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TECHNICAL
REPORT

Modelling Demand for Long-Distance Travel in Great Britain

Stated preference surveys to support the modelling of demand for high-speed rail

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Summary

Background

The UK Department for Transport is developing a model (LDM) to predict passenger demand for long-distance travel, which will be used to examine a number of policy interventions including demand for high-speed rail (HSR), among policies which will influence long-distance car, classic rail and air demand.

In the context of the LDM study, long-distance journeys are defined as (one-way) journeys over 50 miles.

In the summer of 2008, a study was undertaken to examine the feasibility of developing a multi-modal model of long-distance travel (Scott Wilson et al., 2008). Since then, phases 1 and 2 of model development have been undertaken, using National Travel Survey (NTS) data on long-distance travel for estimation of the travel demand model. In the Phase 2 study it was recommended that a Stated Preference (SP) study be undertaken to provide current evidence on the likely propensity of car, classic rail and air travellers to transfer to HSR, thus requiring SP surveys with car, classic rail and air travellers who have made long-distance journeys.

The specific objectives of the SP study were to:

- collect background information on a recently made long-distance journey;
- in the context of that journey, provide (parameter) values for the different service components in the mode choice modelling process that underpins the LDM demand forecasts, including:
  - values of time, and to test whether these vary differentially by mode of travel
  - cost sensitivity, and to test whether these vary by income group and distance
  - out-of-vehicle components, such as frequency, interchanges and access/egress time
  - rail service components, such as rail reliability and crowding
  - whether there exists an additional preference for HSR, over classic rail, above that which can be measured by service attributes;
- quantify where HSR fits in the modal choice hierarchy;
- collect background information on travellers' socioeconomic characteristics, attitudes and travel preferences, and quantify the impact of these on demand for HSR.

Sampling and Survey Approach

The stated preference choice exercises were based around a possible high-speed rail system linking London and Scotland via the west and east coast, with a number of intermediate stops at major cities. The survey was targeted at travellers making journeys within this corridor so that the survey could be centred on an existing long-distance journey to strengthen the realism of the choices considered. Respondents were making long-distance trips for commuting, business, visiting friends or relatives (VFR) or other leisure purposes (which when treated in combination with VFR trips are referred to as VFO) were recruited. The sample included those currently travelling by car, rail or air.

Respondents were recruited through a number of avenues:

- Rail and car travellers were recruited through a large-scale random sample of households where at least one household member had recently made a long-distance journey within the relevant corridor; the subsequent surveys were undertaken using phone-post, e-mail and internet-phone methodology.
- On-train CAPI surveys were undertaken with rail travellers.
- CAPI surveys with air travellers were undertaken at airports.
- Because of concerns that the necessary sample of car (and rail) travellers would not be met through the household survey an additional sample of telephone numbers, geographically representative of the British population, was purchased and used to recruit individuals who had made long-distance journeys by car and rail within the relevant corridor.

Quotas set for each mode were met. Table S.1 summarises the number of surveys undertaken by each methodology, for each mode of travel.

Table S.1: Breakdown of SP Interviews by Mode and Survey Approach

		Existing mode of travel			Total
		Car	Rail	Air	
Survey approach	Phone (from household survey)	838	288		1,126
	Phone (additional sample)	165	30		195
	On train		705		705
	At airport			1,019	1,019
	Total	1,003	1,023	1,019	3,045

The SP survey inclusion criterion requiring the possibility of a sensible high-speed rail option in the stated preference choice exercises made it difficult to recruit respondents who were making long-distance commute trips, for example people commuting from the South West, the South and the East to London were out of scope for the SP survey because they were not travelling within the corridor being considered. As a result only 100 commuters were interviewed (it is noted that commuting trips by air were defined as out of scope because of small numbers). Otherwise, the purpose quotas were broadly met (see Table S.2 for a breakdown of the number of interviews by mode and purpose).

Table S.2: Breakdown of SP Interviews by Mode and Trip Purpose

		Existing mode of travel			Total
		Car	Rail	Air	
Trip purpose	Employer's business	262 (26.1%)	433 (42.3%)	631 (61.9%)	1,326 (43.5%)
	Commute	25 (2.5%)	75 (7.3%)	n/a	100 (3.3%)
	VFO	716 (71.4%)	515 (50.4%)	388 (38.1%)	1,619 (53.2%)
	Total	1,003 (100%)	1,023 (100%)	1,019 (100%)	3,045 (100%)

Stated Preference Choice Exercises

Each respondent was asked to participate in two stated preference choice experiments: one relating to choices between currently available modes for long-distance travel, and one where an additional high-speed rail alternative was introduced with a varying level of service.

Respondents were asked to consider all available mode choice alternatives, simultaneously, for the journey they had been observed to make, that is a maximum of three (car, air and classic rail) in the first experiment or four (car, air, classic rail and high-speed rail) alternatives in the second experiment, plus an option to not make the journey. Respondents were not presented with alternatives that were not possible for their journeys; specifically a car alternative was not presented to respondents who did not have access to a car and an air alternative was not presented to respondents for whom air was not a sensible alternative.

Each mode alternative was described by the following attributes:

- **Journey time**: with separate components for access and egress, wait time and in-vehicle time for rail and air journeys, as well as total journey time, on the basis that reduced journey times are the main advantage of high-speed rail services, but that access and egress times are also an important consideration with respect to the attractiveness of high-speed rail.
- **Journey time variability**: measured as 'percentage of journeys that arrive within 10 minutes of expected arrival time' to be consistent with statistics collected by Train Operating Companies (TOCs), given that high-speed rail may offer significant improvements in rail time variability (and this should be measured directly in the stated preference choice experiments, rather than being incorporated in the alternative-specific constant).

- **Rail and air service frequency**: on the basis that demand for high-speed rail services may be affected by service frequency.
- **Rail interchanges**: as these may impact demand for rail services.
- **Travel cost and crowding**: travel costs were presented for either single or return journeys, and for the individual or group (depending on the conditions for the observed journey). Separate costs were presented for First and Standard class rail services, with different levels of crowding for each.

The service levels for the observed mode were based around the respondents' reported service levels. Service levels for alternative modes were based around data provided from networks. Each attribute was varied across four levels. An example of a choice scenario from the first experiment is shown in Figure S.1; respondents were asked to consider five different choice scenarios.

If the following options were available, which would you choose for your journey between Stockport and Paddington?

	Car	Air	Existing rail
Expected travel times: Time to get to train station / airport Waiting time at airport Time spent in car / train / airplane Time to get from train station / airport	 3 hours 30 mins 	 15 mins 1 hour 1 hour 30 mins	 5 mins 2 hours 30 mins 5 mins
Total Travel time	**3 hours 30 mins**	**2 hours 45 mins**	**2 hours 40 mins**
Percentage of trips "on time" (arrive within 10 mins of expected arrival time)	**90% on time**	**90% on time**	**85% on time**
Service frequency		**One flight every 2 hours**	**One train every 20 mins**
Interchanges			**Need to make 1 interchange**
Total travel cost and crowding	**£37 return**	**£113 return** **All seats will be taken**	*Standard class:* **£88 return** **You will have a seat, but others will be standing around you** *First class:* **£154 return** **3 in every 6 seats will be taken**
Which would you use for your journey?	☐	☐	☐ *Standard* ☐ *First*
Or do not make journey	☐		

Figure S.1: Introduction and example choice screen for Experiment 1, all existing modes

The second choice experiment presented options between existing modes and a high-speed rail alternative. For the new HSR alternative, respondents were told what their 'best' HSR station pair would be based on the minimum total HSR journey time from their given origin and to their destination. They were then presented with the likely car and public transport (PT) access and egress times and asked to indicate which mode they would use to access the HSR service. The HSR in-vehicle times presented were based around a working assumption of an HSR operating speed of 300 km/hour, but were then varied significantly within the stated preference choice scenarios to cover a wide range of possible travel times and speeds.

Each respondent was presented with seven choice scenarios in the second experiment. An example of this experiment is shown in Figure S.2

If the following options were available, which would you choose for your journey between Stockport and Paddington?

	Car	Air	Existing rail	High speed rail
Expected travel times: Time to get to train station / airport Waiting time at airport Time spent in car / train / airplane Time to get from train station / airport	3 hours 30 mins	15 mins 1 hour 1 hour 30 mins	5 mins 2 hours 30 mins 5 mins	15 mins 1 hour 10 mins 10 mins
Total Travel time	**3 hours 30 mins**	**2 hours 45 mins**	**2 hours 40 mins**	**1 hour 35 mins**
Percentage of trips "on time" (arrive within 10 mins of expected arrival time)	**90% on time**	**90% on time**	**85% on time**	**99% on time**
Service frequency		**One flight every 2 hours**	**One train every 20 mins**	**One train every 30 mins**
Interchanges			**Need to make 1 interchange**	**Need to make 2 interchanges**
Total travel cost and crowding	**£37 return**	**£113 return** **All seats will be taken**	*Standard class:* **£88 return** **You will have a seat, but others will be standing around you** *First class:* **£154 return** **3 in every 6 seats will be taken**	*Standard class:* **£130 return** **4 in every 6 seats will be taken** *First class:* **£227 return** **4 in every 6 seats will be taken**
Which would you use for your journey?	☐	☐	☐ *Standard* ☐ *First*	☐ *Standard* ☐ *First*

Or do not make journey	☐

Figure S.2: Introduction and Example Choice Screen for Experiment 2, All Existing Modes Plus High-speed Rail Alternative

The order of the alternatives in both experiments was varied across respondents (although the order for each individual respondent remained the same), in order to control for potential ordering bias in the responses. The order of the attributes was not varied between respondents.

Because of the complexity of the experiments, direct questions were included in the survey to examine whether respondents were able to undertake the choice experiments. Nearly all (99.2%) of the survey respondents indicated that they were able to undertake the choice exercises, with only 23 of the 3,045 respondents reporting problems. These 23 respondents have been excluded from the choice modelling.

Before developing the models we examined how respondents traded between options within the choice experiments (whether they ever switched away from their existing mode of travel). This analysis revealed that there is a higher propensity for travellers to stay with their existing mode of travel in the first experiment, with more trading, particularly to the high-speed rail alternative, particularly for rail users, in the second experiment (see Table S.3).

Table S.3: Trading Exhibited by Respondents in SP Exercises

		Existing mode of travel		
		Car	Rail	Air
Trading	Stay with existing mode in Experiment 1	67%	48%	78%
	Stay with existing mode in Experiment 2	57%	15%	61%
	Stay with existing mode in both experiments	53%	11%	58%

The Choice Model Results

Discrete choice models are used to gain insight into what drives the decisions that individuals make when faced with a number of alternatives. These models are constructed by specifying the range of alternatives that were available to the traveller, describing each of these alternatives with a utility equation which reflects the attractiveness of the alternative by attaching a weight to the levels of each of the attributes that were present in the choice that they faced. Thus each term in the model is multiplied by a coefficient which reflects the size of its impact on the decision-making process (Ben-Akiva and Lerman, 1985).

A summary of the attributes presented for each mode in the SP choice experiments is shown in Table S.4

Table S.4: Attributes Examined in SP Choice Experiments

<table>
<tr><th></th><th>Car</th><th>Air</th><th>Rail</th><th>HSR</th></tr>
<tr><td>Time to get to train station or airport</td><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Waiting time at airport</td><td></td><td>✓</td><td></td><td></td></tr>
<tr><td>Time spent in car, train or airplane</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Time to get from train station or airport</td><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Percentage of trips “on time”</td><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Service frequency</td><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Interchanges</td><td></td><td></td><td>✓</td><td>✓</td></tr>
<tr><td>Crowding (rail had separate crowding by class)</td><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Total travel cost (standard class)</td><td rowspan="2">✓</td><td rowspan="2">✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Total travel cost (first class)</td><td>✓</td><td>✓</td></tr>
</table>

The SP model was set up to work with one-way trips on the basis that this most closely corresponded to what was presented to respondents in the choice experiments (one-way journey times were presented, along with return journey costs). Return travel costs are therefore divided by two for the modelling so that the journey times and costs both reflect one-way journeys.

The models have been set up to reflect choices for individuals, rather than travelling parties, and costs reflect per person costs to maintain consistency with models being developed in parallel to this work using revealed preference (RP) information.

Cases where the respondent has chosen the ‘not to travel’ alternative in a given scenario have been dropped from the models. This decision led to the exclusion of only 1% of the choice data from the model estimation, but substantially improved model run times and model convergence while having little impact on the results.

In the choice exercises the order of alternatives was varied between respondents to reduce ordering bias. The models incorporated position terms to take account of any possible ordering biases. These were not found to be statistically significant, but have been retained to provide transparency on this aspect of the design and modelling.

Initially, separate models were estimated for long-distance commute, employer's business and visiting friends and relatives (VFR) and other travel. VFR and other travel were combined at an early stage of model development on the basis that many of the terms were not significantly different between the segments; throughout the rest of the report the models estimated for VFR and other travel are referred to as VFO travel.

The models were initially developed using the simplified assumption that the observations within the dataset are independent (although we know that this is not true with SP data in which multiple responses are provided by the same respondent). However, this simplifying assumption allows considerably shorter run times during model development and the parameter estimates that are made are consistent, though the estimated errors are smaller than the true errors. The final models then correctly take into account the repeated measures nature of the SP data by applying the bootstrap re-sampling procedure to obtain correct error estimates.

The data collected in this study have supported the estimation of models with well-estimated coefficients in which the importance of each of the relevant attributes is taken into account. The key findings are discussed below.

Values of Time and Cost Sensitivity

The model results provide substantial evidence that sensitivity to travel cost on mode choices varies depending on the purpose of travel, household income and the cost level (that is the sensitivity to a unit change in cost diminishes as costs increase).

In the model estimation procedure, linear and logarithmic (damped) cost functions were tested. The models providing the best fit to the SP data have a series of logarithmic cost terms that vary by income indicating that those from lower income households exhibit greater cost sensitivity than those from higher income households. With this specification no statistically significant linear cost component was found once the repeated measures nature of the SP data was taken in to account. This formulation does, however, bring challenges, as it was found to lead to low demand elasticities when applied within the wider model system. This area would benefit from further research.

We find there is evidence of differences in the disutility of travel time between modes. For employer's business and VFO travel we see evidence that the disutility of travelling by car, per minute, is higher than when travelling by other modes of transport, possibly reflecting the greater opportunities for working, reading or carrying out other activities when travelling by train and airplane, compared with travelling by car. For commuting, the disutility of travelling by car is less per minute than for rail and HSR, which may be a result of higher crowding levels on commuter rail services.

It is important to recognise that the implied values of time can be influenced by differences in the sensitivity of respondents to changes in travel time and to changes in travel cost. Of particular note in this study are the non-linearities captured in the formulation of the cost functions, which imply that values of time increase as journey costs increase. As a result we find that modes with higher mean journey costs – air and rail – have higher mean values of time. We also see substantially higher values for time for higher income households.

In Chapter 4 we illustrate the variation in values of time by plotting the values against journey cost. We also show the cumulative distribution of observed journey costs by mode to provide information on observed cost levels (by mode). Values of time also vary by household income and therefore separate plots are presented for different household income categories.

Values Placed on Out-of-vehicle Components

From the models we can quantify the value travellers place on different service attributes.

We see values of access/egress time of between one and two times the value of in-vehicle time. This is somewhat less than the weight recommended in the Passenger Demand Forecasting Handbook, which recommends a weight of 2.

As anticipated, travellers attach a negative weight to interchanges, particularly those travelling for visiting friends and relatives or other leisure, who typically have larger party sizes (sometimes with children). It is interesting to note that the weights for these long-distance trips are not as large as those generally recommended in the Passenger Demand Forecasting Handbook.

The models also allow a valuation of service frequency and airport wait times in values of equivalent minutes of in-vehicle journey time.

Value of Rail Crowding and Reliability

Long-distance commuters did not respond to crowding levels in the choice exercises until high crowding levels were presented. At this point crowding had an impact on their choices (influencing mode or rail class choices). The resulting crowding penalty for high crowding levels is equivalent to 19 minutes of journey time. It was not possible to discern different crowding penalties for more crowded situations, specifically to distinguish between conditions where others were standing or the individual was required to stand. This may be because of the relatively small number of commute observations in the SP survey sample.

Similarly, those travelling for employer's business did not respond to crowding levels until five out of six, or all seats, were taken. This level of crowding was equivalent to a 9-minute journey time penalty. The penalties increased substantially with increased crowding levels for business travellers. Specifically, situations where others were standing, but the respondent had a seat, were equivalent to a 26-minute journey time penalty. Situations where the respondent had to stand had even higher penalties: equivalent to 45 minutes of journey time if the respondent had not planned to work and 69 minutes of journey time if they had planned to work.

Respondents who were travelling for other leisure or to visit friends or relatives did not respond to crowding levels until the level where they would have to stand for some of the journey, which equated to a 77-minute journey time penalty.

We observe that service reliability is most important to long-distance commuters, valued at nearly 2 minutes for each one-point change in the percentage of trips on time. Values from employer's business and VFO are lower, around 1 minute for each percentage point change in trips on time, but this was still a significant effect.

The Benefits of Being Able to Make a Return Journey in a Day

For long-distance business and VFO travellers we observe a large and positive constant on modes (and to destinations) if the return journey can be made in 1 day (measured by whether the return journey can be made in 6 hours or less), presumably because of convenience and potential savings on overnight stays. This constant applies to all modes, but may be of particular importance in explaining the potential for HSR to compete for mode share for those journeys that currently have longer travel times that make a return trip within one day difficult. This effect may have been confounded with HSR constants in previous studies. The resulting values, in minutes of in-vehicle rail time, are presented in Table S.5.

Table S.5: Value of Being Able to Make a Return Journey in a Day

Purpose	Value of being able to make a return journey in a day (mins of rail in-vehicle time)
Commute	n/a
Employer's business	45
VFO	77

Socio-economic Differences in Modal Preferences

We have found a number of factors that influence travellers' propensity to choose specific modes, over and above the differences in level of service that specific modes provide. These are summarised in Table S.6 (a '+' sign indicates traveller segments that are more likely to use a specific mode, a '–' sign indicates traveller segments that are less likely to use a specific mode).

Table S.6: Socio-economic Differences in Modal Preferences

	Employer's business	VFO
HSR		
Infrequently/never use rail services	–	–
Travel by rail more than once a week	+	
Infrequently make long-distance trip		+
Employer pays	+	
Don't have luggage	+	
Aged 16–29		+
Aged 45 and older	–	
Air		
Female preference for air travel	+	
Duration 3 nights or less		+
Car		
Travellers who use rail less than once a year or never		+
Aged 30–44, making journeys for 'holiday' or 'other'		+

We do not observe any socio-economic differences in modal preferences for those making commute journeys – this is likely to be related to the small sample for commute.

Conclusions on HSR Mode-specific Constants

The research also provides useful insight into whether there exists an additional preference for HSR over classic rail. The structure of the stated preference exercises allowed other attributes (such as reliability and crowding), which may have been confounded in mode-specific constants in previous studies, to be taken into account and isolated. Moreover the more frequent use of modern rolling stock on conventional rail services means that comfort differences can now be excluded.

The models suggest that the value placed on HSR, over and above conventional rail, differs significantly depending on what mode of travel the respondent was using for their journey. For rail users we find weak evidence for any value placed on the 'HSR' branding of the faster train services, and any mode-switching in the SP experiment for these respondents is a result of differences in level of service (shorter travel times outweighing higher travel costs, with the ability to make a return in a day acting as a significant factor). For those currently travelling by car and air we do find a positive and significant constant on HSR; however, it is not clear to what extent this is an artefact of the SP experiment – the HSR option may sound attractive on paper, but respondents may not accurately perceive how this differs (or does not differ) from existing rail options.

We therefore conclude that the HSR constants estimated for the rail users are more credible than those from other respondents, and that an additional constant on HSR over and above that applied to conventional rail should not be included in the forecasting models.

The Location of HSR in the Modal Choice Hierarchy

A range of nesting structures was also tested in the model development. The introduction of these structures accounts for correlation in the error between alternatives and reflects different substitution patterns between alternatives such that:

- for any two alternatives that are in the same nest, the ratio of the probabilities is independent of the attributes or existence of all other alternatives; and
- for any two alternatives in different nests, the ratio of the probabilities can depend on the attributes of the other alternatives in the two nests (Train, 2003).

A key issue for this study was to examine whether there are differences in substitution between different modes. The evidence produced through this study suggests that HSR should be modelled in the same nest as conventional rail, which is then included in a further public transport nest with air, as shown in Figure S.3 below.

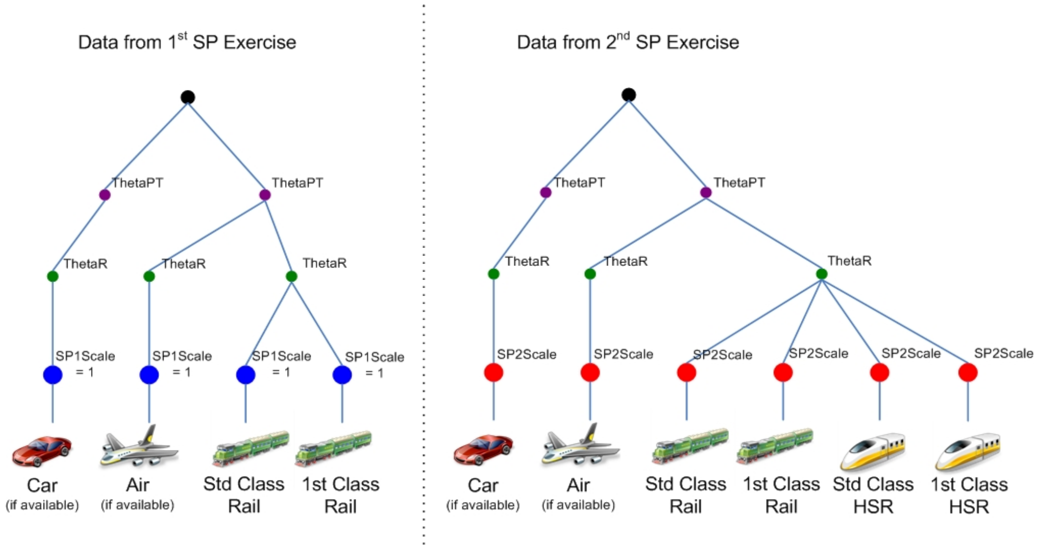

Figure S.3: SP Tree Structure

Within the rail alternatives there was also a consideration of class of travel. Models were estimated to explore whether there were benefits to be gained from nesting class above or below the rail mode (classic rail or HSR). These model tests suggested that there was no significant gain in model fit, and the substitution patterns for the four alternatives of standard classic rail, first class classic rail, standard HSR and first class HSR were best represented by including all four alternatives at the same level of the nest, in a multinomial structure, with an additional constant applied on the first class alternatives.

The evidence from this research implies that there are in principle higher cross-elasticities between rail and HSR and between public transport modes (rail, HSR and air, where relevant) than between public transport modes and car. However, the parameters themselves only tell part of the story: the overall scale of the different responses will also depend on observed market shares, availability of alternatives and so on, so the attribution of the size of response to each specific mechanism has to be made on the basis of model tests.

The SP models that have been developed through this study provide new important evidence to inform the parameterisation of models that may seek to incorporate high-speed rail as a potential new mode. The findings both update the existing evidence base, and add some additional dimensions of sophistication to provide a more nuanced understanding of the likely drivers of demand for HSR within the context of a hypothetical north–south HSR service.