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# ROUTE CHOICE AND THE VALUE OF MOTORISTS' TRAVEL TIME: EMPIRICAL FINDINGS

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Abstract

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This paper contains the empirical findings from a study of motorists' route choices. The purpose of this study was to estimate the value that motorists' place upon time savings when making urban journeys. Revealed preference models of travel behaviour are developed for commuting and leisure journeys and a stated preference experiment is undertaken for these two journey purposes and additionally for those making journeys in the course of their work.

Although the stated preference method is seen to have several advantages over the revealed preference approach in this route choice context, there is the crucial question of whether stated preferences correspond with actual preferences. Various revealed preference and stated preference models of travel behaviour are presented and the results obtained by the two methods are compared in a variety of ways. The findings of these comparisons suggest that stated preferences are an accurate reflection of actual preferences and that such data can be usefully employed for the purpose of valuing travel time savings.

A feature of the study is an investigation into how the value of time varies with socio-economic factors. A method for analysing variations in the value of time due to socio-economic variables is outlined and successfully applied to reveal a number of factors influencing the value of time. A comparison of reported and engineering values was also undertaken which suggests that there is misreporting of attribute values.

Contents

## 1. Introduction

A previous paper (Wardman 1986a) has discussed various theoretical and methodological issues involved in the estimation from route choices of the money value that motorists place upon time savings. This paper presents the empirical findings from a survey of motorists making urban journeys in Tyne and Wear, undertaken in June 1985 as part of the Department of Transport's research project into the value of time.

This survey formed part of a co-ordinated investigation into the value of time for different modes in various circumstances. The other surveys in this final phase of the value of time project were concerned with inter-urban car travel, long distance rail and coach travel and urban bus travel. A feature of each of these four studies was an investigation into how the value of time is influenced by socio-economic factors. Some of the results of these studies are briefly summarised in Bradley, Marks and Wardman (1986).

This study is concerned with motorists' route choices in three contexts: commuting, leisure travel and journeys made in the course of work. Most empirical research into the value of time has focused on journeys to and from work yet values of time derived in such contexts do not necessarily form an appropriate basis for evaluating leisure travel time savings. The study of employers' business trips is concerned with the value that the employee places upon time savings when travelling in the course of work and does not include the benefits accruing to the employer from a time saving to his employees.

The choice of route offered by the Tyne Tunnel and Tyne Bridge for certain cross-Tyne journeys allows the analysis of motorists' actual behaviour. A toll is payable to travel through the Tunnel but the Bridge is toll free and hence the opportunity arises for motorists to trade-off between a quicker but more expensive route and a slower but cheaper route. Such a choice yields information on the value placed upon time savings and revealed preference (RP) models have been developed for commuting and leisure trips. Additionally, stated preference (SP) experiments have been carried out for these two journey purposes and also for employers' business trips.

The SP experiment simulated the choice of route offered by the two crossings of the River Tyne. Respondents were presented with 16 pairwise comparisons of the two routes and were asked to express preferences between them in terms of the five responses of definitely or probably choose the tunnel, no preference and definitely or probably choose the bridge. Each route was characterised in terms of hypothetical levels of delay time, free time, toll charge and petrol cost except that toll was the only cost variable included in the employers' business trips design. The designs of the SP experiments are described in more detail in the accompanying working paper.

Travel time clearly influences route choice and it was considered useful to distinguish between two forms of travel time. Delay time is time spent in congested traffic and delays at junctions and free time refers to uncongested or free flow traffic. It is hypothesised that the disutility of delay time is greater due to the greater stress involved in driving in such conditions and due to frustration arising from a feeling of not getting anywhere. Petrol costs and toll charge were both found to have a significant influence on choice in a pilot survey of motorists' route choices using SP methods (Wardman 1985). Other forms of introducing money costs, such as parking charges or road pricing, were considered to be inappropriate or unrealistic. It is considered that these variables adequately characterise route choice and that introducing further variables would unnecessarily complicate the issue. It was stated that other variables would be the same for each route and hence they will not influence choice.

## 2. The Survey Procedure

In a two stage survey process, motorists were initially contacted at the toll booths at the Tyne Tunnel or when they stopped at traffic lights near to the Tyne Bridge. Some 31953 stage 1 questionnaires were distributed and 8636 (27%) were returned. On the basis of the responses to the stage 1 questionnaire, respondents were screened in and sent the main stage 2 questionnaire. The screening criteria required that the journey made was of 45 minutes or less, as we were interested only in urban journeys, and that the two routes were likely to offer the individual a trade-off between time and cost. Although a trade-off between time and cost for the actual journey is not needed for the SP experiment, it would increase its realism, whilst those who do not face trade-offs contribute little information for the RP model.

2884 respondents expressed a willingness to participate further in the survey and satisfied the screening criteria and 1962 (68%) returned the stage 2 questionnaire. In the event, individuals who did not face a trade-off between time and cost were unavoidably screened in. The initial raw data set was subsequently reduced in both the editing process and in obtaining the RP-SP intersection data set required for the analysis of the two sets of responses for the same individuals. The following criteria were used to obtain this latter data set:-

i) The respondent had supplied adequate RP information and had completed the SP exercise.

ii) In the SP experiment, the choice of route exhibited some variation across the 16 comparisons.

It was required that the respondent had completed at least 14 of the 16 comparisons of bridge and tunnel in the SP exercise. As packs of cards, which described the hypothetical characteristics of each route, were sent out which contained less than the full number, those with at least 14 responses were considered to have completed the exercise. The second criterion was employed for the following reasons:-

a) Respondents who chose only one route may not have understood the SP exercise or may not have taken it seriously. Similarly, the respondent may not have related to the costs and times of the SP exercise, for example, if one route is overwhelmingly dominant for the actual journey made, the respondent may not be able to envisage travelling by the 'alternative' route.

b) Such responses may reflect habit or inertia to change, policy response bias, justification bias or non compensatory decision making (Wardman 1986a). Omitting responses influenced by such factors improves the quality of the SP data and the quality of the RP data is also improved as the analysis is undertaken on the same set of individuals.

The number of respondents omitted according to these two criteria is given in Table 1. Omitting those who always choose the same route is the largest cause of data loss and the consequences of omitting these respondents are considered below.

Table 1: Deriving the RP-SP Intersection Data Sets.

| | COMM | LEIS | EB |
|---|---|---|---|
| Initial Edited Sample | 1027 | 554 | 335 |
| No RP only | 25 | 22 | N/A |
| No RP and no SP | 2 | 3 | N/A |
| No RP and SP all same | 4 | 6 | N/A |
| No SP only | 48 | 35 | 20 |
| SP all same only | 84 | 66 | 46 |
| Remaining Sample | 864 | 422 | 269 |

## 3. Initial Value of Time Estimates

The choice context offers the individual the opportunity to trade-off between time and cost. It is likely that respondents are familiar with the highway network in general and the two distinct routes of crossing the River Tyne. Many respondents had used the alternative route and it does not seem that we are imposing on individuals a consideration of the two routes which has not been made.

Actual discrete choices are modelled using the disaggregate logit model (BLOGIT) of the Australian Road Research Board (Crittle and Johnson 1980). The probability of choosing the bridge is related to the utility difference between routes as follows:-

$$P_b = 1 / [1 + \exp(U_t - U_b)]$$

This utility difference can be expressed in terms of the differences in relevant variables between routes:-

$$U_t - U_b = a_1(X_{1t} - X_{1b}) + a_2(X_{2t} - X_{2b}) + \ldots\ldots + a_n(X_{nt} - X_{nb})$$

The coefficients, which are estimated by maximum likelihood, are scale transformations of the appropriate marginal utilities and should have a negative sign to reflect the disutility of incurring cost or time. As the value of time is the ratio of the marginal utilities of time and money, it is calculated as the ratio of the estimated time and cost coefficients.

A linear logit model was used for the SP responses (Bates and Roberts 1983; Bates 1984). Assumed but sensible probabilities of choosing the tunnel are assigned to each of the responses on the five point scale and these are entered into a logarithmic transformation as follows:-

$$\text{Log}\,[P_t/(1 - P_t)] = a_1(X_{1t} - X_{1b}) + \ldots\ldots + a_n(X_{nt} - X_{nb})$$

The assumed probabilities of choosing the tunnel, for the five responses ranging from definitely prefer tunnel to definitely prefer bridge, are 0.9, 0.7, 0.5, 0.3 and 0.1. The value of time estimates are relatively insensitive to the assumptions made and it was found that the linear logit and disaggregate logit models gave very similar value of time estimates. However, the former obtains estimates with lower standard errors as the no preference responses do not have to be omitted and the greater informational content of the responses over discrete choices is captured. These modelling techniques are discussed in more detail in the accompanying working paper.

Table 2 presents models of route choice for the three journey purposes. The coefficients are all highly significant and of the correct sign and the value of time estimates are plausible. However, the values are high in relation to the behavioural value of time per individual for non work travel recommended by the Department of Transport which at mid 1985 prices was 1.8 pence per minute.

It is considered that the values derived here also relate to the individual. Given that the SP exercise is completed by one individual and that actual route choices are more likely to be made by the driver who also supplies the RP data, the implied values will reflect those of the individual. Moreover, when the RP and SP data is stratified according to car occupancy, as reported below, comparison of the values of time for single car occupants with those for more than one occupant suggests that if the derived values reflect the total value of time for all occupants then car passengers have extremely and implausibly low values of time.

As the SP experiments involve individuals in multiple comparisons of the two routes, and the choices made by some individuals may not be independent, the t ratios may overstate the precision with which the coefficients and values of time are estimated. The t ratios are not adjusted to allow for repeat observations in any of the SP models reported because it is not clear what the adjustment should be. Assuming perfect correlation of errors within every individual's responses, the standard errors should be adjusted by the square root of the number of comparisons, that is multiplied by four. Even with such an obvious over-adjustment, the values of time would still be highly significant. However, it must be borne in mind that the reported t ratios are likely to be too high.

The explanatory power of the RP models is high, due in part to the use of reported values and also because these models contain a number of respondents who do not face a trade-off between time and money and whose choices are thus easily explained. The R Bar squareds for the SP models are low. This poor goodness of fit may stem from the use of arbitrary probability scales assumed applicable to all respondents and from errors in the SP responses. There should be no influence from variables not included in the SP experiment as respondents were informed that these would be the same for each route.

Table 2: RP and SP Models of Motorists' Route Choices

| | COMM RP | COMM SP | LEIS RP | LEIS SP | EB SP |
|---|---|---|---|---|---|
| ASC(T-B) | N/A | 0.081 | N/A | 0.126 | -0.083 |
| | | (1.98) | | (2.14) | (2.51) |
| TOTAL TIME | -0.181 | N/A | -0.163 | N/A | N/A |
| | (9.97) | | (7.27) | | |
| DELAY TIME | N/A | -0.205 | N/A | -0.227 | -0.183 |
| | | (40.96) | | (31.69) | (16.77) |
| FREE TIME | N/A | -0.147 | N/A | -0.156 | -0.143 |
| | | (46.92) | | (35.49) | (17.78) |
| TOLL CHARGE | -0.041 | -0.049 | -0.033 | -0.043 | -0.036 |
| | (10.36) | (34.74) | (6.39) | (22.13) | (18.66) |
| PETROL COST | -0.035 | -0.044 | -0.044 | -0.036 | N/A |
| | (5.06) | (36.64) | (5.13) | (19.80) | |
| VOT(T) | 4.41 | N/A | 4.94 | N/A | N/A |
| | (11.39) | | (7.25) | | |
| VOT(P) | 5.17 | N/A | 3.70 | N/A | N/A |
| | (3.90) | | (3.86) | | |
| VOD(T) | N/A | 4.18 | N/A | 5.28 | 5.08 |
| | | (45.72) | | (29.53) | (24.09) |
| VOD(P) | N/A | 4.66 | N/A | 6.31 | N/A |
| | | (32.65) | | (19.36) | |
| VOF(T) | N/A | 3.00 | N/A | 3.63 | 3.97 |
| | | (46.58) | | (29.13) | (20.42) |
| VOF(P) | N/A | 3.34 | N/A | 4.33 | N/A |
| | | (34.18) | | (19.94) | |
| RHO/R BAR SQ | 0.50 | 0.17 | 0.52 | 0.17 | 0.09 |
| t(DELAY-FREE) | N/A | 16.44 | N/A | 13.95 | 5.48 |
| t(TOLL-PETROL) | 0.88 | 2.66 | 1.26 | 2.90 | N/A |
| OBSERVATIONS | 864 | 13687 | 422 | 6670 | 4271 |
| TUNNEL CHOICES | 403 | 5608 | 205 | 2975 | 1894 |
| BRIDGE CHOICES | 461 | 7130 | 217 | 3193 | 2091 |

Notes: VOT, VOD and VOF denote values of total time, delay time and free time in pence per minute in toll (T) or petrol (P) units

There are, however, problems with the RP values of time. As the toll charge is the same for all travellers, it is not possible to include both the toll variable and the alternative specific constant (ASC) in the RP model as the two variables are perfectly correlated. Hence the two effects can not be separately discerned and the toll coefficient also reflects an alternative specific utility effect and any aversity to toll charges in addition to the direct utility effect of the 40 pence toll charge. The best we can hope is that the toll coefficients do not diverge from their 'true' effect by a large amount. Moreover, the RP value of time defined in terms of petrol cost may also be an unreliable estimate of the value of time. In this route choice context, the petrol cost difference between routes is small for many motorists which reduces the chances that it will influence choice. There are also those for whom petrol costs are irrelevant, for example, they are paid by someone else whilst if petrol costs are treated as more of a fixed cost, for example a weekly cost, they will have a lesser influence upon choice. However, the petrol cost coefficients are highly significant in both RP models.

The two RP models do not distinguish between delay and free time as their coefficients were insignificantly different. Using a likelihood ratio test, chi-squared statistics of 0.46 and 0.48 suggest that the restricted formulation of entering total time in the RP models is to be preferred. This is not the case for the commuting and leisure travel SP models where the F statistics for such a restriction are 267.36 and 195.05. These findings are not so much an inconsistency between the RP and SP models but rather a problem with the RP data which highlights the advantages of the SP approach.

There is insufficient variation in delay time between routes, for example, 47% of the commuting sample had a difference in delay time between routes of 4 minutes or less whilst the equivalent figure for total time is only 12%. Corresponding figures for leisure travel, where there is more off peak travel and hence fewer delays, are 66% and 9% respectively. Although the maximum delay time difference between the two routes in the SP experiment was only eight minutes, careful design ensured that the trade-offs were clearly offered. For example, if free time is the same for each route, the individual is clearly offered the opportunity to 'purchase' savings of a specific amount of delay time. This reduces the likelihood that the small variations between routes, which we are here inevitably dealing with, are ignored and do not have their true influence upon choice.

The delay and free time coefficients are significantly different in the three SP models, the ratio of the two being around 1.3 to 1.4 which is plausible. The results accord with the expectation that travelling in congested traffic incurs greater disutility. Michaels (1966) revealed the importance of strain and tension on route choice and that these are generated by the amount of traffic and the number of junctions. This corresponds to the concept of delay time used here.

It seems to have been worthwhile making this distinction between delay and free time. The distinction is analagous to separating out in-vehicle, walk and wait time for public transport users. These results have policy implications as no distinction is currently made between these two forms of time in urban road project appraisal. Clearly, a project which increases free flow speeds should be evaluated using a different measure of the benefits of time savings to a project which alleviates congestion if travel in congested and uncongested traffic incur different disutilities.

The utility effect attributed to toll variations in the SP models exceeds that for petrol cost and the difference is significant in both the commuting and leisure SP models. The SP experiment does not allow misperception of petrol costs and increases the likelihood that such costs influence choice in relation to what occurs in practice. Whilst this presentation of petrol costs in a sense forces individuals to incorporate them into decision making, there is no reason why this enforced trade-off in itself causes inaccurate value of time estimates to be obtained. However, there may still remain some individuals who do not consider petrol costs and as these individuals effectively have a petrol coefficient of zero, this will reduce the petrol coefficient in relation to the toll coefficient given the toll influences the choices of all respondents. Any aversity to paying tolls regardless of the level of the toll charge, apparent in a pilot study of motorists' route choices using SP methods (Wardman 1985), will be included in the ASC although in the RP model this and the toll coefficient can not be separately estimated.

The RP value of time expressed in petrol cost units is greater for commuting than leisure travel but the four values of time of the SP models and the value of time in terms of toll of the RP models are greater for leisure travel. However, the RP values of time are not significantly different but the SP values are. The somewhat surprising finding that time savings are valued less highly by commuters can be explained if the uses of time saved have greater utility for leisure travel whilst there will be a greater income effect from a given cost variation for commuting, due to the frequency of travel, and this would operate to reduce the value of time.

The values of time for employers' business trips are not greatly different from the other journey purposes but these values reflect the benefits of time savings to the employee only and do not incorporate the benefits to the employer. Much higher values would be obtained if the latter were included (Fowkes, Marks and Nash 1986). The SP exercise required that the toll be paid by the individual and it could not be claimed back so that a trade-off between time and money was introduced. An RP model was not developed as all costs would be reimbursed and thus no trade-off between time and money is involved.

Although there are problems with the RP values of time, the precision of these value of time estimates compares favourably with those derived by discrete choice models in other studies, particularly the leisure travel model which is based on a relatively small number of observations. 95% confidence intervals, expressed as proportions of the central estimates, for the values of time in terms of petrol costs are +/- 50% and +/- 51% for commuting and leisure. Equivalent figures for the values of time in toll units are +/- 17% and +/- 27%.

In this value of time study, ranges for RP values of in-vehicle time of +/- 74% and +/- 90% were obtained for car and public transport for West Yorkshire commuters (Broom et al 1983) and +/- 33% for North Kent rail and coach commuters (Fowkes 1986). Corresponding figures from other studies are +/- 85% by Daly and Zachary (1975), +/- 63% by Davies and Rogers (1973) and +/- 70% and +/- 56% for car and public transport by Daly and Zachary (1977). The SP value of time estimates are extremely precise; corresponding figures being less than +/- 10%, although the standard errors are likely to be under-estimates due to the repeat observations problem.

One of the purposes of this route choice study was to make further comparisons of the values of time derived from RP and SP models. In this value of time study, comparisons of revealed preference, stated preference and transfer price models of travel behaviour have been undertaken (Bates 1984; Broom et al 1983; Gunn 1984).

Table 3 presents the t ratios for a comparison of the value of time estimates derived from the RP and SP models. As delay and free time are not significantly different in the RP models, the values of total travel time from the RP models are compared with the values of delay and free time from the SP models.

Table 3: t Ratios for the Differences in RP and SP VOT Estimates.

| | PETROL | TOLL |
|---|---|---|
| COMMUTING | | |
| time v free | 1.37 | 3.59 |
| time v delay | 0.38 | 0.58 |
| LEISURE | | |
| time v free | 0.64 | 1.89 |
| time v delay | 2.58 | 0.48 |

It can be seen from Table 2 that there are no really large discrepancies between the value of time estimates derived by the two means. Allowing for the standard errors of the estimates, but assuming zero covariance between the estimates of the two methods, there are only two cases out of the eight considered where the difference is significant. Using a simplified comparison, by combining delay and free time into a total time variable in the SP models, one of the four differences between RP and SP values of time was significant.

Whilst these results are not conclusive, there is a degree of similarity between the two techniques. More detailed comparisons of the RP and SP approaches are considered below, involving the analysis of variations in the value of time and using values of time derived at the individual level to explain the actual choice made by motorists.

Table 4 presents the same models as for Table 2 but respondents who always choose the same route in all 16 comparisons of the SP exercise are not omitted from either the RP or the SP models.

Table 4: Not Omitting Those Who Always Choose Same Route in SP

| | COMM RP | COMM SP | LEIS RP | LEIS SP | EB SP |
|---|---|---|---|---|---|
| VOT(T) | 4.47<br>(12.05) | N/A | 5.17<br>(7.77) | N/A | N/A |
| VOT(P) | 5.27<br>(4.17) | N/A | 3.85<br>(4.11) | N/A | N/A |
| VOD(T) | N/A | 4.20<br>(42.17) | N/A | 5.17<br>(26.68) | 5.00<br>(21.24) |
| VOD(P) | N/A | 4.63<br>(30.21) | N/A | 6.28<br>(17.57) | N/A |
| VOF(T) | N/A | 3.02<br>(42.96) | N/A | 3.55<br>(26.33) | 3.94<br>(18.11) |
| VOF(P) | N/A | 3.33<br>(31.65) | N/A | 4.31<br>(18.09) | N/A |
| RHO/R BAR SQ | 0.52 | 0.14 | 0.56 | 0.13 | 0.06 |
| OBSERVATIONS | 948 | 15017 | 488 | 7712 | 5006 |

The values of time vary little in relation to the same models where these respondents are omitted. The most noticeable feature of these results is that the t ratios for the SP values of time are in all instances smaller for the larger samples and R Bar squared also falls. The greater extent to which trade-off behaviour is apparent allows more precise value of time estimates to be obtained.

We would expect that omitting these respondents would be of greater benefit to the SP models. The removal of those whose behaviour is habitual or who have non-compensatory choices would improve the RP as well as the SP models, as their choices are not consistent with the assumptions of the random utility models used, but removing policy response bias and those who did not relate to the exercise or did not take it seriously only improves the SP models. Moreover, the removal from the RP data of those whose responses are influenced by justification bias may actually 'worsen' the RP models. In such cases, where the two routes are made more distinct than is really the case, the choice of route would be more easily explained.

## 4. Further RP Models

Whilst the screening criteria included a requirement that the respondent was likely to face a trade-off between time and cost for the journey made, inevitably there are some respondents in the final sample who do not face such a trade-off. In the commuting and leisure intersection data sets, 661 and 312 respondents were identified as being able to trade-off between time and cost.

Table 5: RP Values of Time - Omitting Those who Face No Trade-Off

| | COMMUTING | LEISURE |
|---|---|---|
| VOT (T) | 4.37 (11.52) | 4.74 (8.03) |
| VOT (P) | 4.92 (3.92) | 3.62 (4.44) |
| RHO BAR SQ | 0.40 | 0.45 |

The most noticeable effect of omitting those who are not in a position to trade is that Rho-Bar squared falls from 0.50 to 0.40 for commuting and from 0.52 to 0.45 for leisure trips. This reflects the omission of easily explained choices. The omission of such observations, which contribute little information, should not have a large impact on the value of time estimates as appears to be the case. Even though the samples are reduced by around 25%, in all cases the t ratios of the value of time estimates are increased. This shows the importance of the choice context in obtaining precise estimates and also the advantages of the SP approach which can simulate the choice context.

Variables which are allowed to influence choice can be controlled in the SP experiment; this being a further attraction. However, there may be an influence upon actual choice from variables other than those included in the SP design.

Respondents were asked to supply information on the quickest and slowest journey times that they would expect for each route at the time at which they travelled. If an individual's utility function is non-linear, the unit disutility of travel time varies according to travel time. Thus, for example, in the weekly journey to work, the total disutility of arriving 10 minutes earlier than usual twice, 10 minutes later than usual twice and at the usual time once will not have the same disutility as that of arriving at the usual time every day. In addition, there may be penalties or disbenefits as a result of late arrivals at work or at events or appointments with a fixed starting time yet arriving early may have some benefit.

When travel time variability was entered in the form of the difference between routes in the range between slowest and quickest times, no significant effects were obtained in either the commuting or leisure models. Nor were any significant effects obtained when two variables were used, representing the difference between routes in the quickest and the slowest times that would be expected. It may be that travel time variability does influence choice but the data collected is not the best with which to explore this quite complicated issue.

Respondents were also asked to supply information for each route on costs in addition to petrol, toll and parking charges if they took such costs into account when using their car. For both journey purposes, less than 10% stated that such costs were relevant. Adjusting the RP models to incorporate car running costs in the place of petrol costs did not lead to any improvement in goodness of fit and there was little variation in the coefficient estimates.

## 5. Further SP Models

The SP experiment offers the opportunity to estimate values of time at a totally disaggregate level albeit with only 16 observations for each individual. Such calibrations perform two useful purposes:-

i) Given that there are problems with the RP models in this choice context, as outlined above, an alternative means of comparing stated and actual preferences is to calibrate values of time at the individual level and for each individual, using a generalised cost formulation, consider whether these SP values of time can replicate the choice made for the actual journey.

ii) In the presence of taste variations across individuals, the aggregation of all individuals in a single model may lead to biased estimates of the average value of time even if the estimates of the average time and cost coefficients are unbiased (Fowkes and Wardman 1985). If values of time are calibrated at the individual level, the appropriate mean value of time estimate (mean of the estimated ratios across individuals) can be compared with the potentially erroneous estimate (ratio of the mean coefficients estimated for all respondents in one model).

For the first of these two exercises, that of comparing simulated and actual choices, the following criteria were adopted:-

a) Respondents must face a trade-off between time and cost for the journey actually made otherwise the comparison would be seriously weakened as dominated choices, providing that they are rational, can be explained by any positive value of time.

b) Respondents were excluded if they preferred the same alternative in all 16 comparisons. These responses would most likely yield values of time which would easily explain actual choices and again the comparison would be weakened.

c) For each individual, all estimated coefficients must be significant. It was found that where t ratios denoted insignificance, implausible values of time were often obtained.

d) To avoid considerable extra computation, the calibrations were of the same form for each individual. Inevitably, the best model is not obtained for each individual but this is not considered to be a serious problem.

Petrol cost and toll charge were combined into a total cost variable to increase the degrees of freedom given the limited number of choices made by each individual. Delay and free time were entered separately but no alternative specific constant (ASC) was included. The ASC was included for a trial set of calibrations but in many cases it was negligeable or insignificant. The comparison was undertaken for a random sample of 50 respondents from both the commuting and leisure travel data sets.

Table 6: Individual SP Values of Time and Actual Route Choices

| | COMM | LEIS | TOTAL |
|---|---|---|---|
| Tunnel Correctly Predicted | 22 | 32 | 54 |
| Bridge Correctly Predicted | 15 | 11 | 26 |
| Tunnel Incorrectly Predicted | 6 | 3 | 9 |
| Bridge Incorrectly Predicted | 7 | 4 | 11 |
| Proportion Correctly Predicted | 74% | 86% | 80% |

Using the estimated values of time for each individual and their costs and times for each route in a generalised cost formulation, a satisfactory proportion of actual choices can be correctly explained, with a better performance in the case of leisure travel. The proportion of choices correctly predicted are significantly better than if respondents were randomly allocated to options according to the proportion using each route in the samples used.

Table 7 presents results from the estimation of values of time at the totally disaggregate level for the random sample of 50 respondents for both commuting and leisure trips. For comparison, Table 8 lists the results from combining these individuals into single models.

Table 7: Values of Time Calibrated at the Individual Level

| | COMMUTING | | LEISURE | |
|---|---|---|---|---|
| | VOD | VOF | VOD | VOF |
| MEAN | 5.31 | 3.87 | 6.60 | 4.39 |
| STD DEV | 1.98 | 1.55 | 2.40 | 2.17 |
| STD ERR | 0.28 | 0.22 | 0.34 | 0.31 |
| MAXIMUM | 10.84 | 7.82 | 13.16 | 14.82 |
| MINIMUM | 2.18 | 1.95 | 2.33 | 2.00 |

Notes: Values of time are in pence per minute

Table 8: Single Model Values of Time

| | COMMUTING | LEISURE |
|---|---|---|
| VOD(TC) | 5.15 (30.39) | 6.20 (27.91) |
| VOF(TC) | 3.64 (35.53) | 4.01 (30.73) |
| R BAR SQ | 0.47 | 0.45 |
| OBS | 797 | 790 |

Notes: Values of time are in pence per minute

The values of time derived by the two methods, using the same linear logit formulation and for the same individuals, are very similar and far from significantly different. It does not seem that inter-personal taste variations are here a problem. As the single models contain individuals for whom models with relatively high t statistics could be calibrated, it is not surprising that R Bar squared increases in relation to the models where all respondents are included.

## 6: Variations in the Value of Time: The Segmentation Procedure

As the value of time is the ratio of the marginal utilities of time and money, variations in these factors will lead to variations in the value of time. Sources of variation in the value of time are summarised as:-

i) Marginal Utility of Money: Income Constraints

ii) Marginal Utility of Time: Time Constraints
: Travel Conditions
: Alternative Uses of Travel Time

The aim of the exercise is to proxy these sources of variation through variations in socio-economic factors and journey characteristics. Thus appropriate data was collected where it was hypothesised that it would have an influence on the value of time.

Variations in the value of time can be explored by calibrating separate models for each category. However, this is wasteful of data if, for example, journey purpose only affects the marginal utility of time or if it is desired to assess the influence of income on the marginal utility of money only. This approach effectively estimates separate coefficients for all variables for each category of interest. An unnecessary increase in the standard errors of the coefficients and values of time can be avoided by restricting the influence of a socio-economic variable to the appropriate marginal utility.

Such an alternative approach uses dummy variables to specify different variables for each category of interest in a single model. This allows a different influence upon choice, that is different coefficients and hence marginal utilities, across these categories (Value of Time Study 1982). A segmentation of one variable can be expressed as:-

$$\sum_{m=1}^{M} d_{km} (X_{kt} - X_{kb})$$

where $d_{km}$ is a dummy variable for each of the M categories of some factor which influences the marginal utility of variable $X_k$. Thus the cost variable might be segmented by income groups or the time variable by journey purpose. This segmentation approach was adopted by all the studies in this final phase of the value of time project to form a common modelling basis (Bates and Roberts 1986).

Segmentations of $X_k$ by several variables can be done simultaneously. Allowing for all possible interactions, that is specifying sufficient variables to exhaust all combinations of categories, would be an enormous task and is unlikely to be worthwhile. A simplification which leads to a more manageable approach, but which assumes interactions to be negligeable, is to segment as follows:-

$$\left(\sum_{m=1}^{M} d_{km} + \sum_{p=1}^{P-1} d_{kp} + \sum_{q=1}^{Q-1} d_{kq}\right)(X_{kt} - X_{kb})$$

where variable $X_k$ is segmented according to three socio-economic variables, m, p and q. The process can be extended to the segmentation of other explanatory variables although in the above case where just one variable is segmented (M+P+Q-2) coefficients must be estimated. If all interactions were allowed for in this segmentation, there would be MPQ coefficients to be estimated. This is clearly impractical although some interactions could be included, for example, if a segmenting variable is highly correlated with another such variable.

If the marginal utility of $X_k$ is influenced by M, P and Q categories of variables m, p and q, it is possible to specify M segmented variables for factor m but to avoid perfect collinearity and a singular matrix, only P-1 and Q-1 segmented variables can be estimated for the effects of p and q. Thus the coefficients for the segmentation according to p and q reflect the incremental effects on the marginal utility of $X_k$ of moving from the base (omitted) level of p and q. The marginal utility for any individual is, in general, no longer a single coefficient but a summation of the relevant coefficients for each of the categories in which the individual is placed.

This segmentation approach, even without interactions, would still require the estimation of a large number of coefficients if all potential sources of variation are initially incorporated into one model. The segmentation process commences with an examination of those influences which theoretical considerations suggest will influence the value of time. Initially, each segmentation considers only a limited number of influences, for example, as in the analysis of income effects reported in Table 10 below, whereupon more complete models are developed bearing in mind possible interactions and correlations between variables. These more complete models are based upon theoretical considerations combined with statistical criteria, such as the significance of incremental effects, significant differences between segmented coefficients and general explanatory power.

As only limited segmentations of the RP data can be undertaken due to the limited number of observations and consequent high standard errors for segmentation purposes, the analysis of variations in the value of time is principally based on the SP data. Limited RP segmentations were undertaken for comparison with equivalent SP models.

## 7. Variations in the Value of Time: Initial Results

Those variables which may influence the value of time are listed in Table 9. This table also indicates whether the effect from a socio-economic variable operates through the marginal utility of time or money and whether significant influences were apparent in the initial limited segmentations.

Table 9: Summary of Sources of Variation Considered and Initial SP Segmentation Results

| | COMMUTING | | LEISURE | | EMP BUS | |
|---|---|---|---|---|---|---|
| | TIME | COST | TIME | COST | TIME | COST |
| Income | N/A | SIG | SIG | SIG | N/A | SIG |
| Age Group | INSIG | INSIG | INSIG | INSIG | INSIG | INSIG |
| Sex | INSIG | INSIG | INSIG | INSIG | INSIG | INSIG |
| Car Occupancy | SIG | INCON | SIG | SIG | INSIG | INSIG |
| Petrol Relevant? | N/A | INSIG | N/A | INSIG | | |
| Nature of Work Hours | SIG | N/A | | | SIG | N/A |
| Household Size | SIG | INSIG | INSIG | SIG | | |
| Departure Time | INCON | N/A | SIG | N/A | INSIG | N/A |
| Journey Time | SIG | N/A | SIG | N/A | INSIG | N/A |
| To/From Home | | | INSIG | N/A | | |
| Fixed Appointment? | | | SIG | N/A | INSIG | N/A |
| Journey Purpose | | | SIG | N/A | SIG | N/A |
| Occupation | | | | | SIG | N/A |
| Employment Status | | | SIG | N/A | INSIG | INSIG |
| Weekend/Weekday | | | INCON | N/A | | |
| Claim Back Toll? | | | | | N/A | INSIG |

Notes: SIG and INSIG denote significant and insignificant influences from that variable on the value of time through a particular marginal utility. INCON represents a significant but theoretically inconsistent effect and N/A indicates the segmentation was not attempted as inappropriate. A blank denotes that the variable does not enter for that journey purpose.

The theoretical influences from socio-economic factors on the value of time have been considered in the accompanying working paper (Wardman 1986a). They will not be discussed in detail here but will be considered as the results of the variations in the value of time are presented. Some of these significant influences are no longer significant in more complete models, for example, the effect is due to correlations with other variables which are the true source of variation.

Individuals who had not supplied relevant socio-economic data were omitted from consideration. This reduced the sample sizes to 820, 382 and 236 individuals for commuting, leisure and employers' business trips which corresponds to 12995, 6036 and 3747 observations in the SP models. The number of individuals in relevant categories of the socio-economic variables, for each journey purpose, is given in Appendix 1.

Given the potentially important influence from income on the value of time, and as an example of the initial segmented models, Table 10 shows the effect of income on the value of time for the SP responses. As the effect of income on the marginal utility of money is considered to be more critical than on the marginal utility of time, the models reported are based on the segmentation of the cost variables, that is an equation of the following form is estimated:-

$$\mathrm{Log}[P_t/(1 - P_t)] = ASC + a_1D + a_2F + \sum_{y=1}^{Y} a_{3y}d_{3y}T + \sum_{y=1}^{Y} a_{4y}d_{4y}P$$

where D, F, T and P are the differences in delay time, free time, toll and petrol between routes and $d_y$ are dummy variables for the Y income groups. As only toll and petrol are segmented, the ratio of the values of delay and free time is constant across income groups.

Table 10: Values of Time and Income (SP)

| | | COMMUTING | LEISURE | EMP BUSINESS |
|---|---|---|---|---|
| DELAY/TOLL | Y1 | 3.57 (16.87) | 4.38 (18.58) | 4.49 (24.50) |
| | Y2 | 3.92 (38.04) | 5.00 (24.86) | 5.16 (25.00) |
| | Y3 | 4.11 (38.47) | 5.17 (22.75) | 6.85 (11.50) |
| | Y4 | 4.70 (33.01) | 6.64 (17.19) | |
| FREE/TOLL | Y1 | 2.58 (16.97) | 3.00 (18.60) | 3.40 (31.53) |
| | Y2 | 2.83 (38.84) | 3.43 (24.68) | 3.90 (32.05) |
| | Y3 | 2.98 (39.10) | 3.54 (22.56) | 5.18 (11.98) |
| | Y4 | 3.40 (33.06) | 4.55 (16.94) | |
| DELAY/PETROL | Y1 | 5.15 (7.14) | 6.04 (8.53) | N/A |
| | Y2 | 4.14 (24.65) | 6.08 (14.19) | N/A |
| | Y3 | 4.53 (24.90) | 6.31 (12.94) | N/A |
| | Y4 | 5.23 (21.24) | 7.69 (10.30) | N/A |
| FREE/PETROL | Y1 | 3.73 (7.24) | 4.14 (8.58) | N/A |
| | Y2 | 2.99 (25.39) | 4.17 (14.45) | N/A |
| | Y3 | 3.28 (25.61) | 4.33 (13.11) | N/A |
| | Y4 | 3.79 (21.61) | 5.28 (10.39) | N/A |

Notes: For commuting and leisure, the income groups are up to £5000, £5-10000, £10-15000 and over £15000. For employers' business the categories are up to £10000, £10-20000 and over £20000. The values of time are in terms of pence per minute

If diminishing marginal utility applies, we would expect the marginal utility of money to fall as income increases and hence the value of time will be an increasing function of income. There may also be an influence from income on the marginal utility of time. Those with higher incomes are able to pursue more activities, given the latter are not costless. If this increases pressures upon available time, the value of time will increase with income although a higher income enables the purchase of more time saving goods and services which would be an offsetting factor. Moreover, if activities which yield high utility are more expensive, and are consumed more by higher income groups, the alternative uses of time saved travelling and hence the value of time will be greater for higher income groups.

Gross household income is used and although this may not perfectly represent the influence of income on the value of time, the problems are reduced given that it is treated in relatively broad bands.

For both commuting and leisure trips, the effect of income is stronger on the toll variable than on petrol and monotonic relationships between the value of time in terms of toll and income exist. All four toll coefficients are significantly different from each other for commuting whilst for leisure travel only the coefficients of the second and third groups are insignificantly different.

For commuting journeys, the monotonic relationship between income and the value of time in terms of petrol is broken by the relatively high value of time for the lowest income group, although there are only 21 individuals in this category, but most of the petrol coefficients are insignificantly different. A monotonic relationship exists in the case of leisure travel but again most of the petrol coefficients are not significantly different.

The employers' business sample is segmented by only three income categories; the introduction of a fourth results in all the coefficient estimates being insignificantly different. A monotonic relationship between the value of time and income exists and the three toll coefficients are significantly different from each other.

It can be seen that for the three journey purposes there is an influence from income on the value of time which is consistent with theory although the relationships appear to be less than proportional. The three other studies in the final phase of this project also found evidence of income effects. A more detailed consideration of empirical findings from various studies concerning the value of time and income can be found in the final report of this project (DTp 1986).

## 8. Variations in the Value of Time: Commuting

Table 9 has listed those variables which influenced the value of time in the straightforward segmentations and which are therefore carried through to the more complete models. In these more complete segmentations, delay and free time were initially segmented separately. However, using F tests and comparing restricted and unrestricted model formulations, the restricted form of segmenting total travel time according to relevant variables performed better. Thus time is segmented according to whether it is delay or free time and the incremental effects are in terms of total time.

Model 1 of Table 11 incorporates those influences which were significant in the initial segmentations and which were consistent with theory. Those working fixed hours have a lower value of time than those working variable hours whilst there is a further significant reduction for those working flexible hours. Those working variable hours depending upon the requirements of the job may work longer hours and hence have a higher value of time as a result of their less available free time. Those working fixed hours face more time constraints and are likely to have a less optimal departure time than those working flexible hours and as such have a higher value of time. The relatively strong influence on the value of time from the nature of work hours was also evident from the mode choices of North Kent commuters using both RP and SP data (Wardman 1986b).

The value of time is higher for those travelling alone although the effect is not large. This presumably reflects the lower disutility of travel time when company is provided. Various formulations were tried in exploring the influence of the number of children in the household on the value of time. The best explanation was obtained by distinguishing between households which contained children aged five or less and those which did not. The value of time is greater for those with children aged five or less which presumably reflects the greater time constraints imposed in caring for young children.

Table 11: Final Commuting SP Segmentations

| | Model 1 | | Model 2 | |
|---|---|---|---|---|
| DELAY | 4.00 | (18.82) | 4.73 | (17.56) |
| FREE | 3.07 | (17.45) | 3.85 | (16.21) |
| TOTAL TIME SEGMENTS | | | | |
| Fixed | - 0.51 | (6.10) | - 0.49 | (5.77) |
| Flexible | - 0.68 | (6.73) | - 0.67 | (6.45) |
| Alone | + 0.20 | (2.70) | + 0.09 | (0.68) |
| Kids LE 5 | + 0.37 | (4.10) | + 0.37 | (4.17) |
| 21-30m | - 0.43 | (5.02) | - 0.42 | (5.42) |
| 31m+ | - 0.70 | (7.23) | - 0.73 | (7.01) |
| up to 7.30 | | | - 0.28 | (2.41) |
| 7.31-8.30 | | | - 0.21 | (1.98) |
| TOLL | | | | |
| £5-10000 | * 1.16 | (3.10) | * 1.16 | (3.25) |
| £10-15000 | * 1.23 | (4.18) | * 1.22 | (4.09) |
| £15000+ | * 1.36 | (5.89) | * 1.34 | (5.91) |
| H'hold LE 2 | | | * 1.00 | (0.10) |
| Alone | | | * 1.04 | (1.28) |
| PETROL | | | | |
| £10000+ | * 1.16 | (3.42) | * 1.13 | (2.86) |
| H'hold LE 2 | | | * 1.00 | (0.15) |
| Alone | | | * 1.00 | (0.19) |

Notes: The values of delay and free time are absolute values and the total time segments show the incremental effects on these values with t statistics in brackets. These values are expressed in terms of toll charge for the base (lowest) income group. The segmentation of toll shows how the value of time varies as we move away from the base group and the t statistics are for the difference between the segmented toll coefficient for that group and the base group. The segmentation of petrol shows how the value of time defined in terms of petrol would vary.

A relatively strong influence on the value of time is obtained when the time variables are segmented according to the time taken for the actual journey made. As journey time increases, the value of time tends to fall; the two incremental effects being highly significant and also significantly different. This may reflect a variation in tastes across individuals in that those with higher values of time tend to choose the quicker route or indeed they may drive faster. Those with higher values of time might also choose to live nearer to their place of employment and thus have lower journey times.

The expected influence from income is apparent on the cost coefficients although, as for the results reported in Table 10 above, the effect is stronger on toll charge. The four toll coefficients are significantly different from each other and reflect a monotonic but less than proportional relationship with income. It was only possible to segment petrol cost by two income groups and obtain significantly different coefficients and the most significant distinction, of whether income was less than £10000 or not, is reported.

Income may influence the marginal utility of time as constraints on available time and opportunity cost effects may vary across income groups as discussed above. However, we would not expect these effects to have a strong bearing on the value of time for commuting journeys. The segmentation of the marginal utility of time by income improved the models although it was only possible to obtain one significant incremental segmentation. Given that there is no compelling reason to maintain this segmentation, and that this segmentation reduced the significance of the corresponding segmentations of the cost variables, it is not included in the models reported.

Model 2 reintroduces variables which were considered in the previous straightforward segmentations but which were found to have insignificant effects or were inconsistent with theory. Significant effects due to the departure times of 7.30 or before and 7.31 to 8.30 are apparent but, as previously, they do not influence the value of time in the expected manner. We might expect that the higher disutility of getting up early would lead to time variations being more highly valued for earlier departure times but this is not the case. However, departure time is highly correlated with the nature of work hours. The latest departure time is dominated by those with variable work hours who appear to have relatively high values of time.

Previously household size had an insignificant effect. This variable would operate on the marginal utility of money as there are more claims on a given household income as household size increases which would tend to increase an individual's sensitivity to cost variations and hence reduce the value of time. This effect remains insignificant. In the initial segmentations, the cost coefficients increased with the number of car occupants, and thus the value of time fell, when we might expect the value of time to be greater due to any contribution from other occupants towards travel costs. This theoretically inconsistent effect is no longer significant in this more complete model. However, the effect of travelling alone on the time coefficients becomes insignificant which may be because the previous significant effect is now being spread across more variables.

With the exception of the segmentation of time by whether the driver was travelling alone or not, there is little difference in the results when these additional segmentations are entered. The socio-economic variables are generally independently distributed, according to contingency table tests, and correlations between influences are not a serious cause for concern.

## 9. Variations in the Value of Time: Leisure Travel

The same process was followed in the case of leisure travel whereby previously significant influences which were theoretically consistent were incorporated into more complete models. Model 1 in Table 12 incorporates these segmentations and also includes a category representing the unemployed, housewives and part time workers. Although the latter category was previously an insignificant influence, it was considered to merit inclusion in a more complete model as such individuals could reasonably be hypothesised to have lower values of time due to the fewer constraints on their available time. However, it is again insignificant whilst there is no longer a significant effect due to whether the journey was made before midday.

In the segmentation of the marginal utility of time according to journey purpose, those making personal business trips were found to have a similar and insignificantly different time coefficient to those making shopping trips as was the case with visiting friends or relatives and recreational trips. If the journey being made was a shopping or personal business trip, the marginal utility of time and hence the value of time was somewhat lower than for those making journeys to visit friends or relatives or for recreational purposes. This may be because the utility derived from the latter activities is greater and thus the opportunity cost of travel time is also greater.

Those making trips to an event or appointment with a fixed starting time had higher values of time although the effect is not particularly large. This presumably reflects greater time constraints and that these individuals are in more of a hurry to get to their destination. If arriving earlier would merely result in idle time, time saved might be relatively lowly valued. A particularly strong effect was apparent in the case of retired individuals. It is to be expected that the retired have lower values of time, due to the greater amount of free time at their disposal but, as stated above, such effects were not apparent for the unemployed, housewives or part time workers.

Income is here allowed an influence on the marginal utility of time as well as the marginal utility of money to reflect different pressures on available time and opportunity cost effects across income groups. It was only possible to obtain one significant time segmentation when the segmentation of the cost variables by income is maintained and the most significant segmentation of time, that of whether income is less than £20000 or not, is reported. This segmentation of time by income does not affect the equivalent segmentation of the cost variables; three toll coefficients and two petrol coefficients can be found to be significantly different when segmented by income regardless of whether this limited segmentation of the time variable by income is included or not.

As for commuting journeys, an effect on the value of time is apparent from the travel time of the journey actually made and it is of the same form. However, although the effect from journey times in excess of 30 minutes is relatively strong, the segmentation for journeys between 21 and 30 minutes is insignificant. The influence upon the marginal utility of time from whether the driver was travelling alone is insignificant but it is similar to that obtained for commuting.

Table 12: Final Leisure SP Segmentations

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| DELAY | 5.65 | (15.58) | 5.43 | (16.85) | 5.19 | (15.96) |
| FREE | 4.22 | (13.75) | 4.04 | (14.98) | 3.80 | (13.83) |
| TOTAL TIME SEGMENTS | | | | | | |
| PB-Shop | - 0.67 | (5.59) | - 0.64 | (5.68) | - 0.61 | (5.38) |
| Fixed Appt | + 0.28 | (2.31) | + 0.29 | (2.47) | + 0.35 | (2.90) |
| PT-HW-UN | - 0.23 | (1.41) | | | | |
| Retired | - 1.21 | (5.79) | - 1.13 | (5.80) | - 1.11 | (5.61) |
| Up to 1200 | - 0.08 | (0.73) | | | | |
| 21-30m | - 0.11 | (0.88) | | | | |
| 31m+ | - 0.71 | (4.32) | - 0.68 | (4.68) | - 0.66 | (4.55) |
| Up to £20000 | - 0.72 | (3.63) | - 0.68 | (3.61) | - 0.66 | (3.49) |
| Alone | + 0.35 | (1.61) | | | | |
| Weekend | | | | | + 0.39 | (3.42) |
| Kids LE 5 | | | | | - 0.11 | (0.71) |
| TOLL | | | | | | |
| £5-15000 | * 1.11 | (2.38) | * 1.11 | (2.68) | * 1.11 | (2.46) |
| £15000+ | * 1.30 | (4.82) | * 1.31 | (5.17) | * 1.29 | (4.80) |
| H'hold LE2 | * 1.20 | (5.11) | * 1.20 | (5.41) | * 1.20 | (5.10) |
| Alone | * 0.87 | (2.79) | * 0.93 | (2.19) | * 0.95 | (1.67) |
| PETROL | | | | | | |
| £20000+ | * 1.42 | (3.12) | * 1.42 | (3.17) | * 1.39 | (3.06) |
| H'hold LE 2 | * 1.20 | (2.23) | * 1.21 | (2.35) | * 1.20 | (2.27) |
| Alone | * 0.81 | (2.51) | * 0.87 | (1.87) | * 0.89 | (1.60) |

In addition to the income segmentations of the cost variables, an influence was also found to exist from car occupancy and household size and their influences on the value of time are relatively strong. The influence of both these variables is limited to two segments; it was found that increasing the number of car occupancy or household size categories produced insignificant coefficient estimates or coefficients which were not significantly different.

Although no influence was found from the number of children in the household for leisure journeys, the value of time was found to diminish as household size increased. The effect of children on the value of time is through the marginal utility of time yet it is highly correlated with household size. However, this latter variable influences the value of time through the marginal utility of money as there are more competing claims on a given household income as the number of household members increases. Those travelling alone were found to be more sensitive to variations in cost which may reflect contributions from other occupants towards travel costs.

The insignificant effects within model 1 are removed and the results presented in model 2. There is little difference between the estimates of the two models.

Model 3 reintroduces the segmentation of the time term by whether the journey was made at a weekend and whether there were any children of five or less in the household. These were previously found to be theoretically inconsistent and insignificant influences respectively. As in the simple segmentations, the effect attributed to weekend travel is significant but inconsistent with theory as we might expect the value of time to be lower at weekends when there are fewer pressures on available time. However, it seems that this may be due to correlations with journey purpose in that there was a greater proportion of trips made to visit friends and relatives or for recreation at weekends and these are associated with relatively high values of time although the influence from journey purpose on the value of time is little different in model 3. There remains no significant effect from whether there are children in the household.

Again the level of association between socio-economic variables is generally low and the coefficient estimates are relatively stable across the models presented and it seems that correlations between the various influences are not a major problem.

## 10. Variations in the Value of Time: Employers' Business Trips

In the initial segmentations, fewer significant influences upon the value of time were found for employers' business trips than for the other two journey purposes. It was found that those working flexible hours had a significantly lower value of time than those working fixed hours. However, there is no compelling reason why this should be the case for employers' business trips, unlike for commuting where those with fixed work hours face more time constraints in arriving at work for a certain time and may have less optimal departure times. Thus this distinction is ignored and those with fixed and flexible hours are combined into one category and compared with those working variable hours. Time saved by the latter group can be used to reduce the working day and thus may be relatively highly valued.

The effects of occupation and journey purpose interact and it is necessary to take account of these interactions. Thus whilst 72% of salespersons are visiting a client and all but one whose occupation is delivery/collection are actually making a delivery/collection, the purposes of the professional/managerial group are split quite evenly across journey purposes. Thus bearing in mind the relationship between occupation and purpose and the number of individuals in each group, the following categories were initially specified:-

| | | |
|---|---|---|
| SEG 1 | Business Meeting (76% Prof/Man) | N = 63 |
| SEG 2 | Visit Client by Salesperson | N = 36 |
| SEG 3 | Del/Coll by Occupation Del/Coll | N = 18 |
| SEG 4 | Del/Coll by all other Occupations | N = 34 |
| SEG 5 | To do a Job/Visit client by Non Salesperson | N = 47 |
| | Other Purpose (Omitted Group) | N = 38 |

These segments were entered into the model, along with a segmentation according to the nature of work hours and an income segmentation of the toll variable. The results are presented as model 1 in Table 13.

Those working fixed or flexible hours have a significantly lower value of time for reasons discussed above. The only journey purpose/occupation segments which were found to be significant were segments 1 and 2 and these are not significantly different. As for the model presented in Table 10, it was not possible to segment toll by four income groups and obtain coefficients which were significantly different from each other. The best segmentation was obtained by using the same three income categories as in the above table and the three toll coefficients were again significantly different.

Table 13: Final Employers' Business Trips Segmentations

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| DELAY | 5.15 | (18.95) | 5.05 | (24.36) | 4.90 | (14.62) |
| FREE | 4.21 | (18.03) | 4.00 | (26.31) | 3.88 | (14.49) |
| TOTAL TIME SEGMENTS | | | | | | |
| Fixed & Flexi | - 0.82 | (4.72) | - 0.79 | (4.93) | - 0.64 | (4.54) |
| SEG 1 | - 0.73 | (2.86) | | | | |
| SEG 2 | - 0.64 | (2.37) | | | | |
| SEG 3 | - 0.31 | (1.11) | | | | |
| SEG 4 | + 0.20 | (1.05) | | | | |
| SEG 5 | - 0.29 | (1.15) | | | | |
| SEG 6 | | | - 0.59 | (3.94) | - 0.43 | (3.21) |
| TC LE 30 | | | | | - 0.02 | (0.04) |
| Self Empl | | | | | + 0.34 | (0.69) |
| Alone | | | | | - 0.51 | (1.41) |
| TOLL | | | | | | |
| £10-20000 | * 1.16 | (3.46) | * 1.15 | (3.82) | * 1.14 | (4.12) |
| £20000+ | * 1.74 | (6.61) | * 1.72 | (6.80) | * 1.63 | (6.10) |
| Self Empl | | | | | * 1.15 | (1.32) |
| Claim Toll | | | | | * 1.04 | (1.16) |
| Alone | | | | | * 1.07 | (0.94) |

Model 2 omits those segmentations which were insignificant and combines segments 1 and 2 (defined as SEG 6) as the latter two effects were insignificantly different. The incremental effects of model 2 are little different from model 1. As for commuting journeys, there is no compelling reason for income to influence the marginal utility of time. Indeed, the most significant of such segmentations suggested that the value of time was reduced as income increased.

Model 3 reintroduces variables which were previously considered in the straightforward segmentations to consider whether they remain insignificant and to assess the impact of their inclusion on the other estimates. Segmentations of the time variable include whether the individual faced a time constraint of 30 minutes or less, that is the respondent had 30 minutes or less to arrive at the destination, and also whether the individual was self employed or travelling alone. Those facing more binding time constraints might be expected to have a higher value of time whilst the influence of car occupancy on the marginal utility of time has been discussed above. Those who are self employed may have higher values of time due to higher opportunity costs of travel time; time saved travelling can be more readily converted into income. However, each of these influences remained insignificant although most of the self employed work variable hours and such respondents were found to possess higher values of time.

The toll variable was additionally segmented according to whether the respondent was travelling alone, was self employed, whereupon business expenses can be set against tax, and by whether the toll could be claimed back in practice. As in the previous simple segmentations, these effects are insignificant. It is reassuring that the incremental toll coefficients for those who could claim back the toll in practice and the self employed are not significant. This suggests that respondents have treated toll as a cost payable by themselves as required in the exercise.

## 11. Further Comparisons of Revealed Preference and Stated Preference

The SP segmentation process commenced by considering the influence of only one socio-economic variable on the value of time in each calibration. This process is inevitably employed if segmentations of the RP data are to be undertaken given the much smaller sample sizes and hence the large standard errors for segmentation purposes.

The global values of time derived by the two means are quite similar but, as stated above, there are problems in interpreting the RP toll coefficient due to the toll being constant for all travellers and there are also problems with the RP value of time defined in terms of petrol costs. However, we are on firmer ground comparing variations in the value of time between the RP and SP models.

In the comparison of the RP and SP models in terms of variations in the value of time, a number of outcomes are possible. An element of consistency between actual and stated preferences exists if both models recover significant differences of the same direction between segmented coefficients or if both obtain insignificant differences. Inconsistent outcomes include significant but conflicting variations in the segmented coefficients of each model, significant differences in the RP model but not in the SP model and significant differences in the SP model but not in the RP model.

The inconsistency of contradictory effects is the most serious but the remaining two inconsistencies are not equally serious. Given that the standard errors of the RP model are high for segmentation purposes, this may account for insignificant differences in the RP model when the SP model has obtained significant differences between segmented coefficients. Allowances must be made for such outcomes which are more a function of the number of observations than a true inconsistency although inspection of the coefficients in the RP model may indicate whether a significant difference of the same form would be likely if more observations were available. If the RP model is able to find significant differences, we require that the SP model also recovers similar effects as it is not hampered by a limited sample size.

As a large number of results are produced, these are not reported here but instead are summarised in Table 14 and will be briefly discussed. The first and most interesting results to be considered are those where significant and theoretically consistent variations in the value of time are found in both the RP and SP models. The segmentation of time by the time taken for the actual journey recovered significant variations for both models and journey purposes with the value of time falling as travel time increased.

The segmentation of time by income recovered significant variations in both the RP and SP models for commuting and leisure travel although the RP segmentations are limited to three income groups. Significant differences in cost coefficients segmented by income were not apparent in either RP model but the coefficients are estimated less precisely for cost than time. There is no strong reason why income should influence the commuting marginal utility of time but it is here used as a proxy for variations in the value of time due to variations in the marginal utility of money which are not otherwise discerned.

Table 14: Summary of the Comparisons of RP and SP Segmentations

| | COMMUTING | | LEISURE | |
|---|---|---|---|---|
| | RP | SP | RP | SP |
| Income (Cost) | INSIG | SIG | INSIG | SIG |
| Income (Time) | SIG | SIG | SIG | SIG |
| Sex (Cost) | INSIG | INSIG | INSIG | INSIG |
| Sex (Time) | INSIG | INSIG | INSIG | INSIG |
| Age (Cost) | INSIG | INSIG | INSIG | INSIG |
| Age (Time) | INSIG | INSIG | INSIG | INSIG |
| Alone/Accomp (Cost) | INSIG | INCON | INSIG | SIG |
| Alone/Accomp (Time) | INSIG | SIG | INSIG | SIG |
| Petrol Relevant? (Cost) | INSIG | INSIG | INSIG | INSIG |
| Nature of Work Hours (Time) | SIG | SIG | | |
| Children in Household (Time) | INSIG | SIG | INSIG | INSIG |
| Household Size (Cost) | INSIG | INSIG | INSIG | SIG |
| Departure Time (Time) | INSIG | INCON | INSIG | SIG |
| Journey Time (Time) | SIG | SIG | SIG | SIG |
| To/From Home (Time) | | | INSIG | INSIG |
| Fixed Appointment? (Time) | | | INSIG | SIG |
| Journey Purpose (Time) | | | SIG | SIG |
| Employment Status (Time) | | | INSIG | SIG |
| Weekend/Weekday (Time) | | | INCON | INCON |

The nature of work hours has been seen to have a significant influence on the marginal utility of time in the SP model. In the RP model, those working variable hours had a significantly higher marginal utility of time than those working flexible or fixed hours although the coefficients for the latter two groups were not significantly different. For leisure travel, those making journeys for recreational purposes or to visit friends or relatives were found to have a significantly greater marginal utility of time to those making personal business or shopping trips in both the RP and SP models.

A significant but theoretically inconsistent effect on the marginal utility of time was obtained in both leisure travel models when a segmentation was undertaken according to whether the journey was made during the week or at the weekend.

There are a number of cases where the SP model obtains significant variations but the RP model does not although such outcomes are not so serious and stem more from the limited number of observations in the RP models. In some cases, the variations in the RP values of time are of the same form and more observations would probably yield a significant effect. For the segmentations of the leisure travel model according to departure time and whether the respondent is retired, those making journeys in the morning and the retired had significantly lower SP values of time. In the leisure RP models, these relationships were also apparent and the t ratios for the differences between time coefficients for these two segmentations were 1.85 and 1.73 which are not far removed from significance. There are several instances of the less interesting outcome of insignificant variations in the value of time in both RP and SP models.

There are no cases of the most serious outcome where the RP and SP models are inconsistent in that significant but contradictory variations in the value of time are obtained. Those cases where both the RP and SP models obtain significant and theoretically consistent effects along with those cases where insignificant variations are apparent in both models form the majority of outcomes. Nor are there any instances of the second most serious outcome where a significant variation occurs in the RP model but is not apparent in the SP model. Moreover, significant variations in the value of time in the SP models are for the most part consistent with the theoretical relationships we would hypothesise to exist.

This comparative analysis suggests that the SP data is of good quality and that stated preferences provide an accurate guide to actual preferences. This is backed up by the findings based on the use of SP values of times to explain individuals' actual route choices and from comparisons between global values of time estimated by the two methods. Similar findings were obtained for the same comparisons of RP and SP models for North Kent commuters' mode choices (Wardman 1986b).

## 12. Reported and Engineering Values

Engineering data was obtained from the Tyne and Wear Highway Network Model which enabled a comparison with reported attribute values. For each route, the model provides a matrix of minimum times and distances between all zones. The assumed speeds relate to 24 hour flows. Petrol costs were calculated using AA recommended fuel costs per mile and allowance was made for different engine sizes.

Although the network data does not give exact measures of the times and distances for each individual's journey, as the times and distances are averages for the movements from one zone centroid to another, the zones are quite finely defined. It would not be unreasonable to assume that the errors due to this aggregation vary randomly both across individuals and between the two routes.

Misperception of the attribute values may be seen as a random influence although in any event choice is a function of perceived attribute values. A more serious problem is justification bias where the systematic distortion of the perceived values may lead to biased values of time. It stems from an attempt to rationalise the choice made and was first noted by Festinger (1957) in his theory of cognitive dissonance. It may take the form of understating the costs and times of the preferred route, exagerrating the costs and times of the alternative route or both.

In considering the relationship between reported and engineering values, the following model, and variations upon it, were calibrated:-

$$R_r = a_1 d_{1r} + a_2 d_{2r} + b_1(d_{1r}E_r) + b_2(d_{2r}E_r)$$

where R and E denote the reported and engineering attribute values for route r. The dummy variable $d_{1r}$ equals one if the individual chooses route r else it is zero. Similarly, $d_{2r}$ is one if the individual does not choose route r otherwise it is zero. Thus the relationship between reported and engineering values is considered in terms of chosen and rejected options rather than Tunnel and Bridge.

If the $a_j$ are both zero and the $b_j$ are both one, the reported and engineering values coincide. If the $a_j$ are equal but not equal to zero or the $b_j$ are equal but do not equal one, the true values are misperceived but this misperception affects the chosen and rejected routes in a similar manner. Justification bias can be said to influence the responses if $a_2$ exceeds $a_1$ or if $b_2$ exceeds $b_1$. The analysis was undertaken on the commuting and leisure travel data sets combined and the results, for the linear model above, are presented in Table 15.

Table 15: The Relationship between Reported and Engineering Values

| | $a_j$ | $b_j$ | R Bar Sq |
|---|---|---|---|
| TIME | | | |
| Chosen | 11.37 (14.48) | 0.688 (21.70) | 0.94 |
| Rejected | 14.58 (15.72) | 0.790 (24.67) | |
| PETROL | | | |
| Chosen | 34.91 (13.61) | 0.686 (22.58) | 0.89 |
| Rejected | 41.55 (14.14) | 0.731 (24.41) | |

The $a_j$ are all significantly different from zero and the $b_j$ are each significantly different from one. Moreover, the estimated coefficients are in all cases larger for the rejected route. The $a_j$ and $b_j$ are significantly different for the comparison of reported and engineering times but they are not for the petrol costs comparison. Noticeably, the slope coefficients are very similar for time and cost as are the ratios of the chosen and rejected intercepts.

Various non-linear models were calibrated and the best fit was obtained, for both time and cost, by taking the logarithm of the dependent variable in the above equation. It was found that $a_2$ exceeded $a_1$ and $b_2$ exceeded $b_1$ for both the travel time and petrol cost models and that these differences were significant. The results reveal a tendency for respondents to overstate the attribute values for the range of costs and times involved here and this overstatement was more pronounced at low engineering values. This overstatement of the true values is greater for the rejected route than the preferred route which suggests that justification bias is apparent. The similarities between the slopes and the ratios of intercepts, apparent in the linear models of Table 15, are maintained.

The presence of justification bias may have influenced the value of time estimates of the RP models and artificially inflated the Rho Bar squareds. Table 16 presents models of route choice based on reported and engineering data for the commuting and leisure samples combined.

Table 16: Route Choice Models Using Reported and Engineering Data

| | REPORTED | ENGINEERING |
|---|---|---|
| Time | -0.172 (12.86) | -0.161 (5.24) |
| Toll | -0.038 (12.56) | -0.020 (7.74) |
| Petrol | -0.041 (7.87) | -0.036 (3.75) |
| VOT(T) | 4.53 (14.09) | 8.05 (7.39) |
| VOT(P) | 4.19 (5.89) | 4.47 (2.24) |
| Rho Bar Sq | 0.53 | 0.35 |

It can be seen that when the engineering data is substituted for the reported data, there is a drastic fall in Rho Bar squared, which is to be expected as choices are now less easily explained, and the values of time are also estimated with much less precision.

A noticeable result is that the value of time defined in terms of toll increases quite markedly when engineering data is used but the value of time in terms of petrol varies little. The value of time in terms of petrol may be similar because the misreporting of petrol costs and journey times is of a similar nature. As the toll is not misreported and is larger in relation to petrol cost and time in the engineering data, the same choices are explained by a relatively high toll charge and hence its coefficient is lower and the value of time in terms of toll is larger. If the misreporting of attribute values is similar across different variables, the consequences of justification bias may not be as serious as first appear.

The presence of justification bias in the RP responses adds to the attractions of the SP approach. If such bias has influenced the value of time defined in terms of toll, this has consequences for the comparison of the RP and SP global values of time. However, the comparison of variations in the value of time should only be affected to the extent that the standard errors of RP models based on engineering data are higher than the corresponding models based on reported data.

## 13. Summary and Conclusions

This study has been concerned with estimating the value that motorists place upon time savings from route choices rather than the more usually employed mode choices. Indeed, to the best of the authors knowledge, the only other study in the UK which estimated the value of time for motorists' making urban journeys from route choices was undertaken by Atkins (1983). This involved a revealed preference and transfer price analysis of the choice between two bridges to cross the River Itchen in Southampton. The lack of suitable locations in the UK seems to be the main cause of the dearth of such studies.

A number of interesting findings have emerged from this study and whilst problems inevitably remain, it has been possible to obtain plausible value of time estimates from both the RP and SP models. However, these values are in excess of those which are currently input to transport appraisal projects. The finding that time spent in congested traffic is of greater disutility than time spent in free flow traffic has policy implications as no distinction is currently made between these two forms of travel time in road project appraisal.

Most value of time studies have focused on commuting journeys but leisure and employers' business trips are also considered here. Actra (1978) recommended making a distinction between the values of time for different non-work journey purposes. It was presumed that the value of time for commuting journeys would be greater than that for leisure travel. This was not found to be the case in the analysis undertaken here. The somewhat surprising finding that the leisure travel value of time is greater may be due to opportunity cost and income effects.

The SP approach has several attractions over the RP method, as has been seen in this study, but the main drawback is a concern that stated preferences are not an accurate guide to actual preferences. This has led economists to regard the use of such methods with some scepticism, preferring instead preferences revealed in the market place. The results obtained here suggest that the SP approach seems to be a reliable means of obtaining information on individuals' preferences. It yields similar values of time to the RP approach, and variations in the value of time are similar to those apparent in the RP models, whilst values of time calibrated at a totally disaggregate level satisfactorily explain the actual route choices made.

The SP approach has proved successful in analysing sources of variation in the value of time; analysis which can be undertaken only to a limited degree with RP data sets of the usual sizes. In only a few instances has the segmentation of the SP data found results which were at odds with theory which further validates the SP approach. The approach was also successfully employed in the other three studies in this final phase of the project (Bradley, Marks and Wardman 1986).

Evidence of the systematic misreporting of attribute values was found and this is a potentially serious problem for models based on reported data.

Some issues have not been satisfactorily resolved, such as the issue of car occupancy, and further research would be required to make firm conclusions as to the value of time savings for car passengers in different circumstances. The issues of group decision making, interdependencies within the household, particularly with repect to income, and the choice processes which underlie SP responses need further research, preferably using in-depth survey techniques which were beyond the scope of this study.

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## Appendix: Segmentation Variables and Sample Sizes

COMMUTING

Income -£5000 21 £5-10000 240 £10-15000 300 £15000+ 259
Sex Male 669 Female 151
Age 16-34 332 35-44 239 45-54 159 55+ 90
Car Occupancy Alone 622 Accompanied 198
Petrol Relevant? Yes 369 No 451
Nature of Work Hours Fixed 455 Flexible 167 Variable 198
Number of Children Aged 5 or Less 267 Others 553
Departure Time -7.30 225 7.31-8.30 520 8.31+ 553
Journey Time -20m 169 21-30m 408 31m+ 243

LEISURE

Income -£5000 37 £5-10000 135 £10-15000 110 £15000+ 100
Sex Male 291 Female 91
Age 16-24 35 25-44 205 45-59 96 60+ 46
Car Occupancy Alone 124 Accompanied 258
Household Size 2 or Less in Household xxx 3+ in Household
Departure Time -12.00 185 12.01+ 197
Journey Time -20m 148 21-30m 161 31m+ 73
Fixed Appointment? Yes 110 No 272
Journey Purpose PerBus 67 Rec 80 Shop 94 Vis F/R 128 Other 13
Employment Status Full Time 283 Part Time 17 Housewife 23
Unemployed 20 Retired 39
Day of Week Weekend 223 Weekday 159

EMPLOYERS' BUSINESS

Income -£10000 95 £10-20000 116 £20000+ 25
Sex Male 212 Female 24
Age Group 16-34 90 35-44 72 45+ 74
Car Occupancy Alone 206 Accompanied 30
Nature of Work Hours Fixed 93 Flexible 42 Variable 101
Departure Time Peak Hours 73 Inter-Peak 163
Journey Time -20m 92 21-30m 102 31m+ 42
Time Constraint 30m 55 None 181
Journey Purpose Deliv/Coll 52 Do a Job 30 Vis Client 53
Business Meeting 63 Other 38
Occupation Salesperson 50 Deliv/Coll 19 Prof/Man 123
Repair/Maintenance/Building 16 Other Tech/Man 28
Employment Status Employee 211 Self Empl/Partner 25
Claim Back Toll? Yes 206 No 30