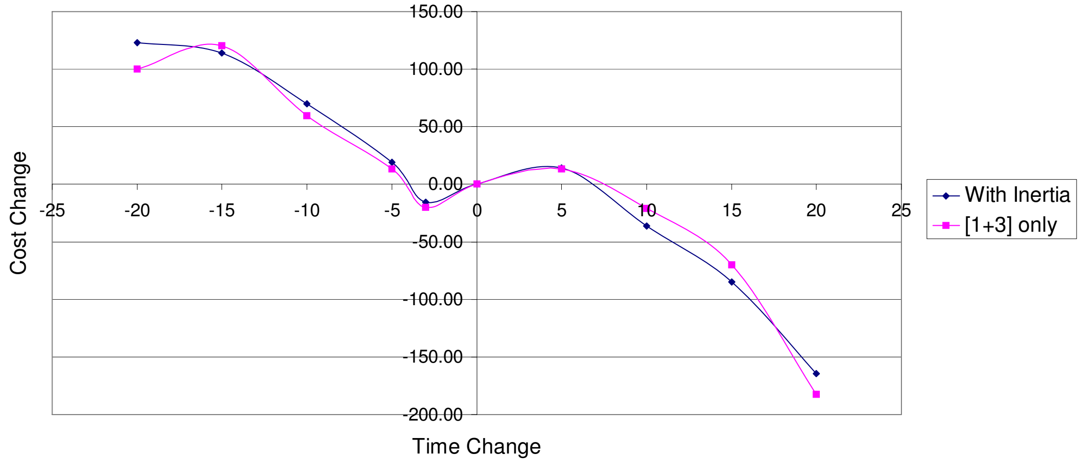
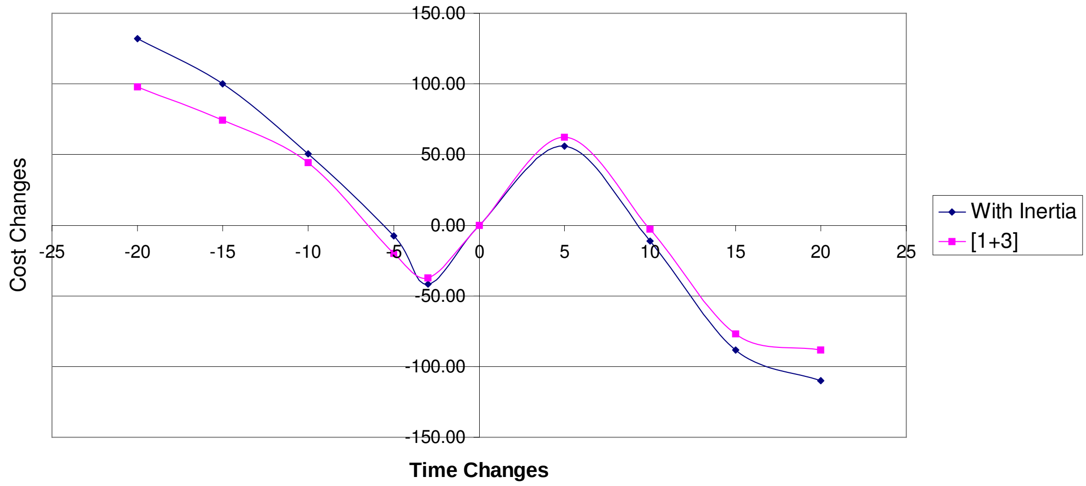


Figure 8c: Other Indifference Curves



The results can be considered analogous to an aggregate log-linear estimation along the following lines. For convenience, we denote the cost saving alternative as A and the time saving alternative as B. Consider a tradeoff in quadrant 3 so that $\Delta c < 0$ for A and $\Delta t < 0$ (time saving) for B. Then the respective utilities are:

$$U_A = -\beta\,\Delta c \qquad U_B = \alpha$$

where we expect both α and β to be positive.

Assuming the logit model, the probability of choosing A is given by

$$p_A = \exp(-\beta\,\Delta c)/[\exp(-\beta\,\Delta c) + \exp(\alpha)].$$

Hence $\ln(p_A/1-p_A) = -\beta\,\Delta c - \alpha$

For $\Delta t = -3$, there are only 4 "observations" (2 of which can be pooled, as they relate to the same value of Δc). From this, we have to estimate the dummy coefficient α (the value of β is of course determined by other pair-wise comparisons as well), and this (here, the utility of $\Delta t = -3$) effectively determines the value of Δc at which 50% would choose the cost saving (so that ln (p/1–p) = 0): this is given by $\Delta c = -\alpha/\beta$. In circumstances where ln (p/1–p) is high even for small cost savings, the result may well be that α has the wrong sign.

To give a simple example, suppose that 90% choose the cost savings at $\Delta c = -75$, and 67% choose it at $\Delta c = -5$. Then the values of ln (p/1–p) are ln (9) = 2.2 and ln (2) = 0.69. Hence 70 β = 2.2–0.69 = 1.51 and β = .0216. Hence α = – (.69 – .108) = –.582. This implies a **negative** utility for $\Delta t = -3$, and correspondingly a negative value of time.

This explanation suggests that the negative values of time are not a feature of the data, but rather of the assumptions made in the analysis, which should not **allow** the value of time to go negative. Given that the data demonstrates a high proportion choosing the cost saving, one reasonable explanation is that there is a significant block of respondents whose value of time is effectively zero for small time changes (though whether this is truly the case, or merely how they respond to the SP, cannot be determined). All such respondents, who effectively treat the time change as zero, choose the cost saving. On top of them, there will be a distribution of non-zero values of time who will contribute to the overall (low) average value of time.

This explanation also fits the observed results on the proportion choosing the time loss or money loss for type 1, when $\Delta t = +5$. In this case, a proportion effectively treat the time increase as zero, and choose it in preference to losing even small amounts of money.

6.5 Models with Distributed Values of Time

One way of dealing with this is to allow for a **distribution** of values of time, with a lower bound of zero. A standard assumption is to assume a lognormal distribution with parameters μ, σ, to be estimated, and this was tested in the AHCG work.

There are a number of ways in which the lognormal distribution can be specified, and there are further variations on the estimation approach. The method proposed by Ben-Akiva, Bolduc & Bradley (1993) scales the utility in money terms, while estimating an overall scaling parameter compatible with the standard logit formulation (so that this is effectively the coefficient on cost), with the value of time lognormally distributed. A variant on this is to allow for co-variates to affect the mean value of time - again, there are different ways of specifying this (see Ben-Akiva, ?1996).

A further important assumption relates to the **domain** of the variation when dealing with SP data: essentially, the question is whether one should postulate a single (random) value of time for each respondent, or allow the randomness to relate to individual choices. If the variation is expected to relate essentially to the respondent, then it would seem that the former approach should be adopted. However, since AHCG also postulated that there would be variation with the sign and size of the design variables, they took the latter approach.

Although AHCG report the findings of lognormal distribution models in terms of values of time (Tables 122 and 123), they do not report the actual coefficients. They indicate that such models give a better fit to the data than "simple" logit models, but after comparing the distributions of implied VOT for log-normal and simple (covariate) models concluded that "the log-normal assumption may not be appropriate in this case", for reasons which we do not fully understand.

For the simplest model (corresponding with our M1), AHCG found that the lognormal specification was only marginally better for the Business sample, but showed a substantial improvement for Commuting and Other (comparable, in LL terms, to the quadratic incremental specification M2b). For the full covariate model AHCG4-4 (where the contributions of the covariates were **fixed** for the purpose of the lognormal estimation), a further significant improvement was found.

With limited time at our disposal, we were not able to develop purpose-built software, and we made use of GAUSS code developed by Train, Revelt and Ruud (1996,1999) at the University of California, Berkeley for error components logit (ECL). This makes use of simulated maximum likelihood techniques, whereas AHCG used Gaussian quadrature: this should not lead to substantial differences.

For practical reasons we confined the lognormal effect to the time coefficient only, and estimated an alternative version of model M6d. Since the time coefficient is expected to be negative, and the lognormal distribution is not defined for negative values, we multiply the time changes by –1 and estimate a positive time coefficient.

The results are shown in Table 29 below. The parameters which are actually estimated for the time coefficient are the mean and standard deviation of the underlying normal distribution. Despite various attempts, we were unable to obtain a converged estimate for Commuters.

Table 29: ECL Choice models with the time coefficient log-normally distributed

	Business	Commute	Other
Time (μ)	-2.5113 (59.42)		-3.0196 (26.31)
Time (σ)	0.3540 (2.43)		1.3064 (10.40)
Cost	-0.0110 (18.74)		-0.0267 (10.34)
Inertia	0.8535 (23.27)		1.0765 (19.80)
Cost Covariate	0.224E-5 (8.18)		0.633E-05 (9.42)
Average LL	-0.609043		-0.575785
No. Obs	9557		8038

The estimated value of σ for Business appears significant (though it would probably not be if we corrected for repeated measurements), but the improvement in LL is marginal. For Other traffic, the value of time has a strongly skewed distribution: the value of σ is highly significant, and the improvement in LL is also highly significant. It is also noteworthy that for Other traffic, the cost coefficients are about 1.5 times as large, compared with the fixed coefficient version (Table 21d).

We can convert the coefficients in Table 29 to values of time, using the standard properties of the lognormal distribution: the results, and the formulae used, are given in Table 30.

Table 30: A comparison of the implied value of time by model type

		Business	Commute	Other
"Fixed Coefficient"	$\beta_t/(\beta_{c0}+\beta_{c1}C)$	9.22	4.47	3.66
"log-normal" mean	$\exp(\mu+\sigma^2/2)\ /(\beta_{c0}+\beta_{c1}C)$	9.39	n/a	5.04
"log-normal" median	$\exp(\mu)\ /(\beta_{c0}+\beta_{c1}C)$	8.82		2.15
"log-normal" mode	$\exp(\mu-\sigma^2)\ /(\beta_{c0}+\beta_{c1}C)$	7.78		0.39
"log-normal" std dev	$\exp(\mu+\sigma^2/2).\sqrt{(\exp\sigma^2-1)}\ /(\beta_{c0}+\beta_{c1}C)$	3.45		10.70
Mean C (pence)		822.9	301.5	623.4

For the purposes where we have achieved an estimation with the lognormal distribution, the results are in line with those of AHCG (for the models without covariates). They support a highly skewed distribution for Other traffic, but not for Business. We may note that, while in the case of Other traffic the high proportions choosing lower cost options could be explained by the concentration at the lower end of the distribution (since 50% have values below 2.15 p/min), this explanation does not apply to the Business sample.

As noted, our lognormal analysis has not reflected the possibility that each individual has a unique value of time, distributed among the population. As was done in AHCG's analysis, the value for a given individual is allowed to vary randomly with the time changes offered. Another possibility is that for a given individual the variation is related to the time changes, particularly when these are "small".

Our conclusion from this is that while the lognormal assumption is appropriate for explaining the estimated negative values of time, it does not provide any explanation, at least in the forms tested, for the variation with the size of time change.

6.5 Other Investigations of the Data and the Design

In an indirect attempt to examine the variation of values of time within a single individual, we returned once more to the data (again, to avoid the problems of "inertia", we confine the analysis to types 1 and 3). On the null hypothesis that the individual has a **single** value of time, we can devise a rationality test by ordering the pair-wise comparisons faced by any respondent according to their implied boundary values (see Appendix A).

Formally, if the four pair-wise comparisons (in types 1 and 3) are ordered with boundary values $B_1 < B_2 < B_3 < B_4$, then the individual's willingness to choose the option with the shorter time **should not increase** as the boundary value increases. Individuals whose responses contradict this can be viewed as "irrational" (though, NB, only on the underlying assumption of a **single** value of time). On this definition, 31% of respondents were classed as "irrational".

The twelve questionnaires differ substantially in their distribution of small time changes. If the main factor affecting this "rationality" test was a tendency for different (lower) values of time in connection with small time changes, we would expect a greater proportion of "irrational" respondents among those questionnaires with more pair-wise comparisons involving small time changes. In fact, no such tendency could be inferred.

A different line of enquiry was to see whether the design implied any inherent bias in terms of the (average) values of time which could be recovered. In order to examine this, we devised a simulation procedure to “manufacture” responses with different assumptions about the underlying average value of time, and to analyse the data to see the power of the design.

1000 individuals were simulated to respond to each of the 96 treatments in the design. Analysis of the 96,000 simulated responses showed a very close match between "assumed" and "modelled" values of time, over the range from 1 to 20 p/min. Thus, at least for the recovery of average values of time, the design appears extremely robust.

Further analysis looked at size and sign effects. For a simulated value of time of 10 pence per minute, the model was able to recover the value of time separately for “large time savings” (–10 minutes or more), “large time losses” (+10 minutes or more) and small time changes in the range [–5,+5].

Finally, we investigated the ability of the design to recover variation in values by the size of the time change (as is done, of course, in Table 83 of AHCG, as well as in the “dummy variable” analysis reported above). Although the results were slightly less robust (which is to be expected given the greater level of disaggregation), the performance was still very acceptable.

The simulations also indicated that if “inertia” was present but not included in the model formulation, then the input values of time were not recoverable. Including the inertia term corrected for this.

Overall, therefore, we consider that we have subjected the design to significant testing, and it has proved remarkably robust. This removes concerns which were expressed previously at the time of the independent reviews commissioned by the Department and bound in with the AHCG Report. We are confident that the results being obtained are **not** artefacts of the design.

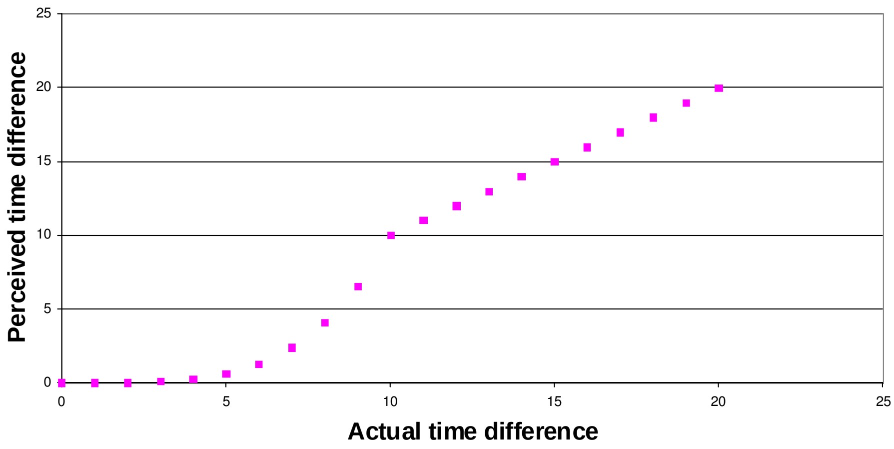
6.6 Thresholds and Perception

An alternative explanation for the apparent low values of time for small time changes is that individuals **do** have a single value of time, but there is some mechanism, which for convenience we refer to as perception-filtering, which downgrades or “discounts” (see Welch & Williams) the absolute size of the change below some “threshold”. Assuming symmetry between positive and negative changes, in line with the analysis reported earlier, the “perceived” time difference ($\Delta\tau$, say) could be written:

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

where θ is the threshold value (eg 10 minutes), and $m > 1$ an estimated parameter, implying a relationship as illustrated in Figure 9.

Figure 9: Perception Filter



The aim is then to define the utility function in terms of $\Delta\tau$ rather than Δt, with the implication that small changes are perceived as smaller than they are. Note that for $\theta = 0$ or $m = 1$, the model resolves to M6d.

With this in mind, we set up a procedure to estimate m and θ. Because of the non-linear nature of the estimation, we firstly confined ourselves to a grid-search over integer values of θ, obtaining Maximum Likelihood estimates of m and other coefficients conditional on θ. This was not possible for all values of θ. The results in terms of model log-likelihood and estimated m are presented in Table 31.

Table 31: Model LL for alternative values of "perception parameters"

	Business		Commute		Other	
Assumed θ	m (t-ratio)*	Average LL	m (t-ratio)*	Average LL	m (t-ratio)*	Average LL
0	1 (fixed)	-0.609129	1 (fixed)	-0.591140	1 (fixed)	-0.578161
4	>70	n/a	>18	n/a		n/a
6	9.14 (3.27)	-0.605034	9.92 (2.63)	-0.583403		n/a
8	4.43 (3.29)	-0.605064	5.12 (2.57)	-0.583472		n/a
10	3.43 (3.22)	-0.605085	4.09 (2.37)	-0.583517		n/a
11	3.15 (4.85)	-0.604423	4.44 (3.42)	-0.582373	8.20 (6.54)	-0.563342
12	2.43 (6.20)	-0.604624	3.19 (5.04)	-0.582492	5.21 (7.60)	-0.563550
13	2.11 (6.64)	-0.604861	2.72 (5.75)	-0.582755		n/a
14	1.91 (6.77)	-0.605066	2.45 (6.13)	-0.583028		n/a
15	1.78 (6.82)	-0.605235	2.26 (11.33)	-0.583280		n/a

*NB the t-ratios test the significance of the difference of m from 1.0, which is the null hypothesis

For all three purposes, the indication is that of the values tested for θ, 11 minutes gives the best result in terms of LL[6]: the value of m is in all cases significantly different from 1. In all cases, the model is a substantial improvement on model M6d with no threshold (as shown in

[6] in subsequent analysis, we were able to optimise both θ and m simultaneously for the Business and Commuting purposes: the estimated values for θ were 10.83 and 11.13 and the improvement in average LL was very small

Table 21d). The complete estimated models (M8) for θ = 11 are set out in Table 32: the specification for M8 is identical to that for M6d, except that Δt is replaced by Δτ.

Table 32: Choice 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

In comparison with Table 20d, most of the coefficients are similar, but the time coefficients have all increased (though only slightly for Business), resulting in higher values of "perceived" time, once the smaller actual time changes have been effectively downgraded. This results in the following comparison in terms of values of time (Table 33), calculated, as usual, at the sample mean journey cost:

Table 33: A comparison of the implied value of time by model type

	Business	Commute	Other
"no threshold" (M6d)	9.34	4.48	3.72
"threshold θ = 11" (M8)	10.74	6.65	5.78

Summarising, the Business value rises by 15%, the Commuter by 48% and the Other value by 55%. Note that they are still not as high as the values estimated only on the "large" time changes (as given in Table 25), which are between 13 and 24% higher.

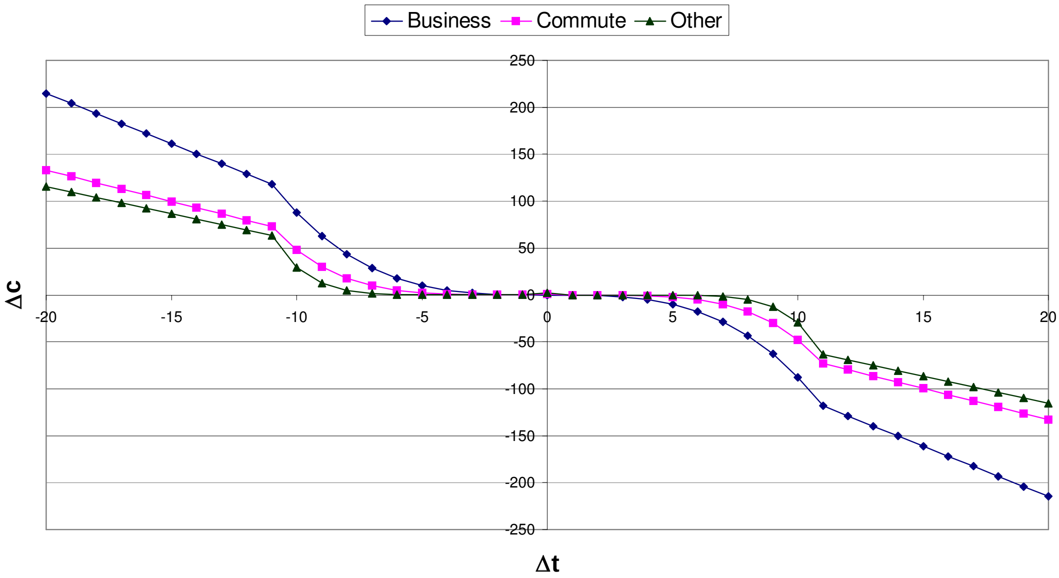
The perception function implies the following "perceived" values for the time changes used in the experiment (Table 34):

Table 34: Implications of the perception function

Presented values	"Perceived" Values		
(minutes)	Business	Commute	Other
10	8.15	7.21	5.03
5	0.92	0.33	0.02
3	0.18	0.03	0.00

There is thus a strong implication that travellers are not responding to the small time changes. If we transform to indifference curves, as before, we obtain the pattern shown in Figure 10. 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**.

Figure 10: Indifference Curves with Perception Effect



Conclusions on Small Time Savings

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. Our preferred model indicates that time changes of 10 minutes or less are increasingly "discounted".

Nonetheless, we are not inclined to take these results at face value. 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.

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.

The evidence is essentially silent on these two alternatives. There must be some doubt, indeed, as to whether Stated Preference is a suitable vehicle for carrying out the investigation of responses to small time changes, despite the commendable effort put into it by AHCG.

In the circumstances, our preferred view is to abide by the theoretical requirements on the shape of the indifference curve. For reasons which have been rehearsed elsewhere, (see for example Fowkes (1999)) we believe that any valuations based on the "small time savings" hypothesis (that small time changes have lower unit value) are not appropriate, either for evaluation or for forecasting models. Thus we believe that explanation b) above is the more plausible, and that the values set out in Table 33 for the threshold model M8, based primarily on the higher time differences, are the most reliable results (before taking account of covariates).

We are aware that this can be seen as somewhat perverse, given the fact that most projects rely for their benefits on "small" time savings – precisely the ones whose SP valuation we are ignoring! In principle, the "perception" function does provide a (possibly) principled way of testing what the impact on benefits would be if a "discounted" approach (à la Welch & Williams) were to be taken. An alternative approach, which requires further consideration, is that while a constant value of time is recommended, the **reliability** attached to predicted small time savings needs to be explicitly dealt with.

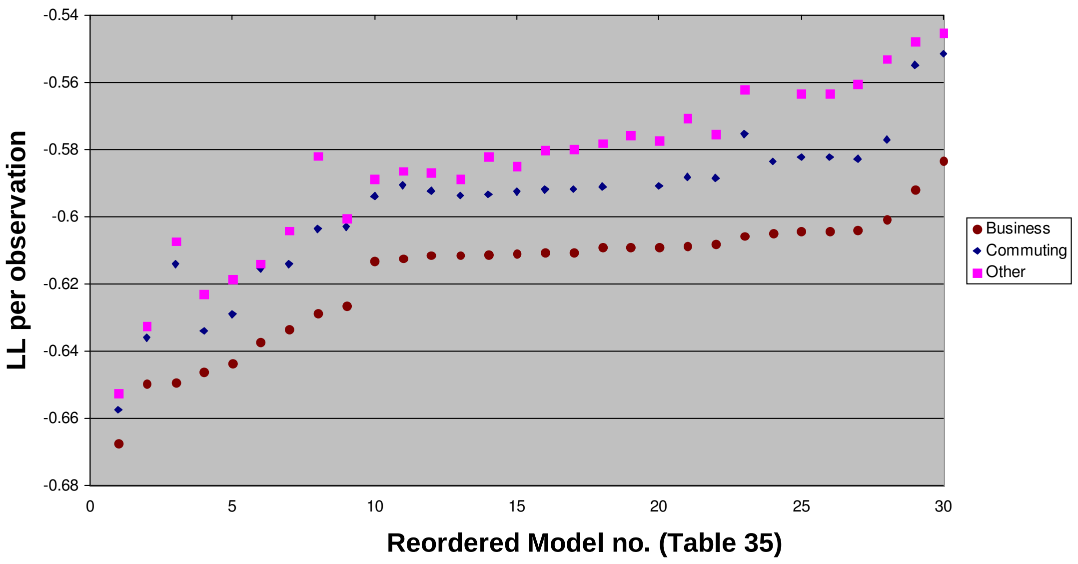
In the last analysis, we conclude that SP is a relatively weak method for eliciting values of small time savings *per se*, and that consequently any recommendations in this area (both for modelling and evaluation) must rely on a mixture of theory interpretation and pragmatism. It will be important to examine critically any other evidence that has attempted to examine this issue, as well as the question of what is actually to be defined as "small" in the context of time changes.

7. OVERALL CONCLUSIONS FROM THE ANALYSIS

7.1 Model Formulation

After a lengthy investigation, which has examined a number of alternative model specifications, a useful summary of the conclusions can be given by considering the level of explanation, represented by the average LL value, for the various models estimated.

Figure 11: Average LL for different models



As an expositional device, we have chosen to plot in Figure 11 the values for the various models in ascending order according to the Business results. In general, the conclusions for the different purposes are very similar, but this approach does indicate where significant differences between the purposes occur. It is also easy to see the significant improvements which are associated with certain specifications.

For reference, the results are also set out in Table 35. To avoid confusion, the reordered model nos. are given in the last column of the table and will be referred to as RM1 etc.

Table 35 Model Development

		Parameters	Business	Commuting	Other	Reordered Model no.
sample (after exclusions)			9557	4737	8038	(RM)
MODEL						
lnCost		2	-0.667525	-0.65766	-0.65249	1
M1(Linear)	(AHCG 4-1)	2	-0.649687	-0.636065	-0.632679	2
AHCG lognormal[~4.1]		3	-0.6495	-0.6143	-0.6074	3
M2 (Quadratic)	(t^2,c^2)	4	-0.646347	-0.6341131	-0.623004	4
M3 (Power)		4	-0.643674	-0.629175	-0.618773	5
M2a	(Δt^2, Δc^2)	4	-0.637375	-0.61551	-0.614007	6
M2b	(Δt^2, Δc^2)cov	6	-0.633499	-0.614272	-0.604248	7
M7 (dummies)		11	-0.628999	-0.603723	-0.582007	8
M5	sign	4	-0.626621	-0.603173	-0.600502	9
M1I	M1 + Inert	3	-0.61318	-0.593923	-0.58873	10
M2aI	M2a+ Inert	5	-0.612433	-0.590738	-0.586458	11
M5I	sign+Inertia	5	-0.611578	-0.592345	-0.587002	12
M1II	inertia T,C	4	-0.611577	-0.593835	-0.588736	13
M6e	I,CΔt cov	4	-0.611291	-0.59333	-0.582053	14
M1IQI	I for 2,4	4	-0.610957	-0.592484	-0.584912	15
M6c	I,TΔc cov	4	-0.610678	-0.592029	-0.580421	16
M6b	I,TΔt,TΔc cov	5	-0.61061	-0.591882	-0.579991	17
M6d	I,CΔc cov	4	-0.609129	-0.59114	-0.578161	18
lognormal	~M6d	5	-0.609043	#N/A	-0.575785	19
M6a	I,TΔt,CΔc cov	5	-0.608962	-0.590903	-0.577363	20
normal	~M6d	5	-0.608888	-0.588225	-0.57063	21
M2bI	M2b+ Inert	7	-0.608058	-0.588621	-0.57558	22
AHCG sign + size [4.2]		15	-0.6058	-0.5755	-0.5622	23
Percept10		5	-0.605085	-0.583517	#N/A	24
Percept11		5	-0.604423	-0.582373	-0.563342	25
Percept *		5	-0.604414	-0.582369	-0.563317	26
3dummiesI		6	-0.604069	-0.582888	-0.560486	27
dummiesI		12	-0.600748	-0.577071	-0.553108	28
AHCG covariates [4.4]		(29,31,34)	-0.5919	-0.5548	-0.5479	29
AHCG lognormal[~4.4]		(30,32,35)	-0.5833	-0.5514	-0.5452	30

RM1 is the Ln Cost specification, which is the worst for all purposes, while RM2 is the basic model (M1) corresponding to AHCG 4-1. RM3 is the AHCG lognormal variant on M1, which produces little improvement for business, but a more substantial improvement for the other purposes.

RMs 4 to 7 show the modest progress available from non-linear specifications. Continuing progress is made in RMs 8 (size dummies) and 9 (sign effects): the Other results for RM8 show a particularly marked improvement, reflecting the strongly "discounted" values of small time changes for this purpose.

RM10 is the first "inertia" specification, and for all purposes there is a perceptible "jump" relative to the "sign effects" specification. RMs 11 to 13 represent minor improvements, though it is noticeable that for Commuting and Others it is RM11 which is in fact the best of this range.

While RM15 allows the inertia effect to vary by quadrants 2 and 4, the remaining RMs in the range 14 to 18 and 20 represent the alternative specifications for the journey covariates (these are all specifications including Inertia). RM19 introduces the lognormal distribution on the chosen specification (M6d) – for Business the improvement is slight, but for Other it is more marked (the model could not be estimated for Commuting).

RM21 is the same model (M6d) but assuming a normal distribution on the time coefficient – this was not reported in the text above, but in fact produces a better fit than the lognormal (though it does not constrain the value of time to be positive). Once again, the greater variability in the Other sample is demonstrated.

RM22 allows for non-linearity (quadratic formulation based on Δt^2) as well as the covariates due to time and cost.

RM23 is the AHCG Model 4-2, with sign and size effects. Note that this produces a far greater improvement for Commuting and Other than it does for Business. RMs 24 to 26 are the most parsimonious models which deal with both the sign (inertia) and size (perception) effects: these have 6 parameters (including the threshold θ) compared with AHCG 4-2 which has 15. The variations associated with different values of the threshold are minor.

RMs 27 and 28 are dummy specifications including inertia – in RM27 the time changes are grouped into three ranges. Although the full specification of RM28 (M7I) outperforms the threshold models for all purposes, it involves substantially more parameters.

The last two RMs are from AHCG and introduce covariates (model 4-4): RM30 allows the value of time to be lognormally distributed. Since we have not yet introduced covariates to our analysis (apart from those related to the journey), these models understandably show a greater level of explanation.

Aside from these, where further investigation into covariates will be reported in a later project note, we conclude that the models based on inertia and thresholds reported in Table 33 are good and parsimonious descriptions of the data, and are far easier to interpret than the equivalent HCG 4-2, which in any case makes use of distinctions by the sign of the time and cost changes which we consider invalid. The differences in overall log-likelihood, with 9 fewer parameters, are -13.16 (Business), 32.56 (Commuting) and 9.18 (Other).

We therefore propose that these models are taken forward into the covariate analysis.

7.2 Recommendations on Sign and Size Effects

At the outset of this paper, we suggested a number of reasons for giving attention to the possible variation in value of time due to the sign and size of the time change. We now recall these, with some conclusions.

i. small amounts of time are less useful than large amounts;

ii. small time savings (or losses) might not be noticed by travellers and any that are not noticed cannot be valued by those affected and so should not be valued by society;

iii. small time savings are said to often account for a large proportion of scheme benefits, so that small errors in measurement might mean that the scheme is really of no benefit to anyone;

iv. allowing small time savings to have ‘full’ value is said to inflate the measured total of benefits and so lead to schemes (often road schemes) being wrongly found to have sufficient net benefit to justify implementation;

v. time savings are less highly valued than are time losses, according to surveys, and so should have a lower unit value when evaluating schemes.

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 is due 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. Our preferred model indicates that time changes of 10 minutes or less are increasingly “discounted”.

Nonetheless, we are not inclined to take these results at face value. 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.

There must be some doubt, indeed, as to whether Stated Preference is a suitable vehicle for carrying out the investigation of responses to small time changes, despite the commendable effort put into it by AHCG. 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 that has attempted to examine this issue, 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 “discounted value” hypothesis, and to base the values of time on the implied rate of tradeoff between time and money for the larger time changes.

We should conclude by saying that while we have disagreed with some important points in the AHCG Report, this should not in any way be taken as casting doubt on the quality of their work, both with regards to the data collection and preparation and the analysis to which it has been subjected.

This paper has been primarily concerned with the analysis of the AHCG data. In terms of implications for appraisal, it follows from our analysis that we concur with AHCG's conclusion that appraisal values should not differ by sign. We also agree that unit values for appraisal should not differ by size, but our preferred model specification will yield different values from AHCG's.

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Appendix A: 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	**U**rban[7]	**T**runk
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)

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 Δt = 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 Δc/Δt - 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	Δt > 0, Δc > 0
2	Δt > 0, Δc < 0
3	Δt < 0, Δc < 0
4	Δt < 0, Δc > 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).

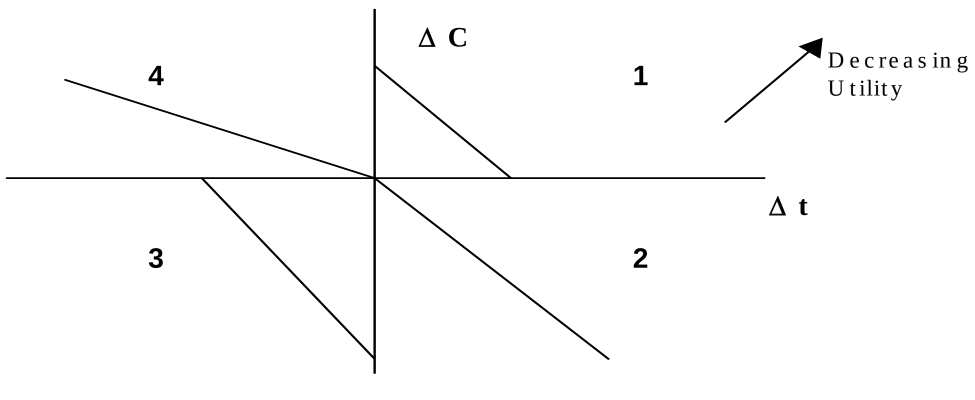

Figure A1: Types of Pairwise Comparison in SP Design (Experiment 1)

[7] 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.

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 – ie 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.

Appendix B: Various estimated models for purpose and size of time change segments

As noted in Section 6.3, the three subsets "small, medium, large" are based on the (absolute) size of time change in the pairwise comparison, as follows:

“small”	(-3, -5, +5)
“medium”	(-10, +10)
“large”	(remainder)

Four separate models are presented: M1, M5, M1I and M5I

Table B1: M1 Business

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time	-0.073041	-18.25	-0.077402	-15.52	-0.045625	-3.69
Cost	-0.005248	-11.33	-0.00782	-17.37	-0.01464	-12.32
Obs	2374		3925		3258	
LL	-1437.1		-2544.99		-2117.68	
Av LL	-0.60535		-0.648405		-0.649995	
VoT	13.92	17.82	9.9	22.61	3.12	4.63

Table B2: M1 Commuting

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time	-0.077809	-7.44	-0.074459	-9.44	-0.039565	-2.67
Cost	-0.00897	-6.07	-0.012114	-11.19	-0.022877	-13.41
Obs	387		1507		2843	
LL	-236.23		-963.1		-1724.19	
Av LL	-0.610415		-0.639084		-0.60647	
VoT	8.67	9.6	6.15	13.51	1.73	3.13

Table B3: M1 Other

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time	-0.052587	-10.85	-0.051249	-8.91	0.047729	3.46
Cost	-0.006958	-11.2	-0.01185	-16.36	-0.019802	-12.99
Obs	1418		2836		3784	
LL	-907.45		-1746.25		-2151.92	
Av LL	-0.639954		-0.615744		-0.568688	
VoT	7.56	16.43	4.32	12.33	-2.41	2.84

Table B4: M5 Business

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time +ve	-0.101146	-16.02	-0.096419	-16.8	-0.087726	-5.8
Time -ve	-0.065927	-16.04	-0.048233	-7.18	0.028792	1.87
Cost +ve	-0.008798	-13.56	-0.011843	-17.94	-0.0226	-13.81
Cost -ve	-0.005149	-8.39	-0.003737	-7	-0.001595	-1.09
Obs	2374		3925		3258	
LL	-1401.96		-2440.13		-2010.89	
Av LL	-0.590547		-0.621689		-0.617216	
T +ve/-ve	1.53		2.00		-3.05	
C +ve/-ve	1.71		3.17		14.17	
VoT +ve	11.5	20.54	8.14	17.8	3.88	6.36
Vot -ve	12.8	9.45	12.91	7.35	-18.05	0.76

Table B5: M5 Commuting

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time +ve	-0.114851	-8.38	-0.106005	-10.54	-0.102691	-5.58
Time -ve	-0.056976	-4.64	-0.057343	-4.99	0.037158	2.11
Cost +ve	-0.016135	-6.61	-0.022525	-11	-0.033095	-12.98
Cost -ve	-0.007332	-4.53	-0.009276	-7.9	-0.011417	-5.81
Obs	387		1507		2843	
LL	-220.06		-928.01		-1645.69	
Av LL	-0.568639		-0.615797		-0.578857	
T +ve/-ve	2.02		1.85		-2.76	
C +ve/-ve	2.20		2.43		2.90	
VoT +ve	7.12	8.24	4.71	13.47	3.1	6.11
Vot -ve	7.77	4.76	6.18	5.14	-3.25	1.68

Table B6: M5 Other

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time +ve	-0.088479	-11.26	-0.079857	-11.6	-0.023123	-1.3
Time -ve	-0.044599	-8.82	-0.02277	-2.5	0.132603	8.33
Cost +ve	-0.012551	-12.94	-0.022388	-14.67	-0.027876	-13.5
Cost -ve	-0.006534	-8.01	-0.007103	-9.14	-0.008636	-4.62
Obs	1418		2836		3784	
LL	-864.47		-1652.32		-2057.03	
Av LL	-0.609637		-0.582622		-0.543611	
T +ve/-ve	1.98		3.51		-0.17	
C +ve/-ve	1.92		3.15		3.23	
VoT +ve	7.05	15.44	3.57	14.45	0.83	1.36
Vot -ve	6.83	8	3.21	2.8	-15.36	3.26

Table B7: M1I Business

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time	-0.085302	-19.58	-0.067226	-12.97	-0.030963	-2.43
Cost	-0.007035	-13.61	-0.007202	-15.26	-0.011478	-9.5
Inertia	0.651525	8.91	0.804521	15.78	0.896911	15.61
Obs	2374		3925		3258	
LL	-1395.23		-2411.32		-1983.92	
Av LL	-0.587713		-0.614348		-0.608937	
VoT	12.12	23.19	9.33	19.13	2.7	2.94

Table B8: M1I Commuting

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time	-0.085033	-7.8	-0.06453	-7.67	-0.033345	-2.18
Cost	-0.010708	-6.82	-0.01347	-11.48	-0.021123	-11.88
Inertia	0.936759	5.36	0.868017	9.71	0.861333	13.81
Obs	387		1507		2843	
LL	-220.45		-911.56		-1620.97	
Av LL	-0.569637		-0.604883		-0.570163	
VoT	7.94	10.77	4.79	10.98	1.58	2.53

Table B9: M1I Other

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time	-0.066308	-12.59	-0.025469	-4.05	0.05509	3.86
Cost	-0.00925	-13.14	-0.010702	-14.11	-0.018395	-11.49
Inertia	0.804784	8.97	0.976129	14.66	0.950941	16.52
Obs	1418		2836		3784	
LL	-864.32		-1627.73		-2002.03	
Av LL	-0.609534		-0.573952		-0.529078	
VoT	7.17	20.38	2.38	4.92	-2.99	3.01

Table B10: M5I Business

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time +ve	-0.087135	-12.04	-0.046518	-6.17	0.03221	1.62
Time –ve	-0.08241	-13.4	-0.098191	-11.31	-0.075916	-4.01
Cost +ve	-0.007461	-10.24	-0.007999	-11.37	-0.013501	-7.94
Cost –ve	-0.006512	-9.1	-0.007013	-10.79	-0.009398	-5.44
Inertia	0.551185	3.79	1.018469	9.75	1.066419	9.56
Obs	2374		3925		3258	
LL	-1394.66		-2391.56		-1963.78	
Av LL	-0.587471		-0.609315		-0.602757	
T +ve/-ve	1.06		0.47		-0.42	
C +ve/-ve	1.15		1.14		1.44	
VoT +ve	11.68	17.66	5.82	8.24	-2.39	1.43
Vot –ve	12.65	11.94	14	13.88	8.08	5.87

Table B11: M5I Commuting

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time +ve	-0.099456	-5.78	-0.030569	-2.28	-0.000876	-0.04
Time –ve	-0.072398	-4.31	-0.111712	-7.86	-0.052204	-2.43
Cost +ve	-0.014015	-5.15	-0.012055	-6.07	-0.022181	-8.86
Cost –ve	-0.008738	-4.52	-0.013605	-9.68	-0.019917	-8.07
Inertia	0.505719	1.4	1.268016	7.32	0.939541	7.36
Obs	387		1507		2843	
LL	-219.08		-901.52		-1617.91	
Av LL	-0.56609		-0.598219		-0.569087	
T +ve/-ve	1.37		0.27		0.02	
C +ve/-ve	1.60		0.89		1.11	
VoT +ve	7.1	7.51	2.54	3.05	0.04	0.04
Vot –ve	8.29	5.63	8.21	8.82	2.62	3.02

Table B12I: M5 Other

	Large		Medium		Small	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Time +ve	-0.074571	-8.02	-0.006566	-0.67	0.119911	5.15
Time -ve	-0.057628	-8.12	-0.067803	-6.43	0.009457	0.48
Cost +ve	-0.011037	-10.19	-0.012533	-8.89	-0.015344	-7.7
Cost -ve	-0.007673	-8.27	-0.010594	-11.5	-0.020922	-8.48
Inertia	0.478875	2.71	1.194195	9.42	1.294803	10.7
Obs	1418		2836		3784	
LL	-860.76		-1608.81		-1995.23	
Av LL	-0.607022		-0.567281		-0.52728	
T +ve/-ve	1.29		0.10		12.68	
C +ve/-ve	1.44		1.18		0.73	
VoT +ve	6.76	13.03	0.52	0.71	-7.81	3.4
Vot -ve	7.51	9.28	6.4	8.1	-0.45	0.46

Appendix C Aggregate Choice Proportions in the Data

This Appendix summarises the data relating to tradeoffs in Quadrants 1 and 3 for the AHCG Experiment 1. The proportions relate to the observations in the estimation sample only, ie after implementing the exclusions defined by AHCG. The data is divided between the three purposes Business, Commuting and Other.

Altogether there are 12 x 4 = 48 pairwise comparisons falling into Quadrants 1 and 3. However, some of these relate to the same tradeoff between time and cost: as a result, there are only 36 different tradeoffs. Table C1 below shows the distribution in the design: the last column indicates whether a particular tradeoff has already occurred in the list.

We therefore combined the data for cases where the tradeoff was the same. For ease of presentation the options A and B were re-ordered so that A' was always the lower cost option (ie in Quadrant 1, A' was the option with zero cost, and in Quadrant 3, A' was the option with the cost saving). Table C2 presents the proportions choosing the option A' at each tradeoff, for the three purposes.

These figures are illustrated in Figures C1 and C2 for the Commuting and Other purposes: for Business, the corresponding Figure is Figure 7 in the main text.

Table C1: “Non-Inertia” Tradeoffs in the Design

Treatment	Δt[A]	Δc[A]	Δt[B]	Δc[B]	Questionnaire	Bvot	
14	10	0	0	70	1	7	
15	0	10	5	0	1	2	
16	-3	0	0	-75	1	25	
17	0	-20	-5	0	1	4	
13	-10	0	0	-10	2	1	
14	0	-50	-5	0	2	10	
15	5	0	0	25	2	5	
17	0	150	10	0	2	15	
12	0	-20	-10	0	3	2	
15	0	50	15	0	3	3.33333	
16	10	0	0	250	3	25	
17	-15	0	0	-105	3	7	
12	0	300	20	0	4	15	
13	-20	0	0	-20	4	1	
16	10	0	0	50	4	5	
18	0	-100	-10	0	4	10	
12	0	125	5	0	5	25	
13	0	-35	-5	0	5	7	
14	10	0	0	35	5	3.5	
16	-3	0	0	-5	5	1.66667	
14	0	-5	-5	0	6	1	
15	0	25	5	0	6	5	dup
17	-3	0	0	-30	6	10	
18	15	0	0	225	6	15	
13	0	-70	-10	0	7	7	
14	15	0	0	50	7	3.33333	dup
16	-5	0	0	-10	7	2	
17	0	250	10	0	7	25	dup
12	0	70	20	0	8	3.5	
15	10	0	0	250	8	25	dup
16	-15	0	0	-105	8	7	dup
18	0	-10	-5	0	8	2	dup
13	0	35	10	0	9	3.5	dup
15	-5	0	0	-35	9	7	dup
16	5	0	0	125	9	25	dup
18	0	-5	-3	0	9	1.66667	dup
12	0	-125	-5	0	10	25	
13	5	0	0	10	10	2	dup
14	0	70	10	0	10	7	dup
18	-10	0	0	-35	10	3.5	
12	-10	0	0	-50	11	5	
14	0	100	10	0	11	10	
15	15	0	0	15	11	1	
16	0	-225	-15	0	11	15	
13	0	-250	-10	0	12	25	
14	0	140	20	0	12	7	
16	10	0	0	20	12	2	
17	-20	0	0	-70	12	3.5	

Table C2: Proportions Choosing Lower Cost Option ("Non-Inertia" Tradeoffs)

Time	Cost	Business (Nos) Choose A'	Business (Nos) Choose B'	Business Proportion lower cost	Commuting (Nos) Choose A'	Commuting (Nos) Choose B'	Commuting Proportion lower cost	Other (Nos) Choose A'	Other (Nos) Choose B'	Other Proportion lower cost
-20	-20	28	177	0.14	6	13	0.32	36	101	0.26
-20	-70	49	124	0.28	4	10	0.29	35	53	0.4
-15	-105	64	53	0.55	13	12	0.52	40	24	0.63
-15	-225	48	33	0.59	16	7	0.7	38	11	0.78
-10	-10	28	73	0.28	8	33	0.2	10	31	0.24
-10	-20	23	62	0.27	7	12	0.37	18	34	0.35
-10	-35	53	68	0.44	30	42	0.42	46	40	0.53
-10	-50	36	57	0.39	16	11	0.59	33	23	0.59
-10	-70	15	23	0.39	16	6	0.73	12	13	0.48
-10	-100	98	104	0.49	15	3	0.83	92	41	0.69
-10	-250	88	78	0.53	4	7	0.36	65	21	0.76
-5	-5	15	41	0.27	11	48	0.19	31	38	0.45
-5	-10	28	50	0.358974	15	18	0.454545	25	23	0.520833
-5	-20	29	44	0.4	28	43	0.39	26	26	0.5
-5	-35	148	121	0.550186	207	97	0.680921	333	134	0.713062
-5	-50	60	39	0.61	27	14	0.66	26	14	0.65
-5	-125	65	46	0.59	49	18	0.73	70	13	0.84
-3	-5	142	147	0.491349	183	141	0.564815	304	208	0.59375
-3	-30	34	21	0.62	45	12	0.79	55	9	0.86
-3	-75	46	27	0.63	54	14	0.79	45	5	0.9
5	10	104	91	0.533333	71	74	0.489655	92	48	0.657143
5	25	101	55	0.647436	69	31	0.69	84	24	0.777778
5	125	140	22	0.864198	117	9	0.928571	221	18	0.924686
10	20	53	122	0.3	5	10	0.33	44	48	0.48
10	35	102	150	0.404762	155	125	0.553571	230	164	0.583756
10	50	83	119	0.41	8	10	0.44	86	47	0.65
10	70	132	57	0.698413	99	40	0.71223	107	28	0.792593
10	100	61	31	0.66	22	5	0.81	50	4	0.93
10	150	66	26	0.72	29	8	0.78	37	3	0.93
10	250	98	16	0.859649	20	3	0.869565	57	8	0.876923
15	15	24	70	0.26	5	23	0.18	22	30	0.42
15	50	47	76	0.382114	23	21	0.522727	24	51	0.32
15	225	17	7	0.71	6	1	0.86	17	1	0.94
20	70	10	24	0.29	0	7	0	10	7	0.59
20	140	78	95	0.45	6	8	0.43	54	34	0.61
20	300	100	92	0.52	10	3	0.77	104	27	0.79

Figure C1: Comuuting - aggregate choices in raw data

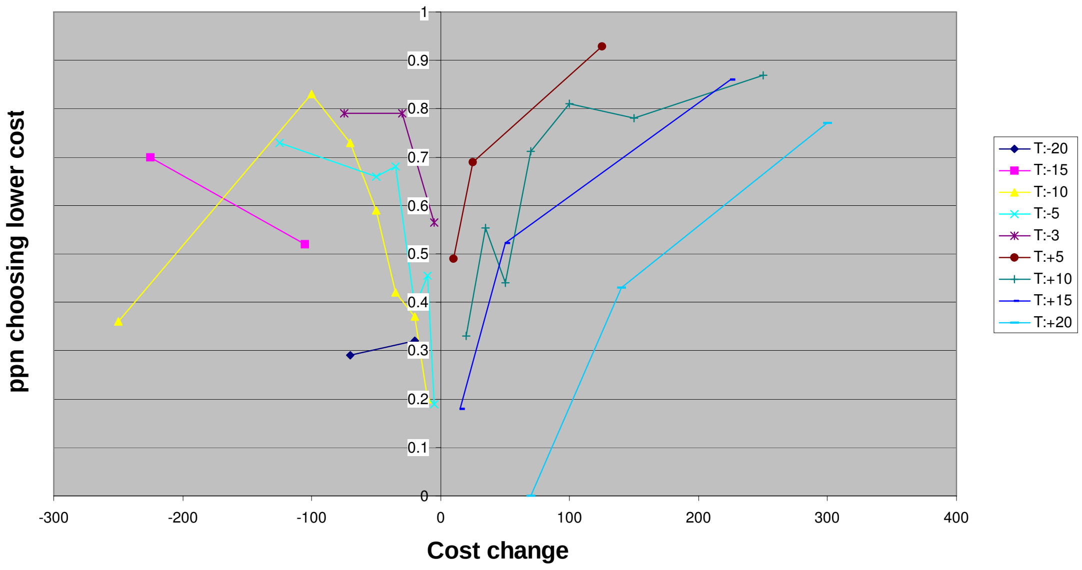

Figure C2: Other Travel - aggregate choices in raw data