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Stated Preference Analysis of Driver Route Choice Reaction To Variable Message Sign Information

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STATED PREFERENCE ANALYSIS OF DRIVER ROUTE CHOICE REACTION TO VARIABLE MESSAGE SIGN INFORMATION

1. INTRODUCTION AND OBJECTIVES

Highway Authorities in many parts of the world have, for some years, been using variable message panels mounted above or beside the carriageway to communicate short messages to motorists. Most such applications have been concerned with hazard warning and speed advice. However, their use to deliberately affect route choice is an area of great current interest. It is recognised that they have a potential role in managing demand to match the capacity available, not only to alleviate acute problems caused by roadworks and accidents, but also to contribute to satisfactory performance of networks operating close to capacity over extended periods of high, but variable, demand.

The installation and operation of the panels is not cheap and there is a widespread belief that overuse, or inappropriate use, of the messages may lead to them losing their credibility with the motorists and thus ceasing to be effective. It is therefore very important to understand the likely response of motorists to various messages before displaying them and even before selecting sites for the installation of panels. A number of researchers have explored drivers' responses to traffic information and route advice offered via variable message signs (VMS). Evidence from traffic counts suggests that messages can persuade somewhere between 5% and 80% of drivers to divert. Clearly this range of estimates is far too wide to support the use of VMS for fine tuning the pattern of demand. A major contributor to the uncertainty, however, is the varying , and often unknown, proportion of drivers whose destination makes the message relevant to them. More detailed studies involving driver interviews downstream of the VMS site to determine the relevance of the message, as well as the response to it, include those by Kawashima (1991) and Durand-Raucher et al. (1993). These studies have produced more precise estimates of compliance but the results are obviously limited to those messages which were on display at the time the interviews were being conducted. A number of researchers have sought to overcome this restriction by examining response to a range of messages presented via a stated preference exercise (see for example Hato et al., 1995; Shao et al., 1995 and Bonsall and Whelan, 1995), via a route-choice-simulator (see for example Firmin, 1996; Bonsall and Merrall, 1995 ; Bonsall and Palmer, 1997) or via a full scale driving simulator or system mock-up (see for example Mast and Ballas, 1976 and Brocken and Van der Vlist, 1991). This research has suggested that response is highly dependent on message content, subjects' network knowledge, and on the extent of any implied diversion.

We see particular value in extending this earlier work to consider a wider range of messages and to determine whether the route-choice-simulator results can be repeated and extended using a somewhat cheaper methodology - namely stated preference analysis.

The objectives of the work reported in this paper were thus:

- to extend to our existing database on drivers' response to traffic information and route advice provided in variable message signs, to include a wider range of messages.

- to construct explanatory models of drivers' route choice behaviour in response to a variety of messages
- to explore the factors influencing this response
- to compare these results with previous results obtained using a variety of data collection methods
- to draw policy conclusions, where appropriate, on the use of variable message signs to influence drivers' route choice
- to draw conclusions, where appropriate, on our data collection and modelling methodology.

2. BACKGROUND

2.1 Influencing Route Choice

Most operational models of network-scale route choice are based on the assumption that drivers are seeking to minimise a simple objective function such as travel time. Modellers' main efforts (as reviewed by Watling, 1994) have been directed towards adequate representation of aggregate equilibrium processes at work in the network rather than towards realistic representation of the dynamics of individual behaviour or the potential for influencing that behaviour.

The network assignment models in widespread use were designed to predict aggregate link flows, but we argue that the changing nature of highway planning, from essentially reactive infrastructure provision to more proactive system management, makes it appropriate to pay more attention to the factors which might be used to influence individual route choice.

Previous studies, reviewed by Bonsall (1992), have identified a number of factors influencing individual route choice. They include: overall expected journey time (minimisation of); delays (avoidance of); congestion (avoidance of); signposted routes (adherence to); tolls (avoidance of); safety and security hazards (avoidance of); unfamiliar routes (avoidance of); and scenic quality (maximisation of). In our current work, we wish to explore the extent to which information about delays and congestion displayed on a variable message sign might influence route choice. We were particularly interested to determine the extent to which the detailed content of the message might influence the response and the extent to which the response is influenced or constrained by driver characteristics or network knowledge.

2.2 The Stated Preference Approach

This study has made use of the Stated Preference (SP) technique in order to evaluate drivers' responses to information on road traffic conditions. Prior to discussing the design and analysis of the SP experiment, we here highlight the salient features of this method of examining travel behaviour.

An SP experiment offers decision makers (eg, individuals, groups, companies) a series of hypothetical scenarios to be evaluated, usually in the form of discrete choices between travel alternatives. The alternatives are characterised by variables whose effects on travel behaviour we wish to examine. A typical SP experiment involves between 9 and 16 choices between two travel alternatives each characterised by four or five variables.

The technique has its roots in consumer behaviour and marketing research (Green and Srinivasen, 1978) and has experienced widespread acceptance and application in transport research since the mid 1980's. It has been extensively applied to the analysis of mode choice, particularly for urban travel, but with a significant number of applications to motorists' route choices (Bradley et al., 1986; Hensher et al, 1990; Wardman, 1991; Brocken and Van der Vlist, 1991; Ortuzar et al., 1994). There are also numerous unpublished SP studies by consultants as a result of the recent increased interest in private sector financing of road schemes, particularly in Great Britain and Eastern Europe (TPA, 1990; Gibb, 1996; Halcrow Fox, 1995; Kocks et al., 1995; Mott MacDonald, 1996) .

The attractions of the SP approach largely stem from its ability to control the choice context and the independent variables that will enter the demand model. In summary, its principal advantages are:

i) It can avoid problems of collinearity between, and insufficient variation in, key variables of interest.

ii) It can be used where an actual choice context does not exist, for example, where tolled roads, road pricing or indeed variable message signs are absent.

iii) It can deal with situations beyond the range of current experiences, for example, somewhat higher car taxes for environmental reasons.

iv) Multiple choice observations can be obtained per person, thereby reducing data collection costs for any level of precision.

The main shortcomings of the SP approach, and conversely the principal attraction of Revealed Preference (RP) models based on actual behaviour, are related to the fact that individuals are not committed to behave in accordance with their SP responses. Random error, such as might be expected as a result of misunderstanding, uncertainty, respondent fatigue and not taking the exercise seriously, will have implications for forecasting, although not for relative values which are derived as the ratios of coefficients, because the coefficients of choice models depend on the residual variation (Bates, 1988). Of greater concern, since it can affect the relative valuations as well as the scale of the model, is error which is of a more systematic nature, such as the strategic biassing of responses in order to influence policy. The evidence in both respects is quite encouraging, since stated preferences have generally been found to correspond reasonably well with revealed preferences (Louviere et al., 1980; Hensher and Truong, 1983; Wardman, 1988, 1991, Bradley and Gunn, 1990; Hensher, 1992; Ortuzar et al., 1994). However, it is widely recommended that, whenever possible, SP models are given some basis in actual behaviour, such as through the estimation of joint RP-SP models (Bradley and Daly, 1991).

An SP approach was adopted for this study because we wished to be able to determine response to a wide range of VMS messages while excluding unwanted external influences. An RP survey would not have been a practical proposition because, even if we had been able to persuade a VMS operator to display our desired range of messages, we could not have controlled the external factors nor afforded the interview costs.

3 STATED PREFERENCE DESIGN AND DATA COLLECTION

3.1 Design

Our SP exercise was based on a trip of around 34km from Warrington to Manchester City Centre as depicted in Figure 1. This journey was chosen because it allowed the SP exercise to be based on the choice between four distinctly different routes which thereby allows a wider range of travel conditions and trade-offs between variables to be considered than in the binary choice context more typically used in SP exercises. Respondents, resident in Warrington, were asked to assume that they were travelling to Manchester City Centre on the M62 motorway (this being the natural route given the location of the survey) and that, as they approach the M62/M6 intersection, they see a VMS panel displaying information on traffic conditions ahead.

A pictorial representation of the choice context was devised. As can be seen in figure 2, this comprised a photograph of the approach to the M62/M6 intersection, showing a 'through-the windscreen' view of traffic conditions on the M62 ahead and on the off-ramp leading to the M6 and a roadside VMS panel displaying a text message about traffic conditions ahead. This information was in the form of estimated delays on three of the four routes and the causes of those delays. The 'through the windscreen' information about current traffic conditions was reinforced with a written description of the traffic conditions at the site.

Respondents were asked to indicate which of the following routes they would use to complete their journey to central Manchester:

- i continue via M62
- ii divert via off-ramp to M6 northbound and thence via the A580
- iii divert via off-ramp to M6 southbound and thence via the M56
- iv divert via off-ramp to M6 southbound and thence via the A57

Note that the M62 and M56 routes provide grade separated routes to within a few kilometres of the destination while the A580 and A57 routes are of lower design standard, the A57 is the lowest quality route and includes several stretches through urban areas.

Respondents were expected to make a choice in the light of the photograph and reinforcing text. Thus they had available the following information:

- local traffic conditions on the M62 ahead (queuing or clear)
- local traffic conditions on the off-ramp to the M6 (queuing or clear)
- expected delays ahead on specified routes (notified via the VMS panel - see Table 1, section c for list)
- cause of these delays (notified via the VMS panel - see Table 1, section d for list)

Figure 1: Map of Trip From Warrington to Manchester

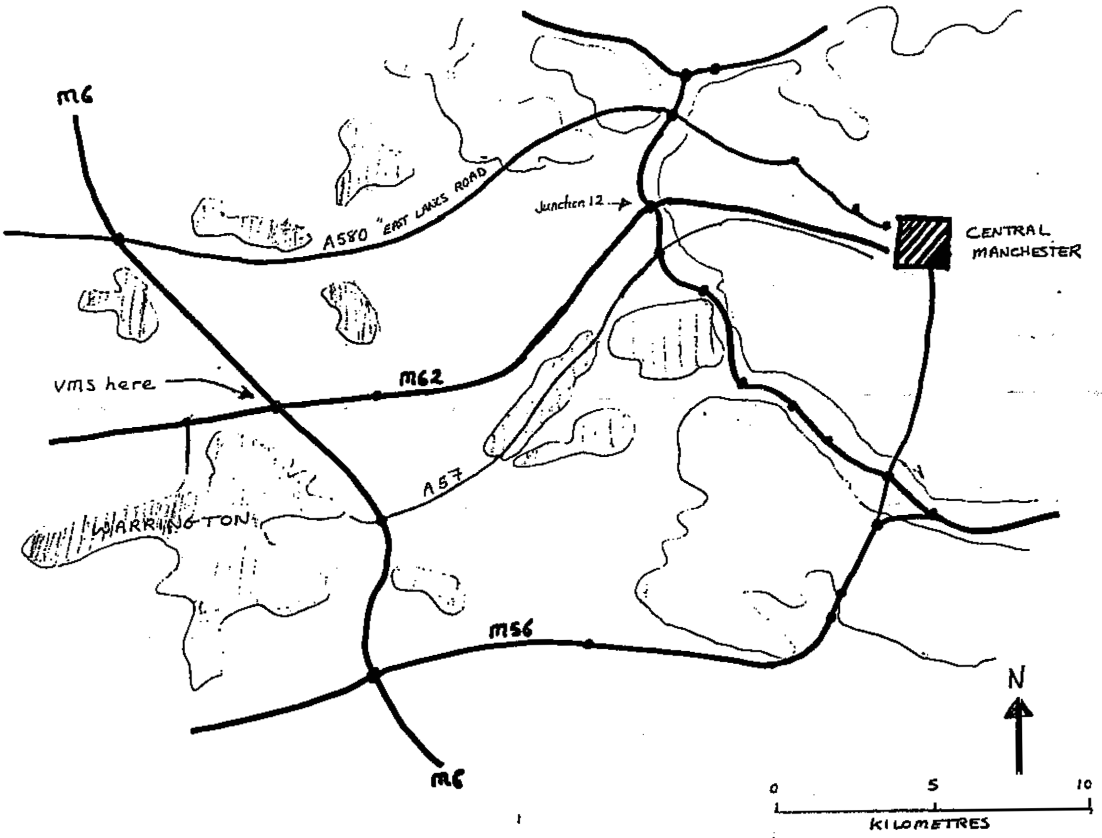
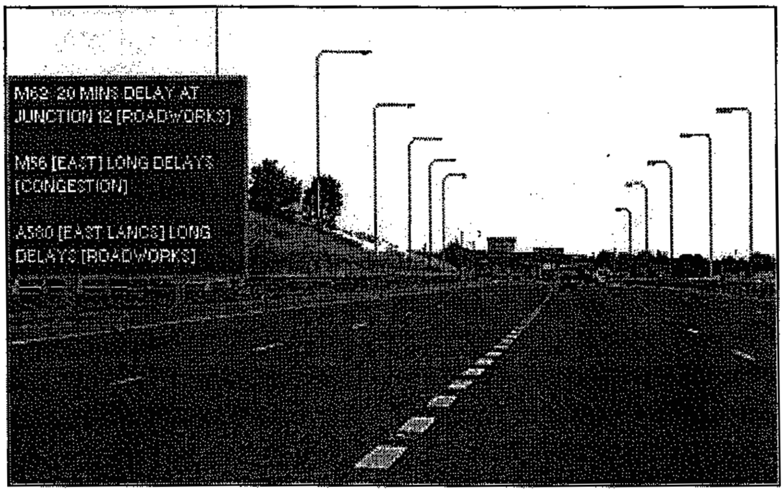


Figure 2: Example of Picture Used In SP Survey



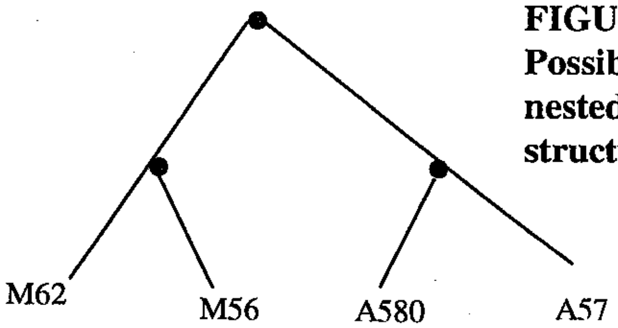
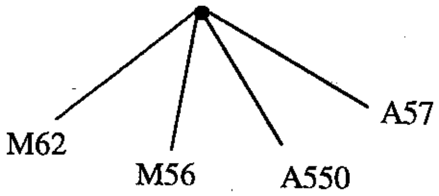


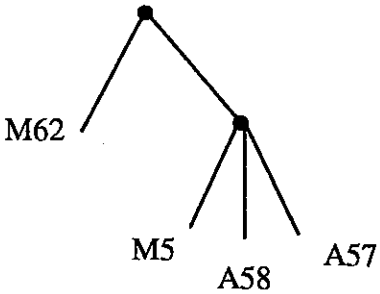
FIGURE 3: Possible nested structure

FIGURE 4: Alternative structures

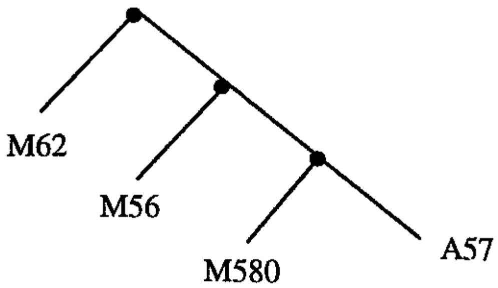
MNL



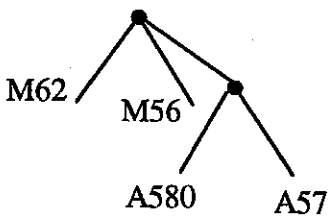
HL1



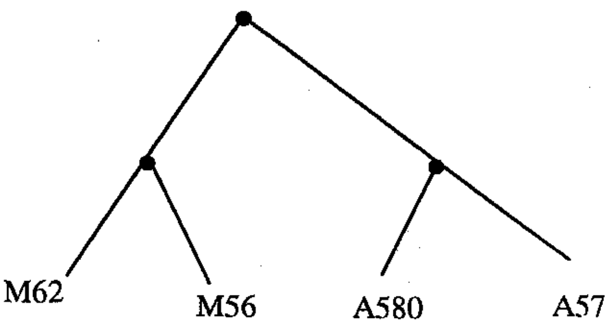
HL2



HL3



HL4



In addition to this they will have had their own perception of the various alternative routes for reaching central Manchester from the M62/M6 intersection. Respondents were therefore asked to provide their own estimate of travel times to central Manchester via four specified routes. We can regard their estimates as being fairly well informed because 91% of our respondents had made at least one journey to central Manchester in the previous year and, for these, the average number of trips made was 53 (for further discussion of this point see later).

Table 1 VMS Messages used in the experiment

a) Format of messages	
Location; Delay; Cause	
b) Locations quoted	
"M62"	"AT JUNCTION 12"
"M56 [EAST]"	
"A580 [EAST LANCS]"	
c) Levels of Delay quoted	
"ALL CLEAR"	
"5 MINS DELAY"	
"10 MINS DELAY"	
"20 MINS DELAY"	
"30 MINS DELAY"	
"DELAYS LIKELY"	
"LONG DELAYS"	
d) Causes quoted	
"[ACCIDENT]"	
"[ROADWORKS]"	
"[CONGESTION]"	
" " (no cause quoted)	

In order to examine whether respondents' reactions to delays are influenced by time constraints, we asked some respondents to imagine that they had to arrive in Manchester by a given time whilst no such constraint was imposed for the remainder.

An orthogonal fractional factorial SP design was used (Kocur et al., 1983) containing three variables at four levels and three variables at two levels. The three variables at two levels were: whether the M62 ahead is queuing or clear; whether the M6 slip road is queuing or clear and whether the journey is being made with a time constraint. The three variables at four levels relate to the information displayed on the roadside VMS about three possible routes - the M62, the A580 and the M56.

As can be seen from Table 1 section c the amount of delay was presented in terms of minutes or, in order to test the effectiveness of qualitative indicators of delay, as "delays likely" or "long delays" As can be seen from Table 1 section d, the design includes three causes of delay, "roadworks", "congestion" and "accident", with a fourth category where no reason was given.

This overall design was accommodated via the 16 sets of 8 questions outlined in Table 2. Note that sets 1-8 differ from sets 9-16 only in that the former included mention of the time constraint in the preamble while the latter did not). In devising this design we had the following concerns:

(1) to ask each respondent no more than 8 SP questions, (so as to minimise response fatigue effects);

(2) not to mix messages which offered no cause for the delay with those that did (to have done so might have caused some confusion and engendered complex patterns of assumed causes);

(3) to ensure that the M62 route was usually penalised more heavily than the others (because it would otherwise have dominated the choices);

(4) to emphasise, in any one set of questions, a range of delay levels rather than a range of causes (in order to simplify the respondents' task); and

(5) to avoid unrealistic combinations of information (thus we replaced rather artificial "5 MINS DELAY [ACCIDENT]" by "ALL CLEAR")

In order to test whether the overall design was satisfactory, in the sense of allowing the accurate estimation of the values of the variables in the design, simulation tests were conducted using synthetic route choice data which mimics how rational individuals might choose (Fowkes and Wardman, 1988). The results of this simulation exercise showed that the designs were capable of supporting the analysis we wished to undertake.

An example of a questionnaire, as distributed to respondents, is included as appendix 1. Note that, following the SP questions, respondents were asked to indicate their estimate of the normal journey time by each route and of the delays that they would expect if queuing was visible at the M62/M6 intersection. Respondents were also asked their age and sex, the frequency of trip making to Central Manchester, the extent to which the different routes had been used and their familiarity with roadside variable message signs.

Table 2: Combinations of messages used in each of the 16 types of Questionnaire

SET	ITEM	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
1+9	M62	20R	10C	20A	30R	20R	20A	30R	10C
	M56	LoC	-	10R	LiR	10R	LoC	-	LiR
	A580	LoR	-	5R	10A	10A	-	LoR	5R
	QM62?	Y	N	Y	N	N	N	Y	Y
	QM6?	N	N	Y	Y	N	Y	Y	N
2+10	M62	20R	10C	20A	30R	20R	20A	30R	10C
	M56	-	LoC	LiR	10R	LiR	-	LoC	10R
	A580	5R	10A	LoR	-	-	10A	5R	LoR
	QM62?	N	Y	N	Y	Y	Y	N	N
	QM6?	Y	Y	N	N	Y	N	N	Y
3+11	M62	20C	10A	20R	30C	20C	20R	30C	10A
	M56	LoA	-	10C	5C	10C	LoA	-	5C
	A580	LoC	-	LiC	10R	10R	-	LoC	LiC
	QM62?	Y	N	Y	N	N	N	Y	Y
	QM6?	N	N	Y	Y	N	Y	Y	N
4+12	M62	20C	10A	20R	30C	20C	20R	30C	10A
	M56	-	LoA	5C	10C	5C	-	LoA	10C
	A580	LiC	10R	LoC	-	-	10R	LiC	LoC
	QM62?	N	Y	N	Y	Y	Y	N	N
	QM6?	Y	Y	N	N	Y	N	N	Y
5+13	M62	20A	10R	20C	30A	20A	20C	30A	10R
	M56	LoR	-	10A	0	10A	LoR	-	0
	A580	LoA	-	LiA	10C	10C	-	LoA	LiA
	QM62?	Y	N	Y	N	N	N	Y	Y
	QM6?	N	N	Y	Y	N	Y	Y	N
6+14	M62	20A	10R	20C	30A	20A	20C	30A	10R
	M56	-	LoR	0	10A	0	-	LoR	10A
	A580	LiA	10C	LoA	-	-	10C	LiA	LoA
	QM62?	N	Y	N	Y	Y	Y	N	N
	QM6?	Y	Y	N	N	Y	N	N	Y
7+15	A162	20	10	20	20	20	20	30	10
	M56	Lo	-	10	Li	10	Lo	-	Li
	A580	Lo	-	5	10	10	-	Lo	5
	QM62?	Y	N	Y	N	N	N	Y	Y
	QM6?	N	N	Y	Y	N	Y	Y	N
8+16	M62	20	10	20	30	20	20	30	10
	M56	-	Lo	Li	10	Li	-	Lo	Lo
	A580	5	10	Lo	-	-	10	5	10
	QM62?	N	Y	N	Y	Y	Y	N	N
	QM6?	Y	Y	N	N	Y	N	N	Y

For codes see next page

Codes for Table 2

code	message
0	ALL CLEAR
-	(NO MESSAGE)
5	5 MINS DELAY
10	10 MINS DELAY
20	20 MINS DELAY
30	30 MINS DELAY
Li	DELAYS LIKELY
Lo	LONG DELAYS
10A	10 MINS DELAY [ACCIDENT]
20A	20 MINS DELAY [ACCIDENT]
30A	30 MINS DELAY
LiA	DELAYS LIKELY [ACCIDENT]
LoA	LONG DELAYS [ACCIDENT]
5c	5 MINS DELAY [CONGESTION]
10c	10 MINS DELAY [CONGESTION]
20c	20 MINS DELAY [CONGESTION]
30c	30 MINS DELAY [CONGESTION]
Lic	DELAY LIKELY [CONGESTION]
Loc	LONG DELAYS [CONGESTION]
5R	5 MINS DELAY [ROADWORKS]
10R	10 MINS DELAY [ROADWORKS]
20R	20 MINS DELAY [ROADWORKS]
30R	30 MINS DELAY [ROADWORKS]
LiR	DELAYS LIKELY [ROADWORKS]
LoR	LONG DELAYS [ROADWORKS]

3.2 Data Collection

Prior to the main survey, a pilot survey was conducted in July 1995. Questionnaires were delivered to households in North East Warrington near to the M62 but no contact was made with residents. The responses obtained did not indicate any problems with the SP exercise but the response rate of 8.6% was very low. A contributory factor here was that the survey was conducted in the first week of the school summer holidays, and some residents would have been on holiday, whilst other households contacted would not have a car. In addition, it was felt that the absence of any personal contact and attempt to obtain the co-operation of the householder was a significant shortcoming. We therefore subsequently adopted an approach whereby the survey staff called at homes and the questionnaires were personally handed to residents with cars available. Respondents were told about the purpose of the survey and advised that it did not matter if they had not made a recent trip to Manchester to guard against non-response on this account. Of the 900 questionnaires which were handed out, 314 were returned giving a response rate of 34.9% which is typical of this surveying method. Adding the questionnaires from the pilot survey gives a total sample of 357 individuals. The data set available for modelling purposes removes those who have not fully completed the questionnaire and contains 289 individuals and a total of 2304 choice observations.

4 EMPIRICAL FINDINGS

4.1 Sample Characteristics

Table 3 shows the respondents' characteristics as revealed in their answers to the questionnaire.

4.2 Modelling Issues

The SP experiment offered choices between four routes. The most straightforward means of analysing discrete route choice is to calibrate a multinominal logit (MNL) model which expresses the probability (P) that an individual i chooses some alternative j as a function of the utilities (U) of the m alternatives in the choice set:

$$P_{ij} = \frac{e^{U_{ij}}}{\sum_m e^{U_{im}}} \qquad (1)$$

In turn, the utility for any alternative j is related to relevant variables representing individuals' travel situations (X_j) and socio-economic characteristics (S_i):

$$U_{ij} = f(\alpha_j X_{ij}, \delta_i S_i) \qquad (2)$$

It is the purpose of the calibration stage to estimate the effects of the attributes of each route (α) and the socio-economic features of the sample (δ) on the choice of route.

Table 3: Respondents' Characteristics

a) Age Distribution (question 6)

Age	<24	24-34	35-44	45-54	55-64	65+
obs	16	110	91	45	18	9
%	5.5%	38.1%	31.5%	15.6%	6.2%	3.1%

b) Sex Distribution (question 5)

Sex	male	female
obs	217	72
%	75.1	24.9

c) Frequency of Visiting Central Manchester (question 2)

mean*	SD	10th-percentile	90th-percentile
59.13	131.56	1	200

d) Previous Use of Each Route (question 3)

	Never		A Few Times		Fairly Often		Very Often	
M62	7	2.4%	61	21.1%	55	19.1%	166	57.4%
M56	81	28.0%	134	46.4%	38	13.1%	36	12.4%
A580	131	45.3%	126	43.6%	19	6.6%	13	4.5%
A57	127	43.9%	128	44.3%	16	5.5%	18	6.3%

e) Estimated Time (mins) to Reach Central Manchester (question 9)

via	Mean	SD	10th-percentile	90th-percentile
M62	27.27	9.55	20	40
M56	37.17	11.71	25	50
A580	37.05	11.84	25	50
A57	39.44	13.91	25	60

f) Estimated Additional Journey Time (mins) to Central Manchester Expected When Queues Are Visible On M62 or M6 Sliproad (question 7 and 8)

via	Mean	SD	10th-percentile	90th-percentile
M62 (queue on M62)	22.38	12.20	10	35
M56 (queue on M6 slip)	25.46	13.86	10	45
A580 (queue on M6 slip)	21.05	12.47	10	40
A57 (queue on M6 slip)	21.20	12.81	7	40

g) Previous Experience of VMS (question 4)

	Obs	%
Yes - Reliable	110	38.1
Yes - Unreliable	90	31.1
Not Seen	89	30.8

The main limitation of the MNL model is its so-called independence of irrelevant alternatives property (Luce and Suppes 1965) which stems from the assumption that the unobserved influences on choice which are contained in the model's error term have a common variance and are uncorrelated across alternatives. The result of this is that, say, an increase in delays on the M62 will be forecast to increase demand on each of the other three routes by the same proportionate amount. In other words, a property of the MNL model is that the cross-elasticities are equal. The most common and straightforward means of allowing for possible different rates of substitutability between travel alternatives is to use the hierarchical logit model. This model adopts a 'nesting' structure which we can illustrate with an example.

We have four routes, two of which are motorways (M62 and M56) and two of which are A roads (A57 and A580). If the motorways have common unobserved influences and the A roads also have common unobserved influences, we would wish to 'nest' the routes as shown in figure 3. The upper nest consists of a composite motorway route and a composite A road route. The utility of a composite route is represented by its expected maximum utility (EMU) and also those variables (Z) which are the same for each of the component routes. Thus the utility for the composite motorway route ($U_{M\text{-}Way}$) would be:

$$U_{M\text{-}Way} = \theta EMU_{M\text{-}Way} + f(Z) \tag{3}$$

where:

$$EMU_{M\text{-}Way} = \log(e^{U_{M62}} + e^{U_{M56}}) \tag{4}$$

The EMU parameter (θ) must exceed zero and be less than or equal to one. If it equals one, the hierarchical logit model becomes equivalent to the MNL, for example, we would effectively have a MNL model amongst four routes if the θ's associated with each composite route in figure 3 approximated one. In the example here, we would forecast the probability of using, say, the M62 as:

$$P_{M62} = (P_{M62}|P_{M\text{-}Way})P_{M\text{-}Way} = \left(\frac{1}{1 + e^{U_{M56} - U_{M62}}}\right)\left(\frac{1}{1 + e^{U_{A\text{-}road} - U_{M\text{-}Way}}}\right) \tag{5}$$

FIGURE 3: Possible nested structure

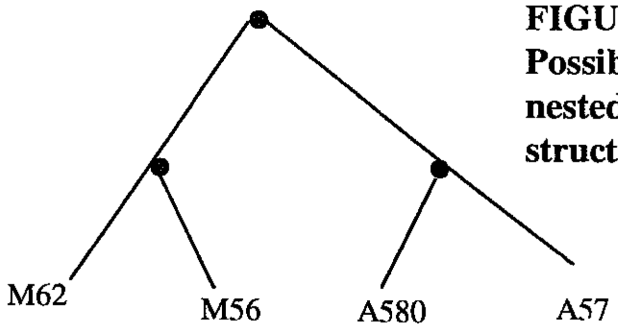
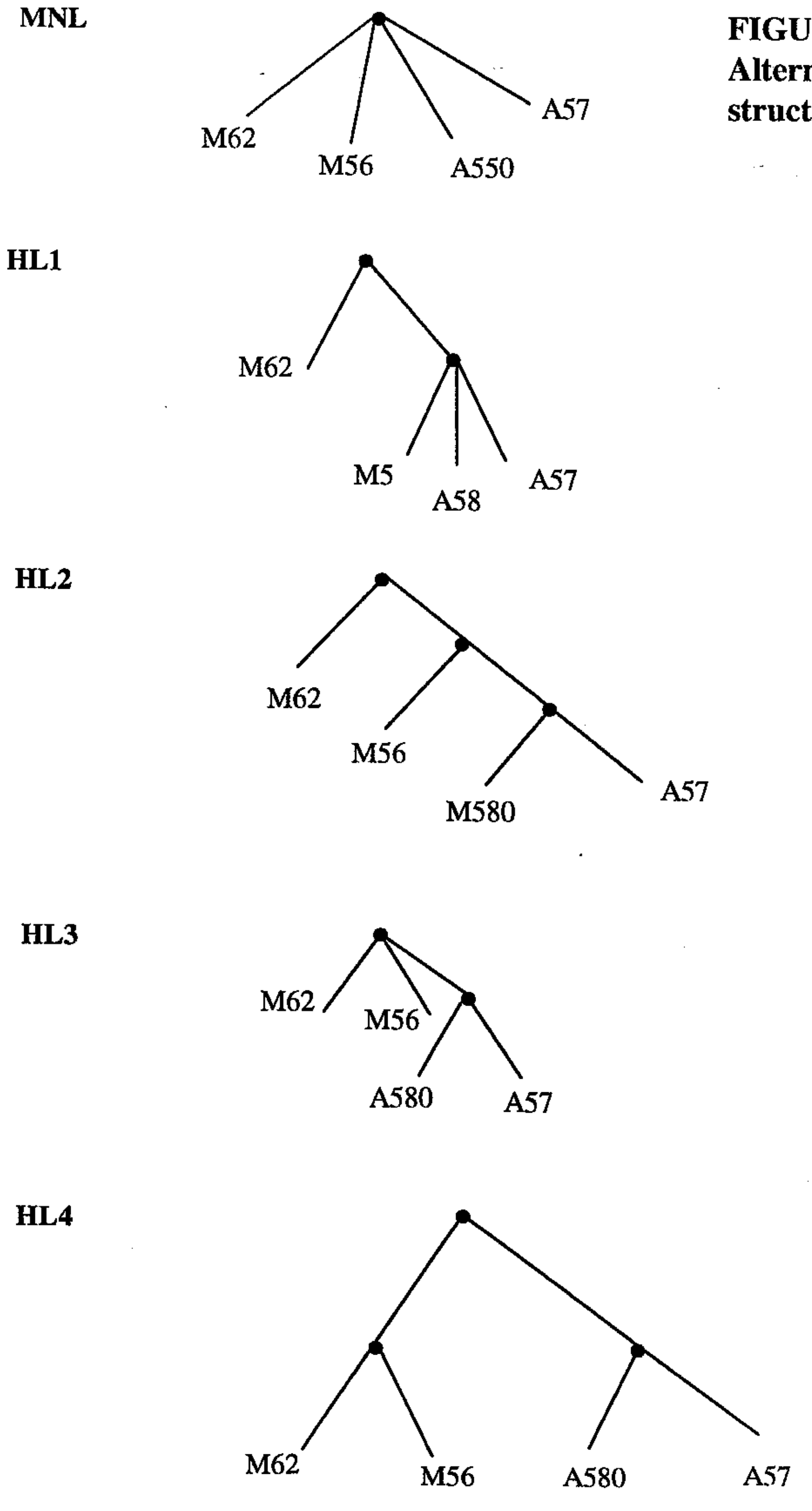


FIGURE 4: Alternative structures



4.3 Model Structure

We have examined the following five model structures which are depicted in Figure 4.

i) Multinominal Logit Model (MNL)

ii) Hierarchical Logit Model (HL1), with an upper nest of M62 against all other routes and a lower nest containing the three other routes which each involve using the off-ramp.

iii) A generalisation of ii) whereby its lower nest is further disagregated. The upper nest therefore contains M62 against all other routes, the middle nest contains the M56 against the A roads and the lower nest contains the two A roads (HL2).

iv) Hierarchical logit model (HL3) with the upper nest containing the M62 motorway, the M56 motorway and a composite A-road alternative, and the lower nest containing the two A-roads.

v) Hierarchical logit model (HL4) with the upper nest containing two composite alternatives relating to motorways and A roads.

Of these, HL3 performed marginally better than the others. This is interpreted as indicating that the two A-roads (A580 and A57) are perceived as having more in common with each other than with either of the motorways and that the two motorways have less in common with each other than do the two A-roads. We suggest that the A-road similarity is associated with design standards and frequent opportunities to exit while the motorway dissimilarity is due to one being the "straight-on" option while the other implies a significant diversion.

In the current study, we wished to explore a wide range of variables and a considerable number of disaggregations. This would put our data set under considerable pressure were we to adopt a hierarchical structure because the latter requires separate coefficients to be estimated for any variable which enters different nests and this is the case for many variables. Thus given that HL3 performed only marginally better than the multinomial logit model, and that its θ parameter was in any event little different to the value of one whereby HL3 would collapse to the multinomial form, we have decided to proceed with the multinomial structure.

4.4 Initial Models

Table 5 presents results for two initial models based on the multinomial logit structure. Both models distinguish between the four specified causes of delays of roadworks *(Road)*, congestion *(Cong)*, accidents *(Acc)* and no reason given *(None)*. The first four coefficients relate to the delay time presented on the variable message sign in minutes *(Mins)* whilst the next two groups of four coefficient estimates denote whether the sign specified "likely delays" *(Likely)* or "long delays" *(Long)*. We will subsequently generalise the models by incorporating socio-economic effects.

Likely and *Long* are dummy variables, as is the variable *(Clear)* which denotes whether the sign indicated that the M56 was clear. The models also contain variables representing the normally expected travel time on each route *(Time)* and the amount of extra time that the respondent thought would be incurred on each route if queuing was visible on the relevant slip road *(Vis-Q)*. This latter formulation provided a somewhat better fit than simply specifying dummy variables for whether there was queuing or not. Three route specific constants (RSC's) were included (RSC_{M56}, RSC_{A580}, RSC_{A57}).

The reported Rho-Squared figure (ρ_c^2) is defined with regard to the log-likelihood of a constants only model and this is lower than the measure defined with respect to chance but the latter is strongly dependent upon the share of each alternative in the sample.

The difference between the two models reported in Table 5 is in terms of the functional form of the delay variable. What we have termed the 'power model' enters delay time *(D)* in a form that allows the unit value of delay time to vary with the amount of delay. Such a utility function takes the form:

$$U_j = \alpha D_j^{\lambda} \quad \textbf{(6)}$$

If λ exceeds one, the unit value of delay time increases with the amount of delay time whereas the value falls as delay time increases when λ is less than one. The linear model is obtained when λ is constrained to equal one and this functional form characterises the vast majority of logit model applications in transport research.

There are a number of desirable features of the models reported in Table 5. It can be seen that all the estimated coefficients have the correct sign and are statistically significant even at a 1% level. The goodness of fit is high for models based on SP data, with values nearer to 0.1 being typical of the more common mode choice applications, although mode specific SP exercises tend to perform better in this respect because there are fewer extraneous influences. The reported values are in units of time (in minutes) and are generally plausible. They are marginal values calculated as the ratio of the derivative of the utility function with respect to the variable in question and the derivative of the utility function with respect to time. In the standard linear model, the value is simply the ratio of two coefficients and is a constant.

Table 5: Initial Models

	Linear Model		Power Model	
	Coeff (t ratio)	Value in mins	Coeff (t ratio)	Value in mins
Road-Mins	-0.102 (14.5)	1.46	-0.036 (14.1)	See Table 7
Cong-Mins	-0.104 (14.6)	1.48	-0.037 (14.4)	See Table 7
Acc-Mins	-0.119 (15.8)	1.70	-0.044 (15.3)	See Table 7
None-Mins	-0.091 (12.1)	1.30	-0.033 (11.9)	See Table 7
Road-Likely	-0.708 (3.1)	10.11	-0.580 (2.5)	8.17
Cong-Likely	-1.921 (5.4)	27.44	-1.810 (5.0)	25.49
Acc-Likely	-2.155 (5.4)	30.78	-2.054 (5.1)	28.93
None-Likely	-0.959 (3.3)	13.70	-0.856 (3.0)	12.06
Road-Long	-2.758 (8.3)	39.40	-2.655 (8.0)	37.39
Cong-Long	-2.486 (7.9)	35.51	-2.362 (7.5)	33.26
Acc-Long	-3.321 (7.2)	47.44	-3.220 (7.0)	45.35
None-Long	-2.686 (6.7)	38.37	-2.581 (6.5)	36.35
Clear	0.693 (3.5)	9.90	0.814 (4.2)	11.46
Vis-Q	-0.036 (13.1)	0.51	-0.037 (13.2)	0.52
Time	-0.070 (14.3)	1.0	-0.071 (14.3)	1.0
RSC_{M56}	-1.639 (12.8)	23.41	-1.552 (12.8)	21.86
RSC_{A580}	-1.715 (13.6)	24.50	-1.632 (13.6)	22.98
RSC_{A57}	-1.970 (14.2)	28.14	-1.766 (13.6)	24.87
ρ_c^2	0.184		0.189	
OBS	2304		2304	
% M62	46%			
% M56	17%			
% A580	13%			
% A57	24%			

4.4.1 The Linear Model

We will first discuss the results obtained from the conventional linear model. In order to assist in interpreting the findings, Table 6 presents t statistics for the relevant differences between estimated coefficients in the linear model. The t statistic for the difference between two coefficient estimates ($\hat{\alpha}_1$ and $\hat{\alpha}_2$) is calculated as:

$$t = \frac{\hat{\alpha}_1 - \hat{\alpha}_2}{\sqrt{Var(\hat{\alpha}_1) + Var(\hat{\alpha}_2) - 2Cov(\hat{\alpha}_1,\hat{\alpha}_2)}} \tag{7}$$

where Var and Cov denote variance and covariance. Table 6 contains 6 comparisons of the delay coefficients, 6 comparisons of the *Likely* coefficients and 6 comparisons of the -*-Long* coefficients according to the cause of the delay. In addition, it presents comparisons of the estimated delay coefficients with the estimated time coefficient and comparisons of the *-Likely* and *-Long* coefficients for each cause of delay.

The results indicate that our respondents are most sensitive to additional delay when its stated cause is an accident. The t statistics presented in Table 6 show that the *Acc-Mins* coefficient estimate is statistically significantly different from the three other delay coefficient estimates even at a 1% level of significance. This finding is consistent with that reported by Bonsall and Merrall (1995) and by Bonsall and Palmer (1995) and is believed to reflect the acute nature of delays due to accidents. *None-Mins* has the lowest coefficient and it is significantly different in two of the three comparisons at the usual 5% level of significance and almost significantly different in the remaining case. This suggests that additional delay has the least influence on route choice when no cause is stated. Again, this result is very much in line with findings from previous work. *Cong-Mins* and *Road-Mins* were estimated to have very similar values.

As can be seen from Table 5, the disutility of additional delay time quoted by the VMS exceeds that of normal journey time for all four causes of delay, with the ratios varying between 1.30 and 1.70 and three of the four coefficients being significantly different from the time coefficient. Delay time might be expected to be more highly valued than journey time due to the uncertainty, stress, frustration and the worse driving conditions involved, although the extent to which motorists consider that the amount of delay time quoted by the VMS is likely to be an overestimate (underestimate) will obviously cause the delay coefficients to be lower (higher) than if delays are interpreted with certainty. It is worth noting that a number of earlier studies have found congestion related delay time to be valued more highly than free flow time. Wardman (1991) found the relative values of 'delay' and 'free flow' travel time to be 1.43 while Oscar Faber TPA (1992) obtained a value of 1.39. Hensher et al (1990) obtained more variable results, with ratios of 1.7 for commuters in company cars and approximately 1.0 for other journey purposes. Note that the current study specified the source of the information as VMS and, for many messages, specified the cause of the delay whereas the previous studies were less explicit about the source or the cause.

Table 6: Differences between Coefficients in Linear Model

Coefficients		t test	$\hat{\alpha}_1-\hat{\alpha}_2$
α_1	α_2		
Cong-Mins	Road-Mins	0.33	-0.002
Acc-Mins	Road-Mins	2.71	-0.017
None-Mins	Road-Mins	1.71	+0.011
Acc-Mins	Cong-Mins	2.34	-0.015
None-Mins	Cong-Mins	1.99	+0.013
None-Mins	Acc-Mins	3.92	+0.028
Cong-Likely	Road-Likely	2.94	-1.213
Acc-Likely	Road-Likely	3.25	-1.447
None-Likely	Road-Likely	0.70	-0.251
Acc-Likely	Cong-Likely	0.45	-0.234
None-Likely	Cong-Likely	2.11	+0.962
None-Likely	Acc-Likely	2.42	+1.196
Cong-Long	Road-Long	0.61	+0.272
Acc-Long	Road-Long	1.01	-0.563
None-Long	Road-Long	0.14	0.072
Acc-Long	Cong-Long	1.52	-0.835
None-Long	Cong-Long	0.40	-0.200
None-Long	Acc-Long	1.05	+0.635
Road-Mins	Time	3.87	-0.032
Cong-Mins	Time	3.95	-0.034
Acc-Mins	Time	5.68	-0.049
None-Mins	Time	2.42	-0.021
Road-Long	Road-Likely	5.22	-2.050
Cong-Long	Cong-Likely	1.21	-0.565
Acc-Long	Acc-Likely	1.93	-1.166
None-Long	None-Likely	3.61	-1.727

What the VMS presented as "likely delays" are valued at between 10 and 31 minutes of normally expected travel time, depending on the stated cause of the delay. Again, it is the specification of "accident" as the cause of the delay which has the largest impact and the *Acc-Likely* coefficient estimate is significantly different from the coefficients for *Road-Likely* and *None-Likely* at the 5% level. The value of delay is again relatively low when no cause is specified with the *None-Likely* estimate significantly lower than the *Acc-Likely* and *Cong-Likely* estimates. This finding reflects previous work by Bonsall and Merall, 1995 and Bonsall and Palmer, 1995. It is notable that the *Road-Likely* coefficient is relatively low; the evidence from the other two dimensions would lead us to expect it to be similar to the *Cong-Likely* coefficient. The relative ineffectiveness of a "Roadworks Likely" message has been observed in other studies and it is speculated that the reason may be a widespread belief that highway authorities more, in an attempt to persuade drivers to keep clear of their roadworks, may take advantage of the inherent uncheckability of a "Delays Likely" message to say that delays are likely at roadworks even when they are not.

The implied values of "long delays" vary between 35 and 47 minutes of normally expected journey time depending on the stated cause. In all four cases, these coefficients are greater than those for the equivalent "likely delays" and in two cases the difference is statistically significant with a further difference almost significant. It is again the accident cause which has the biggest impact on choice. However, there are no significant differences between the *Long* coefficient estimates.

A VMS message indicating that a route is "all clear" (a message which was in fact specific to the M56) has a different effect on choice than does a blank VMS indicating nothing about road conditions. It has a valuation equivalent to 9.90 minutes of normal journey time. This is presumably because the respondents' estimates of normal journey time included an element of delay time.

The value of *Vis-Q* was estimated by using each respondent's stated expectation of delays due to visible queues on the M62 and the off-ramp. Somewhat to our surprise, the results suggest that *Vis-Q* is valued at only half that of normal travel time. Reasons that might be advanced to explain this finding are:

i) Notwithstanding the phrasing of the question, respondents have reported worst case additional delay times arising from visible delays rather than mean values;
ii) There is a tendency to ignore the visible effects when VMS information is presented;
iii) Respondents are unable to make reliable estimates of delays to be expected when queues are visible;
iv) An unwanted correlation in our design between *VIS-Q* and *delay*;
v) Respondents have put less weight on the visible delays in the SP exercise then they would in an actual choice situation.

The first explanation is not thought likely because the mean reported expectation of delay (22 minutes) seems much more reasonable as an estimate of the mean extra time than as an estimate of the worst case extra time and because there is little reason to expect respondents to use worst case estimates in part of the questionnaire but means in another.

In order to gather evidence on the second reason, dummy variable interaction terms were used to allow the *Vis-Q* coefficient to vary according to whether VMS information was provided. The incremental effect indicated that more notice was indeed taken of visible delays when no VMS messages were provided. This effect was also apparent in another study (Bonsall and et al., 1995) and is interpreted as representing the fact that VMS information about conditions ahead is, in some senses, a substitute for visible information about current conditions. However, in the current study the effect was far from statistically significant (t=0.6).

With regard to the third reason, the M56, A580 and A57 all have the same off-ramp and, although they do not have to possess the same expected delays as a result of visible queuing, we would not expect the differences across these routes to be particularly large. Examination of the data showed that although the differences in the means were small (see Table 3.f) there was no clear pattern in the delays expected via the different routes and there were very appreciable mean absolute differences between the delays expected on the M56 and the A580 and on the M56 and the A57 (8.92 minutes and 10.09 minutes respectively). These figures seem rather large and raise concerns about the reliability of this data. However, it is unlikely that unreliable delay times can provide the whole explanation, particularly since the estimated value of *Vis-Q* is so much lower than the value of normal time whereas we would have expected it to be more highly valued.

With regard to the fourth reason, examination of the correlation matrix showed that the highest correlation of estimated coefficients involving *Vis-Q* was 0.23 with *cong-mins*, and thus we are confident that correlation will not have caused any problems here. We must therefore conclude that there is an element of respondents failing to fully account for the visible delays in their SP choice process.

4.4.2 The Power Model

We now turn to the issue of the functional form of delay time in the utility expression, that is, the power model. We are not in a position to simultaneously estimate both α and λ of equation 6. Instead, we examine a range of prespecified values of λ and select the model which provides the best fit. For simplicity we have constrained λ to be the same regardless of the cause of the delay. The value of λ which provided the best fit was 1.3, which improved the goodness of fit statistic (ρ_C^2) from 0.184 to 0.189.

The implied variation in the value of delay time across the range of delay times used in the SP exercise is presented in Table 7. It can be seen that motorists become increasingly sensitive to delay time as it increases and that there is appreciable variation in the value of delay across the different levels of delay time. We note that our result, a power function greater than one, is different to that of other researchers such as Khattak et al. (1993)

Table 7: Values of Delay Time from Power Model ($\lambda = 1.3$)

Delay Time	Road-Mins	Cong-Mins	Acc-Mins	None-Mins
5m	1.07	1.10	1.31	0.98
10m	1.32	1.35	1.61	1.21
15m	1.49	1.53	1.82	1.36
20m	1.62	1.66	1.98	1.48
25m	1.73	1.78	2.12	1.59
30m	1.83	1.88	2.23	1.68

Note: Values of Delay Time are expressed in units of normal journey time.

Comparison of the linear and power models presented in Table 5 lead us to conclude that the new model is to be preferred.

4.5 Summary of Results on the Impact of Different VMS Messages and Visible Delays

We have seen that the impact of expected delays on route choice varies with the specified cause of the delay, that delay time is valued more highly than expected travel time, and that the value of delay time is quite sensitive to the amount of delay time with increasing sensitivity as delay time increases. The results suggest that VMS messages can have a significant impact on traffic flows, an issue which we shall return to in section 6.

Although the ordering of the impacts of the four causes of delay does vary, we can conclude that the accident cause has the largest impact whilst not specifying a reason tends to lead to relatively low values. This seems plausible given the high level of uncertainty that inherently surrounds accidents. It may also be that motorists regard VMS messages relating to delays due to an accident as having more inherent credibility than ones which mention roadworks or which offer no cause at all. Motorists may believe that the traffic authorities might mention delays on VMS signs in order to influence traffic flow in ways that would not necessarily benefit the individual traveller but that the message can be trusted if accidents are mentioned. Whatever the reason, the findings that messages mentioning accidents are more persuasive than ones mentioning roadworks or giving no cause at all is consistent with earlier findings.

The respondents' route choices were influenced by the presence or otherwise of visible delays. However, when allowance is made for respondents' stated expectations of delay when queues are visible some inconsistencies arise. These may be due in part to inaccuracies in the delay times which were reported to be associated with visible queues, or it may be that our pictorial representation of visible queues was not sufficiently convincing, even when backed up by a text statement such as "M6 slip road - visible queuing" or "M62 ahead - looks clear". We are therefore unable to draw firm conclusions regarding the relative effectiveness of information provided by signs and the delays expected on the basis of observed queuing.

5 TRIP CHARACTERISTICS AND SOCIO-ECONOMIC SEGMENTATION

We now explore the extent to which results differ according to the characteristics of the trip and the personal characteristics of the respondents. The variables which we have examined within our preferred model form (multinomial logit model with power function of delay time) are:

- i) Whether there was a binding arrival time constraint
- ii) The age of the respondent
- iii) The sex of the respondent
- iv) The frequency of respondents' trips between Warrington and Manchester
- v) Respondents' familiarity with the alternative routes
- vi) Respondents' prior experience of variable message signs

5.1 Modelling Approach

The approach we have adopted specifies dummy variable interaction terms to allow the coefficients to vary across different categories of relevant characteristics. To do this, we specify dummy variables for n-1 of n categories and create interaction terms as the product of the dummy variables and the independent variables. To illustrate the method, let us specify a simple utility function containing a single independent variable (X):

$$U_j = \alpha X_j^{\lambda} \tag{8}$$

If we wish to examine whether the coefficients of the utility function vary across the n categories of some segmentation variable, we specify the utility function as:

$$U_j = \alpha X_j^{\lambda} + \sum_{k=1}^{n-1} \gamma_k D_{jk} X_j^{\lambda} \tag{9}$$

where D_{jk} is a dummy variable denoting whether an individual or trip is in a particular category. Thus the effect on utility from variable X would comprise two terms for all except the omitted (n'th) category.

There are a number of attractions of this approach over the alternative method of estimating separate models for each category of interest. The incremental coefficients readily indicate not only the sign and size of any effect from a segmentation variable but also its statistical significance whilst formal statistical tests, such as likelihood ratio tests, can be conducted on the fit achieved by different model formulations. Had separate models been estimated, conducting t tests of the differences between coefficients would have been hampered by the absence of any covariance term. Moreover, it would have 'forced' separate coefficients to be estimated for all variables in question whereas the approach we have adopted need allow differences only where theoretically and statistically warranted which is thus more parsimonious and avoids unnecessary reductions in the precision of parameter estimates.

Although we can specify more than one segmentation in a single model (MVA et al., 1987), we initially estimated models which contained only a single segmentation in order to identify the principal sources of variation in coefficients which could then be taken forward to a more complete model.

The following sections present the results of our investigations of each potential segmentation and conclude as to whether it ought to be taken forward to our final, complete, model.

5.2 Segmentation by Time Constraint

Just over half (51%) of respondents were asked to imagine that their journey to Central Manchester involved a time constraint in the form of having to drop someone off for an appointment 45 minutes after passing the roadside sign. The remainder of the sample were given no instructions regarding arrival time constraints.

It is hypothesised that motorists will be more sensitive to delays if there is a risk that they might miss their appointment. We therefore constructed a variable which, for each route, denoted whether the VMS delay time in minutes would cause the time constraint to be broken. An alternative specification allowed, not only for whether the constraint was broken, but also for the extent to which it was broken given the expected journey time on that route and any delays due to visible queues. This latter specification gave a slightly better fit, its precise formulation is given in equation (10).

(*journey time* +*VIS-Q*+*delay*-45) x *delay*, if *journey time* +*VIS-Q*+*delay* > 45 ... (10)

Given the unquantified nature of "Delays Likely" and "Long delays", we cannot construct an equivalent measure of the extent to which these variables would lead to the arrival time constraint being broken. However, it is reasonable to expect the likelihood that such a qualitative delay will be perceived to break the time constraint to increase the higher the respondents' expected journey time. We therefore specified the time constraint variable for the unquantified delays as in equation (11).

(*journey time* +*VIS-Q*+*delay*-45) x *delay*, if *journey time* +*VIS-Q*+*delay* > 45 ... (11)

This variable provided the basis of the segmentation of the *Likely* and *Long* coefficients and provided a slightly better fit than simply segmenting the coefficients by whether a time constraint was specified or not. The route specific constants were segmented simply according to whether a time constraint was specified or not.

It can be seen in Table 8 that none of the twelve incremental coefficients relating to delays were statistically significant. Also seven of the twelve, including all four of those for which we were able to include the value of the expected delay, had a positive sign, indicating reduced sensitivity to delays when there is a likelihood of being late. Clearly this is unsatisfactory, and we were inclined to conclude that, because the constraint is specified for a hypothetical journey, it had either been ignored or else its impact not fully appreciated.

Table 8: Model Segmented by Time Constraint

	Value of coefficient (and t statistic)		
Coefficient	Version of the constraint used	Base value	Incremental value when the time constraint is broken
Road-Mins	1	-0.037 (13.1)	0.004 (0.7)
Cong-Mins	1	-0.041 (13.8)	0.009 (0.9)
Acc-Mins	1	-0.046 (14.3)	0.005 (0.7)
None-Mins	1	-0.033 (11.0)	0.005 (0.6)
Road-Likely	2	-0.591 (1.8)	0.003 (0.3)
Cong-Likely	2	-1.618 (3.4)	-0.012 (0.6)
Acc-Likely	2	-1.936 (3.4)	-0.007 (0.3)
None-Likely	2	-0.614 (1.7)	-0.016 (1.0)
Road-Long	2	-3.046 (5.9)	0.023 (1.4)
Cong-Long	2	-2.766 (5.6)	0.026 (1.7)
Acc-Long	2	-3.230 (4.8)	-0.009 (0.4)
None-Long	2	-2.444 (4.6)	-0.008 (0.4)
Clear		1.019 (3.2)	-0.012 (1.1)
Vis-Q		-0.036 (11.9)	
Time		-0.069 (13.5)	
RSC_{M56}	3	-1.643 (11.1)	0.119 (0.8)
RSC_{A580}	3	-1.876 (12.5)	0.410 (2.7)
RSC_{A57}	3	-2.082 (13.6)	0.503 (3.8)
ρ_c^2		0.194	

Definition of time constraint variables:

1 Dummy x expression in equation (10)
2 Dummy x expression in equation (11)
3 Dummy
Where dummy = 1 if time constraint is specified

However, we note from Table 8 that the effects on RSC_{A580} and RSC_{A57} were significant with a sign which implies that respondents would be more likely to use the A-roads when faced with a time constraint. This provides the basis of an alternative explanation. It may be that, when faced with a tight time constraint and evidence of problems on the motorways, drivers are more inclined to seek to abandon the confines of motorways in favour of the A-roads which offer more opportunities for diversion in the event of problems. Any feeling that motorways are inherently more susceptible to unavoidable delays may have been unwittingly reinforced by our experiment having shown the worst problems on the M62 and never having mentioned any on the A57. If this explanation were valid is perhaps conceivable that an 'avoid motorways' effect outweighs the expected incremental effect on the delay coefficients. On balance, however, we do no feel sufficiently confident in this explanation to warrant including time constraint variables in our preferred model.

5.3 Age Segmentation

We conducted a simple segmentation by age, according to whether the individual was less than 35, on the basis that additional age categories could be specified if the simple segmentation proved successful. The results are presented in Table 9, section A.

There seems to be a general tendency for the incremental effect of being under 35 to moderate the value of the base coefficient - that is for the young respondents to be less sensitive to the specified attributes than are other people. In only one case (*Vis-Q*) is this effect statistically significant but it is certainly worthy of note because it is consistent with evidence from previous work (e.g. Bonsall and Joint 1992) in suggesting that young people are less inclined to comply with VMS advice.

In order to test whether the younger respondents' relative insensitivity to delay information becomes significant when only one incremental effect is sought for all levels of delay, we specified a more parsimonious model where the incremental effects on the delay time coefficients were constrained to be the same across all four causes of delay and the segmentation on *Vis-Q* was maintained.

This model reported in Table 9, section B, yielded a statistically significant effect from age on the value of delay time, with those who are younger being less sensitive to delays and therefore less likely to change their behaviour in the event of expected congestion. For example, the *Road-Mins* coefficient is about 12% lower for those aged under 35 whilst the *Vis-Q* coefficient is about 33% lower. The finding that younger people are less inclined to comply with VMS advice is consistent with previous work (e.g. Bonsall and Joint, 1992). An attempt to further refine our segmentation by disaggregating the 'over 35' group into 'over 45' and '35-44', did not prove worthwhile.

Table 9: Models Segmented by Age

	A		B	
	Base	Incremental effect if Age < 35	Base	Incremental effect if Age < 35
Road-Mins	-0.039 (11.0)	0.006 (1.2)	-0.039 (14.1)	0.0047 (2.5)
Cong-Mins	-0.039 (11.0)	0.005 (0.8)	-0.040 (14.4)	
Acc-Mins	-0.047 (11.8)	0.007 (1.3)	-0.046 (15.3)	
None-Mins	-0.033 (9.1)	0.009 (1.0)	-0.034 (12.0)	
Road-Likely	-0.641 (2.0)	0.116 (0.2)	-0.586 (2.6)	n/a
Cong-Likely	-2.021 (3.8)	0.413 (0.6)	-1.811 (5.0)	n/a
Acc-Likely	-2.081 (3.9)	0.041 (0.1)	-2.059 (5.1)	n/a
None-Likely	-0.793 (2.0)	-0.121 (0.3)	-0.851 (2.9)	n/a
Road-Long	-2.490 (5.8)	-0.364 (0.5)	-2.653 (8.0)	n/a
Cong-Long	-1.928 (5.4)	-1.384 (1.7)	-2.365 (7.5)	n/a
Acc-Long	-3.527 (4.9)	0.587 (0.6)	-3.224 (7.0)	n/a
None-Long	-2.878 (4.8)	0.614 (0.8)	-2.573 (6.4)	n/a
Clear	1.085 (4.1)	-0.603 (1.5)	0.811 (4.2)	n/a
Vis-Q	-0.042 (11.3)	0.013 (2.2)	-0.042 (11.6)	0.014 (2.5)
Time	-0.075 (11.1)	0.006 (0.6)	-0.072 (14.3)	n/a
RSC_{M56}	-1.667 (10.1)	0.279 (1.1)	-1.552 (12.8)	n/a
RSC_{A580}	-1.597 (9.8)	-0.067 (0.3)	-1.630 (13.6)	n/a
RSC_{A57}	-1.684 (9.8)	-0.193 (0.2)	-1.766 (13.8)	n/a
ρ_c^2	0.194		0.191	

5.4 Sex Segmentation

The results of the segmentation by sex are given in Table 10 and the findings are similar to the age segmentation with the general model (A) showing a limited effect on the delay time coefficients. The subsequent model (B) which constrains the incremental effects to be the same across the four causes of delay obtains a statistically significant effect which indicates that the females (25%) in the sample are less sensitive to delay time. Again this finding is consistent with the results of previous studies (Bonsall, 1992b; Conquest et al., 1993; Khattak et al., 1993; Mannering et al., 1994; Bonsall and Merrall, 1995; Emmerink et al., 1996) which found female drivers less willing to divert from their initially determined route.

Table 10: Model Segmented by Sex

	A		B	
	Base	Incremental effect if Female	Base	Incremental effect if Female
Road-Mins	-0.039 (12.6)	0.007 (1.2)	-0.038 (14.3)	0.0065 (3.0)
Cong-Mins	-0.041 (13.0)	0.008 (1.5)	-0.039 (14.7)	
Acc-Mins	-0.046 (13.8)	0.009 (1.5)	-0.045 (15.5)	
None-Mins	-0.034 (10.6)	0.004 (0.5)	-0.034 (12.2)	
Road-Likely	-0.758 (2.7)	0.511 (1.1)	-0.583 (2.5)	n/a
Cong-Likely	-1.602 (4.1)	-1.076 (1.0)	-1.801 (5.0)	n/a
Acc-Likely	-2.460 (4.7)	1.415 (1.7)	-2.061 (5.1)	n/a
None-Likely	-1.029 (3.0)	0.722 (1.1)	-0.859 (3.0)	n/a
Road-Long	-2.900 (6.8)	0.788 (1.2)	-2.656 (8.0)	n/a
Cong-Long	-2.274 (6.5)	-0.426 (0.5)	-2.363 (8.0)	n/a
Acc-Long	-3.504 (5.9)	0.845 (0.9)	-3.222 (7.0)	n/a
None-Long	-2.592 (6.0)	-0.004 (0.1)	-2.589 (6.5)	n/a
Clear	0.786 (3.5)	0.224 (0.5)	0.809 (4.2)	n/a
Vis-Q	-0.040 (12.3)	0.014 (2.1)	-0.037 (13.2)	n/a
Time	-0.078 (13.2)	0.020 (1.1)	-0.072 (14.4)	n/a
RSC_{M56}	-1.554 (10.9)	0.012 (0.1)	-1.551 (12.8)	n/a
RSC_{A580}	-1.568 (11.3)	-0.276 (1.0)	-1.633 (13.6)	n/a
RSC_{A57}	-1.681 (11.3)	-0.369 (0.9)	-1.767 (13.8)	n/a
ρ_c^2	0.195		0.191	

5.5 Segmentation by Frequency of Journeys to Manchester

We segmented respondents according to the frequency with which they had visited Manchester on the basis that this might capture effects relating to familiarity with the routes in question, (a more precise specification of familiarity with each route is considered in section 5.6). Frequency of trip making might proxy for the respondent's information on general driving conditions and hence on how visible queues and messages specifying likely and long delays would be interpreted. A number of different frequency thresholds were tested and the one which proved most effective was five trips per year (≤5 versus >6). 36% of our total sample fell into the low frequency category thus defined. The results in Table 11 reveal that the principal effect of frequency of trip making is on the route specific constants and on *Vis-Q*. The *Vis-Q* coefficient is lower for infrequent travellers which is consistent with the idea that respondents lacking good local knowledge would be less able to appreciate the significance of visible queues at the M62/M6 intersection.

Table 11: Model Segmented by Frequency of Journeys to Manchester

	A		B	
	Base	Incremental effect if Freq ≤ 5	Base	Incremental effect if Freq ≤ 5
Road-Mins	-0.037 (11.3)	0.002 (0.5)	-0.036 (14.1)	n/a
Cong-Mins	-0.039 (12.0)	0.004 (0.7)	-0.038 (14.4)	n/a
Acc-Mins	-0.046 (12.7)	0.005 (0.8)	-0.044 (15.3)	n/a
None-Mins	-0.034 (9.4)	0.004 (0.8)	-0.033 (11.9)	n/a
Road-Likely	-0.441 (1.5)	-0.330 (0.7)	-0.580 (2.5)	n/a
Cong-Likely	-1.819 (4.1)	0.001 (0.1)	-1.812 (5.0)	n/a
Acc-Likely	-1.881 (4.2)	-0.888 (0.8)	-2.057 (5.1)	n/a
None-Likely	-0.771 (2.0)	-0.220 (0.4)	-0.857 (3.0)	n/a
Road-Long	-2.396 (6.3)	-0.878 (1.1)	-2.653 (8.0)	n/a
Cong-Long	-2.410 (5.7)	0.079 (0.1)	-2.362 (7.5)	n/a
Acc-Long	-3.018 (5.8)	-0.771 (0.7)	-3.226 (7.0)	n/a
None-Long	-2.951 (4.9)	0.735 (0.9)	-2.592 (6.5)	n/a
Clear	0.935 (3.8)	-0.311 (0.8)	0.817 (4.2)	n/a
Vis-Q	-0.041 (11.6)	0.013 (2.3)	-0.041 (11.7)	0.012 (2.1)
Time	-0.072 (10.6)	0.005 (0.5)	-0.072 (14.3)	n/a
RSC_{M56}	-1.749 (10.9)	0.471 (1.8)	-1.548 (12.7)	n/a
RSC_{A580}	-1.714 (11.1)	0.185 (0.7)	-1.628 (13.6)	n/a
RSC_{A57}	-1.931 (11.5)	0.380 (1.5)	-1.762 (13.8)	n/a
ρ_c^2	0.193		0.191	

We note a tendency, albeit not statistically significant, for the infrequent drivers to put less weight on the VMS estimates of delay; suggesting perhaps that they do not feel as confident as more frequent travellers about the implications of the delays. We tested a version of the model with a single incremental effect for all quantified delays but it still remained statistically insignificant (t = 0.5). Even though the incremental effects of infrequency on the RSCs are almost significant (and do achieve significance when one incremental effect is used for all three RSCs) we do not find its sign plausible because it implies that infrequent travellers are more likely to use the non-M62 routes. Given our doubts about these infrequency effects we have decided not to take any other than the

Vis-Q incremental effect forward to our preferred model. Table 11, section B shows that, when this is the only incremental effect of infrequency, its effect is to reduce the value of *Vis-Q* by 30%.

5.6 Segmentation by Familiarity with Alternative Routes

Previous research, for example by Mahmassani and Chen (1991), Bonsall and Joint (1991) and Hato et al. (1995), has suggested that familiarity with a network is likely to reduce the desire to comply with directional guidance whilst increasing the ability to respond to traffic information. It might thus be expected that the willingness of motorists to switch from the natural route to Manchester (the M62), and hence their sensitivity to delays, would depend on their familiarity with the alternative routes. We asked respondents how often they had used each route to Manchester, with permissible responses being "very often", "fairly often", "a few times" and "never". Almost everyone (98%) had used the M62 to Central Manchester with 76% having used it fairly often or very often. We defined a dummy variable ('unfamiliar') as being true for a respondent if they said they had never used two of the alternative routes and had used the third a few times at most. This criterion resulted in 30% of our sample being defined as unfamiliar with the alternative routes. It can be seen in Table 12 that no clear or strong effects have emerged from this unfamiliarity segmentation. This may reflect the complexity of any familiarity effect as noted in previous research.

Table 12: Model Segmented by Familiarity with Alternative Routes

	Base	Incremental effect if Unfamiliar with alternatives
Road-Mins	-0.036 (11.4)	-0.002 (0.4)
Cong-Mins	-0.040 (12.5)	0.006 (1.1)
Acc-Mins	-0.045 (13.2)	-0.002 (0.7)
None-Mins	-0.035 (10.4)	0.005 (0.9)
Road-Likely	-0.503 (1.8)	-0.237 (0.5)
Cong-Likely	-2.125 (4.1)	0.675 (0.9)
Acc-Likely	-2.143 (4.5)	0.329 (0.4)
None-Likely	-1.057 (2.8)	0.617 (1.0)
Road-Long	-2.339 (6.6)	-1.552 (1.4)
Cong-Long	-2.315 (5.9)	-0.182 (0.3)
Acc-Long	-3.230 (7.0)	0.009 (0.1)
None-Long	-2.383 (5.5)	-0.873 (0.8)
Clear	0.872 (3.9)	-0.148 (0.3)
Vis-Q	-0.039 (11.4)	0.006 (1.0)
Time	-0.071 (11.5)	0.002 (0.2)
RSC_{M56}	-1.637 (10.9)	0.222 (0.9)
RSC_{A580}	-2.652 (18.2)	0.038 (0.2)
RSC_{A57}	-1.722 (11.2)	-0.211 (0.8)
ρ_c^2	0.193	

An alternative specification was to allow the RSCs to depend on whether the respondent had ever used that route (on the grounds that, all other things equal, a respondent is less likely to choose a route with which he is completely unfamiliar). The proportions stating that they had never used the M56, A580 and A57 routes to Manchester were 28%, 45% and 43%, in contrast to only 2% for the M62. Table 13 shows that those who had never used the route in question are less likely to choose it; for example, the (negative) constant for the A57 is 73% greater for those who have never used it. This finding is highly significant.

We also examined additional incremental effects for each constant where respondents had only used a route a few times but the coefficients were far from significant. Nor was the extension of this segmentation to the delay time coefficients successful.

Table 13: Segmentation of Constants by 'Never Used' the Each Route

	Base	Incremental Effect if Unfamiliar With Alternatives
Road-Mins	-0.037 (14.3)	
Cong-Mins	-0.039 (14.8)	
Acc-Mins	-0.044 (15.4)	
None-Mins	-0.033 (11.9)	
Road-Likely	-0.587 (2.5)	
Cong-Likely	-1.878 (5.2)	
Acc-Likely	-2.090 (5.1)	
None-Likely	-0.826 (2.8)	
Road-Long	-2.736 (8.2)	
Cong-Long	-2.442 (7.7)	
Acc-Long	-3.337 (7.2)	
None-Long	-2.588 (6.5)	
Clear	0.821 (4.2)	
Vis-Q	-0.037 (13.2)	
Time	-0.067 (13.4)	
RSC_{M56}	-1.495 (11.8)	-0.548 (3.8)
RSC_{A580}	-1.338 (10.5)	-0.958 (6.7)
RSC_{A57}	-1.462 (11.0)	-1.070 (9.2)
ρ_c^2	0.213	

5.7 Segmentation by Experience of Variable Message Signs

Previous research, for example by Bonsall and Joint (1991), Janssen and Van der Horst (1992), Hato et al. (1995) and Zhao et al. (1995), has demonstrated that compliance with diversion advice is highly dependant on the credibility of that advice as judged from its previous record of reliability. We therefore asked individuals whether they had ever seen an electronic variable message roadside sign and whether they had found them to be a reliable guide to conditions ahead. 39% stated that they had seen such signs and found them to be reliable, 31% had found them to be unreliable and 30% stated that they had not seen one. Table 14 reports results of segmentation which examine whether there is an impact on the coefficients from perceived unreliability and whether variable message signs had ever been seen.

Table 14: Model Segmented by Experience of Variable Message Signs

	Base	Incremental Effect If Unreliable	Incremental Effect If Not Seen
Road-Mins	-0.041 (10.1)	0.006 (1.4)	0.005 (0.8)
Cong-Mins	-0.039 (10.2)	0.011 (1.7)	-0.004 (0.6)
Acc-Mins	-0.046 (11.2)	-0.002 (0.4)	-0.002 (0.2)
None-Mins	-0.036 (9.2)	0.010 (1.5)	0.005 (0.7)
Road-Likely	-0.664 (1.6)	0.213 (0.4)	0.057 (0.1)
Cong-Likely	-2.387 (3.2)	0.309 (0.3)	1.176 (1.3)
Acc-Likely	-2.004 (4.6)	-0.422 (0.4)	0.083 (0.3)
None-Likely	-0.673 (1.8)	-0.502 (0.7)	-0.385 (0.5)
Road-Long	-2.896 (4.8)	0.858 (1.1)	-0.098 (0.1)
Cong-Long	-2.614 (4.4)	0.307 (0.4)	0.415 (0.5)
Acc-Long	-3.038 (5.9)	-0.022 (0.2)	-0.719 (0.6)
None-Long	-2.583 (5.5)	0.003 (0.1)	0.024 (0.1)
Clear	0.491 (1.6)	0.736 (1.3)	0.390 (0.8)
Vis-Q	-0.034 (8.9)	-0.011 (1.8)	0.005 (0.7)
Time	-0.072 (14.2)		
RSC_{M56}	-1.514 (8.0)	-0.202 (0.7)	-0.049 (0.2)
RSC_{A580}	-1.608 (8.7)	0.011 (0.1)	-0.164 (0.6)
RSC_{A57}	-1.840 (9.4)	0.362 (1.1)	-0.212 (0.7)
ρ_c^2	0.196		

The incremental effects are weak although there is a tendency for those who have found VMS messages to be unreliable to be less sensitive to information on delay times in minutes. None of the incremental effects are statistically significant and a single coefficient estimate, obtained when the incremental effects were constrained to be the same for all four cause of delay, was also insignificant (t=1.3). Not having seen an electronic roadside variable message sign does not have any impacts which approach statistical significance.

The only significant effect is that respondents who have found VMS unreliable have a greater weight on their *Vis-Q* coefficient. This is obviously very plausible on the grounds that those who find VMS unreliable will take more notice of visible queues. The reason why we have not discerned any effects from unreliability on the VMS messages may well be because some respondents interpreted unreliability to mean the VMS understated delays, others interpreted it to mean that VMS overstated delays whilst yet others may have interpreted unreliability as a random effect. Unfortunately, we did not enquire as to what individuals interpreted unreliability to mean. Table 15 reports a model which maintains only the effect of unreliable VMS messages on the *Vis-Q* coefficient. The latter is 50% higher for those who find VMS to be unreliable.

Table 15: Effect of Unreliable VMS on Vis-Q

	Base	Incremental Effect If Unreliable
Road-Mins	-0.036 (14.1)	
Cong-Mins	-0.038 (14.5)	
Acc-Mins	-0.044 (15.3)	
None-Mins	-0.033 (12.0)	
Road-Likely	-0.581 (2.5)	
Cong-Likely	-1.812 (5.0)	
Acc-Likely	-2.051 (5.1)	
None-Likely	-0.867 (3.0)	
Road-Long	-2.654 (8.0)	
Cong-Long	-2.362 (7.5)	
Acc-Long	-3.213 (7.0)	
None-Long	-2.605 (6.5)	
Clear	0.812 (4.2)	
Vis-Q	-0.032 (9.5)	-0.016 (2.7)
Time	-0.072 (14.4)	
RSC_{M56}	-1.554 (12.8)	
RSC_{A580}	-1.631 (12.6)	
RSC_{A57}	-1.768 (13.8)	
ρ_c^2	0.191	

5.8 Preferred Route Choice Model

Our preferred overall model is a multinomial logit formulation with a power term for the delay time and contains all the segmentation variables that have been identified as significant and plausible in the preceding sections. The model is presented in Table 16 and it can be seen that, with the exception of the effect of sex on the delay coefficients which is now somewhat lower, the incremental effects are little different to those obtained in the separate models and all the effects retain their statistical significance. A likelihood ratio test[1] comparing our preferred model with the power model in Table 5 which does not contain any segmentation variables yields a χ^2 of 162.4 which, given a tabulated χ^2 value of 20.09 for 8 degrees of freedom, indicates that the segmented model is statistically superior even at a 1% level of significance.

Table 16: Preferred Overall Model

	Base	Incremental
Road-Mins	-0.041 (14.3)	Age < 35 0.0043 (2.2) Female 0.0040 (2.0)
Cong-Mins	-0.042 (14.6)	
Acc-Mins	-0.048 (15.4)	
None-Mins	-0.036 (12.2)	
Road-Likely	-0.595 (2.6)	
Cong-Likely	-1.876 (5.2)	
Acc-Likely	-2.100 (5.2)	
None-Likely	-0.835 (2.9)	
Road-Long	-2.732 (8.2)	
Cong-Long	-2.450 (7.7)	
Acc-Long	-3.337 (7.2)	
None-Long	-2.623 (6.5)	
Clear	0.815 (4.1)	
Vis-Q	-0.043 (8.6)	Age < 35 0.0129 (2.2) Freq < 6 0.0145 (2.5) Unreliable VMS -0.0133 (2.2)
Time	-0.068 (13.5)	
RSC_{M56}	-1.489 (11.7)	Never Use M56 -0.5440 (3.7)
RSC_{A580}	-1.328 (10.4)	Never Use A580 -0.9590 (6.7)
RSC_{A57}	-1.470 (11.0)	Never Use A57 -1.0420 (8.9)
ρ_c^2	0.217	

Note: The delay time in minutes variables are all raised to the power 1.3 as in the power model of Table 5.

1 The test statistic is calculated as twice the difference between the log-likelihoods of the models and it is distributed χ^2 with degrees of freedom equal to the number of restrictions imposed on the more general model to obtain the restricted version.

Table 17 shows the incremental effects in proportionate terms. Although the proportionate effects of age and sex are not particularly large, the other effects are appreciable.

Table 17: Proportionate Incremental Effects

Age on Road-Mins	-10.5%	Sex on Road-Mins	-9.8%
Age on Cong-Mins	-10.2%	Sex on Cong-Mins	-9.5%
Age on Acc-Mins	-8.9%	Sex on Acc-Mins	-8.3%
Age on None-Mins	-11.9%	Sex on None-Mins	-11.1%
Age on Vis-Q	-30.0%	Never use M56 on RSC_{M56}	+36.5%
Freq < 6 on Vis-Q	-33.7%	Never use A580 on RSC_{A580}	+72.2%
Unreliable VMS on Vis-Q	+30.9%	Never use A57 on RSC_{A57}	+70.9%

Perhaps the main disappointment with respect to the segmentation analysis, apart from the failure to obtain an effect from applying a time constraint, is that we have not been able to detect variations in the *Likely* and *Long* coefficients according to socio-economic or network familiarity factors. We believe that this is, at least in part, due to different interpretations by different respondents of the amount of implied delay time. This will have lead to essentially random variations in the *Likely* and *Long* coefficients across individuals and this will of course have made it more difficult to discern variation in coefficients due to differences in socio-economic or network familiarity factors.

With the benefit of hindsight, we should have asked respondents what they considered the likely delays and long delays to mean in terms of extra minutes delay for each of the causes of delay. This would have reduced the coefficient variation across individuals to just that which might arise because individuals have different valuations of any given level of delay. For example, it is noticeable that when we changed from a dummy variable specification of whether queues were visible to one that entered the respondents' perceived amounts of delay associated with visible queues, the goodness of fit increased quite appreciably from 0.169 to 0.193.

6 FORECASTS OF THE EFFECT OF VMS MESSAGES ON USE OF THE M62

Finally, we use our preferred overall model, outlined in Table 16, to illustrate the effect that various VMS messages and visible queues can have on traffic flows. We are here using our model to make predictions for the situation in which it has been calibrated where there are three good alternatives to the most natural route. In other sets of circumstances the number of alternative routes and the extent to which they are close substitutes will vary and in many circumstances will be less than the case for the Warrington-Manchester journey. In such circumstances the extent of diversion achieved by displaying VMS messages will be much less than we are predicting for the Warrington-Manchester example.

The forecasting procedure is based on the sample enumeration approach, that is, choice probabilities are obtained for each of the 289 individuals in our sample and these are summed to obtain overall market shares. The base situation uses only the reported journey times for each route along with the route specific constants and incremental effects as appropriate. This yields market shares for the M62, M56, A580 and A57 of 76.7%, 8.5%, 8.3% and 6.5% respectively. The natural route to Central Manchester in this context would be the M62 and a larger share than 76.7% might have been expected for the base situation. This discrepancy may be associated with the fact that our model is calibrated against the postulated background of unusually severe problems on the M62 and this may have caused the RSCs for the other routes to be more favourable than would normally be expected. This problem is overcome by using the model in incremental form - thus avoiding use of RSCs. An alternative reason for the discrepancy could be the so called 'scale-factor problem' (Wardman, 1991), whereby systematic bias in the coefficient is associated with an inappropriate residual error in the SP model. The recommended means of overcoming the scale-factor problem is to rescale the model using observed data. Unfortunately we do not have access to such data.

It is normal practice, when faced with a model which does not properly replicate base market shares, to rescale the model using observed data (on the assumption that the error is due to systematic error in the SP responses). We do not have any observed data with which to perform such an operation and so will concentrate our attention on predicted changes to relative market shares rather than on absolute values.

We now present three sets of forecasts according to the nature of the delay variable and allowing for the socio-economic and familiarity effects appropriate for each variable. We have reported both a revised share for the M62 and the proportionate change in demand (in brackets) resulting from changes in the circumstances relating to the M62.

Table 18 reports the effects of VMS messages quoting various levels of delay time in minutes for the cause which has the largest impact on choice (Accidents) and the cause which has the least impact (None). The effects of congestion and roadworks will be very similar and between the effects for the two reported causes. Separate forecasts are also provided for the sex and age segmentation which were estimated to delay time. Note that the forecasts assume no queues visible on the M62 or M6. It can be seen that information on delays can have a very large impact on the number of motorists using a particular route, with slightly lower impacts for females and those aged under 35.

Table 18: Forecasts of Effects of Delay Time on Proportion Using M62

	All	Female	Male	Age<35	Age≥35
No Delays (Base)	76.7	77.0	76.6	76.3	77.0
5m Delay - Accident	69.9 (-9%)	70.9 (-8%)	69.6 (-9%)	69.8 (-9%)	70.0 (-9%)
10m Delay - Accident	58.4 (-24%)	60.6 (-21%)	57.7 (-25%)	59.0 (-23%)	58.0 (-25%)
20m Delay - Accident	29.0 (-62%)	33.2 (-57%)	27.6 (-64%)	30.9 (-60%)	27.5 (-64%)
30m Delay - Accident	8.6 (-89%)	11.5 (-85%)	7.7 (-90%)	10.1 (-87%)	7.5 (-90%)
5m Delay - No Reason	71.8 (-6%)	72.8 (-6%)	71.5 (-7%)	71.7 (-6%)	71.9 (-7%)
10m Delay - No Reason	63.8 (-17%)	65.8 (-15%)	63.1 (-18%)	64.3 (-16%)	63.3 (-18%)
20m Delay - No Reason	41.5 (-46%)	46.3 (-40%)	40.0 (-48%)	43.8 (-43%)	39.7 (-48%)
30m Delay - No Reason	19.8 (-74%)	25.2 (-67%)	18.0 (-77%)	22.7 (-70%)	17.5 (-77%)

Table 19 presents forecasts of the effects of the qualitative indicators of delay on the number using the M62. Again it can be seen that there is a dramatic effect, with a message of long delays due to accidents reducing the M62 share by 84%.

Table 19: Forecasts of Effects of 'Qualitative' Factors on Proportion Using M62

	Overall
No Delays (Base)	76.7
Likely Delays - Roadworks	65.2 (-15%)
Likely Delays - Congestion	36.0 (-53%)
Likely Delays - Accident	31.2 (-59%)
Likely Delays - No Reason	59.9 (-22%)
Long Delays - Roadworks	19.9 (-74%)
Long Delays - Congestion	24.6 (-68%)
Long Delays - Accident	12.2 (-84%)
Long Delays - No Reason	21.6 (-72%)
All Clear M56	69.6 (-9%)

Table 20 shows the impact of changes in visible delays and provides forecasts for the segmentation for which significant variation in the *Vis-Q* coefficient was discerned. Forecasts are provided for situations where each individual perceives delays of 20 minutes and 30 minutes due to visible queues and also for the level of delay time which each individual reported that they associated with visible delays on the M62. Even though we believe that the estimated *Vis-Q* coefficient understates the impact of visible queues, the results in Table 20 show that route choice is sensitive to delays that the individual perceives as a result of observing queuing. There is also appreciable variation in the impact across the different segmentation categories.

Table 20: Effect of Changes in Visible Delays on Proportion Using M62

	All	Age<35	Age≥35	Freq<6	Freq≥6	VMS Unreliable	VMS Not Unreliable
No Visible Delays (Base)	76.7	76.3	77.0	76.1	77.0	77.1	76.5
Visible Delays (perceived worth 20 mins)	58.7 (-24%)	59.3 (-22%)	58.2 (-24%)	59.9 (-21%)	58.1 (-25%)	60.1 (-22%)	58.1 (-24%)
Visible Delays (perceived worth 30 mins)	48.5 (-37%)	49.6 (-35%)	47.5 (-38%)	50.6 (-34%)	47.2 (-39%)	50.2 (-35%)	47.7 (-38%)
Visible Delays (perceived as stated)	56.5 (-26%)	59.1 (-23%)	54.4 (-29%)	57.0 (-25%)	56.2 (-27%)	55.9 (-27%)	56.7 (-26%)

Finally, we address two issues concerned with the constants in our preferred model. The effect of the *'never use'* incremental coefficient is seen to be quite important: if we assume that none of the sample had ever used routes other than the M62, then the M62 share is predicted to increase from 76.7% to 85.0%, whereas if all the sample had used all the alternative routes at least once, the share is predicted to fall to 71.9%. Clearly, the transferability of the absolute values of our predictions is constrained by the presence of constants specific to our routes. However, this problem can be overcome by using the model in incremental form (Kumar, 1980). For example, Table 21 shows results for four hypothetical cases where a motorway is in competition with one other route with differing levels of base market share. Notice the sensitivity of the predicted share to the message even where the motorway was initially very dominant.

Table 21: Effect of VMS messages on use of motorways with various levels of base market shares

Base Motorway Share	Motorway Share When "10 MINUTE DELAY" is displayed	Motorway Share When "20 MINUTE ACCIDENT DELAY" is Displayed
80%	62%	27%
60%	38%	12%
50%	29%	8%
33%	17%	4%

7. CONCLUSIONS

7.1 General

It can be expected that motorists will consider changing routes, when they have the opportunity to do so, if their expectations of traffic conditions ahead are amended due to changes in the information available to them. This could arise due to roadside variable message signs (VMS), observation of traffic conditions immediately ahead or in-car information systems such as RDS/TMC dedicated messages, autonomous in-car guidance devices or even conventional radio messages.

The research reported in this paper has examined the impact on route choice of changes in information occurring as a result of roadside VMS, including a comparison of the relative effectiveness of quantitative and qualitative descriptions of delay, and 'through the windscreen' observation.

Although the effects of information on route choice behaviour will vary according to the number of alternative routes that are available and the extent to which they are close substitutes, and the analysis reported here was based on a situation of four closely competing routes, our results show that route choice can be strongly influenced by the provision at appropriate points of information on traffic conditions ahead. In addition to this overall effect, a number of other interesting findings emerged.

Additional delays mentioned on the VMS panel have been found to be valued more highly than normally expected travel time with ratios, from our linear model, between 1.30 and 1.70 depending on the stated cause of the delay. These values are consistent with other evidence of which we are aware. The high value presumably reflects the greater stress, frustration and unreliability of driving in conditions where delays are present.

Qualitative descriptions of delays were found to be able to have an appreciable impact on route choice. "Long delays" were valued at between 35 and 47 minutes depending on the stated cause while "delays likely" were valued at between 10 and 31 minutes - again depending on the stated cause.

It was apparent that the unit value of expected delay time increases as the amount of delay time increases, at least within the range of delay times offered in this study. The variation in the value of delay time between 5 and 30 minutes is considerable.

It was found that different stated causes of delay had different impacts. Delays attributed to accidents have the biggest impact on route choice whilst if no cause was quoted the messages have a relatively low effect. These findings are consistent with evidence from other sources.

Visible queues were found to have a significant effect on route choice, particularly for more experienced drivers (those over 35, and having made more than 5 trips to Manchester in the previous year) and by those who say that they find VMS signs unreliable.

Other effects which differed significantly according to the characteristics of the driver included:

- reaction to quantified delays on the VMS panel (younger and female drivers less influenced) and
- general likelihood of using alternatives to the M62 in response to VMS advice (those who had never used the alternative routes before were less likely to be persuaded by VMS advice).

7.2 Policy Implications

Our results have suggested that traffic information shown on VMS panels can significantly affect drivers' route choice and that the scale of the effect is dependent on the content of the message (notably the extent of any delay, whether a cause is quoted and what that cause is); the local circumstances (e.g. visible evidence of congestion and relative journey times in normal conditions) and the drivers characteristics (notably their previous network knowledge and attitude to VMS signs but also their age and sex).

The fact that quoting, or not quoting, a cause can influence drivers' response is a very useful finding which could be employed to influence the amount of diversion upwards or downwards in the interests of optimising flow levels on different links.

The use of unquantified estimates of delay such as LONG DELAYS or DELAYS LIKELY, in the knowledge of how these phrases are likely to be interpreted in different circumstances, similarly offers a useful tool. It must be recognised, however, that the public's interpretation of such phrases will evolve depending on how they are used.

Finally it should be noted that a blank VMS screen is interpreted differently from a positive ALL CLEAR message and that there is some evidence to suggest that drivers may be second guessing the motives of those who control the messages.

All these findings have important implications for the design of VMS systems and for the use of VMS messages as part of comprehensive traffic management and control schemes.

7.3 Methodological Considerations

The work reported in this paper has been innovative in a number of respects. Nevertheless a number of issues of a methodological nature would benefit from further research.

We were disappointed that our attempt to explore the effect of a journey time constraint seems to have been ineffective and conclude that the constraint was not sufficiently strongly emphasised in the preamble to the questionnaire for it to have been acted on as it would be in real life.

Our findings on the value of qualitative descriptions of delay might have benefitted from our having asked respondents for their interpretation of each phrase. We suspect that our pictorial representation of local queues was not sufficiently convincing to have caused respondents to react to such queues to the extent that they would have done in real life.

Further work on our dataset might usefully explore whether different hierarchical structures might be appropriate for different sub groups within our population and whether the λ in the power function on delay time might vary with different stated reasons for delay.

Comparison of our predictions with field evidence of the impact of specified messages would require a carefully controlled field survey involving roadside interviews conducted downstream of the VMS site while the specified message was on display. Roadside interviews would be required in order to determine the drivers' destinations and thus the characteristics of the alternative routes available to them. The expense and organisational difficulties of such a survey have so far made this an unacheivable goal

Ongoing work at the Leeds University Institute for Transport Studies is seeking to compare the effectiveness of VMS messages with that of messages delivered via radio or other in-vehicle systems. We are also conducting a detailed comparison of findings for our route choice simulator and from a matched SP exercise (Shires et al., 1996).

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REFERENCES

Bates, J.J. (1988) "Econometric Issues in Stated Preference Analysis". *Journal of Transport Economics and Policy*, **22**, pp 59-69.

Bonsall, P.W. (1992) "The Influence of Route Guidance Advice on Route Choice in Urban Networks". *Transportation*, **19**, pp 51-73.

Bonsall, P.W. (1992b) "Acceptance of Route Guidance Advice: an International Comparison". *Proceedings of the International Conference on V.N.I.S.*, pp 617-625, Oslo September 1992.

Bonsall, P.W. and Merrall, A.C. (1995) "Analysing and Modelling the Influence of Roadside Variable Message Displays On Drivers' Route Choice". *Presented At WCTR*, Sydney.

Bonsall, P.W. and Palmer, I.A. (1997 forthcoming) "VMS Signs - the Importance of Phrasing the Message". *In:* Emmerink, R and Nijkamp, P. (eds) Behavioural and Network Impacts of Driver Information Systems.

Bonsall, P.W., Clarke, R., Firmin, P.E., and Palmer, I.A. (1994) "VLADIMIR and TRAVSIM - Powerful Aids for Route-Choice Research". *Proceedings of the European Transport Forum, Seminar H*, pp 65-76, September 1994 PTRC London.

Bonsall, P.W., Whelan, G. and Page M. (1995) "Stated Preference Experiments To Determine the Impact of Information and Guidance on Drivers' Route Choice". *Proceedings of the European Transport Forum, Seminar E*, September 1995, PTRC, London.

Bonsall, P.W. and Whelan, G.A. (1986) "Using Stated Preference Techniques to Assess the Impact of VMS Information on Drivers' Propensity to Divert to Park and Ride." *ITS Technical Note 400*, University of Leeds.

Bradley, M.A. Marks, P. and Wardman, M. (1986) "A Summary of Four Studies Into the Value of Travel Time Savings". *Proccedings of Seminar M, PTRC Summer Annual Meeting*, Brighton.

Bradley, M.A. & Daly, A.J. (1991) "Estimation of Logit Choice Models Using Mixed Stated Preference and Revealed Preference Information". *Proceedings of 6th International Conference on Travel Behaviour*, Quebec, Canada.

Bradley, M.A. & Gunn, H.F. (1990) "A Stated Preference Analysis of Values of Travel Time in the Netherlands". *Paper presented at Transportation Research Board Annual Meeting*, Washington.

Brocken, M.G.M. and Van der Vlist (1991) "Traffic Control with Variable Message Signs". *Proceedings of VNIS*, **part 1**, IEE.

Durand-Raucher, Y., Yim, Y. and Ygnace, J. (1993) "Traffic Information and Driver Behaviour in Paris Region". *Proceedings Pacific Rim Transtech Conference,* Seattle ASCE, **Vol 1.** 167-9

Fowkes, A.S. and Wardman, M. (1988) "Design of Stated Preference Travel Choice Experiments, with Special Reference to Taste Variation". *Journal of Transport Economics and Policy,* **Vol 22,** pp 27-44.

Green, P.E. and Snnivasem, V. (1978) "Conjoint Analysis In Consumer Research: Issues and Outlook". *Journal of Consumer Research,* **5,** pp 103-123.

Gibb Transportation (1996) "A1 Motorway Poland Stated Preference Report" Prepared for Polish Motorway Agency, Polish Ministry of Transport.

Hato, E., Taniguchi, M. and Sugie, Y. (1995) "Influence of Traffic Information on Driver's Route Choice". *Presented at WCTR,* Sydney.

Hensher, D.A. (1992) "Integrating Revealed Preference and Stated Response Data into a Jointly Estimated Hierarchical Mode Choice Model". *Working Paper* **ITS-WP-92-9,** Institute of Transport Studies, Graduate School of Business, University of Sydney.

Hensher, D.A., Milthorpe, F.W., Smith, N.C. and Barnard, P. (1990) "Urban Tolled Roads and the Value of Travel Time Savings". *Economic Record,* **66,** pp. 146-156.

Hensher, D.A. & Truong, T.P. (1983) "Valuation of Travel Time Savings from a Revealed Preference and a Direct Experimental Approach". *Research Paper* **269,** School of Economic Studies, Macquarie University, Australia.

Janssen, W. and Van der Horst, R. (1992) "Descriptive Information in Variable Route Guidance Messages". *Conference Record of Papers: 3rd International Conference on Vehicle Navigation & Information Systems,* IEEE, Oslo, **214-20.**

Kawashima, H. (1991) "Informatics in Road Transport: an Overview of Examples in Japan and Future Issues". *Paper presented at 4th German-Japanese Seminar on Transportation Systems.*

Kocks, Transprojekt Warsaw and Tecnecon (1995) "A2 Motorway Traffic Study Final Report" Prepared for Polish Motorway Agency, Polish Ministry of Transport.

Kocur, G., Adler, T., Hyman, W. and Aunet, B. (1982b) "Guide to Forecasting Travel Demand with Direct Utility Assessment". United States Department of Transportation, Urban Mass Transportation Administration, Report UMTA-NH-11-0001-82-1, Washington DC.

Kumar, A. (1980) "Use of Incremental Form of Logit Models in Demand Analysis." *Transportation Research Record,* **775,** pp 21-27.

Louviere, J.J., Henley, D.H., Woodworth, G., Meyer, R.J., Levin, I.P., Stoner, J.W., Curry, D., & Anderson, D.A. (1980) "Laboratory Simulation versus Revealed Preference Methods for Estimating Travel Demand Models". *Transportation Research Record*, **794**, pp 42-51.

Luce, R.D. and Suppes, P. (1965) "Preference, Utility and Subjective Probability". *In:* R.D. Luce, R.R. Bush and E. Galanter (eds), "Handbook of Mathematical Psychology. John Wiley & Sons, New York.

Mast, T.M. and Ballas, J.A. (1976) "Diversionary Signing Content and Driver Behaviour". *Transportation Research Report*, **No. 600**, TRB, Washington.

Mott MacDonald (1996) "Brest-Minsk-Russian Border Highway Investment Project: Institutional Development of Belavtostrada" Report Prepared for EBRD, London.

MVA Consultancy, Institute for Transport Studies University of Leeds, Transport Studies Unit University of Oxford (1987) "Value of Travel Time Savings" Policy Journals, Newbury, Berkshire.

Ortuzar, J. de D., Iacobelli, A., Ivelic, A.M. and Munizaga, M (1994) "Evaluating Private Highway Projects Under Concession: Route Choice Modelling with Mixed RP/SP Data". *Proceedings of Seminar G, PTRC Summer Annual Meeting*, held at Warwick University.

Oscar Faber TPA (1992) "Trans-Pennine Rail Strategy Study: Study Report". Prepared for GMPTE, Merseytravel, SYPTE, WYPTE, Cheshire County Council, Derbyshire County Council, Humberside County Council, Lancashire County Council and Peak Park.

Shires, J., Palmer, I. and Bonsall, P. (1996) "A Comparison of SP Data With VLADIMIR Data", *ITS Technical Note* **xxx**.

TPA (1990) "Birmingham Northern Relief Road Results of Stated Preference Surveys". Report prepared for Department of Transport.

Wardman, M. (1988) "A Comparison of Revealed Preference and Stated Preference Models of Travel Behaviour". *Journal of Transport Economics and Policy*, **22**, pp 71-91.

Wardman, M. (1991) "Stated Preference Methods and Travel Demand Forecasting: An Examination of the Scale Factor Problem". *Transportation Research*, **25A**, pp 79-89.

Watling, D. (1994) "Urban Traffic Network Models and Dynamic Driver Information Systems". *Transport Reviews*, **14**(3).

Zhao, S.C., Marumachi, Y., Harata, N. and Ohta, K. (1995) "A SP Model for Route Choice Behaviour in Response to Travel Time Information With Marginal Error". *Paper presented at WCTR*, Sydney.

Appendix 1 - Example of questionnaire

ITS

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July 1995

Dear Sir/Madam,

We are part of a team studying the behaviour of car drivers. As part of this study, we are seeking to find out how people respond to information on traffic conditions.

We would very much appreciate it if a car driver in your household could answer the attached questionnaire and return it in the FREEPOST envelope provided. The first part of the questionnaire asks some general questions and the second part asks how you would respond to a series of hypothetical travel situations for a journey into Manchester that we would like you to imagine making.

Your reply will be subject to statistical analysis and treated in the strictest confidence. If you have any queries or comments about this questionnaire, please do not hesitate to contact either myself or my colleague (Mark Wardman) on 0113 233 5349. The success of the study depends upon a high response rate. Thank you for your co-operation.

Yours sincerely

Peter Bonsall

Reader in Transport Planning

First of all we would like to ask some general questions about yourself and the trips you make to Manchester.

1. **Approximately how many miles do you drive per annum?**

Less than 5,000 miles	☐	10,000-15,000 miles	☐
5,000-10,000 miles	☐	Over 15,000 miles	☐

2. **About how many times have you travelled to Central Manchester in the past year?**

_______ times

3. **How often have you used each of the following four routes to Manchester?**

M62	Never	☐	A Few Times	☐
	Fairly Often	☐	Very Often	☐
M56	Never	☐	A Few Times	☐
	Fairly Often	☐	Very Often	☐
A580 (East Lancs Road)	Never	☐	A Few Times	☐
	Fairly Often	☐	Very Often	☐
A57 (via Irlam)	Never	☐	A Few Times	☐
	Fairly Often	☐	Very Often	☐

4. **Have you ever seen an electronic variable message roadside sign?**

Yes - and I have found them to be a reliable guide to conditions ahead ☐
Yes - but I have found them to be an unreliable guide to conditions ahead ☐
No ☐

5. **Are you?** Male ☐ Female ☐

6. **Please state which age group you are in?**

Under 24	☐	35 to 44	☐	55 to 64	☐
24 to 34	☐	45 to 54	☐	65 and over	☐

We would now like to know how you would react to traffic conditions as described on an electronic roadsign.

Please imagine that you are on the M62 heading east and approaching the junction of the M62 with the M6 (Junction 10/21A). You are making a journey to Central Manchester (Piccadilly). It is 2pm on a Saturday afternoon and you have to drop someone off for an appointment in Central Manchester at 2.45pm.

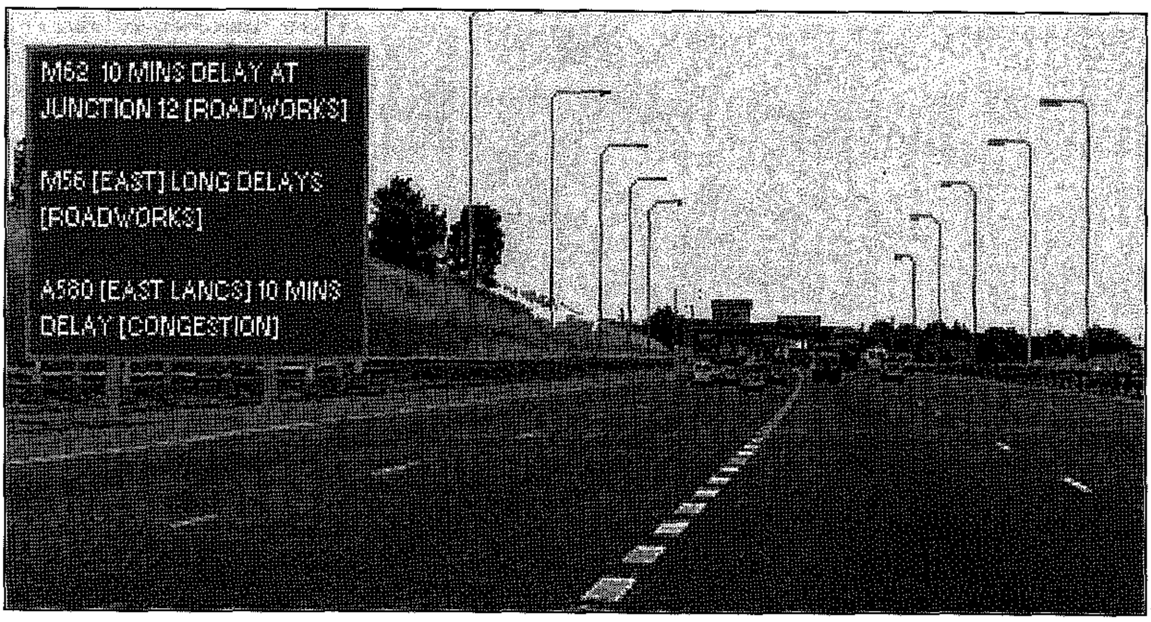
You can see the traffic conditions ahead (on the M62 and on the slip road to the M6) and also an electronic roadsign. We would like to know which route you would choose in each of the cases set out on the following pages.

Case 1

M6 SLIP ROAD - VISIBLE QUEUING M62 AHEAD - LOOKS CLEAR

CHOICE (Please tick)	M62 ☐	M56 via M6 ☐	East Lancs Road (A580) ☐	A57 (via Irlam) ☐

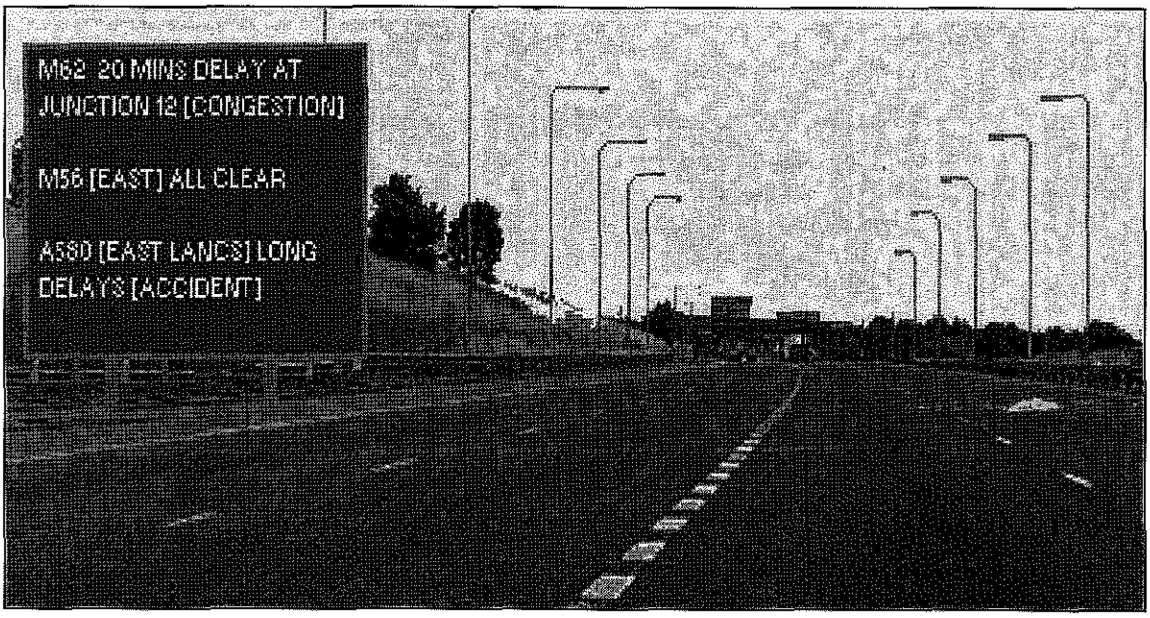
Case 2



M6 SLIP ROAD - VISIBLE QUEUING M62 AHEAD - VISIBLE QUEUING

CHOICE (Please tick)	M62 ☐	M56 via M6 ☐	East Lancs Road (A580) ☐	A57 (via Irlam) ☐

Case 3



M6 SLIP ROAD - LOOKS CLEAR

M62 AHEAD - LOOKS CLEAR

CHOICE (Please tick)	M62 ☐	M56 via M6 ☐	East Lancs Road (A580) ☐	A57 (via Irlam) ☐

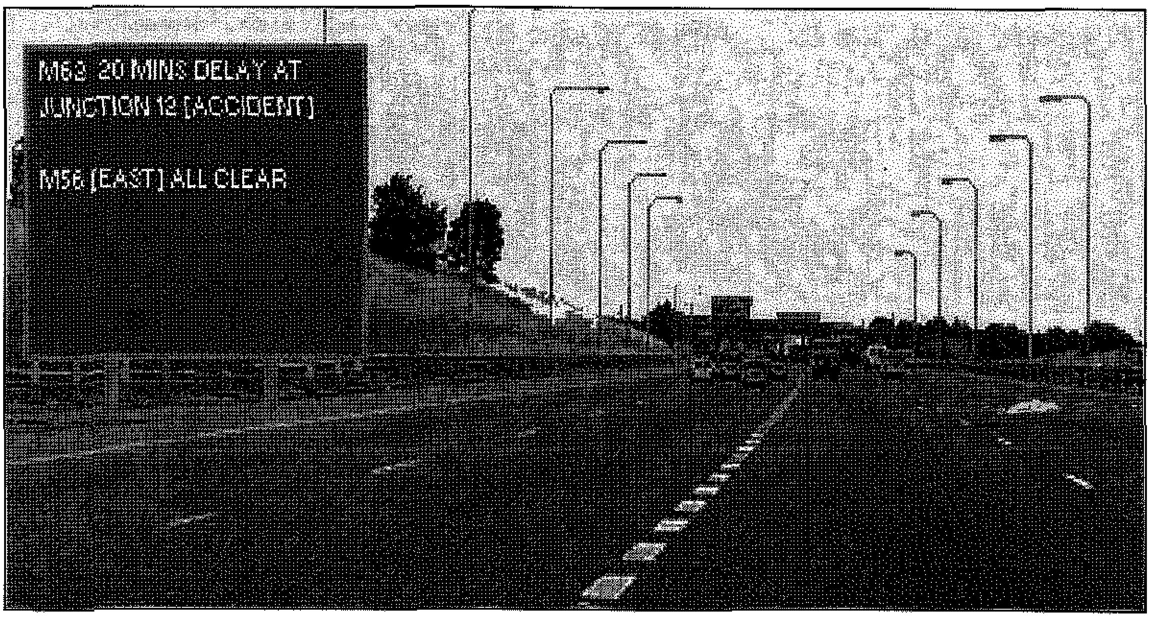
Case 4

M6 SLIP ROAD - LOOKS CLEAR

M62 AHEAD - VISIBLE QUEUING

CHOICE (Please tick)	M62 ☐	M56 via M6 ☐	East Lancs Road (A580) ☐	A57 (via Irlam) ☐

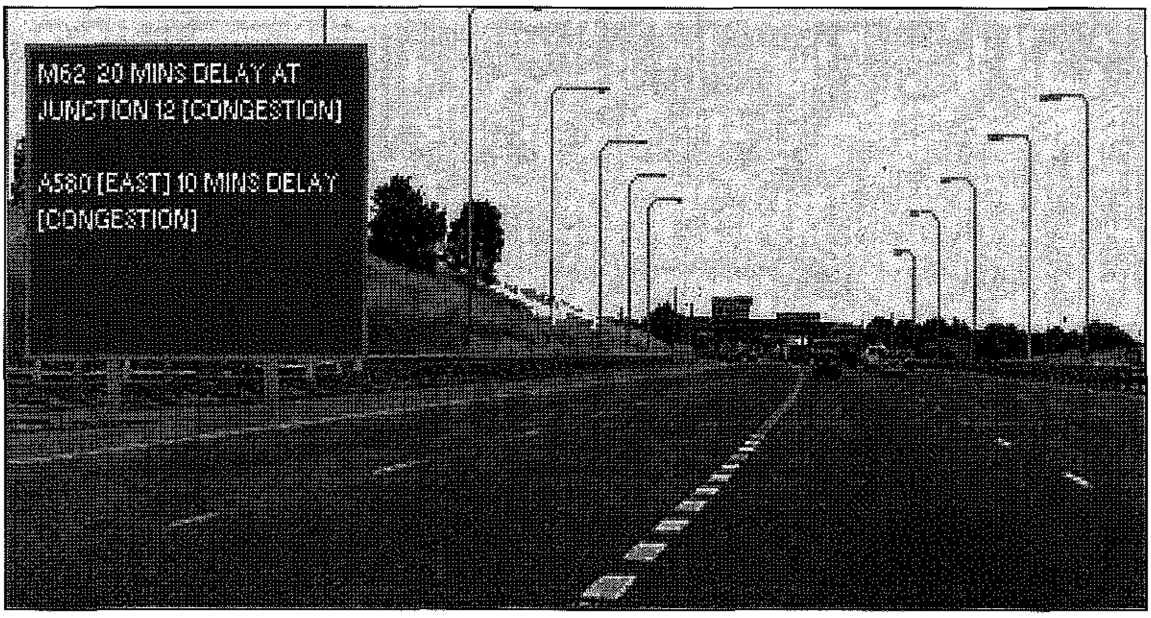
Case 5



M6 SLIP ROAD - VISIBLE QUEUING M62 AHEAD - VISIBLE QUEUING

CHOICE (Please tick)	M62 ☐	M56 via M6 ☐	East Lancs Road (A580) ☐	A57 (via Irlam) ☐

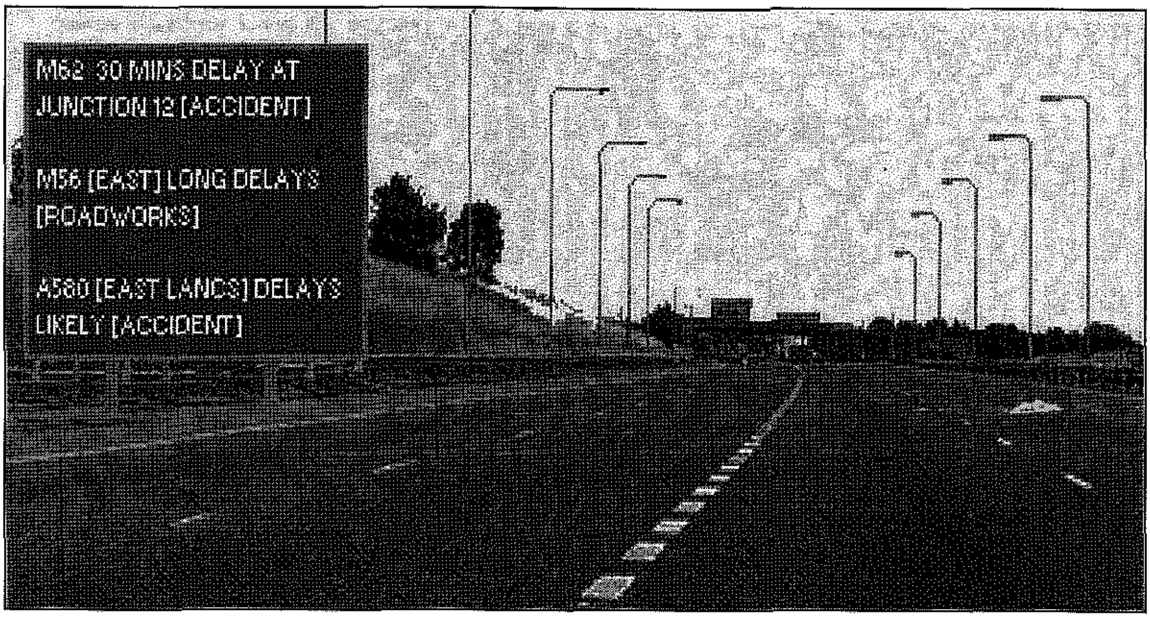
Case 6



M6 SLIP ROAD - LOOKS CLEAR M62 AHEAD - VISIBLE QUEUING

CHOICE (Please tick)	M62 ☐	M56 via M6 ☐	East Lancs Road (A580) ☐	A57 (via Irlam) ☐

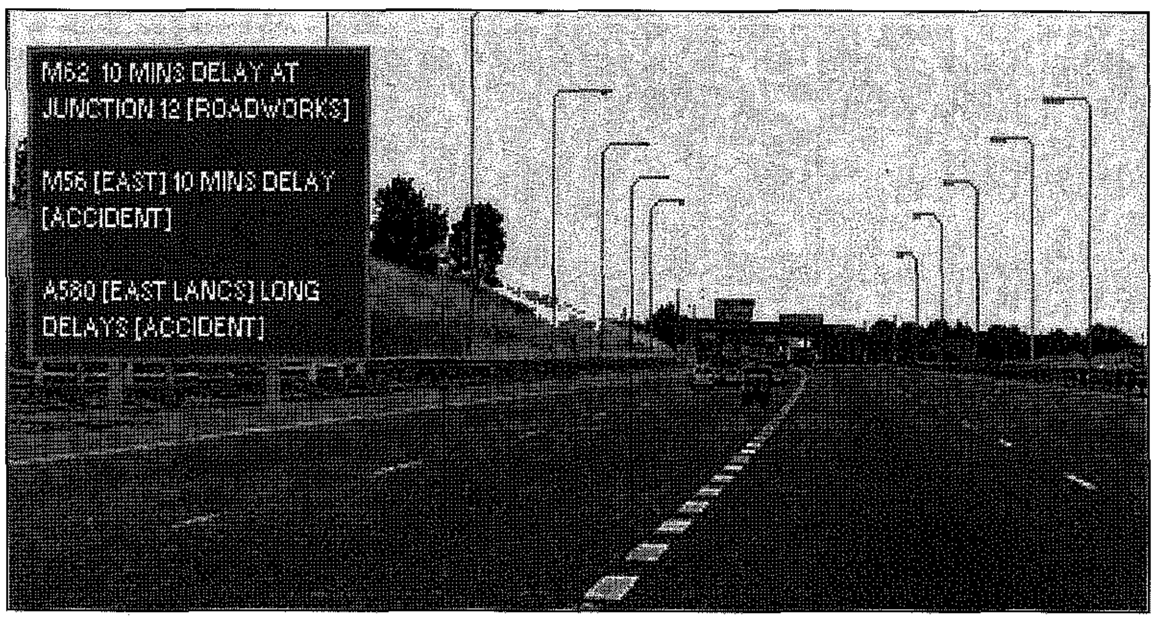
Case 7



M6 SLIP ROAD - LOOKS CLEAR M62 AHEAD - LOOKS CLEAR

CHOICE (Please tick)	M62 ☐	M56 via M6 ☐	East Lancs Road (A580) ☐	A57 (via Irlam) ☐

Case 8



M6 SLIP ROAD - VISIBLE QUEUING M62 AHEAD - LOOKS CLEAR

CHOICE (Please tick)	M62 ☐	M56 via M6 ☐	East Lancs Road (A580) ☐	A57 (via Irlam) ☐

Finally we would like to ask you some questions about your perceptions of queuing traffic and journey times to Central Manchester

Please give your best guess even if you are not sure

7. **When we said you could see queuing on the M62, how much extra time did you think that this would add to the journey to Central Manchester via the M62?**

_____ minutes

8. **When we said you could see queuing on the M6 slip road, how much extra time did you think that this would add to the journey to Central Manchester via the:**

M6/M56 _____ minutes

East Lancs Road (A580) _____ minutes

A57 (Irlam) _____ minutes

9. **How long do you think it would take to get from the junction of the M62 and the M6 (Junction 10/21A) to Central Manchester (Piccadilly) on a Saturday afternoon?**

Via the M62 _____ minutes

Via the M6 and M56 _____ minutes

Via the East Lancs Road (A580) _____ minutes

Via the M6 and A57 (Irlam) _____ minutes

If you have any comments, please write them in the space below.

Thank you very much for your assistance.

Please return the questionnaire in the FREEPOST envelope provided - No stamp required.