Monograph:

Wardman, Mark (1986) Route Choice and the Value of Motorists' Travel Time: Theoretical and Methodological Issues. Working Paper. Institute of Transport Studies, University of Leeds , Leeds, UK.

Working Paper 223

Institute of Transport Studies
University of Leeds

Published paper

Wardman, M. (1986) *Route Choice and the Value of Motorists' Travel Time: Theoretical and Methodological Issues.* Institute of Transport Studies, University of Leeds. Working Paper 223

Working Paper 223

October 1986

ROUTE CHOICE AND THE VALUE OF MOTORISTS' TRAVEL TIME: THEORETICAL AND METHODOLOGICAL ISSUES

M Wardman

Sponsored by the Department of Transport

Contents

Abstract

Wardman, M. (1986) Route Choice and the Value of Motorists' Travel Time: Theoretical and Methodological Issues. Working Paper 223, Institute for Transport Studies, University of Leeds.

In June 1985, a survey of motorists making urban journeys within Tyne and Wear was undertaken as part of the Department of Transport's research project into the value of time. This paper considers the theoretical and methodological issues involved in estimating the value that motorists' place upon travel time savings from their actual route choices and their responses to a simulated route choice experiment.

The reasons for undertaking this survey and for choosing this particular location are discussed. The experimental design and the modelling technique used in the stated preference analysis are examined and the problems which face both a revealed preference and a stated preference investigation of motorists' route choices are considered.

One of the aims of the study is to consider variations in the value of time according to socio-economic factors and journey characteristics. The theoretical sources of variations in the value of time are discussed as is the modelling approach which was adopted to analyse these potential variations. The empirical findings from the actual survey of motorists making urban journeys is the subject of a subsequent working paper.

Acknowledgement

The findings reported in this paper were obtained as part of a research project into the value of time, undertaken for the Department of Transport by a joint team from the MVA Consultancy, Leeds University Institute for Transport Studies and Oxford University Transport Studies Unit. The members of the team in this final phase of the project were:-

Dr J J Bates (MVA)
Mr M Bradley (TSU)
Dr A S Fowkes (ITS)
Dr P B Goodwin (TSU)
Mr H F Gunn (Hague Consulting Group)
Prof K M Gwilliam (ITS)
Dr P M Jones (TSU)
Mr R P Kilvington (TSU)
Ms P Marks (ITS)
Mr M Roberts (MVA)
Mr M Wardman (ITS)

I am indebted to other members of the project team for their assistance throughout the course of the study, particularly John Bates, Tony Fowkes and Phillipa Marks. The views expressed in this paper do not necessarily represent those of the Department of Transport, nor of other members of the study team.

1. Introduction

As part of the Department of Transport's research project into the value of time, a study of motorists making urban journeys within Tyne and Wear was undertaken. This involved both a revealed preference (RP) and stated preference (SP) analysis of motorists' choices between the Tyne Tunnel and the Tyne Bridge for commuting and leisure journeys and an SP analysis of journeys made in the course of work. The study was undertaken for the following reasons:-

a) Previous studies have largely been based on the journey to work. Value of time estimates were required for other journey purposes in the specific context of urban travel.

b) A comparison of the value of time estimates obtained from actual and hypothetical choices could be made in an attempt to further validate the SP approach. Within this value of time study, previous validation exercises have included a comparison of transfer price and stated preference models with the revealed preference approach (Bates 1984; Broom et al 1983; Gunn 1984).

c) The value of time is likely to depend upon a variety of factors. By collecting appropriate socio-economic data and details of journey characteristics, it is possible to consider how motorists' values of time vary with such factors.

d) It was desired to make a comparison of the attribute values reported by individuals with the 'true' or engineering values and also to compare the values of time derived from reported and engineering data.

This survey formed part of a co-ordinated investigation into the value of travel time savings for different modes in various circumstances. The other surveys in this final phase of the project were concerned with inter-urban car travel, long distance coach and rail travel and urban bus travel. The findings of these four studies are summarised in Bradley, Marks and Wardman (1986) and DTp (1986). In each of these specific contexts, the extent to which the value of time varies according to socio-economic factors and journey characteristics has been considered.

Tyne and Wear was chosen as the location for the survey as the Tyne Tunnel and Tyne Bridge offer a realistic choice of routes for certain cross Tyne journeys whilst traffic flows are such that we could expect to obtain adequate samples. A toll is payable at the Tyne Tunnel but the Tyne Bridge is toll free and thus potential arises for trading off between a quicker but more expensive route via the Tunnel and a slower but cheaper route via the Bridge whereupon actual choices yield information on the value placed upon time savings. The numerous origin-destination combinations in Tyne and Wear which can be served by the two crossings, which are some six miles apart, would give the required variation in the data. Moreover, up to date highway network data was available which allows a comparison of reported and engineering values.

Value of time estimates have been obtained in such a route choice context in the UK by Atkins (1983) who conducted an RP and a transfer price analysis of motorists' choices between two crossings of the River Itchen in Southampton. However, the number of locations in the UK suitable for estimating values of time from motorists' route choices is limited and is reflected in the dearth of such studies.

This paper considers various theoretical and methodological issues relating to the estimation, from route choices, of the money value that motorists place upon time savings. The empirical findings from the analysis of motorists' route choices are presented in a separate paper (Wardman 1986a). A more detailed discussion of the theoretical issues involved in value of time estimation can be found in the final report of this value of time project (DTp 1986).

2. Value of Time Estimation Methodology

The conventional economic approach to the analysis of consumer behaviour assumes that individuals maximise utility subject to constraints relating to available time and income (Becker 1965; DeSerpa 1971, 1973; Bruzelius 1979). Thus in the derived demand for travel, the individual will choose that option which possesses the greatest utility (least disutility). Assuming that for any individual the utility of option j is related to n relevant attributes in a linear additive form, that is:-

$$U_j = a_{0j} + a_1X_{1j} + a_2X_{2j} + \ldots + a_nX_{nj} \qquad (1)$$

the utility difference between two options, say tunnel and bridge is:-

$$U_t - U_b = a_{0t} - a_{0b} + a_1(X_{1t} - X_{1b}) + \ldots + a_n(X_{nt} - X_{nb}) \qquad (2)$$

and the tunnel is preferred if the utility difference is positive.

The parameter a_k is interpreted as the marginal utility of attribute k. The value of time is defined as the money equivalent of the utility effect due to a change in travel time and the marginal utility of travel time is converted into a money equivalent through deflating by the marginal utility of money. If variable X_1 is cost and X_2 is time, the ratio a_2/a_1 is the money value of time. Equation 2 can be converted into a generalised cost formulation by dividing through by the marginal utility of money.

This choice process assumes that the individual trades-off the utilities associated with relevant attributes in determining that option with the greatest overall utility. In choosing between a quicker but more expensive route and a slower but cheaper route, the individual reveals information about the value placed on time savings.

The observed behaviour of travelling either via the Tyne Bridge or the Tyne Tunnel can be analysed by means of discrete choice models and of these the logit model is the most commonly used. Choice is based upon the relative utilities of available options but there are certain factors which enter equation 1 above which cannot be recognised or measured for all individuals. Thus a stochastic element is added to this deterministic expression to represent the net effect of such omitted factors, that is:-

$$RU_j = U_j + e_j \qquad (3)$$

and the random utility of option j deviates from what has been termed representative utility according to e_j. It is now possible to consider the probability of an individual choosing option j as dependent on the variables which enter equation 1 and the stochastic element. Assuming the errors for each option to be independently and identically distributed and of a Weibull distribution, the multinomial logit model can be derived (Domencich and McFadden 1975) as:-

$$P_j = \exp(U_j) \ / \sum_m \exp(U_m) \qquad (4)$$

where P_j is the probability that the individual chooses option j from the m alternatives in the choice set. In the special case of a choice between just two options, say tunnel and bridge, equation 4 simplifies to the binomial logit model of:-

$$P_b = 1 \ / \ [1 + \exp(U_t - U_b)] \qquad (5)$$

where P_b is the probability that an individual chooses the bridge which in this binary choice context is a function of the utility difference between routes which in turn can be expressed in terms of the differences in relevant variables between the tunnel and bridge.

The model is estimated by means of maximum likelihood, using the BLOGIT program of the Australian Road Research Board (Crittle and Johnson 1980). The estimated coefficients of the utility function are scale transformations of the appropriate marginal utilities and should each have a negative sign to reflect the disutility of incurring cost or travel time. This scale factor cancels out when taking ratios of coefficients to yield unique estimates of relative valuations.

SP techniques have numerous attractions, although these will vary according to the particular context in which they are applied, and in this study the SP approach will be seen to have several advantages. As SP techniques can simulate choice situations, the more ideal trade-offs between time and cost allow the value of time to be estimated with greater precision. Indeed, it may not be possible, or may be prohibitively expensive, to obtain value of time estimates by RP methods, for example, the inter-urban car study in this project. The SP approach also offers advantages in the analysis of variations in the value of time due to the greater number of observations of choice obtained. A discussion of various forms of SP experiment and estimation techniques can be found in Green and Srinivasen (1978) and Cattin and Wittink (1982).

The advantages of SP techniques are due to their hypothetical nature but this also provides the main limitation: to what extent do stated preferences reflect actual preferences? The hypothetical nature of SP experiments has led to some scepticism by economists concerning the use of such techniques, preferring instead preferences revealed in the market place, although the techniques are gaining more widespread acceptance and application in transport research. A comparison of value of time estimates derived by RP and SP methods allows some assessment of the merits of the SP technique to be made.

As SP responses are to be compared with actual behaviour, it is important that the SP experiment involves similar choices to those made in practice and that the RP and SP data are modelled in a comparable manner. The SP experiment required individuals to consider the same two options as were faced in practice, the Tyne Tunnel and Tyne Bridge, and to state a preference between the two on the basis of the hypothetical costs and times advanced.

Each route was characterised in terms of four variables which were hypothesised to influence choice. Money costs were introduced in the form of toll charge and petrol cost; other forms of introducing money costs such as road pricing or parking charges were considered unrealistic or inappropriate in this context. Travel time was split into two components: time spent in delays and congested traffic conditions (delay time) and time spent in free flow traffic (free time). This distinction was made as the disutility of time spent in congested traffic conditions may be greater due to the greater stress and frustration involved and it is analagous to the distinction made between walk, wait and in-vehicle time for public transport users. Respondents were informed that those factors not introduced into the experiment would be the same for each route and hence they will not influence choice. It was considered that introducing further variables would unnecessarily complicate the issue and that these four variables satisfactorily characterise the route choice process.

In the 16 choices between routes offered to each individual, permissible responses were on a five-point scale as follows:-

Definitely use Tunnel
Probably use Tunnel
No Preference/Might use either
Probably use Bridge
Definitely use Bridge

If we ignore the no preference responses, a disaggregate logit model based on the preference between bridge and tunnel can be applied to obtain value of time estimates in the same manner as for actual choices. However, we might use an alternative method to make better use of the informational content of responses on a five-point scale and also to avoid omitting the no preference responses.

Such an alternative means of modelling the responses is to use a linear logit model, that is ordinary least squares applied to a logarithmic transformation of the probability of choosing a route. The greater informational content of the responses, albeit on a limited five point scale, is captured by assigning a weight to each response representing the probability of choosing that route (Bates 1984). Thus an equation of the following form is calibrated:-

$$\text{Log}\,[P_t/(1-P_t)] = a_0 + a_1(X_{1t} - X_{1b}) + \dots + a_n(X_{nt} - X_{nb}) \qquad (6)$$

The constant term a_0 reflects a net alternative specific utility effect, that is a tendency to prefer one route other things being equal, which can also be specified in a disaggregate logit model. As choice is based on only two alternatives, the regression can be based on the differences in relevant variables between the two routes.

Given the controlled nature of the SP experiment, the unrecognisable and unmeasurable influences upon the relative utility of the two routes are much reduced in relation to the actual choice context. However, the error term additionally reflects errors involved in the use of the arbitrary probability scale and errors due to divergences between actual and stated preferences. Thus whilst the greater sample sizes, more ideal trade-offs between time and money and the fewer unaccounted for influences upon choice allow the SP method to obtain value of time estimates with lower standard errors than the RP approach, these additional errors tend to reduce this advantage.

Whilst the linear logit model assumes that the error term is normally distributed, and the disaggregate model assumes errors of a Weibull distribution, the two distributions are similar for a given standard deviation. The former model is the form of logit model applied to aggregate data, for example, the market share of two modes, and it is of a comparable nature to the disaggregate logit model. Probability is related to representative utility in the same way as for the disaggregate model and the representative utility functions of the RP and SP models contain the same independent variables.

A numeric scale could be applied to the responses without the logarithmic transformation and the scale would be taken to reflect the utility difference between options rather than the probability of choosing a particular route. However, Bates and Roberts (1983) found that the linear logit model appeared more suitable. As is shown below, this latter model, with its assumed probabilities, was found to recover similar value of time estimates to those obtained by a disaggregate logit model.

The probabilities assigned to each response are arbitrary and the scale is assumed appropriate to all individuals. However, sensible assumptions can be made, such as assigning no preference responses a probability of 0.5, whilst the definitely responses should be high and a probability of 0.9 of choosing route x when it is definitely preferred seems reasonable. The extreme values of one and zero can not be used as the logarithm of zero can not be taken and division by zero is not defined. It also seems appropriate to make the probability scale symmetric around the no preference response.

Whilst errors in the dependent variable do not lead to biased coefficient estimates if the error term satisfies classical assumptions, some misgivings concerning the use of this estimation technique may remain. Thus two validation exercises were undertaken to justify using this approach.

3. Tests of the Modelling Technique

Analysis was undertaken to examine the sensitivity of the value of time estimates to the assumed probabilities in the linear logit model. It would be a cause for concern if the estimates varied widely according to the assumptions made. Table 1 lists the different assumed probabilities in each of the cases considered and Table 2 gives the results of this sensitivity analysis undertaken on the data which was collected. The relevant variables which entered equation 6 above were delay time, free time, toll charge and, in the case of commuting and leisure travel, petrol costs.

Table 1: Assumed Probabilities of Choosing Tunnel for Each Trial

	DEFINITELY TUNNEL	PROBABLY TUNNEL	NO PREFERENCE	PROBABLY BRIDGE	DEFINITELY BRIDGE
A)	0.9	0.7	0.5	0.3	0.1
B)	0.7	0.6	0.5	0.4	0.3
C)	0.95	0.6	0.5	0.4	0.05
D)	0.8	0.8	0.5	0.2	0.2
E)	0.7	0.9	0.5	0.1	0.3

Table 2: Values of Time for Various Probability Assumptions

PURP/TRIAL	VOD(T)	VOF(T)	VOD(P)	VOF(P)	R^2
COMM A	4.18 (45.72)	3.00 (46.58)	4.66 (32.65)	3.34 (34.18)	0.17
COMM B	4.19 (46.03)	3.00 (46.87)	4.66 (32.90)	3.34 (34.31)	0.17
COMM C	4.14 (42.65)	3.02 (43.58)	4.56 (30.61)	3.33 (32.19)	0.16
COMM D	4.25 (44.05)	2.98 (44.78)	4.78 (31.25)	3.36 (32.35)	0.16
COMM E	4.38 (33.77)	2.95 (34.07)	4.98 (23.84)	3.38 (24.36)	0.10
LEIS A	5.28 (29.53)	3.63 (29.13)	6.31 (19.36)	4.33 (19.94)	0.17
LEIS B	5.25 (29.01)	3.57 (29.28)	6.37 (19.52)	4.34 (20.09)	0.18
LEIS C	5.14 (27.81)	3.62 (27.42)	6.26 (17.17)	4.41 (18.76)	0.16
LEIS D	5.38 (28.10)	3.53 (27.67)	6.49 (18.52)	4.28 (19.04)	0.16
LEIS E	5.55 (21.33)	3.46 (21.03)	6.69 (14.17)	4.17 (14.35)	0.10
EB A	5.08 (24.09)	3.97 (20.42)	N/A	N/A	0.09
EB B	5.15 (24.56)	4.02 (20.80)	N/A	N/A	0.09
EB C	4.92 (21.91)	3.89 (18.83)	N/A	N/A	0.07
EB D	5.40 (24.49)	4.16 (20.46)	N/A	N/A	0.09
EB E	5.80 (20.16)	4.39 (16.60)	N/A	N/A	0.06

Notes to Table 2: VOD and VOF denote the value of delay and free time respectively in pence per minute. The terms T and P in brackets denote whether the value of time is expressed in terms of toll charge or petrol cost. t statistics are given in brackets.

It appears that the value of time estimates and explanatory power are relatively insensitive across the reasonable assumptions made in the first three trials. The largest variations occur in the unrealistic case of trial E where the definitely and probably values of trial A are interchanged whilst there also appears to be a slight variation in the value of time estimates when the distinction between a definite and probable preference is ignored, that is in trial D where both these responses are assigned the same probability. The t statistics, which are highly significant in all cases, also show little variation except in trial E where, along with R Bar squared, they are somewhat lower. Similar results were obtained when the same exercise was conducted using SP data based on the choice between train and coach for North Kent commuters to Central London (Wardman 1986b).

A further assessment was made by comparing the results obtained from a disaggregate logit model and a linear logit model for the SP responses for the three journey purposes. The number of observations is slightly reduced for the former model as responses of no preference are ignored. The actual coefficient estimates for the two models are not directly comparable and hence the value of time estimates, which are given in Table 3 along with their t statistics, are compared. For each journey purpose, the disaggregate logit model results occupy the first column and the linear logit model results are based on the sensible probabilities of trial A.

Table 3: Disaggregate and Linear Logit Model Value of Time Estimates

	COMMUTING		LEISURE		EMP BUS	
VOD(T)	4.25	4.18	5.32	5.28	5.46	5.08
	(41.76)	(45.72)	(28.28)	(29.53)	(23.02)	(24.09)
VOF(T)	2.92	3.00	3.45	3.63	4.20	3.97
	(40.43)	(46.58)	(27.40)	(29.13)	(19.15)	(20.42)
VOD(P)	4.69	4.66	6.60	6.31	N/A	N/A
	(27.66)	(32.65)	(17.84)	(19.36)	N/A	N/A
VOF(P)	3.22	3.34	4.28	4.33	N/A	N/A
	(27.76)	(34.18)	(17.66)	(19.94)	N/A	N/A
t(delay-free)	14.80	16.44	13.84	13.95	5.88	5.48
t(toll-petrol)	2.14	2.66	2.91	2.90	N/A	N/A
Rho/R Bar Sq	0.14	0.17	0.14	0.17	0.07	0.09
Observations	9999	13687	6168	6670	3985	4271

The number of observations for commuting journeys for the disaggregate logit model is restricted to 9999 to avoid amendments to the estimation program.

It appears that the two approaches give very similar results whilst disaggregation of the leisure sample by the four sub-purposes of personal business, recreation, visiting friends/relatives and shopping also revealed a high level of similarity between the two methods.

It seems, therefore, that the linear logit model using assigned probabilities to the SP responses is a satisfactory technique for estimating the value placed upon travel time savings. Its advantages are that it makes use of all the responses and the strength of preference, the latter admittedly on a limited scale and by a method which introduces error, whilst there would be computational difficulties involved in using the disaggregate logit model when more sophisticated models of choice are developed to consider variations in the value of time given the number of observations and variables that would be involved. For a given number of variables and observations, the linear logit model uses far fewer computing resources.

The SP experiment involves individuals in multiple comparisons of routes. It may be that the errors for the set of comparisons made by the individual are correlated, for example, those who consistently prefer one route in all 16 comparisons for any of the reasons which are listed below. Such correlations will influence the precision with which the coefficients are estimated and the most likely outcome seems to be that the variance-covariance matrix will be underestimated.

It has been suggested that the estimated standard errors be adjusted by multiplying them by the square root of the number of comparisons undertaken by each individual. This is likely to be an over-adjustment given that this correction factor is based on perfect correlation between errors. However, adjusting the results presented above by this maximum correction factor, in this case by a factor of four, would still result in value of time estimates which are highly significant. However, it must be borne in mind that the t ratios output from the calibrations are likely to exaggerate to some extent the precision with which parameters are estimated.

4. Design of the SP Experiments

SP experiments, whether they involve the ranking, rating or pairwise comparison of options, are commonly based on an orthogonal design, that is the variables which enter the design are independently distributed and hence the correlations between these variables are zero (Bates 1984; Kocur et al 1981). This has statistical advantages in that individual coefficient estimates cannot be 'clouded' due to correlations with other variables and a variable can be omitted from the analysis without affecting the estimates of the remaining coefficients. However, the designs of these SP experiments are not orthogonal. They were based on the following criteria:-

i) The boundary or 'iso-utility' values of time implied by a choice between alternatives should exhibit sufficient variation across the experiment, so that individuals' values of time can be revealed for a wide range of tastes. It is preferable to avoid an unnecessary reduction in the informational content of the responses by including pairwise comparisons which yield little or no information about the value of time.

ii) It is essential to avoid unrealistic combinations of attribute levels which may cause perceptual problems. This would also reduce the advantages of realism obtained in basing the SP experiment upon an actual choice situation. Hensher and Truong (1983) question designs which remove individuals from what they term 'experientially meaningful combinations'.

iii) The correlations between variables should not be too high. In the event correlations were low; the maximum correlation between the differences in variables was 0.35.

iv) It must be clear to the respondent what is being traded off. If all variables vary between the two options to be compared the task becomes more difficult for the respondent. As we were concerned with urban journeys, the opportunity to offer large cost or time savings is naturally limited. Small differences may be ignored if several variables differ between options and care must be taken that the inevitably small time or cost savings are clearly offered.

Whilst orthogonality has attractions for the estimation of a single coefficient, value of time estimates are derived as ratios of coefficients. If the design is not orthogonal, some insight is obtained into how these coefficient estimates vary together. If the covariance between estimated time and cost coefficients is positive, this will act so as to reduce the variance of the ratio of these coefficients and hence more precise value of time estimates are obtained. Furthermore, simultaneously obtaining a satisfactory set of trade-offs, avoiding unrealistic combinations of attribute levels and offering clear trade-offs when small attribute variations are involved, that is satisfying the first two and the fourth criteria above, is not easily achieved for pairwise comparisons based upon an orthogonal design.

For commuting and leisure journeys two designs were used, the times and costs of each being slightly different in an attempt to avoid the SP experiment being unrealistically different to the circumstances of the actual journey made. For the employers' business trips experiment, a separate design was used and toll charge was the only money cost introduced. For the comparisons of the two routes, the iso-utility or boundary values of time for each design are given in Table 4.

Sets 1 and 2 were each used for commuting and leisure journeys and there are two cases in each design where there is no uniquely implied value of time or simple relationship between the implied values of delay and free time. There are four such cases in the employers' business trips design. All values are expressed in terms of total cost although this is simply toll charge for employers' business trips.

Table 4: Iso-Utility or Boundary Values of Time for Each Design

SET 1	VOD:	1.25	4.00	8.00	10.00	
	VOF:	1.00	1.42	2.50	4.00	7.50
	VOD/VOF:	1.00	1.33	1.60	2.00	3.33
SET 2	VOD:	1.67	3.33	5.00	7.50	
	VOF:	0.83	1.25	2.50	4.44	7.50
	VOD/VOF:	1.00	1.50	2.25	2.50	3.00
EMP BUS	VOD:	3.33	4.16	6.66	8.33	
	VOF:	2.08	3.13	4.44	6.25	8.00
	VOD/VOF:	1.00	1.66	2.50		

A wide range of values of time are implied and in most of the 16 comparisons the trade-off is clear, for example, a uniquely implied value of free time requires that delay time is the same between routes or a direct trade-off between delay and free time requires that the costs are the same for each route. This reduces the likelihood that small differences between routes, which we are here inevitably dealing with, are ignored and do not have their real influence upon choice.

The design assumes no particular relationship between the utility effects from given variations in toll charge and petrol cost although it does assume that the value of delay time exceeds that of time spent in free flow traffic.

It is important to test the experimental design to ensure that it is capable of recovering accurate value of time estimates across a wide but realistic range. This was done for sets 1 and 2 combined and also for the employers' business design. The simulation process was undertaken using a disaggregate logit model and involved constructing synthetic data sets where choice is based on relative utility which in turn is a function of values of time and an error component. The error terms conformed to the required Weibull distribution. The simulations were undertaken on a data set of 1600 observations of choice, equivalent to 100 individuals. Some of the results for set 1 and set 2 combined, that is 800 observations for each set, are given in Table 5.

The design performs well across a very large range of underlying values of delay and free time, the only large discrepancy occurring in the final case where the true values are very large. The design also performs well when the value of delay time is made less than the value of free time even though the design is partly based on an assumption that the former exceeds the latter. No problems arise when toll charge and petrol cost variations are assigned different utility effects or when a total time term is entered when the values of delay and free time are made identical. The design of the employers' business trips SP experiment also performed satisfactorily.

Table 5: Actual and Estimated Values of Time for Synthetic Data Sets

VOD (Actual)	VOD (Est)	VOF (Actual)	VOF (Est)
2.0	1.80	1.0	0.95
2.0	1.89	4.0	3.84
3.0	2.91	1.5	1.52
3.0	3.11	3.0	3.08
4.0	4.02	2.0	2.06
4.0	4.12	6.0	5.90
5.0	5.11	3.0	3.05
5.0	5.05	5.0	4.91
6.0	5.97	4.0	3.92
8.0	8.05	5.0	4.94
10.0	10.27	8.0	7.85
12.0	12.76	10.0	10.29

Notes to Table 5: The value of time is defined in terms of total cost; petrol cost and toll charge were given the same weight in the utility expression.

Such tests of the SP design and modelling technique form an important aspect of the application of the SP experiment. As shown, the SP design and the modelling technique perform quite satisfactorily.

5. Issues in the Analysis of Motorists' Route Choices

Some of the issues which are discussed are unique to motorists' route choices and this context in which values of time are to be estimated whilst other issues apply to inter-attribute valuation in general.

i) Misperceptions

Misperceptions arise due to imperfect knowledge concerning attribute levels or the utility effect of some attribute level, that is the X_k or the a_k of equation 1 above may be incorrectly perceived. The misperception of attribute values is more likely to arise in relation to alternative routes/modes given that the individual has experience of the preferred option although the true marginal costs involved in car use are an oft-cited example of misperception. Benshoof (1970) in a study of motorists in Newcastle found evidence that the characteristics of different routes were not accurately measured by motorists. Misperception of the utility effects of a particular attribute level can occur for either route for attribute levels which have not been experienced, for example, those which are presented in the SP experiment.

Insofar as actual choices are based upon perceived attribute values, unbiased estimates of relative valuations can be obtained. However, if the a_k are misperceived, we may obtain unbiased estimates of these misperceived utility effects but they may be subject to revision through increased familiarity and more perfect knowledge, for example, if a switch to the alternative occurs. Misperception of attribute values cannot arise with the SP experiment as the attribute values are presented but the utility effects associated with various attribute values may still be incorrectly perceived.

Another aspect of imperfect knowledge is that individuals may be unfamiliar with the highway network. The route taken may depend, either wholly or in part, upon signposts and as no real choice is made there is no basis for developing a discrete choice model of travel behaviour for such individuals. However, it seems reasonable to assume that motorists in Tyne and Wear making urban journeys, particularly commuters, will be quite familiar with the highway network in general and the two distinct routes which could be used to cross the Tyne.

ii) Justification Bias

A tendency for consumers to justify their choices ex post was first outlined by Festinger (1957) in his theory of cognitive dissonance. It may take the form of understating the true costs or times of the preferred option, exaggerating the costs or times of the alternative or both in an attempt to rationalise the choice actually made. Whilst misperception can be seen as a random influence on reported attribute values, justification bias has a systematic effect and as such is a more serious problem; it may well lead to biased value of time estimates being obtained from an analysis of actual behaviour as choice is not based upon these reported values. Data was obtained to allow a comparison between reported and engineering values.

In the case of the SP responses, justification bias may manifest itself in a greater tendency to choose that route which is currently preferred which may influence the value of time estimates. However, extreme cases of such behaviour, where the currently preferred route is chosen as preferred in all 16 pairwise comparisons, can be identified and in such instances it is possible to improve the quality of the RP data, as well as the SP data, by omitting those whose SP responses are of this form.

iii) Habit and Inertia

The term habit is used to refer to a resistance to change which would not occur if the assumptions of standard economic theory applied and travellers regularly reappraised the choices made on the basis of the level of relevant variables (Goodwin 1977). There may also be a psychological aversity or inertia to changing from the present routine. Thus there may be no change in behaviour after some change in relevant characteristics even though a knowledge of an individual's relative valuations would lead us to expect a change in behaviour. Thus actual choices may not be satisfactorily explained by reference to the current level of relevant variables which may have a distorting influence upon the estimates derived. There may be a tendency in the SP responses to choose the currently preferred route regardless of the level of the attributes which may also influence the SP value of time estimates. As with justification bias, it may be possible to improve the quality of data entering into both the RP and SP models by omitting the extreme cases where the currently preferred route is always preferred in the SP exercise.

However, we might expect habit and inertia to be less apparent in the case of route choice than for the choice between car and other modes and also less widespread for infrequently made trips such as leisure travel. Moreover, as the SP experiment requires an evaluation of the two routes, habit effects may be reduced.

iv) Policy Response Bias

What has been termed policy response bias represents the error which is introduced into responses to hypothetical questions in an attempt to influence policy (Bonsall 1983). Thus, for example, in the case of the transfer price method, there may be a tendency for respondents to understate that price increase necessary to cause a change in behaviour in an attempt to reduce the likelihood that a price increase occurs or to reduce the extent of any such price increase.

The SP approach appears to offer a lesser invitation to such bias. If the respondent perceives journey time and cost variations to be equally likely, the policy response bias incentive leads the respondent to state as preferred that which is actually preferred in the hope that this state of affairs will actually come to pass. However, in this motorists' route choice context, there may still be some incentive to policy response bias if, as seems likely, variations in toll charges are seen to be more policy sensitive than variations in the other attributes.

v) Non-Compensatory Decision Making

The neo-classical economic approach to consumer behaviour assumes that individuals trade-off the utilities associated with various attributes in identifying that option with greatest overall utility. Whilst this theory may be generally applicable, there are alternative theories of choice which may apply to some individuals, such as the elimination by aspects or lexicographic choice processes (Earl 1983; Foerster 1979, 1980; Golob and Richardson 1980; Tversky 1972). For those individuals who possess such choice processes, the models derived from utility maximisation theory, such as the logit model, are no longer appropriate in the process of value of time estimation if indeed there is any benefit from a time saving for such individuals. It may be possible to omit respondents with lexicographic choice rules on the basis of the SP responses, at a cost of erroneously omitting individuals with very high or low values of time, but other forms of non-compensatory choices are even less easily identified with the data available and still remain a potential problem.

It is a cause for concern that the choice rule used in answering hypothetical questions may differ from that which underlies actual choices. However, this problem is more likely to arise with more difficult SP exercises, such as rankings, in an attempt to simplify the task whilst the SP experiment here requires a similar choice to that made in practice.

vi) Variables Relevant to Motorists' Route Choices

It is important to identify those variables which are likely to have more than a negligible influence upon choice. Clearly an RP model requires information on such variables to be able to satisfactorily explain actual choices. The SP experiment must be based on such variables to be realistic; variables having a less important effect can be stated as being the same for each route without serious consequences.

Clearly, travel time influences route choice and it is often cited as the most important or indeed the only variable in motorists' route choices (Carpenter 1979; Outram 1976; Outram and Thompson 1977, 1978) although minimum distance has also been cited as the single most important criterion (Ratcliffe 1972; Wright and Orram 1976). Given that these studies did not consider tolled routes, the extent to which money costs could influence choice is less apparent although minimising distance may reflect a desire to minimise running costs and does not necessarily minimise journey time. Carpenter (1979) found that motorists increased their journey distance by between 10% and 100% in order to save time and hence a trade-off is implied in that greater costs would be incurred in this travel time saving. A pilot survey of motorists' route choices using SP methods (Wardman 1985) found both toll charge and petrol cost to have a significant influence whilst an exploratory study of private travel (Value of Time Study 1983b) led to the conclusion that petrol costs had a different impact to other out-of-pocket expenses, such as parking charges, although this seems to be due to an aversity to paying for the use of roads rather than the irrelevance of petrol costs. Variables will vary in their importance across individuals and whilst travel time may in general be the most important variable, this does not imply that money costs are irrelevant. There are, however, problems with both the cost variables.

There may be an aversity to the payment for the use of roads through toll charges in addition to paying other motoring based taxes. This was found to be the case in the above pilot survey. Thus the response to a given toll charge reflects not only an effect through the marginal utility of income but also an aversity in principle to paying tolls. However, this aversity will be reflected in an alternative specific constant in favour of the bridge given that the latter is toll free and that this aversity is constant regardless of the level of the toll charge.

In the particular context of a choice between the Tyne Bridge and Tyne Tunnel, there are problems for the RP analysis arising from the toll being constant at 40 pence for all travellers. As the toll variable will take the value of 40 or zero, depending upon route, it is perfectly correlated with an alternative specific constant. The inclusion of both variables would lead to a singular matrix and hence only one of these variables can be included whereupon it is not possible to separately discern each effect. Furthermore, McFadden (1979) has shown that the alternative specific constant is biased if a choice based rather than a random sample is used.

As stated above, the true costs involved in car use are often misperceived and tend to be underestimates of true marginal costs. The perceived costs involved in car use, upon which choice is partly based, approximate the petrol costs. Thus petrol costs are included in the RP and SP analysis.

The petrol cost difference between the Tyne Bridge and the Tyne Tunnel may not be large whereupon it may not influence actual choices even though the respondent supplies the petrol costs for each route. The petrol may have been paid for by someone else or by the employer in which case it will not influence choice. Some motorists may treat petrol cost as say a fixed weekly cost and thus it will have a lesser influence upon choice. Given that the petrol coefficient is an average across individuals, it will be reduced according to the number of individuals for whom petrol costs are irrelevant and who effectively have a zero petrol cost coefficient. However, an attempt was made through appropriate questions to allow the identification of those for whom petrol costs would have little influence upon choice so that the model of route choice could be adapted accordingly.

Mode choice studies by Quarmby (1967) and Daly and Zachary (1977) proxied car costs by distance. After converting the estimated coefficient into cost units there was a close correspondence to estimates based on fuel costs. In a mode choice study of West Yorkshire commuters (Value of Time Study 1983a), an attempt was made at resolving the car cost issue by substituting crow-flight distance for car running costs in the mode choice model. The results suggested that reported car costs were reliable and had a similar influence upon choice as public transport costs, that is the cost coefficients for public and private transport were very similar. Moreover, in most mode choice RP studies, petrol costs rather than distance are included in the representative utility function. Other motorists' route choice studies by Atkins (1983), Dawson and Everall (1972), McDonald (1983) and Thomas and Thompson (1970) have been based on toll charges although where the toll charge is constant for all motorists the same problem arises as outlined above.

The issue of whether petrol cost provides a firm basis for a trade-off between time and cost for urban journeys is made more crucial in the RP model given the problems in interpreting the toll coefficient. However, the problems are much reduced in the SP experiment.

In the SP experiment, the toll variable provides a firm basis upon which to trade-off between time and money as the hypothetical circumstances readily allow the required variation. Furthermore, petrol costs are given and therefore do not require calculation and this presentation of petrol costs, in a manner equivalent to having a taxi meter installed in the vehicle, increases the likelihood that petrol costs influence choice. Whilst this in a sense forces individuals to incorporate petrol costs into decision making, there is no reason why this enforced trade-off in itself causes inaccurate value of time estimates to be obtained. However, insofar as petrol costs still do not influence the choices of all individuals, but the toll charge does, the estimated petrol cost coefficient will be less than that for toll charge.

vii) A Note on Employers' Business Trips

The analysis of employers' business trips in this study is concerned only with the value of travel time savings for the employee when making journeys in the course of work. It does not consider the benefits which accrue to the employer of a reduction in the time that employees spend travelling, which may consist of converting time saved into increased output although the distinction disappears if the respondent is self employed.

The analysis of the total benefits which accrue as a result of savings in time spent travelling in the course of work merits a separate study and would not have been possible given the resources available to this study. A discussion of the value of business travel time, along with empirical findings from a survey of long distance business travel, can be found in Fowkes, Marks and Nash (1986). The survey of employers' business trips undertaken here has several features which distinguish it from the surveys of commuting and leisure travel.

When making journeys in the course of work, the money costs involved are generally paid by the employer beforehand or are reimbursed after the journey. As the individual does not face any money costs, and given that there is freedom in the choice of route, the quickest route will always be chosen. Observations of actual behaviour would yield no information on the money value placed upon time savings. Thus an RP study of employers' business trips was not undertaken.

In the SP experiment, the money costs introduced must be payable by the individual so that trade-offs between time and money in the choice of route imply values of time when making business trips. It was considered unnecessary to introduce petrol costs but the individual was offered the opportunity to buy time savings by paying a toll to travel through the tunnel. It was made clear that the individual would have to pay the toll and it could not be claimed back. This means of introducing money costs was used in preference to a foregone alternatives approach of giving the individual a certain amount of money to cover the journey because the latter was considered to be more complicated and imply a less direct trade-off between time and money than the method adopted. The case where the toll could be claimed back regardless of which route was used was avoided because of the dishonesty it implied and the consequences of the unknown transaction costs involved in making a claim for a relatively small amount of money.

viii) Decision Making Units

For both the RP and SP analysis, there is an important issue as to whether the respondent makes the decisions alone or jointly with someone else, for example in the case of group travel, whilst even if the respondent alone is the decision-making unit, externalities in the utility function may mean that choice is also based on a consideration of other individuals.

When group travel is involved and choices are the result of group decision-making, the 'joint utility function' does not necessarily reflect the value of time of any of the individuals involved or an average value of time across the individuals involved. However, insofar as the effects are random they are not a serious problem.

If the respondent is the sole decision-maker, but receives some contribution from fellow-passengers towards the cost of the journey, the implied value of time may vary as the respondent can more afford to purchase time savings. However, in the SP experiment, it is not clear whether the individual inteprets the costs as those payable or deflates them according to the degree costs are shared. The implied value of time may also vary if the respondent considers the wellbeing of other car occupants when making choices.

Furthermore, even if the respondent is the sole decision-maker for the journey being considered, perhaps travelling alone, there is the question of claims from other household members on household income and other inter-dependencies such as occur when the respondent is travelling to meet some other member of the household.

In many cases, it is important to recognise that the individual may not be acting as an independent economic unit and that this has an influence on the value of time which is estimated.

ix) Variations in Route Choice and Journey Characteristics

It is known that in congested urban networks motorists vary the precise route taken for journeys to and from work (Heywood 1985; Jones 1983) and to some extent this is the opposite of habitual behaviour. As we are here concerned with the choice between two general routes, rather than the choice of precise sub-routes, variations in the latter are not a serious cause for concern. However, there may be problems if individuals regularly vary their choice of general route, for example, if we have not accounted for all relevant influences and constraints upon choice.

The RP questions were based on expected costs and journey times as these will influence and provide the best explanation of choice. On the day that the motorist was surveyed, the journey characteristics may have been different from usual and if this had been known prior to making the journey the alternative route might have been chosen and thus these actual characteristics would yield misleading value of time estimates. For the regularly made journey to work, the respondent was asked to state that route which was usually used and this was related to expected costs and times for each route. In the case of infrequently made leisure trips, the actual route chosen was related to the expected costs and times. Data was collected on the variability of travel times for the two routes. In the SP experiment, the costs and times are presented in a deterministic manner and thus if times and cost are perceived as variable, it is reasonable to assume that the individual interprets these attribute values as usual values.

x) Trip Chaining

In the journey between points A and B that the individual reports, and upon which the RP analysis and SP experiment are based, the individual may have stopped-off at some point C; that is the reported trip may be made up of a number of sub-trips. In such instances, we would be explaining the choice of routes as dependent upon the costs and times between points A and B when in fact the costs and times between A and C or between C and B have a more direct influence upon route choice although if point C is near to the reported destination B the problems are less serious.

If the stopping-off point does have a crucial bearing upon choice, there may be a greater tendency in the SP experiment to prefer that route which was chosen for the actual journey and the extreme case where one route is always preferred can be identified. A question was asked concerning whether respondents stopped off in the course of their actual leisure journey or usual journey to work whilst for non employers' business trips, home had to be either an origin or a destination which will reduce the extent of trip chaining in relation to a situation where this constraint is not imposed.

6. Sources of Variation in the Value of Time

It is highly likely that the value of time will vary according to a number of factors. Past studies have found the value of time to be related to such factors as income (Davies and Rogers 1973; Fowkes 1986; Hensher 1976; Quarmby 1967), the size of time savings (Hensher 1976; Lee and Dalvi 1969, 1971; Thomas and Thompson 1970) and the type of time involved (Daly and Zachary 1975; Gunn 1984; Rogers et al 1970; Quarmby 1967). However, there has been relatively limited empirical consideration of the numerous variables which may influence the value of time

As project evaluation is a guide to efficient decision making and allocation of scarce resources, the benefits accruing to a transport investment must be accurately measured. However, applying a 'global' value of time may not be wholly appropriate on efficiency grounds. If the value of time does vary according to socio-economic factors, it is necessary to account for these factors in the particular project being evaluated in order to obtain the correct money value of the time saving benefits. A clear example of this is that if the value of delay and free time diverge, it would be inappropriate to evaluate the benefits which accrue from a project which reduces congestion with a value of time that applies to free flow traffic.

A further reason for considering variations in the value of time is to extend the comparison of RP and SP models of travel behaviour to compare values of time for various segments of the sample. If the SP approach is a satisfactory means of value of time estimation, we not only require that it recovers similar global values of time, but that it also obtains similar variations in the value of time.

As the value of time is derived as a ratio of the marginal utilities of time and money, variations in these will lead to variations in the value of time. The sources of such variations are summarised as:-

(i) Marginal Utility of Money

(a) Income constraints

(ii) Marginal Utility of Time

(a) The opportunity cost/alternative uses of travel time

(b) Travel conditions

(c) Time constraints

It is reasonable to hypothesise that as income increases the marginal utility of money falls, that is the so-called law of diminishing marginal utility applies, whereupon the value of time will be an increasing function of income. Data was collected on gross household income and whilst this is not a perfect measure of the income influence the problems are reduced given that income will be treated in relatively broad bands.

The effective marginal utility of money may also vary according to household size given that the income data relates to that of the household. As household size increases, a given household income is spread across more household members and hence the amount of income which can be used to purchase time savings by any individual is reduced. The utility effect of a given cost variation would be greater than if the whole household income was at the disposal of the respondent and the greater constraints upon income will increase the estimated cost coefficient and hence reduce the estimated value of time. The petrol cost coefficient is also influenced by the extent to which petrol costs are not borne in full by the individual or do not influence choice which in turn will influence the derived value of time.

There may also be some influence on the cost coefficients from car occupancy if other occupants contribute towards the cost of the journey, for example, sharing the costs of journeys to and from work.

If the reported costs or those given in the SP experiment are the costs which are to be shared amongst occupants, the actual cost difference between routes is not that which enters the choice model and thus these drivers will have a lower cost coefficient as a given utility difference is explained by a too large cost difference. If each occupant pays a fixed sum so that the cost difference between routes is unaffected, there may still be an influence on the cost coefficients through the implied income effect. However, higher value of time estimates obtained for those motorists with car occupants does not necessarily represent the total benefits of a time saving that would accrue to the vehicles occupants.

The value of time may vary according to the alternative uses which can be made of travel time savings. Time savings converted into some relatively pleasurable activity, which may be proxied by journey purpose, will be relatively highly valued as may be travel time variations for the commuter who has to be at work early if getting up early has a relatively high disutility. For those who can more readily reschedule activities, such as those with flexible work start times, a time saving may be more highly valued if it allows constraints surrounding the transferability of time to be overcome and a more optimal allocation of time to activities to be achieved. However, if time saved would be converted into idle time waiting for the start of an event or appointment with a fixed starting time, it may not be particularly highly valued although if there are pressures involved in getting to such an event or appointment on time, travel time variations will be relatively highly valued.

There may also be an effect through income if activities with higher utility are more expensive and hence more affordable by higher income groups. Those working variable hours depending upon the requirements of the job and who are travelling in the course of work may have a relatively high value of time as time saved travelling can be directly converted into more leisure time.

It is clear that the alternative uses of time will vary across individuals and circumstances and that the extra utility from consuming more of some activity is unknown. Thus such effects are proxied by such variables mentioned above. If the motorist likes spending time travelling, that is travel is no longer a derived demand, and prefers to travel than to consume more of some other activity, then a time saving will no longer be of value.

Early considerations of travel time savings within the neo-classical theory stated that time savings could be converted into money via the wage rate and hence this opportunity cost formed an appropriate basis for valuing travel time savings. However, amongst other things, this ignores additional influences on the marginal utility of travel time.

The value of time is also likely to depend upon the conditions of travel; the most commonly cited example being the travel environments of different modes. In a motorists' route choice context, the marginal utility of time may vary according to whether the driver is travelling in free flow or congested traffic conditions; time spent in the latter being more highly valued due to the more difficult and stressful conditions of travel and psychological effects stemming from a feeling of frustration in not getting anywhere quickly. Michaels (1966) revealed the importance of strain and tension on route choice and that these were generated by the amount of traffic and the number of junctions which corresponds with the concept of delay time used here. Hence the SP design distinguishes between these two components of travel time and data on each was obtained for the RP analysis. There may also be variations in the marginal utility of time according to whether the individual travels alone or not due to the pleasantness or otherwise of the company whilst travel conditions will also vary according to such factors as the comfort of the car and weather conditions.

Time constraints are also likely to influence the marginal utility of time, a time saving being more highly valued as the amount of free time available to the individual is reduced although there are similarities with opportunity cost effects. There are socio-economic variables which proxy for this effect and which generally reflect different time constraints across individuals.

There may be effects due to interdependencies within the household, for example, caring for young children may increase time constraints. This effect may be confused with that from household size, as the number of children and household size are highly correlated. The latter influences the value of time through the marginal utility of money yet it has an opposite effect on the value of time to that from the number of children which operates on the marginal utility of time. Insofar as a higher income allows the individual to pursue a more active lifestyle, time constraints will be more prevalent although offsetting this is that a larger income allows the purchase of more time saving goods and services.

Those with more available free time, such as the retired, the unemployed and perhaps those who work part time may also place a lower value upon travel time savings whilst those who work long hours, perhaps those with variable hours depending upon the requirements of the job, face more constraints on their available time. Individuals may have more free time at certain times of the week, for example, at weekends.

The value of time may also vary due to non-linearities in the utility function. Thus the marginal utility of time may vary according to the duration of the journey; the so called law of diminishing marginal utility would lead us to expect a given time saving to be of greater value when it occurs at high journey times. Non-linearities can be assessed by specifying representative utility functions which are non-linear in parameters or by using piecewise linear functions where, for example, different journey times are each represented by their own dummy variable. Both approaches were used in the analysis of a pilot survey of motorists' route choices (Wardman 1985).

However, the SP design includes variables at only a limited number of levels and as such does not provide a firm basis for analysing non-linearities. Moreover, if the utility functions are non-linear, there is the question of which is most appropriate functional form, particularly if the form of the non-linearity varies across individuals. Thus the straightforward linear approximation will be maintained. This restricts the value of time to being constant regardless of the amount of time saved and the same for travel time gains and losses. However, within this linear formulation, non-linearities due to variations in the marginal utility of time and money are introduced as time and income constraints vary across categories of individuals.

7. The Segmentation Procedure

These various influences on the value of time can be analysed by adapting the models outlined above. The coefficients of the representative utility function can be estimated for different segments of interest by calibrating separate models for each category of respondent. 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 estimates separate coefficients for all variables for each category of interest. An unnecessary increase in the standard errors associated with the coefficients and values of time can be avoided by effectively restricting the estimation of separate coefficients to variables of interest.

Such an alternative approach, proceeding by means of both theoretical considerations of the sources of variation and statistical findings, uses dummy variables to specify different variables within a single model for each of the categories of interest to allow a different influence upon choice, that is different coefficients, across categories (Value of Time Study 1982). A segmentation of one variable can be expressed within the representative utility function 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 d_{k1} is one if the respondent lies in category one and the segmented variable therefore corresponds with the original value of the independent variable else it is zero whereupon the whole term is zero. There will therefore be M coefficients estimated for 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 project to form a common modelling basis (see also Bates and Roberts 1986).

Such segmentations of variable X_k can be done simultaneously for several categories of interest. Allowing for all possible interactions, that is specifying sufficient separate variables to exhaust all combinations of categories, would be an enormous task and is unlikely to be a worthwhile process. A simplification which leads to a more manageable approach, but which assumes interactions are negligible, 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, say travel time, is segmented according to factors m,p and q which may represent, for example, time constraints, the opportunity cost of time and travel conditions. The process can be extended to the segmentation of other 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 of just the variable X_k, there would be MPQ coefficients to be estimated which is clearly an impractical approach 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 respectively, 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 from p and q. Thus the coefficients for the segmentations according to p and q reflect the incremental effects on the marginal utility of X_k of moving from the base level of p and q, that is of moving from the omitted categories. 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 entered into the model. It is preferable to proceed by initially examining a limited number of influences and thereby obtain some idea as to the significant effects, bearing in mind the correlations between socio-economic variables.

Subsequently more complete models are developed. Theoretical considerations combined with statistical criteria, such as the significance of incremental effects, significant differences between coefficients and general explanatory power, allow the determination of a preferred model.

Even if global values of time only were required, a segmentation approach still has attractions when there are systematic variations in tastes across travellers. The value of time from random utility models is derived as a ratio of mean estimates rather than as a mean of ratio estimates. Fowkes and Wardman (1985) suggest that segmentations of the denominator term are worthwhile as, in the presence of taste variations where the marginal utility of money varies across individuals, these two values are in general not equal and the latter is more appropriate. If the marginal utility of money varies with income, segmentations of the cost variables according to income groups would be worthwhile. Bates (1983) also suggests the segmentaion approach as a simple means of avoiding potential problems arising from taste variations.

Socio-economic data was collected where it was hypothesised that such variables might influence the value of time either directly or as a proxy for other unmeasurable variables. Potential sources of variation which can be explored are listed in Table 6.

Table 6: Segmentation Variables

COMMUTING	LEISURE	EMPLOYERS BUSINESS
Household Income A	Household Income A	Household Income A
Journey Time B	Journey Time B	Journey Time B
Age A	Age A	Age A
Sex A	Sex A	Sex A
Car Occupancy A	Car Occupancy A	Car Occupancy A
Consider Petrol Costs P	Consider Petrol Costs P	Claim Toll Back T
Household Size A	Household Size A	Occupation B
Departure Time B	Departure Time B	Departure Time B
Nature of Work Hours B	Employment Status B	Nature of Work Hours B
To or From Home B	To or From Home B	Frequency of Trip B
	Sub Journey Purpose B	Sub Journey Purpose B
	Fixed Appointment B	Fixed Appointment B
	Day of Week B	Employee/Self Empl A

Notes to Table 6: The letter after each socio-economic variable denotes the segmentation to be undertaken. Thus P represents that the variable may influence the petrol coefficient. The further effects are T (toll only), B (delay and free time) and A (all coefficients). In addition to these segmentations, the differential utility effects of delay and free time and also toll charge and petrol cost can be compared as can differences between the three main journey purposes.

8. Summary and Conclusions

In the choice context under consideration, motorists are faced with two distinct routes for the journey that they are making. It is likely that motorists are familiar with the highway network for the journey made, particularly commuting journeys, and that there is little resort to following the route indicated by signposts. The SP experiment benefits from being based on an actual choice situation.

The exploratory study of private travel (Value of Time Study 1983b) suggested that an RP study of urban route choice, based on the trade-off between time and cost, was possible where motorists were reasonably familiar with the highway network. A pilot survey (Wardman 1985) showed that an SP analysis of motorists' route choices was feasible.

The design of the SP exercise and the modelling procedure to be adopted have been quite extensively examined and constitute a satisfactory simulated choice experiment. However, as discussed, problems do exist in the estimation of the money value placed upon time savings in this urban route choice context, particularly for the RP analysis.

The study is of interest in that it is based on route choice rather than the more commonly employed mode choice, leisure travel and employers' business trips are considered in addition to the more usual analysis of commuting journeys whilst variations in the value of time due to socio-economic factors, which have received relatively little consideration, are explored. A comparison of RP and SP models of travel behaviour can also be undertaken as can some assessment of the relationship between reported and engineering attribute values. These issues are considered in the accompanying working paper (Wardman 1986a) which reports the empirical findings from an actual survey of motorists making urban journeys in Tyne and Wear.

References

Atkins, S.T. (1983) 'The Value of Travel Time: An Empirical Study Using Route Choice' PTRC Summer Annual Meeting, Brighton.

Bates, J.J. (1983) 'Stated Preference Techniques for the Analysis of Transport Behaviour' Conference on Transport Research, Hamburg.

Bates, J.J. (1984) 'Values of Time from Stated Preference Data' PTRC Summer Annual Meeting, Brighton.

Bates, J.J. and Roberts, M. (1983) 'Recent Experience with Models Fitted to Stated Preference Data' PTRC Summer Annual Meeting, Brighton.

Bates, J.J. and Roberts, M. (1986) 'Value of Time Research: Summary of Methodology and Findings' PTRC Summer Annual Meeting, Brighton.

Becker, G.S. (1965) 'A Theory of the Allocation of Time' Economic Journal Vol 75.

Benshoof, J.A. (1970) 'Characteristics of Drivers Route Selection Behaviour' Traffic Engineering and Control 11.

Bonsall, P.W. (1983) 'Transfer Price Data - Its Use and Abuse' PTRC Summer Annual Meeting, Brighton.

Bradley, M.A., Marks, P.A. and Wardman, M. (1986) 'A Summary of Four Studies into the Value of Travel Time Savings' PTRC Summer Annual Meeting, Brighton.

Broom, D., Lowe, S.R., Gunn, H.F. and Jones, P.M. (1983) 'Estimating Values of Time: An Experimental Comparison of Transfer Price Methods with the Revealed Preference Approach' PTRC Summer Annual Meeting, Brighton.

Bruzelius, N. (1979) 'The Value of Travel Time' Croom Helm, London.

Carpenter, S.M. (1979) 'Drivers' Route Choice Project: Pilot Study' Transport Studies Unit, University of Oxford.

Cattin P. and Wittink, D.R. (1982) 'Commercial Use of Conjoint Analysis: A Survey' Journal of Marketing Vol 46.

Crittle, F.J. and Johnson, L.W. (1980) 'Basic Logit (BLOGIT) Technical Manual' ATM No. 9, Victoria, Australia

Daly, A.J. and Zachary, S. (1975) 'Commuters' Values of Time' Report T55, Local Government Operational Research Unit, Reading.

Daly, A.J. and Zachary, S. (1977) 'The Effect of Free Public Transport on the Journey to Work' TRRL Report, SR 338, Crowthorne.

Davies, A.L. and Rogers, K.G. (1973) 'Modal Choice and the Value of Time' Report C143, Local Government Operational Research Unit, Reading.

Dawson, R.F.F. and Everall, P.F. (1972) 'The Value of Motorists' Time: A Study in Italy' TRRL Report LR 426, Department of the Environment, Crowthorne, Berkshire.

Department of Transport (1986) 'Research into the Value of Time: Final Report' Prepared for the Department of Transport by MVA Consultancy London, ITS University of Leeds, TSU University of Oxford, Unpublished

DeSerpa, A.J. (1971) 'A Theory of the Economics of Time' Economic Journal Vol 81.

DeSerpa, A.J. (1973) 'Microeconomic Theory and the Valuation of Travel Time: Some Clarification' Regional and Urban Economics, Vol 2.

Domencich, T.A. and McFadden, D. (1975) 'Urban Travel Demand: A Behavioural Analysis' North Holland, Amsterdam.

Earl, P.E. (1983) 'The Economic Imagination: Towards a Behavioural Analysis of Choice' M.E. Sharpe Inc, Armonk, New York.

Festinger, L. (1957) 'A Theory of Cognitive Dissonance' Stanford University Press.

Foerster, J.F. (1979) 'Mode Choice Decision Process Models: A Comparison of Compensatory and Noncompensatory Structures' Transportation Research 13A.

Foerster, J.F. (1980) 'Nonlinear and Noncompensatory Perceptual Functions of Evaluation and Choice' in New Horizons in Travel Behaviour Research, ed. Stopher, Meyburg and Brog, Lexington Books, Lexington, Mass.

Fowkes, A.S. (1986) 'The UK Department of Transport Value of Time Project: Results for North Kent Commuters Using Revealed Preference Methods' International Journal of Transport Economics.

Fowkes, A.S., Marks, P.A. and Nash C.A. (1986) 'The Value of Business Travel Time Savings' Working Paper 214, Institute for Transport Studies, University of Leeds.

Fowkes, A.S. and Wardman M. (1985) 'The Logit Model and the Consequences of Inter-Personal Taste Variations' Paper Presented at UTSG Annual Conference, Birmingham.

Golob, T.F. and Richardson, A.J. (1980) 'Noncompensatory and Discontinuous Constructs in Travel-Behaviour Models' in New Horizons in Travel Behaviour Research, ed. Stopher, Meyburg and Brog, Lexington Books, Lexington, Mass.

Goodwin, P.B. (1977) 'Habit and Hysteresis in Mode Choice' Urban Studies Vol 14.

Green, P.E. and Srinivasen, V. (1978) 'Conjoint Analysis in Consumer Research: Issues and Outlook' Journal of Consumer Research, Vol 5.

Gunn, H.F. (1984) 'An Analysis of Transfer Price Data' PTRC Summer Annual Meeting, Brighton.

Hensher, D.A. (1976) 'The Value of Commuter Travel Time Savings: Empirical Estimation Using an Alternative Valuation Model' Journal of Transport Economics and Policy, Vol 10

Hensher, D.A. and Truong, T.P. (1983) 'Values of Travel Time Savings from a Revealed Preference Approach and a Direct Experimental Approach' Research Paper 269, School of Economic and Financial Studies, Macquarie University, Australia.

Heywood, R. (1985) 'Route Choice in Congested Urban Networks' Working Paper 209, Institute for Transport Studies, University of Leeds.

Jones, C.B. (1983) 'Variability in Drivers' Route Choice' Unpublished MSc Dissertation, Institute for Transport Studies, University of Leeds.

Kocur, G., Adler, T., Hyman, W. and Aunet, B. (1982) 'Guide to Forecasting Travel Demand with Direct Utility Assessment' United States Department of Transportation, Urban Mass Transportation Administration, Report No UMTA-NH-11-0001-82-1, Washington DC.

Lee, N. and Dalvi, M.Q. (1969) 'Variations in the Value of Travel Time' Journal of the Manchester School of Economics and Social Studies, Vol 39.

Lee, N. and Dalvi, M.Q. (1971) 'Variations in the Value of Travel Time: Further Analysis' Journal of the Manchester School of Economic and Social Studies, Vol 39.

McDonald, J.F. (1983) 'Route Choice and the Value of Commuting Time: An Economic Model of Dichotomous Choice' Transportation Research 17B.

McFadden, D. (1979) 'Quantitative Methods for Analysing Travel Behaviour of Individuals: Some Recent Developements' in Behavioural Travel Modelling, ed. Hensher and Stopher, Croom Helm, London.

Michaels, R.M. (1966) 'Attitudes of Drivers Towards Highways and their Relation to Route Choice' Highway Research Record 122.

Outram, V.E. (1976) 'Route Choice' MAU Note 256, Mathematical Advisory Unit, Department of the Environment.
Outram, V.E. and Thompson, E. (1977) 'Driver Route Choice' PTRC Summer Annual Meeting, Warwick.

Outram, V.E. and Thompson, E. (1978) 'Drivers Perceived Cost in Route Choice' PTRC Summer Annual Meeting, Warwick.

Quarmby, D.A. (1967) 'Choice of Travel Mode for the Journey to Work: Some Findings' Journal of Transport Economics and Policy, Vol 1.

Ratcliffe, E.P. (1972) 'A Comparison of Drivers' Route Choice Criteria and those Used in Current Assignment Processes' Traffic Engineering and Control 13.

Rogers, K.G., Townsend, G.M. and Metcalf, A.E. (1970) 'Planning for the Work Journey' Report C67, Local Government Operational Research Unit, Reading.

Thomas, T.C. and Thompson, G.I. (1970) 'The Value of Time for Commuting Motorists as a Function of their Income Levels and the Amount of Time Saved' Stanford Research Institute.

Tversky, A. (1972) 'Choice by Elimination' Journal of Mathematical Psychology 9.

Value of Time Study (1982) 'Components of Variation in the Value of Time' Prepared by MVA Consultancy, ITS University of Leeds and TSU University of Oxford, Unpublished.

Value of Time Study (1983a) 'Evaluation of Transfer Pricing Methods' Prepared by MVA Consultancy, ITS University of Leeds and TSU University of Oxford, Unpublished.

Value of Time Study (1983b) 'Progress Report for Meeting on 22 November 1983' Prepared by MVA Consultancy, ITS University of Leeds and TSU University of Oxford, Unpublished.

Wardman, M. (1985) 'An Analysis of Motorists' Route Choice using Stated Preference Techniques' Working Paper 212, Institute for Transport Studies, University of Leeds.

Wardman, M. (1986a) 'Route Choice and the Value of Motorists' Travel Time: Empirical Findings' Working Paper 224, Institute for Transport Studies, University of Leeds.

Wardman, M. (1986b) 'A Comparison of Revealed Preference and Stated Preference Models of Mode Choice' Unpublished.

Wright, C. and Orram, H. (1976) 'The Westminster Route Choice Survey: A New Technique for Traffic Studies' Traffic Engineering and Control 17.