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Meta-analysis of UK values of travel time: An update

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ABSTRACT

Numerous travel demand studies have been carried out over the past five decades, many of which produce estimates of the value of travel time. This includes a rich body of largely unpublished evidence, which can provide valuable insights into the impact of variables such as GDP, travel distance, purpose and mode on this critical parameter for transport modelling and appraisal. The work reported in this paper updates and extends our previous meta-analyses of UK values of time (Wardman, 1998, 2001a, 2004) by adding recent studies and widening the range of explanatory variables included. Our current research covers 226 studies carried out between 1960 and 2008, yielding a total of 1749 valuations (a 50% increase relative to our previous work) and making this the largest data set of its kind to the best of our knowledge. This is also the most comprehensive study to date of parameters other than in-vehicle time and includes valuations of walk, wait, headway, congested, free flow, late, departure time shift and search time. Exploratory analysis of the data set provides interesting insights into methodological trends in travel demand modelling.

For each valuation, over thirty quantitative and categorical variables were recorded and then included in a multivariate regression model to explain variations in the value of time. A large number of statistically significant effects were obtained from this meta-analysis, some of which are in marked contrast with, or not present in, our previous work. One finding that stands out is that the estimated elasticity of the value of time with respect to GDP per capita is 0.9 and highly significant, a much closer correspondence to the widely used convention of a unit income elasticity over time than we have previously obtained. The ratio between walk and wait time and in-vehicle time was found to be substantially lower than the commonly used value of two. We also found large and significant differences between the results from studies based on different types of Stated Preference survey presentation. Other important effects include variations by mode used, mode valued, travel purpose, attribute type and distance. It is envisaged that the results are of direct relevance in the British context, as inputs to appraisal or for benchmarking, whilst the methodological implications are of broader interest and the results, in terms of time equivalents and variations in values of time, can be transferred to other contexts.

1. Introduction

The value of travel time is one of the most crucial concepts for transport planners, modellers and policy makers and, as a consequence, a very large number of studies have been carried out over the past five decades that have estimated this parameter for different user types under different circumstances in different countries. Some studies have had the specific

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objective of valuing travel time savings whilst others had an interest in a broader range of service quality attributes and in some studies valuations are a bi-product of behavioural analysis for forecasting purposes.

There have been several efforts by national bodies to determine rigorous values of travel time, largely focussing on in-vehicle time (IVT) and generally with the aim of ensuring consistency and good practice in project appraisal (MVA Consultancy et al., 1987; Hague Consulting Group, 1990; Pursula and Kurri, 1996; Ramjerdi et al., 1997; Dillen and Algers, 1999; Gunn et al., 1999; Hague Consulting Group et al., 1999; Small et al., 1999; Beca Carter Hollings and Ferner, 2002; Mackie et al., 2003; Fosgerau et al., 2007; Axhausen et al., 2008; Börjesson et al., 2009; Ramjerdi and Flügel, 2010). However, even where other national evidence is substantial, such studies have invariably made little attempt to integrate that evidence.

In contrast to classic literature reviews, the aim of meta-analysis is to quantify variations in relevant parameters, here the value of time, across different contexts. There have been a number of meta-analyses of transport evidence, notably of price elasticities (Kremers et al., 2002; Wardman and Shires, 2004; Hensher, 2008) and values of time (Wardman, 1998, 2001a, 2004; Zamparini and Reggiani, 2007; Shires and de Jong, 2009).

Meta-analysis is critically dependent upon assembling large data sets of past empirical evidence so as to be able to quantify the main causal factors with a sufficient degree of confidence. Such variation can occur within studies, as with different modes and purposes, and analysis at the study level can provide valuable evidence. The principal advantage of meta-analysis lies in exploiting evidence from a wide range of studies which thereby allows it to provide powerful insights that cannot be obtained from studies in isolation.

Meta-analysis should be seen as a complement rather than challenge to or replacement of specific studies, in much the same way as a thorough literature review is a valuable antecedent to fresh empirical research. The fact that meta-analysis is not primary research should not be allowed to detract from some undoubted significant attractions:

- Since meta-analysis draws together and explains a wealth of empirical evidence, it can provide guidance on the preferred values to be used in a range of different circumstances. This is particularly valuable where there is conflicting evidence across studies and in providing a means of interpreting the results of a single study.
- It is generally preferable to base recommended values on, or challenge established conventions with, the results of numerous studies rather than a few or a single one.
- It is possible to draw conclusions relating to spatial and particularly temporal variations in valuations that are beyond the scope of a single study; a particularly important one is how the value of time varies over time. Methodological insights can also be provided.
- Results not otherwise in the public domain for reasons of commercial confidentiality can be exploited because the means of analysis maintains their anonymity. Other unpublished evidence is sourced since it is wasteful not to exploit existing evidence to the maximum extent possible.
- Traditional literature reviews focus on mean values rather than the variation and there is always a risk that a comparison of means, rather than some more systematic quantification of all effects, is distorted by confounding factors.

Of course, meta-analysis cannot examine the value of time in the level of detail that specific behavioural studies can. There might also be instances of confounding effects, such as longer distance studies offering larger time savings or containing a different blend of journey purposes or income levels. Such possibilities need to be borne in mind in interpreting results.

The work reported in this paper builds upon our previous studies (Wardman, 1998, 2001a, 2004) of UK value of time evidence by incorporating results from studies reporting between 2001 and 2008 and by covering a wider range of explanatory variables. The updated data set makes this, as far as we are aware, the most extensive meta-analysis of this kind yet conducted.

The structure of this paper is as follows. Section 2 discusses the previous meta-analyses we have conducted and sets our current research firmly in that context. Section 3 outlines the key features of the data collected whilst Section 4 reports the empirical findings. Illustrative outputs of the meta-model are provided in Section 5, and Section 6 contains our concluding remarks and recommendations.

2. Background

The origins of our meta-analysis studies were in 1996 in response to the absence of any detailed literature review in the UK Department for Transport's second national value of time study (Hague Consulting Group et al., 1999) and our awareness of a considerable body of relevant research, particularly what might be termed 'grey literature', which had not been published in the academic literature or indeed elsewhere but which nonetheless constituted a wealth of high quality research output.

Our first study (Wardman, 1998) focused solely on IVT and included 444 observations from 105 studies from the period 1980–1996. The findings generally confirmed expectations. Familiarity with the empirical literature reveals that the value of time increases with journey duration, and a distance elasticity of 0.210 was recovered. Valuations based on the controversial numeraire of toll were found to be 25% lower whilst there were some sensible variations by mode. Business travellers' had values between 96% and 154% higher than leisure travellers whilst commuters evidenced values 14% higher. However, the GDP elasticity was very low, at 0.075, and this was attributed to very limited variation in GDP.

Table 1
Attributes, studies and values from second meta-analysis (Wardman, 2001a).

Attribute	Studies	Values	Attribute	Studies	Values
In-vehicle time	132	518	Out-of-vehicle time	19	61
Congested time	7	21	Headway	46	140
Free flow time	7	21	Departure time shift	11	74
Walk time	40	131	Search time	5	9
Access time	17	46	Late time	5	18
Wait time	12	33	Interchange	20	44

Note: free flow and congested time are specific to car travel. Where car journey time is not distinguished in this way, it enters IVT.

The emphasis of our second study (Wardman, 2001a) was to extend coverage to include walk time, access time, wait time,[1] service headway, parking search time (car IVT spent finding a parking space), car congested and free flow time, departure time shift (departing at an earlier or later time than desired), late arrival time and public transport interchange. The same time period was covered but an additional 35 studies were identified. The number of IVT valuations, including free flow time previously subsume within IVT, increased by 21% to 539. In total, 140 studies provided 1116 monetary valuations across all variables. Table 1 illustrates the distribution of values and studies.

The main findings were that congested time was on average valued 70% higher than IVT with a figure of 110% for search time. The unit values of walk time, wait time, headway and departure time shift were found to vary with their levels but with walk and wait time apparently having less than their usual premium of twice IVT. The distance elasticity was 0.1. Business valuations were found to be around 120% times larger than commuting values which in turn were around 20% larger than leisure values. Interestingly, SP based valuations were lower than their RP equivalents whilst the sensitivity to cost was highest for toll charge and lowest for fuel costs much in line with expectations. The estimated GDP elasticity was 0.51 but not statistically significant, presumably due to limited GDP variation in the time period. Variations by mode were largely as expected.

A particular emphasis of our third study (Wardman, 2004) was to cast light on how the value of time varied over time. As such, it not only included evidence that had emerged since the second study but also made a distinct effort to cover a significant amount of pioneering evidence of the 1960s and 1970s that we had previously neglected. However, the emphasis was restricted to valuations of IVT, walk time, access time, wait time and headway. The data set covered 1167 observations in total, from 171 studies conducted between 1963 and 2000, and represented 278 (31%) more values for these variables and 38 (29%) more studies (see Table 2).

Again, a positive distance elasticity, in this case 0.18, was estimated for IVT, with car travel having a slightly higher elasticity of 0.25. The elasticity for walk and wait values with respect to overall duration was found to be 0.11 but there was an absence of any effect for headway. The variations with journey purpose were in line with the previous study and a highly significant GDP elasticity of 0.72 was estimated. Values of walk and wait time obtained from RP studies were found to be appreciably larger than SP values. Modal variations were largely as expected; with bus time regarded to be around 40% more highly valued than car and rail travel time, bus users having values of around half those of other users and evidence of car users being more averse to walking and waiting.

This study impacted on official UK Department for Transport recommendations, contributing to the lower GDP elasticity of 0.8 for trips other than employer's business and the wait time multiplier, denoting the premium attached to waiting time relative to IVT, increased from 2 to 2½.

In this our third update, we have not only covered UK literature since 2000 but we have broadened the range of attributes to cover, with the exception of interchange, those in our first update. The number of valuations is now 1749 from 226 studies. The increase in the valuations of IVT, free flow time, walk time, access time, wait time and headway compared to the third study is 31%, from 1167 to 1529. The 220 valuations of congested time, out-of-vehicle time (OVT),[2] departure time shift, search time and late time are 20% larger than the second study (see Table 3).

3. Data assembly and characteristics

Data was collected from each study on a wide range of factors that might explain variations in the valuations. These were: year and quarter of data collection, sample size; journey distance and the spatial contexts of urban, rural, inter-urban and region; type of data, covering RP and SP; journey purpose; choice context, covering mode, route and 'abstract' choice; mode used and mode valued; cost numeraire; omission of non traders and use of logic checks; SP presentation type, including pen and paper, cards, computer assisted, internet and phone; the dimensions of SP exercises, as represented by the number of attributes and comparisons; whether the purpose of the study was forecasting or valuation and whether its purpose would have been clear to respondents.

[1] The value of wait time reported here is always directly estimated to wait time and never taken from wait times calculated as a function of headway. Any such values are returned to headway values.

[2] OVT covers walk time, wait time, access/egress time and, where estimated, combinations of them.

Table 2
Attributes, studies and values from third meta-analysis (Wardman, 2004).

Attribute	Studies	Values	Attribute	Studies	Values
In-vehicle time	169	698 (+29%)	Access time	20	54 (+17%)
Free flow time	7	21 (+0%)	Wait time	22	61 (+85%)
Walk time	56	174 (+33%)	Headway	52	159 (+14%)

Table 3
Attributes, studies and monetary valuations from this (fourth) meta-analysis.

Attribute	Studies	Values	Attribute	Studies	Values
In-vehicle time	211	933 (+34%)	Out-of-vehicle time	20	70 (+15%)
Congested time	9	29 (+38%)	Headway	67	210 (+32%)
Free flow time	9	39 (+86%)	Departure time shift	14	89 (+20%)
Walk time	63	192 (+10%)	Search time	5	9 (+0%)
Access time	25	78 (+44%)	Late time	8	23 (+28%)
Wait time	27	77 (+26%)			

Note: we here split access and walk for consistency with previous tables. However, the distinction is subsequently discontinued since, upon inspection, access is mainly walk time.

Attribute specific information was collected on the mean levels of walk time, wait time, headway and departure time shift and whether the departure time shift related to an earlier than desired departure, a later than desired departure or did not distinguish between the two and whether it was explicitly offered or was implicit in the choice of departure. The earlier and later departure times were generally defined with respect to some identified desired departure time or else, as is common with car trips, as variations around the actual departure time which was implicitly the desired departure time.

We only collected multiple observations from a study if they differed according to these factors and we were careful to avoid using multiple publications from the same study unless different results were reported. Valuations based on the wage rate or some proportion of it, and hence not directly estimated, are not included in the data set. With hindsight, we feel that the only opportunity missed was to collate value of time evidence segmented by income group.

Of the 226 studies, only 7% yielded just one parameter value, 42% provided between 2 and 5 values, 28% between 6 and 10 values, 10% between 11 and 15 values and 13% over 15 values.

3.1. Characteristics of the studies

Table 4 indicates the sources of the studies and values. The critical importance of exploiting the grey literature is readily apparent.

Table 5 illustrates the distribution of our sample of valuations by journey purpose. There is a reasonable spread of the main purposes and only minor variation by attribute.

We distinguish between the mode used and, as far as IVT is concerned, the mode valued. SP models can provide us with all the combinations of mode used and mode valued. RP models can, and here do, provide valuations by mode used which is necessarily the same as the mode valued. Relevant contexts are motorists' route choice and rail users' choices between different operators, departures or routes. They can also provide mode specific valuations for combinations of mode used but are not able to provide mode values when that mode has not been used. Table 6 provides details. Some studies deliver values for specific modes (*Single Mode*) whereas others pool across different users of modes or modes valued and to account for the latter we weight all values according to their constituent modes (*All*).

As far as mode used is concerned, there is little difference between the *Single Mode* and *All* figures. Each reveals car to be the most researched mode, partly because of the investigation of policies and investments aimed at reducing car use and

Table 4
Sources of studies.

Source	Valuations	Studies
Journal/Book	59 (3%)	15 (7%)
Conference Paper	51 (3%)	10 (4%)
Published Report	291 (17%)	24 (11%)
Unpublished Operator Commissioned Report	307 (18%)	48 (21%)
Unpublished Government Commissioned Report	931 (53%)	111 (49%)
Unpublished Academic Report	110 (6%)	18 (8%)
Total	1749	226

Table 5
Valuations by purpose (row percentages).

Attribute	Business	Commute	Other	No Dist	Total
Time	156 (15%)	271 (27%)	373 (37%)	210 (21%)	1010
Walk/Wait/OVT	15 (4%)	154 (37%)	140 (33%)	108 (26%)	417
Late	3 (13%)	6 (26%)	9 (39%)	5 (22%)	23
Departure time shift	13 (15%)	22 (25%)	25 (28%)	29 (33%)	89
Headway	24 (11%)	51 (24%)	81 (39%)	54 (26%)	210
Total	211 (12%)	504 (29%)	628 (36%)	406 (23%)	1749

Note: Commute includes peak and other includes off-peak. No Dist denotes that no distinction was made by purpose. Time covers IVT, search, free flow and congested.

Table 6
Valuations by mode used and mode valued (column percentages).

	Mode used		Mode used (IVT only)		Mode valued (IVT only)	
	Single mode	All	Single mode	All	Single mode	All
Car	730 (52%)	834 (48%)	382 (51%)	437 (47%)	248 (38%)	332 (36%)
Bus	247 (18%)	351 (20%)	112 (15%)	168 (18%)	95 (14%)	180 (19%)
Rail	336 (24%)	450 (25%)	211(28%)	270 (29%)	256 (39%)	318 (34%)
Underground	62 (4%)	69 (4%)	23 (3%)	27 (3%)	23 (4%)	28 (3%)
Light rail	2 (0%)	13 (1%)	1 (0%)	8 (1%)	25 (4%)	60 (6%)
Air	8 (1%)	11 (1%)	8 (1%)	10 (1%)	2 (0%)	6 (1%)
Other	19 (1%)	21 (1%)	12 (2%)	13 (1%)	7 (1%)	9 (1%)
Total	1404	1749	749	933	656	933

partly because car is the main means of travel. The proportion attributable to rail users is in no small measure due to the UK railway industry's widespread use of behavioural analysis techniques (ATOC, 2009). The distribution solely for IVT is very similar to all valuations and there is a satisfactory balance across mode users.

With regard to mode valued, which relates only to IVT, there is here more emphasis on rail and less on car, presumably due to the investigation of new rail schemes intended to influence mode share. Again there is a good spread across the main modes and little difference between the *Single Mode* and *All* distributions.

Table 7 illustrates the distribution of our sample by journey distance band. A mean distance band is identified for each value and, in the vast majority of cases, due to distance segmentations or the focus on specific (e.g., urban) markets, the variation around the mean will not be large. Around 60% of all valuations are for short distance travel of up to 10 miles, reflecting the dominance of short distance trips. Walk and wait times are important features of urban mode choice studies and hence the short distance trips here dominate whilst in contrast departure time shifts, particularly for rail travel, are more of an issue for longer distance journeys. Overall, there are sufficient values in different distance bands to be able to discern variations in valuations by distance.

The valuations in various time period bands are reported in Table 8. There is a good spread of IVT values, and indeed the values in entirety, across years, and this provides a firm basis upon which to examine inter-temporal variations. IVT, as expected, has been popular throughout, as have walk and wait time. Departure time shifts are of comparatively recent interest whilst late time, never that often estimated, now tends to be replaced in reliability studies with the standard deviation of travel time. However, we felt that there were insufficient observations of the latter in Great Britain to make it worthwhile pursuing. The interest in congested and free flow time apparent in the early 1990s has not been retained whilst that period also provides the bulk of the headway valuations. There is a noticeable peak in studies in the 1990–1995 period. This coincides with the broad acceptance in the UK of SP as an analytical tool, as well as high levels of interest in new tram and rail schemes and in road pricing and tolled infrastructure where SP was deemed particularly suitable.

A number of interesting trends are apparent in Table 9 which covers presentational issues. The dominance of RP in the earlier years is apparent as is then the growth in the popularity of SP studies. Card presentation dominated early SP appli-

Table 7
Valuations by distance (miles) band (row percentages).

Attribute	0–10	11–20	21–50	50–100	101–200	200+	Total
Time	532 (53%)	63 (6%)	169 (17%)	56 (5%)	138 (14%)	52 (5%)	1010
Walk/wait/OVT	353 (85%)	6 (1%)	26 (6%)	13 (3%)	12 (3%)	7 (2%)	417
Late	8 (35%)	10 (43%)			1 (4%)	4 (17%)	23
Departure time shift	13 (15%)		30 (34%)	10 (11%)	24 (27%)	12 (13%)	89
Headway	140 (67%)	4 (2%)	29 (14%)	14 (7%)	14 (7%)	9 (4%)	210
Total	1046 (60%)	83 (5%)	254 (15%)	93 (5%)	189 (11%)	84 (5%)	1749

Table 8
Valuations per year by attribute (row percentages).

Attribute	1960–1979	1980–1984	1985–1989	1990–1995	1995–1999	2000–2004	2005–2008	Total
In-vehicle	28 (3%)	30 (3%)	93 (10%)	309 (33%)	170 (18%)	175 (19%)	128 (14%)	933
Walk	15 (6%)	8 (3%)	26 (10%)	119 (44%)	56 (21%)	33 (12%)	13 (5%)	270
OVT		1 (1%)	5 (7%)	24 (34%)	31 (44%)	9 (13%)		70
Wait	13 (17%)	8 (10%)	2 (3%)	24 (31%)	10 (13%)	18 (23%)	2 (3%)	77
Search			2 (22%)	3 (33%)	4 (44%)			9
Late		7 (30%)	10 (43%)	1 (4%)		2 (9%)	3 (13%)	23
Departure time			8 (9%)	29 (33%)	27 (30%)		25 (28%)	89
Congested			3 (10%)	14 (48%)	4 (14%)		8 (28%)	29
Free flow			2 (5%)	27 (69%)	4 (10%)		6 (15%)	39
Headway			25 (12%)	99 (47%)	36 (17%)	30 (14%)	20 (10%)	210
Total	56 (3%)	54 (3%)	176 (10%)	649 (37%)	342 (20%)	267 (15%)	205 (12%)	1749

Table 9
Studies per year by type of SP presentation (column percentages).

Type	1960–1979	1980–1984	1985–1989	1990–1995	1995–1999	2000–2004	2005–2008	Total
Paper	1 (8%)	3 (23%)	12 (38%)	27 (35%)	23 (46%)	14 (50%)	17 (59%)	97 (40%)
Cards		4 (31%)	13 (41%)	8 (10%)	5 (10%)		1 (3%)	31 (13%)
PC			4 (12%)	31 (40%)	21 (42%)	10 (35%)	7 (25%)	73 (30%)
Adaptive			1 (3%)	5 (6%)				6 (2%)
Internet						1 (4%)	1 (3%)	2 (1%)
Phone						1 (4%)	2 (7%)	3 (1%)
SP Total	1 (8%)	7 (54%)	30 (94%)	71 (91%)	49 (98%)	26 (93%)	28 (97%)	212 (87%)
RP	12 (92%)	6 (46%)	2 (6%)	7 (9%)	1 (2%)	2 (7%)	1 (3%)	31 (13%)

cations, largely due to concerns about the clarity of SP presentation and its ability to randomise the scenarios. The 1990s witnessed the advent of computer assisted interviewing. Its popularity, on the grounds of customisation and efficiency, has not quite been sustained, most likely on cost grounds. Pen and paper based methods, which are cheap and can yield very large samples where there is a captive market, have always been widely used and indeed have gained in popularity. No doubt competitive pressures in the commercial market will have contributed whilst the dominance of relatively simple SP exercises also facilitates this. This method has achieved most use over the period. Purely phone based methods are not widely used and concerns about the representativeness of samples obtained using internet based surveys may well have been the reason for its limited attractiveness.

Table 10 indicates the distribution of methods over time. After the early prevalence of RP methods, ranking exercises dominated the initial SP applications. This method was 'imported' from its, even then, extensive application in marketing research, particularly in the United States (Cattin and Wittink, 1982). However, it soon gave way to choice exercises, largely on the grounds that these were both easier and more closely reflected real-world decision making. Methods using metric rating scales, beloved of psychologists, have hardly featured.

There is a commonly held view, particularly prevalent in Europe, that SP exercises should be kept simple. In contrast, Hensher (2006) argues that it is relevance not complexity that is key whilst Louviere (2001) places the desirability of simple SP exercises in the realm of "urban myth". The 'European' view is reflected in Table 11, which shows SP studies with four or less attributes dominating, and relatively little variation in the distributions over time. Whilst it would not be fair to state that the very simplest form of SP exercise dominates UK practice, it should be recognised that the two attribute 'Bradley design' does dominate national value of time studies in Europe (Hague Consulting Group, 1990, 1998; Hague Consulting Group et al., 1999; Fosgerau et al., 2007; Börjesson et al., 2009; Ramjerdi and Flügel, 2010)

Task complexity has also been taken to cover the number of comparisons a respondent is asked to make. As is apparent in Table 12, the most common number of comparisons is 7–9, probably because standard experimental designs often generate 8 or 9 scenarios, and this category has gained in popularity over time with a reduction in the number of studies comprising a

Table 10
Studies per year by study type (column percentages).

Type	1960–1979	1980–1984	1985–1989	1990–1995	1995–1999	2000–2004	2005–2008	Total
RP	12 (92%)	6 (46%)	2 (6%)	7 (9%)	1 (2%)	2 (7%)	1 (3%)	31 (12%)
SP choice	1 (8%)	2 (15%)	19 (58%)	49 (61%)	38 (76%)	23 (82%)	27 (93%)	159 (65%)
SP ranking		5 (39%)	12 (36%)	23 (29%)	10 (20%)	3 (11%)	1 (3%)	54 (18%)
SP rating				1 (1%)	1 (2%)			2 (1%)

Note: Some studies used more than one method. Choice also covers the categorical 'definitely choose' and 'probably choose' response scales.

Table 11
Number of attributes per SP choice study (column percentages).

Number	1980–1984	1985–1989	1990–1995	1995–1999	2000–2004	2005–2008	Total
2	1 (33%)		1 (2%)	1 (3%)	2 (8%)	4 (12%)	8 (5%)
3		3 (16%)	11 (20%)	7 (18%)	5 (21%)	6 (18%)	33 (19%)
4		13 (68%)	37 (63%)	25 (64%)	13 (54%)	16 (48%)	104 (59%)
5	2 (67%)	3 (16%)	9 (15%)	6 (15%)	3 (13%)	6 (18%)	29 (16%)
6			1 (2%)		1 (4%)	1 (3%)	3 (2%)
12					1 (4%)		1 (1%)

Note: Some choice studies used more than one choice exercise and varied the number of attributes.

Table 12
Number of SP choice comparisons per study (column percentages).

Number	1980–1984	1985–1989	1990–1995	1995–1999	2000–2004	2005–2008	Total
4–6			2 (3%)	2 (5%)	1 (4%)	5 (17%)	11 (7%)
7–9	1 (50%)	8 (40%)	30 (52%)	28 (76%)	17 (74%)	18 (62%)	102 (60%)
10–12		6 (30%)	13 (22%)	6 (16%)	3 (13%)	4 (14%)	32 (19%)
13–16	1 (50%)	4 (20%)	10 (17%)	1 (3%)			16 (9%)
17–20		2 (10%)	3 (5%)		2 (9%)	2 (7%)	9 (5%)
36						1 (3%)	1 (1%)
Total	2	20	58	37	23	29	169

Note: Some studies comprised more than one choice exercise

Table 13
Overall time multipliers.

Attribute	Mean	Obs	Std dev	Std error
Walk	1.65	296	0.74	0.04
OVT	1.43	73	0.76	0.09
Wait	1.70	90	0.81	0.09
Search	1.38	10	0.53	0.17
Late	6.35	15	3.77	0.97
Departure time shift – earlier	0.62	27	0.54	0.10
Departure time shift – later	0.65	30	0.64	0.12
Departure time shift – earlier and later	0.74	16	0.54	0.14
Congested	1.54	29	0.33	0.06
Headway	0.78	219	0.47	0.03

Note: The time valuation and monetary valuation data sets are slightly different since not all studies contain both cost and IVT terms. Std dev denotes the standard deviation of the relevant multiplier whilst standard error is the standard deviation of the mean.

large number of comparisons. Contributory factors include a recognition that robust models can be estimated from fewer than, say, 16 choices per respondent and concerns over fatigue effects (Bradley and Daly, 1994), particularly given the not uncommon practice of offering two SP exercises in a single study.

3.2. Characteristics of the valuations

Whilst we are mainly looking to explain variations in monetary valuations, it is common practice to express valuations of attributes other than IVT in equivalent units of IVT. Not only are these more transferable across different contexts, including the international dimension, but such 'multipliers' also lend themselves more readily to interpretation and assessment. In addition, there is no need to make adjustments over time for income growth.[3] Table 13 indicates the IVT multipliers, drawn directly from the data set, and reveals a number of interesting findings.

The mean walk and wait time valuations are significantly less than the multiplier of two commonly applied. Car time spent in congested traffic conditions is valued, on average, 54% more highly than time spent in free flow traffic whilst time spent searching for a parking space is 38% more highly valued than IVT. Late arrival time is particularly highly valued and headway is valued less per minute than IVT. There is little difference between the valuations of departing earlier or later and these are also valued less than IVT.

[3] Of course, even though our meta-model is based on explaining monetary valuations, it can be, and is here, used to derive formulae for valuations in equivalent time units.

Table 14
Time multipliers.

Attribute	Type	Mean	Obs	Std dev	Std error
Walk	RP	1.84	39	0.92	0.15
	SP	1.62	257	0.70	0.04
Wait	RP	2.32	27	0.92	0.18
	SP	1.43	63	0.59	0.07
Congested	RP	1.51	4	0.55	0.28
	SP	1.55	25	0.30	0.06
Headway	RP	0.91	11	0.60	0.18
	SP	0.78	208	0.47	0.03

These valuations vary little by journey purpose with two notable exceptions. The value of late arrival was over six for commuters but less than two for other purposes whilst departure time shift had a value of 1.00 for commuters but around 0.55 for others. Nor was there any clear pattern in the valuations by distance band and mode. However, a notable finding was that the valuations of walk, wait time and headway were larger in RP studies, as is apparent in Table 14. Two factors may have contributed to this. Firstly, the customisation of SP exercises tends to focus on IVT and cost. Secondly, it can be difficult to convey realistic variations in these attributes when, for example, the distance to access a mode and walking speed do not vary and when travellers aim to arrive say two minutes before departure of their service. These might increase the chances that walk and wait time are not fully accounted for in the SP choices, thereby deflating their estimated values.

4. Empirical findings

4.1. Modelling approach

The form of model used to explain variations in monetary values (V) takes a multiplicative form:

$$\mathrm{VoT} = \tau \prod_{i=1}^{n} X_i^{\alpha_i} e^{\sum_{j=1}^{p} \sum_{k=1}^{q-1} \beta_{jk} Z_{jk}} \tag{1}$$

where there are n continuous variables (X_i) and p categorical variables having q categories (Z_{jk}). We specify $q-1$ dummy variables for a categorical variable of q categories and their coefficient estimates are interpreted relative to the arbitrarily omitted category. The α_i are interpreted as elasticities and the exponential of β_{jk} denotes the proportionate effect on the valuation of a particular category relative to its omitted category. A logarithmic transformation of Eq. (1) allows the estimation of the parameters by ordinary least squares.

$$\ln(\mathrm{VoT}) = \ln(\tau) + \sum_{i=1}^{n} \alpha_i \ln(X_i) + \sum_{j=1}^{p} \sum_{k=1}^{q-1} \beta_{jk} Z_{jk} \tag{2}$$

We tested a linear-additive function in place of Eq. (1) but this provided a somewhat inferior fit to the data.

Two types of variable were specified. Main effects relate to the independent effect of a particular variable, such as distance or mode, on a valuation. Interaction effects are essentially the product of two main effects, thereby permitting, say, the effect of distance to vary by mode.

Table 15 presents the model estimated on the 1749 monetary valuations expressed in pence per minute in quarter 4 2008 prices. The adjusted R^2 goodness of fit measure of 0.615 is respectable given the disparate nature of the studies, the inherent inability of this type of approach to examine the detailed context of studies, and the sampling distribution surrounding any individual valuation. It is assumed that the variation in the values which cannot be explained by the key variables examined is randomly distributed across the sample. We discuss the results for each of the eleven broad categories of variables in turn.

4.2. Attribute specific constants

A dummy variable was specified for nine of the ten attributes, with IVT serving as the arbitrary base. The coefficient for free flow time was not significant, indicating that it can be taken to have the same value as IVT in general. This is an important finding, since there is some ambiguity as to whether studies that have valued generic car IVT have yielded a valuation that relates to free flow time, congested time or some combination.

Car parking search time was not significant, presumably because it is essentially car IVT although in any event there are not many observations for this attribute, whilst no effect could be discerned for out-of-vehicle time which covers those instances where no distinction was made between walking, access and wait time. There was no support for additionally dis-

Table 15
Meta-model results.

	Coeff (t)	Elasticity or Effect
Constant	*−6.207 (6.7)*	
Attribute specific		
Headway	*−0.593 (8.3)*	−45%
Late	*1.177 (7.6)*	+224%
Congested	*0.295 (2.4)*	+34%
DepShift	*−0.256 (3.0)*	−23%
ln_WalkTime	*0.098 (3.8)*	0.098
ln_WaitTime	*0.075 (1.7)*	0.075
Income		
GDP	*0.899 (8.2)*	0.899
Distance		
Miles	*0.161 (7.3)*	0.161
+Miles_Car	*0.044 (2.3)*	0.044
+Miles_Late_Inter	*−0.243 (3.9)*	−0.243
+Miles_Other_Inter	*−0.042 (2.5)*	−0.042
Purpose		
EB	*0.754 (14.0)*	+113%
PeakCommute	*0.109 (3.2)*	+12%
EB_Dep_Shift	*0.430 (2.2)*	+54%
Mode used		
BusUser	*−0.400 (9.9)*	−33%
RailUser	*0.358 (7.0)*	+43%
+RailUser_Inter-urban	*0.230 (3.4)*	+26%
AirUser	*1.445 (8.0)*	+324%
+CarUser_Headway	*0.182 (2.0)*	+20%
+CarUser_WalkWait	*0.158 (2.6)*	+17%
Mode (IVT) valued		
RailValued	*−0.145 (2.7)*	−13%
AirValued	*0.596 (3.2)*	+81%
BusValued_CarUser	*0.169 (2.8)*	+18%
Numeraire		
Fuel	*0.115 (1.6)*	+12%
Toll	*−0.235 (2.6)*	−21%
Data type		
RP_IVT	*0.197 (2.3)*	+22%
RP_walk	*0.355 (2.7)*	+43%
RP_wait	*0.369 (2.2)*	+45%
SP presentation		
Adaptive	*0.270 (1.9)*	+31%
Phone	*0.380 (3.9)*	+46%
Internet	*0.742 (3.1)*	+110%
Area		
LondonSouthEast	*0.242 (6.5)*	+27%
Other		
Mode_Choice	*0.076 (1.8)*	+8%
Ln_Comps	*−0.068 (2.7)*	−0.068
Adjusted R^2	*0.535*	

Note: Unweighted ordinary least squares regression. GDP per capita 2008 Q4 was 5927

tinguishing generic access time to a mode from purely walk time. The remaining six attributes had significant coefficient estimates.

Headway is found to have a value 45% lower than in-vehicle, all other things equal, and this seems reasonable, as does the 23% lower value for departure time shift. Congested travel time is estimated to be 34% more highly valued than free flow time, reflecting the added anxiety, frustration and difficulty of driving in these conditions. This is lower than the figure in Table 14, although nonetheless reasonable, and this may be because now IVT in general is implicitly in the base. For shorter distances, late arrival time is valued 3¼ times more highly than IVT, in line with the premium of three used in the UK railway industry (ATOC, 2009), but falls with distance. Some high multiplier values of late time apparent in the time-based data set in Table 14 are not in the monetary valuation data set.

It was found that specifying the mean level of walk and wait time implicit in the SP exercise in the place of dummy variables provided a better fit, albeit that the coefficient for waiting time is only significant at the 10% level. However, the

Table 16
Income and distance elasticities from segmented models.

Segment	GDP (*t*-stat)	Distance (*t*-stat)
IVT	1.04 (7.7)	0.17 (6.2)
Non-IVT	0.70 (3.6)	0.08 (1.9)
⩽30 miles	1.02 (7.6)	0.04 (1.2)
>30 miles	0.85 (4.4)	0.38 (6.8)
Business	0.85 (2.8)	0.45 (7.3)
Commute	1.06 (5.0)	0.08 (1.5)
Other	0.90 (8.2)	0.16 (7.3)
Car user	0.96 (6.2)	0.08 (2.5)
Bus user	0.99 (5.6)	0.01 (0.0)
Rail user	0.96 (5.6)	0.33 (6.7)
Car valued	0.98 (5.6)	0.17 (2.0)
Bus valued	0.70 (3.6)	0.07 (1.7)
Rail valued	0.88 (5.1)	0.28 (8.4)

elasticities are not large; increasing walk time from 1 min to 20 min increases the unit value of walk time by 34%, with a corresponding figure of 25% for wait time. We return to the implied walk and wait time values in IVT units in Section 5.

4.3. Income

The measure of income used was an official, seasonally adjusted national index of gross domestic product (GDP) per person. A highly significant GDP per capita elasticity of 0.899 (±24%) was estimated which is in line with the widespread convention of increasing values of time in line with income but is considerably above those found in the meta-analysis of Shires and de Jong (2009), covering 1299 IVT values across 30 countries, which ranged between 0.47 for business travel and 0.68 for commuting. The inevitable approximations in adjusting income across countries as well as cultural differences could have influenced these income elasticities. Our inter-temporal elasticity is also somewhat larger than the cross-sectional income elasticities centring around 0.5 typically obtained from disaggregate behavioural studies (Wardman, 2001b).

There are reasons why cross-sectional income elasticities might be lower, such as those who strive for higher incomes placing a greater valuation on money, but it should also be noted that exact repeat studies have observed little or no increase in the real value of time over time (Hague Consulting Group et al., 1999; Gunn, 2001; Tapley et al., 2007). The latter could, of course, be consistent with an income elasticity of one if there are offsetting effects over time on the marginal utility of time, such as travellers becoming more resigned to congestion or the comfort of vehicles and the opportunity to use travel time productively increasing significantly over time.

We experimented with a time trend to discern inter-temporal effects. This provided a worse fit when it replaced GDP whilst it was highly correlated with GDP when entered alongside it. The latter model was of the form:

$$\ln(\mathrm{VoT}) = \alpha_1 \ln(\mathrm{GDP}) + \alpha_2 T \ln(\mathrm{GDP}) \tag{3}$$

where T is a time trend. α_2 was -0.01 with a t ratio of 0.7. We therefore conclude that the GDP elasticity is stable over time. Whilst it would be illuminating to examine the effect of specifying a disposable income index, no such consistent measure exists over the entire time period.

Table 16 demonstrates from separate models estimated to specific market segments that the variation in the GDP elasticity is relatively minor. None of the GDP elasticities are significantly different from the overall estimate of 0.9.

4.4. Distance

A highly significant elasticity of 0.161 (±27%) was estimated, which reflects the increasing discomfort of longer distance journeys and the larger opportunity cost of time spent travelling. It increases to 0.205 for car IVT, presumably due to a differential comfort effect compared to rail, but falls to 0.119 for valuations of attributes other than IVT[4] and late arrival time and for inter-urban travel. The other incremental effect is for late arrival time, which has a distance elasticity of −0.082 for inter-urban trips. It is not unreasonable that the value of arriving late is less for longer distances since there will be a higher expectation and acceptance of unreliability for such journeys.

Whilst distance effects could reflect differential journey purposes by journey length, the values of time tend to be segmented by purpose. A more likely confounding effect that needs to be borne in mind is that those with higher incomes, and hence higher values of time, tend to travel farther. SP exercises for longer journeys will also tend to offer larger time savings and this might have an influence on estimated valuations.

[4] Miles_Other_Inter is an incremental effect for walk time, wait time, departure time shift and headway for inter-urban journeys over 30 miles.

Table 16 provides distance elasticities for separate models by market segment. The results tend to confirm those of the main model, with the distance elasticity being lower for non-IVT and higher for rail users and for car valued. The insignificant parameters for short distance and bus could well be due to the limited variation in distance within these segments.

Finally, we identified all the 'within-study' valuations which differ only in terms of distance. This allows for a very controlled analysis of the impact of distance. We estimated the implied distance elasticity (β) from a regression model of the form:

$$\ln \frac{\mathrm{VoT}_R}{\mathrm{VoT}_B} = \alpha + \beta \ln \frac{D_R}{D_B} \tag{4}$$

R denotes a 'reference' value of time and B is some 'base' value, here taken to be for the lowest distance (D) for which a study provides a separate value. Data is pooled across all studies which provide values of IVT that differ only according to distance. Our meta-data set yields 142 such observations and the results are reported in Table 17. The estimated IVT distance elasticity is broadly comparable with that of the meta-model.

4.5. Journey purpose

The incremental effects for commuting and peak travel were not significantly different and hence were combined. Our results indicate that peak time and commuting trips have a value of time 12% above other types of trips and that business travel has a value of time more than twice as high as other trips. These results seem plausible. Further segmentations, such as by specific leisure categories, did not prove fruitful although some small sample sizes might have had a bearing here.

Table 18 presents results for within-study variations of value of time estimates by purpose. It was found that the number of studies where purpose is the only difference between parameter estimates is in double figures, which allows for meaningful analysis. These results confirm the relatively small variation between commuting and other trips. The relatively large ratio for peak relative to off-peak may have been influenced by the presence of congested time in the former.

We examined a number of interactions, testing whether, for example, the purpose effect varied by mode, distance or by attribute. The only significant effect was that business travellers value departure time shifts 54% more highly than other travellers. We might have expected the value of late time to be higher for commuters and perhaps business travellers but there were too few observations to be able to recover robust results.

4.6. Mode used

We distinguish between mode used and mode valued, which turn out not to be highly correlated. Mode used relates to the characteristics of the person, and chiefly income, and mode valued is related to the characteristics of the mode, such as comfort, environment and security.

Compared to the base category of car user, bus users were found to have a value of time 33% lower, presumably stemming from lower incomes. On the other hand, rail users have values 43% higher than for car users, increasing to 80% for inter-urban travellers. The latter, somewhat surprising, result was confirmed from within-study evidence where train users had values 36% larger than car users, *ceteris paribus,* although only for a sample of four studies. There were 13 cases where bus and car users' values could be directly compared within a study and the 33% lower value for bus users confirms the results of the meta-model. Air transport users have values around 4¼ times larger than car users. Whilst in the studies covered these users will tend to be high income, there are confounding effects at work here, such as the dominance of business travel and the long distances involved.

Table 17
Within-study distance elasticity.

Constant	0.090 (2.3)
Distance	0.225 (6.9)
Adj R^2	0.26
Obs	142

Table 18
Within-study purpose effects.

Valued	Ratio	Std dev	Std error	Obs
Commute vs Leisure	1.15	0.48	0.08	36
Peak vs Off-Peak	1.40	0.44	0.11	16
Commute vs Shopping	1.16	0.62	0.16	15
Shopping vs Leisure	0.84	0.50	0.14	13

We also tested whether the values of the other attributes varied by user type. The only significant effects were that car users value headway 20% more highly and walk and wait time 17% more highly than others.

4.7. Mode valued

With respect to the valuation of IVT by mode valued, the estimate for bus was, surprisingly, insignificantly different from the base of car travel. The only significant effect that could be discerned was that car users value bus time 18% higher than car time, presumably reflecting the less attractive travel environment. Air travel is valued 81% more highly, presumably because it is less comfortable and possibly also reflecting an element of dislike of flying. Time spent on a train is valued 13% less than car time, independent of the slight differential distance effect, and this is likely to be due to the opportunity to make use of time spent on a train and perhaps also comfort effects.

The within-study evidence is not entirely consistent with the meta-model results, as is apparent in Table 19. Whilst bus is seen to have a higher value of IVT than car, although not quite significantly so, public transport in general has a higher IVT value than car. On the other hand, train has a lower value than bus and a slightly larger value than car, *ceteris paribus*.

4.8. Numeraire

Numeraire represents the type of cost variable used in the estimation of the value of time. We distinguished toll, parking charge, fuel cost, public transport fare and various generic cost combinations. The toll effect emerged significant, denoting a valuation 21% lower all else being equal. This presumably reflects protest responses against charging for the use of road space. Although not significant at the 5% level, we have retained the fuel effect, indicating 12% higher values, since it will reflect the failure of some respondents to account for fuel cost in the decision making and hence a lower coefficient than for other costs, such as public transport fares and parking, paid for at the point of use.

4.9. Data type

A longstanding concern is the extent to which respondents' stated preference reflects their actual preferences, given the artificial nature of SP and the fact that respondents are not committed to behaving in accordance with their stated preference. The notion of strategic bias, where respondents send a protest response or aim to influence policy makers by deliberately distorting their answers, is a potentially serious problem in SP applications, whilst other forms of non-commitment bias may exist.

We might expect that any strategic bias would lead to an oversensitivity to cost, since this is the most amenable to change by operators and authorities and is the one that does most commonly change. This would lead to lower monetary values in SP than RP studies. Our findings are in line with this hypothesis. Whilst the coefficients are not estimated with a high level of precision, they are if we specify a single RP effect.

The results denote that the value of IVT is on average 22% higher in RP studies whilst the values of walk and wait time are just over 40% higher. The latter may be a combination of strategic bias and the factors discussed in relation to Table 14 regarding customisation and credibility of walk and wait times in SP exercises which leads to a larger divergence than solely for IVT.

We have identified 28 within-study cases where values of IVT are obtained from RP and SP data but are identical in other respects. The mean of the ratios of the RP and SP values of IVT is 1.33, with a standard error of 0.14. This is stronger than the finding obtained in the meta-model. However, neither are as strong as the Brownstone and Small (2005) finding of RP values of time being more than twice SP based values.

4.10. SP presentation format

There is no discernible difference in valuations according to whether the SP presentation was pen and paper, cards or computer aided. This is a reassuring finding. However, valuations from adaptive surveys and telephone surveys were found to be, respectively, 31% and 46% higher than traditional methods. Even more surprisingly, internet surveys are found to yield valuations 110% higher than traditional surveys. These figures must be interpreted with care, based as they are on very few studies, but it may well be that internet samples are not representative whilst doubts about the reliability of SP exercises

Table 19
Within-study mode IVT effects.

Valued	Ratio	Std dev	Std error	Obs
Bus vs Car	1.20	0.73	0.12	37
Train vs Car	1.08	0.72	0.13	31
PT vs Car	1.16	0.79	0.14	31
Train vs Bus	0.88	0.35	0.10	13

delivered over the phone naturally arise. Note that the highest correlation involving the SP presentation coefficients was −0.11 between the internet dummy and GDP. At a minimum, the results add further to calls for rigorous testing of these newer forms of collecting SP data.

4.11. Region

Travellers in London and the South East of England were found to have valuations 27% higher than elsewhere in the UK, presumably reflecting higher average incomes but also possibly influenced by the generally more unpleasant, crowded and congested travelling conditions. No other effects from spatial, regional or density variables could be discerned.

4.12. Other

There was no difference between the values obtained from route and abstract choice contexts, although mode choice contexts provide values which are 8% higher albeit not quite significant at the 5% level. This could be because such contexts are more familiar and realistic, although the magnitude of the effect is minor.

With respect to the number of comparisons in SP exercises, a significant, negative elasticity was obtained. It may be that as respondents become fatigued they choose to pay more attention to cost rather than time attributes. However, the effect is minor; increasing the number of comparisons from 8 to 16 would only reduce the estimated value of time by 4.6%.

4.13. Insights into study quality and fitting to conventional wisdom

A comment that is frequently made about meta-analysis is that it does not control for differences in quality across studies. More than that, there may be a tendency for studies to report models that have key parameters that accord with the 'conventional wisdom'. Note, however, that these concerns would also arise in traditional literature reviews.

As far as quality is concerned, not all studies report variances of the estimated values. Nonetheless, sample size is a reasonable proxy for precision and we used it in weighted estimation. The search for the best fit returned a model that placed almost no weight on the sample size with, as might then be expected, very little effect on the coefficient estimates and associated *t* ratios.

Where studies have estimated revised models in order to overcome 'deficiencies' or perhaps to recover models which correspond more closely with accepted evidence, we feel that there is a tendency to provide some justification for this. Common examples are the removal of individuals whose responses fail 'logic tests' or which exhibit non-trading behaviour in the sense of choosing the same option throughout. We recorded such instances and tested whether the valuations differed according to such omissions but no remotely significant effects were apparent.

Related to this is that we might suspect different incentives to revise models according to whether the purpose of the study was valuation, whereupon the relativities are more important, or forecasting, when it is the absolute coefficients that are critical. No significant difference was apparent according to the purpose of the study.

As far as we are able to detect, and on average, we conclude that there is little reason to place more weight on some evidence than other and that the results obtained from UK choice modelling studies are not a 'self-fulfilling prophecy'. We would also add that we have not removed 'outliers' from our meta-data set.

Table 20
Meta-model implied monetary values of IVT (pence/minute in Q4 2008 prices).

	Miles	Absolute values				Relative to car users' value of car IVT		
User		Bus	Rail	Car	Car	Bus	Rail	Car
Valued		Bus	Rail	Bus	Car	Bus	Rail	Bus
Commute	2	4.4	8.0	7.7	6.7	0.65	1.20	1.15
	10	5.6	10.4	10.0	9.3	0.61	1.12	1.07
	50	n/a	17.0	n/a	13.0	n/a	1.31	n/a
	100	n/a	19.0	n/a	14.9	n/a	1.27	n/a
Other	2	3.9	7.2	6.9	6.0	0.65	1.20	1.15
	10	5.1	9.3	8.9	8.4	0.61	1.12	1.07
	50	n/a	15.2	n/a	11.6	n/a	1.31	n/a
	100	n/a	17.0	n/a	13.4	n/a	1.27	n/a
	200	n/a	19.0	n/a	15.4	n/a	1.23	n/a

Note: values are for outside London and the South East, RP data, nine comparisons and other terms at their base level. n/a denotes this distance is not applicable for the mode in question.

Table 21
Implied IVT values of walk and wait time.

Walk	Miles	Car		Rail		Bus	
Wait		Walk	Wait	Walk	Wait	Walk	Wait
2	2	1.42	1.42	1.45	1.45	1.25	1.25
5		1.56	1.52	1.59	1.55	1.37	1.34
10		1.67	1.60	1.70	1.63	1.47	1.41
20		1.78	1.69	1.82	1.72	1.57	1.49
2	10	1.33	1.32	1.45	1.45	1.25	1.25
5		1.45	1.42	1.59	1.55	1.37	1.34
10		1.55	1.49	1.70	1.63	1.47	1.41
20		1.66	1.57	1.82	1.72	1.57	1.49
2	50	1.05	1.05	1.23	1.23	1.06	1.06
5		1.15	1.12	1.35	1.31	1.16	1.14
10		1.23	1.18	1.44	1.38	1.25	1.20
20		1.31	1.24	1.54	1.46	1.33	1.26
2	100	0.99	0.99	1.19	1.19	n/a	n/a
5		1.08	1.06	1.31	1.28	n/a	n/a
10		1.16	1.11	1.40	1.34	n/a	n/a
20		1.24	1.17	1.50	1.42	n/a	n/a
2	200	0.93	0.93	1.16	1.16	n/a	n/a
5		1.02	1.00	1.27	1.24	n/a	n/a
10		1.09	1.05	1.36	1.31	n/a	n/a
20		1.17	1.10	1.45	1.38	n/a	n/a

Note: valuations expressed relative to IVT for that mode.

Table 22
Implied IVT values of headway, departure time and late time.

Miles	Headway			Departure time			Late time		
	Car	Rail	Bus	Car	Rail	Bus	Car	Rail	Bus
2	0.64	0.64	0.55	0.75	0.89	0.77	3.15	3.75	3.24
10	0.60	0.64	0.55	0.70	0.89	0.77	2.93	3.75	3.24
50	0.47	0.54	0.47	0.55	0.76	0.66	1.06	1.45	1.25
100	0.45	0.53	n/a	0.52	0.74	n/a	0.87	1.23	n/a
200	0.42	0.51	n/a	0.49	0.72	n/a	0.71	1.04	n/a

Note: for employer's business, the departure time valuations would be 54% higher.

5. Illustrative outputs

Here we report some 'forecasting' applications of the meta-model which both illustrate its key properties and demonstrate its usefulness. Appendix A reports formulae for deriving valuations for rail and bus from car driver valuations, which are not uncommonly the only or most reliable evidence available, and formulae that express the valuations of walk time, wait time, headway, departure time shifts and late time as multipliers of IVT, which is standard practice.

Table 20 presents values of IVT, in 2008 quarter 4 prices and incomes, across the key dimensions. The absolute values seem quite plausible, the distance effect is apparent and seems quite sensible, particularly relative to a lot of other empirical evidence, and the mode effects also seem reasonable. The relativities indicate that there is not a great deal of difference by distance, which is in line with official recommendations in many countries, and that it is the bus market which, not surprisingly, is out of line with other markets.

Table 21 reports the multiplier values for walk and wait time, typically regarded to be twice the value of IVT. The figures include the positive RP effect and, whilst exhibiting variation across levels of walk and wait time, which slightly increase the multiplier, and across distance band, which tends to have a somewhat larger effect in the reverse direction, we observe that the multipliers are rarely close to the usual weights attached to walk and wait time. If we had not included the RP premium, the values would have been particularly low. If the logarithm of walk and wait were replaced simply with constant terms, the pattern of results would be little different.

Given the challenge of these results to conventional wisdom, and indeed the relatively low mean walk and wait multipliers reported in Tables 13 and 14, we would recommend that further research is specifically focussed on the value of walk and wait time, rather than these parameters being a secondary part of broader research projects.[5] Not only might attitudes to walk and wait time be investigated by exploratory means, but issues of non-linearity, distance, person type and walking and waiting conditions should also be explored in considerable detail.

[5] We note that few of what are termed national value of time studies deal explicitly with walk and wait time values.

Finally, Table 22 provides the IVT multipliers for headway, departure time and late time. The figures for headway and departure time shift, which exhibit a modest reduction with journey distance, seem entirely reasonable. A reduction in the late time multiplier with distance is plausible, and one that has implications for any new studies in this area, but the magnitude of the variation is rather large. The small sample size should here be borne in mind.

6. Conclusions

This paper reports what we believe is the most extensive meta-analysis of values of time yet undertaken. It covers 1749 monetary valuations obtained form 226 British studies. This includes 933 values of in-vehicle time (IVT) but, unlike many national value of time studies, the focus is not restricted to IVT. The analysis covers 210 headway values, 192 walk time values, 89 departure time shift values and 77 wait time values, with the remaining 248 observations spread across congested time, free flow time, access time, out-of-vehicle time, search time and late time.

We have made considerable use of 'grey literature' which allows us to provide a valuable account of the practice of choice modelling in the UK over 40 years. The number of valuations by type of time valuation and the types of SP presentation, methodology used, attributes per SP exercise and comparisons per SP exercise in studies since 1963 are recorded here.

The meta-model recovered a large number of significant effects and has considerable potential for wider application and to inform policy. A large number of notable findings have emerged:

- The GDP elasticity, estimated over a 45 year period, was found to be 0.9 with a relatively narrow confidence interval. It varied little across market segments and was stable over time. This justifies the widespread practice of uplifting the value of time in line with income and contrasts sharply with cross-sectional evidence which points to an income elasticity of around 0.5 and exact repeat studies which imply little or no growth in the value of time over time.
- A highly plausible and precise distance elasticity of 0.16 was recovered, with slight variations for car travel and times other than IVT. There is an indication that the value of late arrival time falls somewhat for longer distance journeys. The distance elasticity was confirmed in the very controlled, within-study, comparison of values that differed only according to distance
- Commuters were found to have values of time only slightly larger (≈10%) than other non-business travellers, *ceteris paribus*. This was confirmed by within-study evidence.
- Mode user type variations in meta-analysis largely proxy for income variations, and in that respect it is encouraging that bus users are found to have somewhat lower values of time. Nonetheless, and not surprisingly, car users value walk time, wait time and headway more highly than do public transport users. In terms of mode valued, and surprisingly, bus travel time is found to be only slightly more highly valued than for other modes. The evidence relating to relationship between car and rail is not clear cut.
- A toll numeraire reduces the value of time by just over 20%, reflecting protest responses, whilst there is evidence that valuations obtained from SP data, particularly for walk and wait time, are lower than RP based valuations. This is confirmed by within-study evidence.
- There is little variation in valuations across the main presentation formats of pen and paper, computer and cards. Some concerns, admittedly based on limited evidence, relate to internet and phone based presentations.
- Car time spent in congested traffic conditions is, on average, valued 34% more highly than time spent in free flow traffic. Whilst there are inevitably uncertainties about what type of time has been valued in studies that return generic values of car time, quite significantly our evidence indicates this to be equivalent to free flow time.
- The results seems to indicate that walk and wait time are valued at somewhat less than twice IVT, with some evidence that valuations depend upon the levels the variables take. The meta-model also provides useful insights into the valuations of departure time shift, headway and late time.

Meta-analysis is also valuable in providing insights into research needs and we make a number of recommendations for further research. Most national studies focus on the value of IVT, to the detriment of the other time values covered here. Our view is that further detailed research is needed in particular with regard to walk and wait time to investigate how these values vary with the levels they take, distance, walking and waiting conditions, person type and indeed methodological issues such as realism and method. Additionally, it would seem that the value of reliability is strongly influenced by distance. This is credible and should be used to influence further work in this area. Whilst SP is a widely accepted analytical tool, and the valuations were not greatly different from the RP values, further evidence in this area, particularly built around robust RP models, is always welcome, whilst the newer means of SP presentation, such as internet and telephone, require further validation. Finally, the conflicting evidence on income elasticities from time-series based meta-models, cross-sectional choice models and exact repeat studies warrants further investigation.

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Appendix A

Value of time formulae (see Tables A1 and A2).

Table A1
Formulae for values relative to car users' values of car IVT.

User	Valued	Formula
Rail	Rail	$D^{-0.044}e^{0.213+0.230\mathrm{Inter}}$
Bus	Bus	$D^{-0.044}e^{-0.400}$
Car	Bus	$D^{-0.044}e^{0.169}$

Note: *D* denotes distance and Inter is a journey of over 30 miles.

Table A2
Formulae for IVT valuations of walk, wait, headway, departure time shift and late time.

Formula	Car	Rail	Bus
Walk	$\mathrm{WK}^{0.098}D^{-0.044-0.042\mathrm{Inter}}e^{0.316}$	$\mathrm{WK}^{0.098}D^{-0.042\mathrm{Inter}}e^{0.303}$	$\mathrm{WK}^{0.098}D^{-0.042\mathrm{Inter}}e^{0.158}$
Wait	$\mathrm{WT}^{0.075}D^{-0.044-0.042\mathrm{Inter}}e^{0.330}$	$\mathrm{WT}^{0.075}D^{-0.042\mathrm{Inter}}e^{0.317}$	$\mathrm{WT}^{0.075}D^{-0.042\mathrm{Inter}}e^{0.172}$
Headway	$D^{-0.044-0.042\mathrm{Inter}}e^{-0.411}$	$D^{-0.042\mathrm{Inter}}e^{-0.448}$	$D^{-0.042\mathrm{Inter}}e^{-0.593}$
Depart time	$D^{-0.044-0.042\mathrm{Inter}}e^{-0.256+0.430\mathrm{EB}}$	$D^{-0.042\mathrm{Inter}}e^{-0.111+0.430\mathrm{EB}}$	$D^{-0.042\mathrm{Inter}}e^{-0.256+0.430\mathrm{EB}}$
Late	$D^{-0.044-0.243\mathrm{Inter}}e^{1.177}$	$D^{-0.243\mathrm{Inter}}e^{1.322}$	$D^{-0.243\mathrm{Inter}}e^{1.177}$

Note: mode values expressed relative to the IVT value for that mode and user type. WK and WT denote levels of walk and wait time, *D* is distance in miles, Inter denotes a journey of over 30 miles and EB is employer's business. Since there is no RP parameter relating to headway, departure time and late time, presumably due to a lack of such evidence, we have not used the RP parameter relating to IVT in the denominator. We have used it for walk and wait time where there is evidence which then enters the numerator.

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