Article:

Wardman, M and Ibanez, JN (2013) Testing Contextual and Design Effects on Inter-Urban Motorists' Responses to Time Savings. Journal of Transport Economics and Policy, 47 (1). 123 - 141 (19). ISSN: 0022-5258

Journal of Transport Economics and Policy, Volume 47, Part 1, January 2013, pp. 123–141

Testing Contextual and Design Effects on Inter-Urban Motorists' Responses to a Toll Motorway's Travel Time Savings

Mark Wardman and J. Nicolás Ibáñez

Address for correspondence: Mark Wardman, Institute for Transport Studies, University of Leeds, Leeds LS2 9JT (m.r.wardman@its.leeds.ac.uk). J. Nicolás Ibáñez is at the Institute for Prospective Technological Studies, DG Joint Research Centre, European Commission, Inca Garcilaso 3, 41092 Seville, Spain.

We are very grateful for referees' comments which have enabled us to improve significantly upon the initial submission. We would also like to thank the Department for Transport for funding this research.

Abstract

In the context of inter-urban motorists' route choices and the travel time savings offered by the UK's first toll motorway, a range of SP exercises tested various contextual and design effects. The design aspects relate to how the marginal benefit of time savings is influenced by the size and sign of the time saving, task complexity, presentation format, and whether the choice context is real. The contextual factors cover the impact of journey duration, attribute credibility, and where in the journey the time savings occur. The conclusions are largely credible but in some cases challenge established views and contribute significantly to understanding in this area.

Date of receipt of final manuscript: January 2012

1.0 Introduction

With the growing interest in the use of stated choice experiments to investigate travel choices and to infer estimates of willingness to pay for specific attributes (for example, travel time savings), many analysts are starting to question the influence that the design of a choice experiment has on the choice responses and the associated attribute trade-offs. Building on the literature on the role of the dimensionality of choice experiments, this paper focuses on testing how inter-urban motorists' sensitivities to travel time are influenced by important design and contextual factors, as well as providing fresh methodological insights. The design aspects of the study relate to how the marginal utility of travel time is influenced by the size and sign of the journey time variations offered, the complexity of the Stated Preference (SP) task in terms of the number of variables presented, whether journey time was presented as an absolute amount or as a variation on the current level, and whether the choice context was an existing one or hypothetical. We also examine the important contextual factors of how the sensitivity to travel time variations depends upon the overall journey duration, where in the overall journey the time variation occurs, and the perceived credibility of the time variation.

The empirical setting within which we investigate these design dimensions is the 27-mile (43 km) M6 Toll road (M6T), the United Kingdom's first toll motorway which was opened in December 2004 as an alternative to a congested section of the existing M6 motorway. It can provide, dependent on time of day, significant time savings and improved reliability, and provides an ideal real-world context upon which to base SP experiments exploring time and cost trading through route choice.

The paper is structured as follows. Section 2 describes the survey in the context of the design and contextual factors to be explored. The collection of the data and its key characteristics are discussed in Section 3. The results of the main effects model are reported in Section 4, followed by a detailed consideration of the design and contextual effects in Section 5. Concluding remarks are provided in Section 6.

2.0 Survey Design

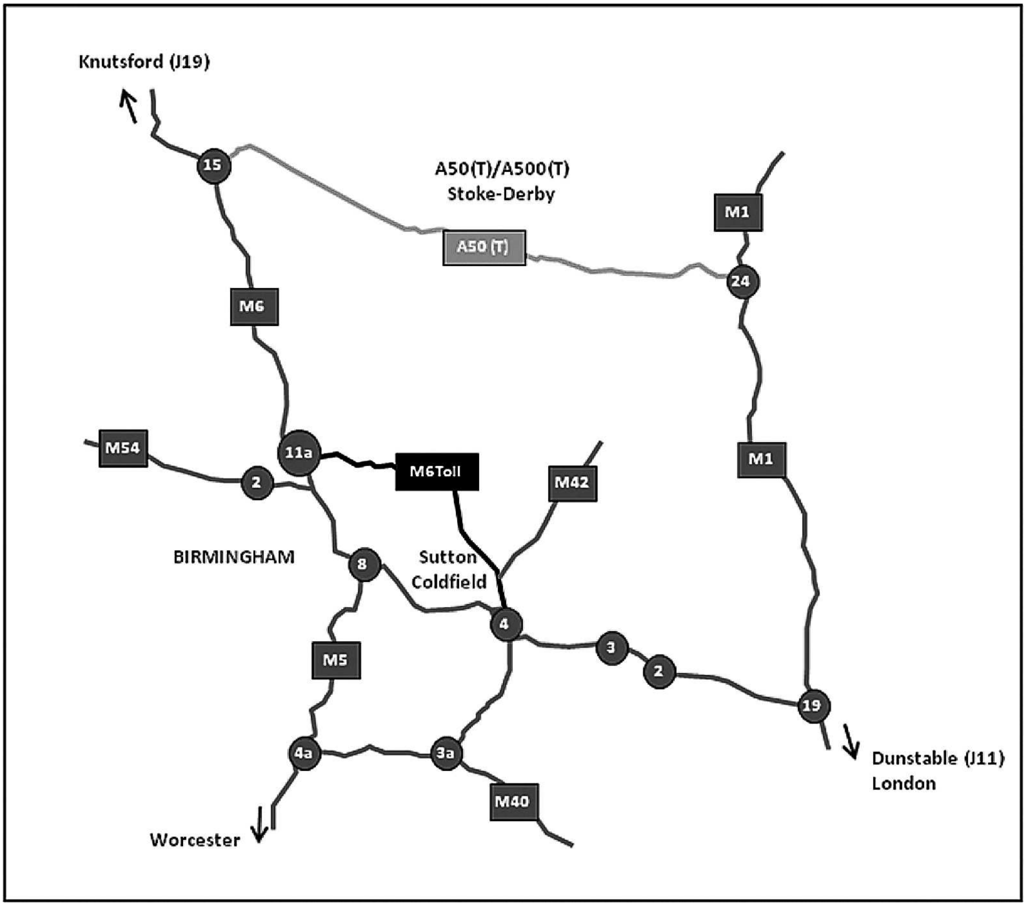
The SP experiments were based around that portion of a motorist's journey through the West Midlands where a toll could be paid to use the M6T and save time over the M6. Focus groups also revealed that non-motorway primary (A) roads[1] provide realistic alternatives to the congested M6. The choice context is depicted in Figure 1.

Three different SP choice contexts were used:

- a 27-mile M6T corridor between Junctions 4 and 11a;
- an 80-mile corridor between M6 Junction 15 (Stoke) and M1 Junction 19;
- a 150-mile corridor between M6 Junction 19 (Knutsford) and M1 Junction 11 (Dunstable).

[1]A-roads are all-purpose, non-motorway roads that are part of the national strategic road network.

Figure 1
The M6T and Survey Corridor



The SP variants used for each generic choice context are set out in Table 1, with Table A.1 in the Appendix providing more detail about the attribute levels. Standard orthogonal fractional factorial designs were used.

While the choice context in the 27-mile M6T corridor (SP1B) could be applied to all motorists, this would limit the analytical possibilities. Using the Stoke-M1 corridor makes it realistic to offer the A50(T)/A500(T) as a free alternative to the often highly congested M6 (SP1A, SP1C), supporting a wider range of time–cost trade-offs and, because it is 10 miles shorter, permitting sensible fuel cost differences to be introduced. This corridor also allows the evaluation of an M6T option extended over the entire 80 miles offering larger time savings and toll charges (SP2A). The third route choice context, based around an entirely new tolled motorway (SP2B), allows a yet wider set of time–toll trade-offs to be presented.

Table 1
The SP Exercises

Corridor	*Code*	*Routes*	*Attributes*	*Comment*
Route Choice Exercises				
Stoke-M1	SP1A-1	M6 M6T A50/A500	Time, Toll, Fuel	Absolute times
Corridor	SP1A-2	M6 M6T A50/A500	Time, Toll, Fuel	Absolute times
	SP1A-3	M6 M6T A50/A500	Time, Toll, Fuel	M6T quicker
	SP1A-4	M6 M6T A50/A500	Time, Toll, Fuel	M6 slower
	SP1A-5	M6 M6T A50/A500	Time, Toll	No fuel
	SP1A-6	M6 M6T A50/A500	Time, Toll	No fuel, higher tolls
	SP1C-1	M6 M6T A50/A500	Time, Toll, Fuel	Toll on M6
	SP1C-2	M6 M6T A50/A500	Time, Toll, Fuel	Toll on M6
	SP2A-1	M6 M6T A50/A500	Time, Toll, Fuel	Extended M6T
	SP2A-2	M6 M6T A50/A500	Time, Toll, Fuel	Higher toll
	SP2A-3	M6 M6T	Time. Toll	Omit A road and fuel
M6T	SP1B-1	M6 M6T A road	Time, Toll	Absolute times
Corridor	SP1B-2	M6 M6T	Time, Toll	Absolute times
	SP1B-3	M6 M6T	Time, Toll	M6T quicker
	SP1B-4	M6 M6T	Time, Toll	M6 slower
	SP1B-5	M6 M6T	Time, Toll	Different tolls
	SP1B-6	M6 M6T	Time, Toll, Information	M6 Roadworks
	SP1B-7	M6 M6T	Time, Toll, Information	M6 Accident
	SP1B-8	M6 M6T	Time, Toll, Information	M6 Congestion
Knutsford–Dunstable	SP2B	New Motorway M6 M6T	Time, Toll	Larger tolls and time savings
Route and Departure Time Choice Exercises				
Stoke-M1	SP3A	M6 M6 (earlier/later) M6T M6T (earlier/later)	Time, Toll, Departure Time Shift	Lower or zero tolls and quicker journey times at different departure time
M6T Corridor	SP3B	M6 M6 (earlier/later) M6T M6T (earlier/later)	Time, Toll, Departure Time Shift	

For the M6T and Stoke-M1 corridors, the route choice exercises were extended by introducing a departure time dimension (SP3A, SP3B) whereby motorists faced the additional possibility of saving time and toll by travelling on either the M6 or M6T at a different time.

2.1 Design effects

The size and sign of time savings are based on the M6 within the M6T corridor since this actually exists (unlike some of our other route options), it is familiar to respondents, and we did not vary the times on the M6T in the SP exercises based on this corridor, since it would have been unrealistic to do so. The M6's widely varying congestion levels not only delivered a wide range of journey times for motorists' actual journeys, but also supported realistic variations in its journey times in the SP exercise. Both of these contribute to the extensive range of sign and size of time variations for the M6 that are depicted in Table 2.

Table 2
Variations on Surveyed Journey M6 Travel Times as a Result of Times Offered in M6 Corridor SP Exercises

	Reported M6 Times	*Network M6 Times*
Implied Time Savings in SP Exercise		
0–5 m	875	319
6–15 m	855	0
16–25 m	349	0
26–35 m	264	0
36 m+	303	0
Implied Time Losses in SP Exercise		
1–5 m	418	284
6–15 m	1,143	803
16–25 m	962	629
26–35 m	873	338
36 m+	863	234
Total	6,905	2,607

Note: The default is to base the variations on the reported times for the surveyed journey, but in 27 per cent of cases the M6 time was not reported and hence network times were used.

Given the choice context under investigation, there are only a limited number of main attributes that need to characterise each route.[2] Indeed, the number of alternatives is also naturally limited. However, it is the total number of items of information that a respondent needs to evaluate that would seem to be an appropriate measure of complexity. While the number of items here has a narrow range, as is apparent in Table 3, nonetheless some interesting results subsequently emerged.

The SP choice contexts vary in the extent to which they are real. The SP1 exercises are based entirely around the existing choice context. SP3A and SP3B depart slightly by offering additional options where the toll and journey time are less for travel at a different time. The SP2A exercises offer an extended, hypothetical M6T while SP2B offers an entirely hypothetical new motorway. In addition, some SP exercises presented the M6T (M6) as minutes quicker (slower) than the absolute M6 (M6T) times.

2.2 Contextual effects

The contextual effects of journey duration and where in the journey the time saving occurs are supported through appropriate sampling. Analysis of respondents' perceptions of the credibility of SP attribute levels is sensibly based around existing and familiar choice

[2]While reliability might spring to mind as an additional main factor in the SP exercise, adequately presenting it is not straightforward. Nonetheless, we collected information on the perceived reliability of each existing route, on a categorical scale, and have used this in modelling route choice. With hindsight, given the somewhat worse driving conditions on the M6, we should have specified travel time in free flow and in various degrees of congestion. However, we note that the disutility of time spent on the M6T was, as might be expected, found to be lower than time spent on the M6.

Table 3
Numbers of Alternatives, Attributes and Items

		Attributes			
Code/Corridor	*Alternatives*	*M6*	*M6T*	*A/New*	*Items*
Stoke-M1 Corridor					
SP1C-1-2	3	3	3	2	8
SP1A-1-4, SP2A1-2	3	2	3	2	7
SP1A-5-6	3	1	2	1	4
SP2A-3	2	1	2	–	3
SP3A	4	1 & 2*	2 & 3*	–	8
M6T Corridor					
SP1B-1	3	1	2	1	4
SP1B-6-8	2	2	2	–	4
SP1B-2-5	2	1	2	–	3
SP3B	4	1 & 2*	2 & 3*	–	8
Knutsford–Dunstable New Motorway					
SP2B	3	1	2	2	5

* SP3A and SP3B have the existing and revised departure times as separate alternatives for the M6 and M6T.

contexts. When the SP exercise related to currently available routes (SP1A, SP1B, SP1C), we asked whether the journey times and, where appropriate, fuel costs for each route were credible. Respondents indicated whether, across the entire design, they regarded them to be very credible, probably credible, not at all credible (too quick/low), or not at all credible (too slow/high).

3.0 Data Collection and Characteristics

The SP exercises were administered through mail-back self-completion questionnaires distributed in November 2006 to respondents who were making a journey in the M6T corridor with a realistic choice between the M6 and M6T, and who were identified through a survey of M6T users at the toll booths and at Roadside and Motorway Service Area surveys. The questionnaire and SP formats are reproduced in the Appendix. The overall response rate was 22 per cent. As expected, there was a high degree of familiarity with the choice context under investigation; 92 per cent made journeys in the corridor more than once a year.

All respondents were presented with two SP exercises. The first covered an existing route choice context (SP1A, SP1B, SP1C), except for some making sufficiently long journeys who were offered the new motorway design (SP2B), and the second covered, among other things, the departure time exercise (SP3A, SP3B) and the extended M6T exercise (SP2A). We have removed those who did not answer the credibility questions, leaving 2,457 out of 2,543 motorists. The distribution of perceived credibility responses is reported in Table 4. A breakdown of usable responses by SP exercise is given in Table A.2 in the Appendix.

Table 4
Perceived Credibility of Journey Time and Fuel Cost

	Very credible	*Probably credible*	*Not credible Too quick/high*	*Not credible Too slow/low*
M6 Time	8.6%	74.6%	11.2%	5.6%
M6T Time	24.5%	66.5%	6.1%	2.9%
A50/500 Time	1.5%	84.9%	9.5%	4.1%
M6/M6T Fuel	5.1%	77.3%	11.3%	6.3%
A50/500 Fuel	3.5%	73.2%	7.9%	15.4%

Table 5 indicates a wide range of end-to-end actual journey times and the quintiles of where in the journey M6T time saving occurred. The actual journey times are based on network data[3] but correlate very highly with reported times ($\rho = 0.88$). The figures for where the journey time saving occurred are calculated for all exercises except the artificial SP2B. There were no high correlations between the contextual and design interactions entered into the estimated model.

4.0 Empirical Findings: Main Effects

It is important to establish whether the large data set collected is of sufficient quality to support more detailed analysis of design and contextual effects. To this end, the main effects model is presented in Table 6. The jack-knife procedure within Alogit (Hague Consulting Group, 2000) accounts for multiple observations per respondent and the Bradley–Daly hierarchical logit structure (Bradley and Daly, 1991) accommodates differences in scale across the generic designs.[4] There are a number of desirable features of the results.

First, the coefficient estimates are correct sign and generally highly significant. The goodness of fit, in our experience, somewhat exceeds that typically achieved in SP choice studies.

Second, the relative magnitude of the time coefficients is consistent with expectations. Time spent on the M6T is regarded as least onerous, with time on the A-road most onerous. Departing earlier or later than desired are regarded similarly and are equivalent to around 40 per cent of the value of time, which seems reasonable. The terms relating to information provision in the SP exercise are specified relative to the M6T. Compared to a base of information indicating 'Delays on M6', a statement that there are 'Delays on M6 due to' a specific reason is not significantly different, which seems reasonable. Information to 'Expect 25m delay on M6' is equivalent to around 14 minutes of M6 time compared to the base of 'Delays on M6'. However, information that there are 'No M6 delays' is equivalent to almost 11 minutes relative to 'Delays on M6'. Taking the

[3]Network-based journey times are estimates drawn from traffic route assignment processes utilising link capacities, speed–flow relationships, traffic volumes, and distances.

[4]Previous analysis indicated very little scale variation within the generic designs.

Table 5
Journey Time Distributions

Time		*Position*	
<1 hour	19.0%	1st Quintile	23.6%
1–2 hours	28.7%	2nd Quintile	32.9%
2–3 hours	23.0%	3rd Quintile	26.7%
3–4 hours	20.4%	4th Quintile	12.4%
4–5 hours	4.8%	5th Quintile	4.4%
5–6 hours	4.1%		

latter two together, an expected 25-minute delay is encouragingly valued at around 25 minutes! The three current routes were rated as very reliable, reliable, sometimes reliable, unreliable, and very unreliable, and dummy variables were specified for each route to discern their effects. A monotonic effect of the expected form can be observed, with a very reliable route being valued 21.6 minutes better in M6T time than the base of a very unreliable route.

Third, the sensitivities to cost are plausible. Those who stated that they do not consider fuel costs when making actual route choices had an insignificant fuel cost coefficient (Fuel-NotConsider). In contrast, those who stated that they did consider fuel costs have

Table 6
Main Effects Model

Route Specific Constants		Reported Route Reliability Category	
ASC_{M6T}	1.2787 (20.2)	*Very Reliable*	1.1007 (13.3)
ASC_{A}	−0.1121 (0.9)	*Reliable*	0.7067 (7.3)
ASC_{SP2B}	−0.6545 (1.2)	*Sometimes Reliable*	0.5111 (6.6)
		Unreliable	0.1969 (2.0)
Route Specific Time Coefficients		*Very Unreliable*	Base
$Time_{M6}$	−0.0684 (38.7)		
$Time_{M6T}$	−0.0510 (18.5)	SP Type Scale Factors	
$Time_{A}$	−0.0729 (41.3)	$\theta_{Stoke\text{-}M1}$	1.00
		$\theta_{M6TCorr}$	0.94 (2.3)
Departure Time Shift		θ_{SP2A}	0.76 (8.8)
Earlier Time	−0.0267 (27.5)	θ_{SP2B}	0.51 (7.9)
Later Time	−0.0269 (27.3)	θ_{SP3A}	0.62 (7.0)
		θ_{SP3B}	0.79 (5.5)
Information Categories			
Delays on M6	Base	Log-Likelihood	−17,969.22
Delays on M6 due to	−0.0172 (0.2)	ρ^2 (constants)	0.223
Expect 25m Delays on M6	0.9668 (6.5)	Observations	26,979
No Delays on M6	−0.7323 (8.1)		
Cost Terms			
Toll	−0.0068 (66.9)		
Fuel-Consider	−0.0046 (11.3)		
Fuel-NotConsider	−0.0003 (0.1)		

Note: *t* ratios for the scale factors (θs) are specified with respect to one. Times are in minutes and costs in pence.

a highly significant coefficient (Fuel-Consider) but, presumably due to a resistance to paying tolls, this is significantly lower than the toll coefficient.[5] The value of time defined in terms of the toll numeraire is some 32 per cent lower than when expressed in terms of the fuel cost (Fuel-Consider) numeraire, almost identical to the 30 per cent figure obtained from an extensive value of time meta-analysis (Abrantes and Wardman, 2011).

Finally, we compare the estimated values against other evidence. A convenient way of doing this is to make use of the meta-analysis of 1,749 monetary valuations of time attributes obtained from 226 British studies (Abrantes and Wardman, 2011). Using a sample enumeration approach to calculate a value of time in pence per minute for each motorist, the 'meta-model' yields mean values (standard errors) of 17.92 (0.08) for business, 8.06 (0.07) for commuting, and 9.10 (0.03) for other in-toll units. The value of time in toll units here varies between 7.50 for the M6T and 10.72 for A-roads, with previous analysis indicating little difference by purpose. If we discount the problematic issue of business travel values obtained from SP surveys, then our valuations are highly consistent with a wealth of British evidence.

5.0 Contextual and Design Effects

5.1 Model structure

The contextual and design effects on the sensitivity to variations in time on route i (T_i) are represented by incremental interaction terms, as in equation (1), specified as either $n-1$ dummy variables (d_j) representing n categorical effects or as a continuous interaction (X):

$$U_i = \alpha_i T_i + \beta_i X T_i + \sum_{j=1}^{n-1} \gamma_{ji} d_{ji} T_i + \cdots. \tag{1}$$

The model containing these effects is reported in Table 7, and its structure is set out in Table A.3 in the Appendix. Incremental effects are denoted in italics, with the base category indicated. An analogous approach is used for the cost terms where, for completeness, these are examined.

Given that we might expect the amount of random error to vary with both complexity and credibility, we have modified the specification of the scales to distinguish jointly these two effects.

The Stoke-M1 (SP1A, SP1C) and M6T corridor (SP1B) experiments were those where the credibility questions were asked. These SP exercises contained either three or four items, or seven or eight items. Where there were seven or eight items, there could be the five credibility statements as in Table 4. We therefore distinguished between whether all attributes were deemed credible ($\theta_{\text{CredAll-78}}$), three or four were credible ($\theta_{\text{Cred34-78}}$), one or two were credible ($\theta_{\text{Cred12-78}}$), or none were credible ($\theta_{\text{CredNone-78}}$). Where there were three or four items, we specified scales for whether all ($\theta_{\text{CredAll-34}}$), some ($\theta_{\text{CredSome-34}}$), or none ($\theta_{\text{CredNone-34}}$) were credible. These replace $\theta_{\text{Stoke-M1}}$ and θ_{M6TCorr} of Table 6.[6]

[5]There was no difference in the toll coefficient according to whether fuel was considered in actual route choice.
[6]Where fuel was reported as not influencing choice, it was defined as credible for the purposes of this analysis.

Table 7
Contextual and Design Effects Models

Route Specific Constants	
ASC$_{M6T}$	1.3312 (10.3)
ASC$_{A}$	−0.1510 (0.9)
ASC$_{SP2B}$Realistic	−1.7700 (2.0)
ASC$_{SP2B}$Unrealistic	−1.1751 (1.9)
Route Specific Time Coefficients	
Time$_{M6}$	−0.1026 (5.6)
Time$_{M6T}$	−0.0793 (4.4)
Time$_{A}$	−0.1004 (5.6)
Increment: Where M6T is in Journey	
Time$_{M6T}$0–20%	−0.0028 (0.8)
Time$_{M6T}$21–40%	−0.0024 (1.1)
Time$_{M6T}$41–60%	Base
Time$_{M6T}$61–80%	0.0007 (0.2)
Time$_{M6T}$81–100%	−0.0026 (0.3)
Increment: Presentation of Times	
Time$_{M6T}$Absolute Times	Base
Time$_{M6T}$ Quicker	0.0020 (1.0)
Time$_{M6}$Absolute Times	Base
Time$_{M6}$Slower	−0.0025 (1.2)
Increment: Time Savings or Losses	
Saving ⩽ 5m-Reported	0.0002 (0.1)
Saving6–15m-Reported	0.0063 (2.1)
Saving16–25m-Reported	0.0036 (0.7)
Saving26–35m-Reported	−0.0006 (0.1)
Saving > 36m-Reported	0.0067 (0.7)
Loss ⩽ 5m-Reported	Base
Loss6–15m-Reported	0.0040 (1.5)
Loss16–25m-Reported	0.0059 (1.7)
Loss26–35m-Reported	0.0035 (1.0)
Loss > 35m-Reported	−0.0021 (0.4)
Saving ⩽ 5m-Network	0.0042 (0.7)
Loss ⩽ 5m-Network	Base
Loss6–15m-Network	0.0009 (0.2)
Loss16–25m-Network	0.0059 (2.1)
Loss26–35m-Network	0.0091 (3.9)
Loss > 35m-Network	0.0105 (4.1)
Increment: Credibility	
Time$_{M6}$Very Credible	Base
Time$_{M6}$Probably Credible	−0.0008 (0.7)
Time$_{M6}$Too Quick	−0.0007 (0.4)
Time$_{M6}$Too Slow	0.0017 (0.8)
Time$_{M6T}$Very Credible	Base
Time$_{M6T}$Probably Credible	−0.0043 (3.9)
Time$_{M6T}$Too Quick	−0.0058 (2.0)
Time$_{M6T}$Too Slow	−0.0009 (0.3)
Increment: SP2B Realistic or Not	
Time$_{SP2B}$Realistic	Base
Time$_{SP2B}$Unrealistic	0.0352 (1.5)
Increment: Actual Journey Time	
EB-ActualTime$^{0.5}$	−0.0026 (9.0)
Other-ActualTime$^{0.3}$	−0.0047 (10.6)
Reported Route Reliability Category	
Very Reliable	1.3826 (9.3)
Reliable	0.9517 (6.8)
Sometimes Reliable	0.6225 (6.6)
Unreliable	0.2165 (2.0)
Very Unreliable	Base
Departure Time Shift	
Earlier Time	−0.0230 (19.7)
Later Time	−0.0231 (19.8)
Information Categories	
Delays on M6	Base
Delays on M6 due to	0.2406 (2.9)
Expect 25m Delays on M6	1.4233 (6.6)
No Delays on M6	−0.5921 (5.9)
Cost Terms	
Toll	−0.0110 (9.9)
Fuel-Consider	−0.0045 (7.6)
Fuel-NotConsider	0.0008 (0.1)
Increment: SP2B Realistic or Not	
Toll$_{SP2B}$Realistic	Base
Toll$_{SP2B}$Unrealistic	0.0028 (2.0)
Increment: Number of Items	
Toll$_{M6T}$Items	0.0006 (5.1)
Increment: Credibility	
Fuel$_{M}$Very Credible	Base
Fuel$_{M}$Probably Credible	0.0002 (0.6)
Fuel$_{M}$Too High	0.0003 (0.7)
Fuel$_{M}$Too Low	0.0005 (0.9)
Fuel$_{A}$Very Credible	Base
Fuel$_{A}$Probably Credible	0.0006 (1.4)
Fuel$_{A}$Too High	0.0008 (1.3)
Fuel$_{A}$Too Low	0.0008 (1.6)
SP Type Scale Factors	
$\theta_{CredAll-78}$	1.0
$\theta_{Cred34-78}$	0.95 (0.8)
$\theta_{Cred12-78}$	0.87 (1.4)
$\theta_{CredNone-78}$	0.98 (0.2)

Table 7
Continued

Increment: Credibility		SP Type Scale Factors	
$Time_A$ Very Credible	Base	$\theta_{CredAll\text{-}34}$	0.83 (2.4)
$Time_A$ Probably Credible	−0.0082 (6.9)	$\theta_{CredSome\text{-}34}$	0.87 (1.4)
$Time_A$ Too Quick	−0.0065 (3.6)	$\theta_{CredNone\text{-}34}$	0.83 (1.3)
$Time_A$ Too Slow	−0.0066 (3.8)	$\theta_{SP2A\text{-}12}$	0.77 (5.2)
		$\theta_{SP2A\text{-}3}$	0.48 (7.5)
Increment: Number of Items		$\theta_{SP2BRealistic}$	0.38 (10.6)
$Time_M$ Items	0.0083 (3.6)	$\theta_{SP2BUnrealistic}$	0.60 (2.0)
		θ_{SP3A}	0.66 (4.9)
		θ_{SP3B}	0.87 (1.8)
ρ^2 (constants)	0.239	Log-Likelihood	−17,606.67
Observations	26,979		

Note: *t* ratios for the scale factors (θs) are specified with respect to one. Times are in minutes and costs in pence.

Turning to the remaining SP exercises where there were no credibility questions, the extended M6T exercise has two variants. SP2A-1 and SP2A-2 contain seven items across three alternatives compared to three items across two alternatives in SP2A-3, and hence $\theta_{SP2A\text{-}12}$ and $\theta_{SP2A\text{-}3}$ replace θ_{SP2A} of Table 6. The new Knutsford–Dunstable motorway exercise might have a different scale not only because it is more hypothetical, but also because about half of those who completed it had been handed it by mistake. We therefore specified two scales, $\theta_{SP2BRealistic}$ and $\theta_{SP2BUnrealistic}$, to replace θ_{SP2B}. θ_{SP3A} and θ_{SP3B} are as in Table 6.

5.2 Duration effects

The disutility of a minute spent travelling can be expected to increase with duration, due to discomfort and fatigue effects, while generally the less time that is available for consumption because of time spent travelling, then the greater the benefit from converting it into consumption activities. Although it could be argued that the marginal disutility of time falls with duration on proportionality grounds, there is convincing cross-study evidence that the value of time increases with journey duration (Abrantes and Wardman, 2011).

We initially conducted piecewise estimation that segmented separately the time, toll, fuel, and earlier/later time coefficients across the duration bands of up to $\frac{3}{4}$ hour, $\frac{3}{4}$–$1\frac{1}{4}$ hours, $1\frac{1}{4}$–2 hours, 2–3 hours, 3–4 hours, 4–6 hours, and over 6 hours. There were no statistically significant effects on the toll, fuel, and earlier/later time coefficients. In stark contrast, an almost monotonic effect was apparent on the travel time coefficients. This is not confounded with higher income respondents travelling farther, since the correlation of income and duration was −0.07.

We proceeded to fit a continuous relationship for time, with *X* of equation (1) taking the form of AT^{λ}, where AT is the actual end-to-end time. The incremental effects (β and λ) are not expected to vary by route, but are allowed to vary by purpose. The marginal disutility of travel time on route *i* is (MU_{Ti}):

$$MU_{Ti} = \alpha_i + \beta AT^{\lambda}, \qquad (2)$$

Table 8
Implied Values of Time by Duration

	Journey Purpose					
	Business		*Commuting*		*Other*	
Actual time	*VoT*	η_{VoT}	*VoT*	η_{VoT}	*VoT*	η_{VoT}
30m	9.06 (5.91)	0.11 (0.16)	7.14 (3.99)	0.0 (0.0)	8.90 (5.75)	0.06 (0.09)
60m	9.86 (6.71)	0.14 (0.20)	7.14 (3.99)	0.0 (0.0)	9.30 (6.16)	0.07 (0.11)
120m	10.98 (7.84)	0.18 (0.25)	7.14 (3.99)	0.0 (0.0)	9.81 (6.67)	0.08 (0.12)
180m	11.85 (8.70)	0.20 (0.27)			10.15 (7.00)	0.09 (0.13)
240m	12.58 (9.43)	0.22 (0.29)			10.42 (7.27)	0.09 (0.14)
300m	13.22 (10.07)	0.23 (0.30)			10.65 (7.50)	0.10 (0.14)

Note: Values are pence per minute and relate to time on the M6, with values for the M6T in parentheses. η_{VoT} is the elasticity of the value of time with respect to duration.

which can increase or decrease with AT or be constant. Given cost enters in linear-additive form with parameter γ, the value of time duration elasticity (η) denoting the proportionate change in the value of time after a proportionate change in journey duration is:

$$\eta_i = \frac{\beta\lambda}{\gamma \mathrm{VoT}_i} \mathrm{AT}^{\lambda}. \tag{3}$$

The four combinations of the value of time increasing or falling with AT and the elasticity increasing or falling with AT can occur according to the values of β and λ. The value of λ was estimated by an iterative grid search process, in intervals of 0.1, to achieve the best fit.

No significant effect from AT could be detected for commuters, which might be due to their relatively narrow range of durations, while highly significant positive but small effects on the value of time and elasticity were discerned for business and other trips.[7]

Illustrative values of time and elasticities are reported in Table 8. These are derived using the base $\mathrm{Time}_{\mathrm{M6}}$ coefficient, an incremental effect reflecting a design with six items evaluated and all other incremental effects at their base level. Without the duration effect, this gives a time coefficient of −0.0528. The toll coefficient is specified for six items, yielding a figure of −0.0074. To cover a time coefficient at the other 'extreme', the figures in parentheses are based on the $\mathrm{Time}_{\mathrm{M6T}}$ coefficient.

The pattern of variation is credible if we take the business values to represent personal rather than company values, and if the lower value for commuting results from the implied income effect from paying £7 or more every day to use the M6T.

The implied value of time duration elasticities (η_{VoT}) are generally lower than the distance elasticity of 0.20 reported in the meta-analysis of Abrantes and Wardman (2011), but, in our view, more plausible than the duration elasticities ranging from 0.32 to 0.41 from re-analysis of the 1994 UK Value of Time study (Whelan and Bates, 2001)

[7]Note that income varied little by purpose, averaging £57,000 for business, £55,000 for commuting, and £45,000 for other, and therefore should not be a serious confounding effect.

and 0.2 to 0.45 obtained by Axhausen *et al.* (2008), both of which would imply very large variations in values of time. Our results also contrast with other evidence (Whelan and Bates, 2001; Axhausen *et al.*, 2008; Daly, 2010) in finding the value of time to increase with distance not because of a reduction in the marginal utility of money, but because of an increase in the marginal disutility of time.

5.3 Size and sign of time savings

Studies in a number of areas have addressed whether unit valuations depend upon the magnitude of a variation and whether it is a gain or a loss. With regard to travel behaviour, the sensitivity to time losses and larger variations tend to have higher unit values. We note two points, however. First, there is likely to be under-reporting of the absence of sign and size effects. Second, we here deal with a wide range of time variations, as opposed to the traditional concern of whether (very) small travel time variations have any value at all, since large time variations are common in the context of new road infrastructure designed for inter-urban travel.

Using the dummy variable incremental terms as set out by equation (1), we have specified five categories of time saving and of time loss on the M6, following Table 2, and distinguished between variations based on reported and network data. The base categories are losses of less than five minutes. Given the lesser variation in the network estimates of current M6 times, there are significantly fewer savings than for the reported times.

The size and sign of time savings results reported in Table 7 are for M6 users only, since they are most familiar with the M6, but the findings were not materially different when based on all the SP1B exercise respondents. Only one of the nine incremental effects based on reported times was significantly different from zero. With regard to the network-based variations, the one saving and the losses between 6 and 15 minutes were not significantly different to the base. While the three largest losses have statistically significant and increasingly positive incremental effects, they are relatively minor, implying only a 10 per cent variation in the M6 time coefficient when the losses exceed 35 minutes. We therefore conclude that there is no convincing evidence for either sign or size effects.

5.4 Where in the journey?

We might hypothesise that the valuation of the time saving offered by the M6T depends upon where it occurs in the overall journey. Focus groups revealed that some drivers used the M6T for 'a rest' or as 'a break from the M6'. We might hypothesise that any such relief would be more appreciated towards the middle of a journey rather than at the outset or where the journey has been almost completed. We allowed both the ASC_{M6T} and $Time_{M6T}$ to vary separately across quintiles of the journey, using the incremental approach of equation (1). The segmentation of $Time_{M6T}$ provided the better fit, and is reported, but no significant effects are apparent compared to the base of the M6T saving occurring in the middle part of the journey ($Time_{M6T}$ 41–60%).

5.5 Attribute presentation as absolute or difference

In some instances the M6 (M6T) was presented as minutes slower (quicker) than the M6T (M6). Presentation in 'difference' form is not uncommon, but could influence the values obtained by, for example, placing more emphasis on a time variation. We tested whether this presentation format induced a different response, with dummy variable interactions as in equation (1). There were no significant effects on their respective coefficients from presenting the M6T as quicker ($Time_{M6T}Quicker$) and presenting the M6 as slower ($Time_{M6}Slower$).

5.6 Complexity

Some practitioners argue that SP exercises need to be relatively simple, whereas for others such views are deemed to be 'urban myth' (Louviere, 2001) or at least secondary to ensuring relevance (Hensher, 2006). There is, however, evidence to indicate that task complexity influences the implied willingness to pay and error variances of choice models (Widlert, 1998; Swait and Adamowicz, 2001; DeShazo and Fermo, 2002; Arentze *et al.*, 2003; Hensher, 2004; 2006; Caussade *et al.*, 2005).

These studies tend to examine the number of attributes and alternatives separately. We here define complexity as the total number of items of information evaluated per choice scenario, as set out in Table 3, which is the sum of attributes across all alternatives. We have analysed the effects on the coefficients themselves and also on the scale of the model.

To test whether there was an effect on the coefficient estimates, the number of items in an SP exercise (N_s) were entered as variable X in equation (1). Although the emphasis here is the sensitivity to time, it is illuminating to extend this, in an analogous fashion, to the toll cost. Fuel cost only ever appears in a design with seven or eight items and hence is not considered.

It turned out that the incremental effects on the time coefficients for the M6 and M6T were similar (0.0049 and 0.0063) and hence a common term was estimated ($Time_{M}Items$). Given the A-roads are almost always associated with seven or eight items, we did not pursue this incremental effect. Similarly, a toll on a route other than the M6T was mainly associated with seven or eight attributes and hence the incremental effect is specific to the M6T ($Toll_{M6T}Items$).

A significant effect from the number of items on the sensitivity to time and toll is apparent. In both cases, sensitivity falls as the number of items increases, consistent with respondents ignoring more items as their number increases. Table 9 illustrates the impact for the time coefficients specified at their base values, with the journey durations varying around mean levels by purpose. The level of disutility for three items, for time spent on the M6 and M6T, is reported along with an increase to eight items. There would be very appreciable differences in the sensitivity to time between just three and eight items evaluated. As far as the toll coefficient is concerned, it would be 33 per cent lower at eight items compared to three. The latter is generally less than the effect on the time coefficients, implying in many cases somewhat lower values of time in toll units as the number of items increase, as can be seen in Table 9. This is intuitively reasonable; if respondents do ignore attributes, we would expect them to maintain more focus on cost not least for strategic reasons, since this varied more easily in practice.

Turning now to the scale with regard to complexity, insignificant differences are more prevalent than significant ones. These relate to: some credibility with seven or eight items and some credibility with three or four items ($\theta_{Cred34\text{-}78}$ vs. $\theta_{CredSome\text{-}34}$, $\theta_{Cred12\text{-}78}$ vs. $\theta_{CredSome\text{-}34}$); not credible with seven or eight items and not credible with three or four items ($\theta_{CredNone\text{-}78}$ vs. $\theta_{CredNone\text{-}34}$); and the departure time shift exercise for the M6T

Table 9
Relative Magnitude of Complexity Effects

		Time on M6		*Time on M6T*	
Utility		3 items	8 items	3 items	8 items
Business	1 hr	−0.0978	−42.4%	−0.0563	−41.3%
	$2\frac{1}{2}$ hrs	−0.1095	−37.9%	−0.0680	−34.3%
	4 hrs	−0.1180	−35.2%	−0.0765	−30.5%
Commute		−0.0777	−53.4%	−0.0544	−76.3%
Other	$1\frac{1}{2}$ hrs	−0.0958	−43.3%	−0.0725	−57.2%
	3 hrs	−0.1000	−41.5%	−0.0767	−54.1%
	5 hrs	−0.1037	−40.0%	−0.0804	−51.6%
Values of Time		3 items	8 items	3 items	8 items
Business	1 hr	10.63	9.08	6.12	5.32
	$2\frac{1}{2}$ hrs	11.90	10.97	7.39	7.58
	4 hrs	12.83	12.34	8.32	8.58
Commute		8.45	5.84	5.91	2.08
Other	$1\frac{1}{2}$ hrs	10.41	8.76	7.88	5.00
	3 hrs	10.87	9.43	8.34	5.68
	5 hrs	11.27	10.03	8.74	6.27

Note: Values are pence per minute. Utility for eight items is relative to that for three items.

corridor with the other M6T corridor scales (θ_{SP3B} vs. $\theta_{CredAll\text{-}34}$, $\theta_{CredSome\text{-}34}$, and $\theta_{CredNone\text{-}34}$).[8] The differences in scale that are significant are: all credible with seven or eight items, or three or four items ($\theta_{CredAll\text{-}78}$ vs. $\theta_{CredAll\text{-}34}$) and exercise SP2A with seven or three items ($\theta_{SP2A\text{-}12}$ vs. $\theta_{SP2A\text{-}3}$). However, these relativities are not intuitively reasonable if we would expect more error variance for more items and hence a lower θ, particularly since the additional items do not introduce relevant but previously omitted attributes. Moreover, it is only in the former case where the difference in scale is large. When the scale distinction according to the number of items is removed, the incremental effects on the coefficients themselves are diminished, but only slightly.

It would seem that the impact of what we have termed task complexity, limited though its variation is across our SP exercises, is primarily upon the coefficients rather than the scale, implying that even for what might still be regarded as relatively straightforward exercises, some respondents ignore some attributes. The degree of variation in the coefficients is quite worrying, as is in some cases the variation in the value of time.

5.7 Credibility

A fundamental requirement of SP experiments, asserted since the earliest applications, is that the scenarios offered should be realistic. At its simplest level, credibility relates to the perceptions of the extent to which the absolute values offered could, taken as a whole, realistically occur in practice.

[8] There is no point comparing θ_{SP3A} with the other scales for the Stoke-M1 corridor, since the number of items is generally very similar.

There are two issues here. One is that we asked those who were presented with SP exercises based around a current situation (SP1A, SP1B, SP1C) whether the times and fuel costs were credible, as reported in Table 4. The other is that some respondents were mistakenly given the SP exercise based on the new Knutsford–Dunstable motorway (SP2B). Incremental terms, along the lines of equation (1), were specified to test these issues.

While five of the nine incremental effects on the time coefficients are statistically significant, no clear pattern is apparent. If respondents tend to disregard unrealistic attributes, we might expect the incremental effects to be positive rather than negative as observed here. Alternatively, respondents might 'compensate' for the perceived unrealism, whereupon the incremental coefficient would be positive (negative) where the times were regarded as being too slow (quick). Moreover, none of the significant effects is actually significantly different from any other, and indeed the largest incremental coefficient, for those who felt that the time on the A-road was probably credible, would only represent 11 per cent of the A-road time coefficient at the average leisure journey time of 189 minutes and with six items.

As for the six incremental coefficients relating to fuel, where arguably it is easier to convey incorrect levels due to variations in fuel efficiency, but where there is more uncertainty among respondents as to the actual level, we found no significant differences from the base category.

Turning to the scale effects, there are no significant differences among the four relating to the SP exercises with seven or eight items ($\theta_{\text{CredAll-78}}$, $\theta_{\text{Cred34-78}}$, $\theta_{\text{Cred12-78}}$, $\theta_{\text{CredNone-78}}$), nor among the three relating to the SP exercises with three or four items ($\theta_{\text{CredAll-34}}$, $\theta_{\text{CredSome-34}}$, $\theta_{\text{CredNone-34}}$). When the different scales by credibility were abandoned, the incremental coefficient estimates were not materially altered.

Finally, we report on the consequences of mistakenly distributing the 150-mile new motorway SP exercise to those for whom it would not be a practical option given their actual journey. For those for whom this SP exercise would be realistic, their average journey distance was 198 miles, roughly corresponding to Greater Manchester to London. This falls to 73 miles for those for whom the exercise would not be realistic.

There is no difference in the route specific constant between the two categories of traveller (ASC_{SP2B}Realistic and ASC_{SP2B}Unrealistic). The incremental coefficient for time ($Time_{SP2B}Unrealistic$) for those for whom the exercise would be unrealistic is not significant, and nor is there a significant difference between the scales for the two categories ($\theta_{\text{SP2BRealistic}}$ and $\theta_{\text{SP2BUnrealistic}}$). The only significant effect is that for the incremental toll effect ($Toll_{SP2B}Unrealistic$).

While there are approximations in our elicitation of views on credibility, since credibility could vary across scenarios, we might reasonably expect to be able to detect some effect from the not-credible categories. No clear evidence in support of this has materialised, for either the incremental effect or the scale. The reaction to being given SP attributes that were tailored to much longer journeys than undertaken seems very limited.

5.8 Is it real?

In addition to the realism of the attribute levels, another dimension concerns the realism of the choice context. We have here used a mixture of actual and hypothetical choice contexts. Two-thirds of the data relates to the existing choice situation (SP1A, SP1B, SP1C). The three other choice contexts (SP2A, SP2B, SP3) vary in the extent to which they are hypothetical.

We can observe a pattern within the scale parameters in Table 6. The highest scales, and hence least residual variation, are for the Stoke-M1 corridor ($\theta_{\text{Stoke-M1}}$) and the M6T corridor (θ_{M6TCorr}) which relate to existing choice contexts. At the other extreme, there is most residual variation for the completely artificial context of an entirely new motorway (θ_{SP2B}). The choice contexts which are variations on the existing routes have scales between these two extremes. Our results, which exhibit quite large variations in scale, would seem to indicate that this is an important issue, although contrasting with the findings for the credibility of the attribute levels themselves.

6.0 Conclusions

This research provides new insights into a range of issues surrounding the empirical sensitivities of motorists to variations in travel time, their willingness to pay tolls to save travel time, and important methodological issues. Given the importance of the car in the inter-urban travel market, and also the increased emphasis on private financing of new road infrastructure, it is surprising that there is not more published evidence.

Our conclusions are based on very robust models, estimated to a large data set, that yield a number of plausible valuations and relationships which compare favourably with a wealth of British value of time empirical evidence. The familiar real-world route choice context will have contributed to this robustness, and provides a firm foundation for our examination of various design and contextual effects. The conclusions drawn from this research are significant, original, and in large part credible, but in some cases surprising.

The results contribute to our understanding of how the value of time varies with journey duration. The value of time variation is plausible and would not imply unrealistic variations, unlike some other studies, across different distance bands. Moreover, our findings challenge other evidence by attributing the value of time variation with duration to increases in the marginal disutility of time rather than reductions in the marginal utility of money. Novel as it is, the analysis did not reveal any difference in the sensitivity to time savings according to where in the journey the distinct time saving occurred. In-depth, exploratory research might usefully investigate these two issues in more detail.

A longstanding issue is whether the unit value of time depends upon the amount of time saved and whether it is a gain or a loss on the time currently experienced. We offered some relatively small time savings, but the choice contexts provide the opportunity to offer realistically very large savings on the current M6 times. We conclude that there is no support for the unit value of time varying with the size of time savings, over a very large range, which is not consistent with either conventional economic theory or reference dependence theory. Even more challenging to other evidence is that the results do not support differential values for time savings and time losses.

We speculate that these findings relating to size and sign effects could have resulted from the basis in a real-world, familiar choice context, rather than the common practice of offering choices between unlabelled, abstract alternatives, and also that our SP exercises almost invariably offered absolute time values, from which gains and losses and their magnitude can be deduced, rather than explicitly offering savings or losses on a current journey. Nonetheless, we found that presenting journey times on the M6 (M6T) as minutes slower (quicker) than the M6T (M6) did not have any impact. We conclude that more research is needed on whether presenting time on a current route (or mode or unlabelled alternative) as a variation on some reference journey time is more likely to induce sign and size effects than if absolute times are offered. There is also a role for in-depth, exploratory research to explore size and sign effects, where in the journey effects and presentational issues in an explicitly detailed manner.

There is a large amount of evidence relating to complexity. Our contribution is that this does not seem to impact on the scale of the model, but the number of items in an SP exercise does influence the coefficient estimates, presumably because there is a greater tendency to ignore attributes when there are more items. Given the limited range of items that we tested, the extent of its impact is rather alarming. We also demonstrate that those who state that they ignore an attribute in actual decision making — in this case fuel cost — do actually have an insignificant coefficient estimate, and that the isolation of this leads to a more credible fuel cost coefficient.

There is little evidence concerning the impact of the credibility of SP exercises. Our findings suggest that the realism is not as critical as has long been widely considered. More controlled experiments, which deliberately vary the degree of realism, would seem to be justified to test this further. Finally, while our evidence indicates that the realism of the attribute values is not paramount, the results do show that the error variance of models increases the more the SP exercise departs from real-world choice contexts.

References

Abrantes, P. and M. Wardman (2011): 'Meta-analysis of UK values of time: an update', *Transportation Research A*, 45(1), 1–17.

Arentze, T., A. Borgers, H. Timmermans, and R. DelMistro (2003): 'Transport stated choice responses: effects of task complexity, presentation format and literacy', *Transportation Research E*, 39, 229–44.

Axhausen, K. W., S. Hess, A. König, G. Abay, J. J. Bates, and M. Bierlaire (2008): 'Income and distance elasticities of values of travel time savings: new Swiss results', *Transport Policy*, 15, 173–85.

Bradley, M. A. and A. J. Daly (1991): 'Estimation of logit choice models using mixed stated preference and revealed preference information', Proceedings of 6th International Conference on Travel Behaviour, Quebec, Vol. 1, 117–33.

Caussade, S., J. de D. Ortúzar, L. I. Rizzi, and D. A. Hensher (2005): 'Assessing the influence of design dimensions on stated choice experiment estimates', *Transportation Research B*, 39, 621–40.

Daly, A. J. (2010): 'Cost damping in travel demand models. Report for Department for Transport'. Available on-line at www.dft.gov.uk/pgr/economics/rdg/costdamping.

DeShazo, J. R. and G. Fermo (2002): 'Designing choice sets for stated preference methods: the effects of complexity on choice consistency', *Journal of Environmental Economics and Management*, 44, 123–43.

Fosgerau, M., K. Hjorth, and S. V. Lyk-Jensen (2007): 'The Danish value of time study: final report', Danish Transport Research Institute.

Hague Consulting Group (2000): ALOGIT 4.0EC, The Hague.

Hensher, D. A. (2004): 'Identifying the influence of stated choice design dimensionality on willingness to pay for travel time savings', *Journal of Transport Economics and Policy*, 38, 425–46.

Hensher, D. A. (2006): 'How do respondents process stated choice experiments? Attribute consideration under varying information load', *Journal of Applied Econometrics*, 21, 861–78.

Louviere, J. J. (2001): 'Choice experiments: an overview of concepts and issues', in J. Bennett and R. Blamey (eds), *The Choice Modelling Approach to Environmental Valuation*, Edward Elgar, Cheltenham.

Swait, J. and W. Adamowicz (2001): 'The influence of task complexity on consumer choice: a latent class model of decision strategy switching', *Journal of Consumer Research*, 28, 135–48.

Whelan, G. A. and J. J. Bates (2001): 'Variations in the value of time by market segment', Working Paper 565, Institute for Transport Studies, University of Leeds.

Widlert, S. (1998): 'Stated preference studies: the design affects the results', in J. Ortuzar, D. Hensher, and S. Jara-Diaz (eds), *Travel Behavior Research: Updating the State of Play*, chapter 7, 105–23, Pergamon, UK.

Appendix

The appendix to this article is available at http://tinyurl.com/ckm34dv