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TECHNICAL
REPORT

Comparison of the Long-Distance Model and PLANET Long-Distance

Phase 2, Demand Model

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Preface

High Speed Two Limited (HS2) was established in January 2009 to investigate the feasibility and credibility of building new high-speed rail (HSR) lines between London and Scotland. During 2009, HS2 developed a modelling framework for the assessment of high-speed rail options and, given the time available, the framework had to be based on an existing set of models. The PLANET suite was selected as a suitable set of models to assess different high-speed rail options.

The core of this model is PLANET Long-Distance (PLD), which is an updated version of the PLANET strategic model developed for the Strategic Rail Authority (SRA) in 2001–03. PLD is a multi-modal model of all-day travel across Great Britain that focuses on long-distance travel demand, considering rail, car and air travel for trips selected to cover the market for the current HSR proposals. It is a trip-based incremental model, forecasting changes in travel demand as a result of an intervention relative to an exogenously-defined future do minimum matrix.

The Long-Distance Model (LDM) was developed on behalf of the Department for Transport (DfT). It is a multi-modal all-day model of long-distance travel demand that covers all of Great Britain. Long-distance demand is defined as trips more than 50 miles in length. The LDM is designed to be able to assess the impact of policies on all four existing modes used for long-distance travel (rail, car, air and coach) and is able to predict demand for HSR drawing on information from stated preference surveys collected during December 2009 and January 2010. The LDM is a tour-based model that is applied absolutely to base and future scenarios to pivot off base matrices.

HS2 has commissioned two phases of work to compare the growth rate and demand model predictions from the PLD and LDM models, and to recommend how these should be handled in future HS2 analysis. Phase 1 is a comparison of the levels of growth in long-distance rail, car and air trips predicted by the two models between 2008 and 2021, and is reported separately. Phase 2 is a detailed comparison of the predicted demand for HSR in a scenario in which HSR is assumed to be available in the 2008 base year with a base-year comparison, so there is no impact of differential growth in trips over time. These phases were preceded by work undertaken in Phase 0, which delivered inputs necessary to the Phase 1 and 2 work. The Phase 2 work is reported in this document.

This document should be of interest to readers interested in the models available to HS2 and the DfT for predicting demand for high-speed rail schemes and other transport projects. Sections of the document are technical in nature, and some familiarity with transport modelling terminology is assumed.

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Abbreviations

CA:	car available
CAT:	classic access time
CO:	car-owning
DfT:	Department for Transport
GJT:	generalised journey time
HSR:	high-speed rail
IVT:	in-vehicle time
LDM:	long-distance model
LOS:	level of service
NCA:	no car available
NCO:	non-car-owning
NRTS:	National Rail Travel Survey
OD:	origin-destination
P/A:	production/attraction
PDFH:	Passenger Demand Forecasting Handbook
PLD:	PLANET Long-Distance
PT:	public transport
RP:	revealed preference
SAC:	station-access cost
SP:	stated preference
VFR:	visiting friends or relatives
VOT:	value of time
XLDM:	incremental spreadsheet application of LDM
XLDMA:	incremental spreadsheet application of LDM, assignment choice between high speed rail and classic rail

XLDMC: incremental spreadsheet application of LDM, continuous (probabilistic) choice between high speed rail and classic rail

XPLD: incremental spreadsheet application of PLD

Y-network: the extended HS2 network from London to Manchester and Leeds via Birmingham

Subscripts used for lambda values

D: destination choice

R: choice between classic rail and HSR

PT: choice of public transport mode

M: choice of mode between public transport and car

F: frequency choice

Summary

High Speed Two Limited (HS2) was established in January 2009 to investigate the feasibility and credibility of building new high-speed rail (HSR) lines between London and Scotland. During 2009, HS2 developed a modelling framework for the assessment of high-speed rail options and, given the time available, the framework had to be based on an existing set of models. The PLANET suite was selected as a suitable set of models to assess different high-speed rail options.

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Below we summarise the structure of the incremental applications of LDM and PLD before going on to discuss the comparison between their predictions, additional PLD analysis and detailed analysis to compare the models at the production/attraction (P/A) level.

Incremental application of LDM

The reduced-segmentation versions of the LDM frequency, mode and destination choice models have been implemented in incremental form as an Excel spreadsheet that uses Visual Basic macros to implement the incremental model code. The incremental model, termed XLDM, predicts demand for HSR from P/A trip matrices split by mode, purpose and segment that are output from a base-year run of the LDM. Changes in generalised cost resulting from the introduction of HSR are calculated from level of service (LOS) supplied from 2008 base-year runs of the LDM. The 2008 base (without HSR) run is used to output classic rail LOS, and the 2008 with HSR Y-network run is used to output HSR LOS. All calculations are undertaken using the 406-district zoning system used in the LDM.

Two versions of XLDM have been implemented. The first predicts HSR versus classic rail choice as a probabilistic choice, consistent with how the original LDM model was estimated and implemented. The second predicts the HSR versus classic rail choice on the basis of minimum generalised cost. The second implementation does not correct the parameters to take account of the different calculations that are made in the minimum generalised cost version and consequently the generation and mode switch effects are always lower than in the choice-model version. If such a structure were to be used for forecasting, correction to the parameters would be required.

The total demand for HSR in 2008 predicted by the probabilistic version of XLDM has been compared with the HSR demand predicted by URS Scott Wilson when it applies the reduced-segmentation versions of the LDM models in absolute form. Total HSR trips match very closely for commute and visiting friends or relatives (VFR) /other, and closely for business.

Incremental application of PLD

The PLD mode-choice models have also been implemented as an Excel spreadsheet containing Visual Basic macros to implement the incremental model code. The incremental application, termed XPLD, uses the PLD model parameters (in 2008 values), and applies these parameters to LOS changes output from the reduced-segmentation version of the LDM to calculate changes in generalised cost, and then applies the changes in generalised cost to calculate changes in trips relative to the long-distance P/A trip matrices output from the LDM.

Important implications of this approach are that changes are forecast relative to LDM, rather than PLD base-matrix totals and on the basis of changes in LOS taken from LDM rather than from PLD. The LDM base matrices use the simpler LDM definition of a long-distance trip as all trips greater than 50 miles in length, rather than the more complex definition used in PLD.

When XPLD is used to predict demand for HSR, total demand for HSR is around half the level Atkins predicts when it forecasts 2008 HSR demand for the Y-network in real PLD, with the largest difference in trips between the two approaches observed for the VFR/other purpose. Tests demonstrated that the PLD predicted demand for HSR was highly sensitive to the values of HSR generalised access/egress time, and so differences in the definition of LOS between LDM and PLD are judged to be a significant factor in the substantial difference in total HSR trips.

Comparison of XLDM and XPLD predictions

During detailed validation of the XLDM model, it was discovered that some of the assumptions regarding HSR generalised access/egress could be improved: specifically the interchange penalty was high and the access legs to the first station were not weighted in a consistent way compared to classic rail as a main mode.

Enhanced HSR generalised access/egress LOS was generated with improved assumptions. This had only a minor impact on predicted demand for HSR in both XLDM and XPLD, with the effects of the two changes cancelling one another out, but nonetheless the enhanced LOS is taken to be a better definition and so was used for all subsequent comparisons.

The total demand predicted for HSR in a hypothetical 2008 situation is 96,700 trips per day in the XLDM probabilistic model, 86,100 in the XLDM minimum generalised cost model and 61,600 in XPLD. Checks for individual production zones suggest XLDM and XPLD demands are reasonably consistent in production zones with good access to HSR, but that XPLD demand for VFR/other travel may be lower for production zones where access to HSR is more difficult.

In terms of the composition of HSR demand, the probabilistic version of LDM predicts significantly higher levels of generation than PLD, in particular for business. For all purposes, the LDM frequency response is more sensitive than PLD. It is noted that the LDM frequency parameters are estimated from observations of long-distance travel and include switching from shorter distances, whereas in PLD the frequency response is assumed to be one-third as sensitive as the next-level choice in the structure, based on professional experience; it is not clear that the PLD parameters are specifically based on long-distance travel or are drawn from contexts in which destination-switching is excluded.

The sensitivity of the LDM business model to frequency changes is relatively high, so that the generation response comprises 45 percent of total demand. A recommendation from this study is that the model structure for the LDM business model is reviewed if further model development work is undertaken; this review should look for evidence from other HSR schemes on the proportion of HSR demand for business that comes from generation.

If the LDM model is applied using the minimum generalised cost approach for HSR/classic rail choice, the proportion of HSR demand from generation is significantly reduced, whereas the proportion of classic rail capture is significantly increased. Therefore **the choice of modelling approach for the classic rail versus HSR choice has a significant impact on the composition of the predicted demand for HSR**. It is noted that proportions of generation and classic capture in the minimum generalised cost version of LDM are in line with those predicted by PLD. The significant changes in the composition of demand observed for the LDM model indicate that the model should be recalibrated if the approach for modelling HSR/classic rail choice is revised to minimum generalised cost.

Analysis has been made to examine the role of redistribution in the LDM predictions, which is done by distinguishing HSR demand from generation, redistribution from other zones summed across all modes, and pure-mode capture from the same destination. **The**

analysis runs demonstrate that redistribution makes a significant contribution in the LDM model, accounting for 20 to 40 percent of total HSR demand.

HSR fare elasticities have been run for all three sets of models, applying a 10 percent increase in HSR fare. **The elasticities in LDM are relatively high, with a total fare elasticity of -1.3. However, significantly higher elasticities are obtained if the LDM model is run with the minimum generalised cost approach, and the elasticities are higher still in PLD, with a total fare elasticity of -4.6.** This analysis demonstrates a significant reassignment effect to classic rail. Nonetheless the mode-choice fare elasticity is above two, demonstrating the predicted demand for HSR to be highly sensitive to the no-premium-fare assumption.

On the basis of the HSR access/egress time sensitivity tests and the HSR fare elasticity runs, **it is recommended that sensitivity tests should be run for the full PLD HS2 model to assess the sensitivity of predicted HSR demand to changes in modelled HSR costs and times.**

Additional PLD analysis

Following discussion at a technical meeting held on 10 January 2012 at HS2's offices, a series of additional analyses were run with the objective of understanding why the spreadsheet implementation of PLD (XPLD) predicts much lower levels of HSR demand than real PLD.

Comparison of the PLD and LDM rail cost skims in the base case without HSR demonstrated consistency in rail in-vehicle times. However, other components showed significant differences. In particular mean access/egress times are substantially higher in real PLD (given that the weighting of four was not applied we are not clear why this is the case); the PLD network skims have less frequent services; and the number of interchanges is substantially lower.

When the *difference* in cost skims that results from the introduction of HSR was calculated, the key difference was in access/egress times. In the with-HSR case, in PLD access to HSR services by classic rail forms part of rail in-vehicle time whereas, in the LDM-derived LOS access by classic rail forms part of access/egress time. Access/egress time is weighted by four in the generalised journey time calculation that determines the choice between classic rail and HSR, and as a result in XPLD, which uses PLD-derived LOS, HSR is predicted for a lower proportion of P/A pairs, specifically P/A pairs where the access legs to HSR are short.

The impact of mode-choice iteration on the levels of demand predicted for HSR in PLD was investigated.[1] The results suggest slightly higher HSR demand would be obtained if results from the first, rather the final, mode-choice iteration were used. However, this effect appears to be small.

The operation of XPLD was revised following the technical meeting. The key change was to change the choice between classic rail and HSR to use generalised journey time to

[1] When PLD is run, there is iteration between the mode-choice model, and the assignment models. Changes in the skims from the assignment models impact on the predicted mode choices, and so an iterative process is required in order to reach a point where demand and supply levels are in equilibrium.

mimic the calculation applied in the real-PLD rail assignment. This change has resulted in the total level of HSR demand predicted by XPLD falling further, from around half the real-PLD value to under 30 percent of the real-PLD value. This reduction follows from the high weight of four applied to access/egress time in the generalised journey time calculation.

Analysis of six test P/A pairs demonstrated significantly higher levels of base rail demand in PLD than in the LDM synthetic base matrices used for this work. The PLD base matrices are likely to be of higher quality than the synthetic LDM base matrices used in XPLD. These differences in base-matrix totals contribute to higher total rail demand in PLD for P/A pairs where both XPLD and PLD predict demand for HSR.

Multi-routing, whereby a proportion of rail demand between a P/A pair uses HSR at some point in the journey and a proportion uses classic rail for the entire journey, plays an important role in the real-PLD rail assignment. XPLD predicts demand for HSR as an all-or-nothing choice and so cannot emulate real-PLD behaviour for P/A pairs where multi-routing occurs. However, because the split in the multi-routing is balanced between cases with more and less than 50 percent of demand assigned to HSR, it is likely that the net effect of multi-routing is small.

It is our view that the different treatments of HSR between PLD and LDM, with HSR choice determined as an assignment choice within a single rail network in the former, and on the basis of completely separate HSR network with classic rail as an access mode in the latter, mean that it is not possible for XPLD to emulate the real-PLD results using the LDM-based LOS. If the LDM-based LOS were to be revised to achieve greater consistency in the treatment of access time between classic rail and HSR, then a better correspondence between XPLD and real-PLD predictions for HSR would be expected.

Finally, it should be emphasised that the issue of low predicted HSR demand relates to the application of LDM-based LOS in XPLD. The levels of demand predicted for HSR in the real version of LDM are much more consistent with those predicted in PLD.

Additional P/A pair analysis

Following discussion at the project steering group meeting on 20 February 2012 at HS2's offices, additional analysis was undertaken to compare the XLDM and XPLD models for individual P/A pairs. To facilitate comparison between the two models, these tests were made assuming HSR was introduced for individual P/A pairs offering 0, 15 and 30 minute time savings relative to classic rail.

Comparison of the continuous HSR/classic choice version of XLDM (XLDMC) and the assignment version of XLDM (XLDMA) demonstrated that XLDMC gives much larger mode shift and generation effects. Detailed investigations to understand these differences showed the main cause of the increased mode shift and generation effects to be the 'diversity benefit' that results from the addition of a new alternative when HSR is introduced into the LDM system.

The diversity benefit is large in minutes because of the small lambda values in the LDM, a consequence of the long tour lengths for long-distance travel. In XLDMA and XPLD there is no diversity benefit resulting from the introduction of HSR, despite the fact there would be a frequency benefit and in many cases a benefit arising from diversity of access points.

The XLDMA and XPLD models gave broadly similar results, with demand for HSR dominated by capture from classic rail. XPLD is more sensitive for generation and capture from modes other than rail, but XLDMA gives higher rail capture due to some capture from other destinations.

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CHAPTER 1 Introduction

1.1 Background

The comparison of the LDM and PLD models was undertaken in three phases:

Phase 0	preliminary extraction of data from LDM and PLD during which RAND Europe supported URS Scott Wilson in its work to extract the required data from LDM and Atkins extracted the required data from PLD
Phase 1	comparison of LDM and PLD growth rates, the work being led by URS Scott Wilson with RAND Europe acting as expert advisors to support the work
Phase 2	comparison of LDM and PLD demand for HSR in the 2008 base year (the work documented in this report). RAND Europe led this work with expert input from URS Scott Wilson.

The detailed requirements for the Phase 2 work are discussed further in the following section.

1.2 Comparison of demand models

To enable a comparison of the LDM and PLD demand models, the PLD demand model and the relevant parts of the LDM model – specifically the mode, destination and frequency models, as well as the choice between HSR and classic rail – have been programmed in a spreadsheet system. In both cases, the models have been implemented in incremental logit form. This is the standard methodology used for PLD, though the software is new, but for LDM more substantial changes to the model were required for it to work in an incremental form. These changes are documented in Chapter 2.

To ensure as much consistency as possible, the segmentation of the LDM frequency-mode-destination models has been reduced to income, car ownership and purpose only, with average values calculated for other segmentation variables during the Phase 0 work. It is noted that the PLD model does not incorporate segmentation by income, but it was not practical to remove the income segmentation from the LDM without fundamentally changing the operation of the model, as income plays an important role in the frequency, mode and destination choices and is a key dimension for reporting results.

Base matrices split by mode, purpose and segment (car ownership and income) were output from the LDM during the Phase 0 work, using the 406-zone structure of the

LDM. These matrices have been supplied on a P/A basis, in units of tours multiplied by two so that the matrices sum to trips. These P/A trip matrices form the basis for the incremental application of both the LDM and PLD models. Maintaining the matrices in P/A trip format for the model comparisons enables analysis to be made of differences in productions by individual home zones, and by production and attraction regions. It is noted that in order to allow segmentation by income, the 'base matrices' for this work have been defined from the synthetic matrices obtained from applying the LDM model in the base year, rather than from the base matrices used in the LDM assignments. This means that the income-segmented base matrices used in this work are not the base matrices used for forecasting when the real version of LDM is applied. (The LDM is an incremental model which pivots off matrices of base-year demand.)

To perform the demand comparisons, the only changes tested were those that result from adding a notional 2008 HSR scheme, using a service specification defined in the Phase 0 work for a Y-network. By applying the HSR scheme in the base year, assuming HSR to be immediately available, the impact of differential growth over time between LDM and PLD is eliminated from the demand comparisons. For testing purposes, we also made some other notional changes, as reported below.

An important consideration in formulating the model parameters to be applied in the incremental models was that the normalisation approach used should be consistent between the two models.[2] The PLD model uses the normalised (RU2) formulation, whereas the original LDM parameters are specified using the non-normalised (RU1) formulation. We used the RU2 formulation in the incremental models, consistent with the equations set out in Annex B of the brief. This meant that the PLD parameters could be used without modification, but that the LDM parameters needed to be converted from RU1 to RU2 form. Section 2.1 documents how the modified RU2 parameters were determined for the incremental application of the LDM model.

For the LDM model, the standard approach for allocating rail demand between HSR and classic rail is to apply a logit choice model. By contrast, PLD allocates rail demand between HSR and classic rail in the EMME assignment on the basis of minimum generalised cost. To investigate the impact of these two different approaches, the LDM incremental model has been coded so that it is able to produce forecasts of demand for HSR using both the existing logit approach, and on the basis of minimum generalised cost.[3] Results from the two approaches are then compared to investigate the impact this choice has on the predicted demand for HSR services.

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[2] Nested logit models are widely used for travel demand analysis. The nested logit model allows asymmetry among the alternatives. This generalisation is obtained by introducing additional parameters into the structure which express the ratio of the standard errors of utility between alternatives in different subsets. However, there is no unique way to parameterise these ratios. Two approaches have been used, called RU1 and RU2. It has been shown that RU2 is always consistent with Random Utility Theory, whereas RU1 may require constraints or extensions to the model to make it so. Please see Daly and Patil (2010) for more details.

[3] It should be noted that that this coding of the LDM is not consistent with the model estimations that have been made and should be considered only as an illustration of the likely impact of the differences between logit choice models and assignment models. The LDM would have to be re-estimated if it were decided to adopt the assignment approach for real forecasting work.

Differences between the LDM and PLD demand models have had an important impact upon the tests that have been run. Table 1 highlights some of the key differences between the two models, the implications that these differences have had for the comparisons presented in this report and a reference to the sections of this report where these issues are discussed further.

Table 1: Key differences between LDM and PLD demand models

Feature	LDM	PLD	Implications	Section
Zone system	406 zones (districts)	235 zones (PLD zoning aggregates to LDM zoning)	XLDM and XPLD both work with LDM zoning system. Comparison of XPLD to real PLD is only possible for zones where LDM and PLD zones map one-to-one.	Detailed P/A comparisons: 5.2, 5.3, 5.4, Chapter 6
Car ownership/ availability segmentation	Segments into NCO & CO. Car and air demand predicted for CO segment.	Segments into NCA & CA. No car or air demand predicted for CA segment.	In XPLD, base-matrix air and rail demand from the NCO segment is shifted into the CO segment.	XLDM: 2.3 XPLD: 3.3
Income segmentation	5 segments	No segmentation	XLDM is applied separately by income band, then aggregated for comparison with XPLD. LDM can predict demand for HSR by income band.	LDM results by income band: 4.4
Treatment of coach	Modelled	Not modelled	XPLD does not forecast demand for coach.	XPLD: 3.3
Normalisation	RU1	RU2	LDM parameters are converted to RU2 form for XLDM.	Conversion to RU2: 2.1 Comparison of RU2 parameters: 3.2
HSR/classic rail choice	Probabilistic choice in mode-choice model	Choice is made in assignment, not the demand model.	Both probabilistic and assignment versions of XLDM to facilitate comparison with XPLD. Diversity benefit from the introduction of the new HSR mode in LDM	Comparison of XLDM and XPLD results: 4.2 Discussion of the diversity benefit issue: 6.2
Treatment of access/egress to HSR	HSR stations are modelled as if airports and classic rail forms an access mode.	HSR is modelled within the rail network, thus classic rail is not an access mode.	When XPLD is applied, predicted demand for HSR is much lower than in real PLD because weighting of classic rail access means it is chosen for far fewer P/A pairs.	Improvements to LDM assumptions: 2.3, Appendix B Comparison of XPLD and real PLD: 3.4
Treatment of access/egress to classic rail	Different treatment of HSR access	Consistent with HSR	When XPLD is applied using LDM LOS for classic rail and LOS, results are inconsistent with real PLD.	LDM assumptions: 2.3, Appendix B

CHAPTER 2 Incremental application of LDM

The incremental application of the LDM follows the detailed procedure set out in Annex B of the brief, which is reproduced for completeness in Appendix A of this report. The incremental spreadsheet application of LDM is termed 'XLDM'.

Two steps needed to be undertaken before the incremental model could be implemented in spreadsheet form. First, the model parameters needed to be converted into the appropriate form; this process is described in Section 2.1. Second, trip rates by purpose and segment needed to be calculated because of the form of the frequency model; this step is described in Section 2.2.

Once these two steps had been completed, the inputs to the incremental model had all been specified and the spreadsheet version of the model could be developed. Section 2.3 describes the spreadsheet model that has been developed. Finally, Section 2.4 describes the validation tests that have been performed to ensure that the incremental version of the choice version of the model is working correctly.

It should also be noted that XLDM cannot apply the full pivoting procedure of the LDM. The LDM procedure, set out in Daly, Fox and Patruni (2011), deals with exceptional cells in the matrix, including zeros, in a more sophisticated way. This means that the incremental model will not reproduce exactly the results from a full run of the LDM.

2.1 Model parameters

The LDM model was estimated with parameters defined using the non-normalised (RU1) logit model form. It was necessary to convert these into the normalised (RU2) form for application in the incremental model to comply with the requirement in the brief that both incremental models should use parameters specified in a consistent manner. The only generalised cost changes that need to be tested are those associated with introducing HSR, so only the LDM parameters that govern the sensitivity to generalised cost changes for HSR and classic rail need to be converted from RU1 to RU2 form.

The first step in converting the parameters from RU1 to RU2 form was to define the sensitivity at the lowest level in the model structure. PLD works with generalised costs, but in the case of the LDM it makes more sense to work with generalised time units because the commute[4] and visiting friends or relatives (VFR)/other models work with generalised

[4] 'Commute' includes trips for education.

time. In the case of business, which uses a utility formulation rather than a generalised time formulation, sensitivity to car time has been taken to define sensitivity at the lowest level.

Sensitivity to generalised time or car time then forms the lowest level sensitivity (lambda) in the RU2 formulation. The higher level lambdas are then calculated from the structural parameters (the thetas) estimated in the RU1 formulation that define the *relative* sensitivity of adjacent choices in the structure.

It is noted that the LDM works with tour-level LOS and that the lambda parameters have been calculated on this basis.

Table 2 summarises the conversion of the commute LDM parameters from RU1 to RU2 forms. Destination choice is the lowest in the structure, followed by classic rail/HSR choice, choice of public transport mode (rail or coach), choice between public transport and car, and finally frequency choice.

Table 2: Conversion of commute LDM parameters from RU1 to RU2 form

RU1 specification		RU2 specification	
Utility parameters:		Lowest level lambda:	
Generalised time	-0.00652	λ_D	-0.00652
Structural parameters, working up structure:		Lambda parameters, working up structure:	
θ_{PT_D} / θ_{Rail} = $\theta_{RailSubModes\_D}$	0.76272	λ_R	-0.00497
θ_{PT_D}	0.27534	λ_{PT}	-0.00180
θ_{M_PT}	1.00000	λ_M	-0.00180
θ_{F_M}	0.71614	λ_F	-0.00129

(All lambdas give sensitivities to generalised time in minutes.)

It can be seen that the sensitivities to public transport mode choice and the choice between public transport and car are equal in the commute model.

For business, the LDM uses a model formulation where sensitivities to cost and LOS were imported from a stated preference survey conducted with long-distance travellers in December 2009 and January 2010. By calculating the ratios of the different model parameters, it is possible to express the sensitivities to cost and rail LOS components relative to car time, which allows all components of the generalised cost change resulting from the introduction of the HSR scheme to be converted into car-time units. These calculations are presented in Table 3. The day trip term is applied if the return rail in-vehicle time is less than six hours.

Table 3: Relative sensitivities of business LOS components to car time

Parameter	Definition	Value	Scaled to car time
SPCarIVT	Car time	-0.00541	1.00000
SPRailIVT	Rail in-vehicle time	-0.00402	0.74248
SPRailFreq	Rail frequency	0.01398	-2.58358
SPAcEg	Rail access/egress time	-0.00575	1.06327
SPInters	Rail interchanges	-0.04689	8.66612
SPDayTrip	Day trip term	0.18990	-35.10040
SPHHInc13	Sensitivity to cost, hh. incomes < £30k pa	-0.0001181	0.02182
SPHHInc45	Sensitivity to cost, hh. incomes £30–50k pa	-0.0000736	0.01360
SPHHInc68	Sensitivity to cost, hh. incomes > £50k pa	-0.0000586	0.01083

The car-time parameter then forms the lowest level lambda in the RU2 specification. Table 4 summarises the conversion of business LDM parameters from RU1 to RU2 form. Classic rail/HSR choice is the lowest in the structure, followed by destination choice, choice of public transport mode (rail or air), choice between public transport and car, and finally frequency choice at the top of the structure.

Table 4: Conversion of business LDM parameters from RU1 to RU2 form

RU1 specification		RU2 specification	
Utility parameters:		Lowest level lambda:	
Car time	-0.00541	λ_R	-0.00541
Structural parameters, working up structure:		Lambda parameters, working up structure:	
$\theta_{Rail} / \theta_{PT\_D} = \theta_{D\_RailSubModes}$	0.89035	λ_D	-0.00482
θ_{PT_D}	0.79968	λ_{PT}	-0.00385
θ_{M_PT}	0.56717	λ_M	-0.00218
θ_{F_M}	1.00000	λ_F	-0.00218

(All lambdas give sensitivities to generalised car time in minutes.)

It is noted that the mode-choice and frequency lambda values are equal in the business model, and as such the frequency response of the model is highly sensitive to changes in generalised cost resulting from introducing the HSR scheme.

Table 5 summarises the conversion of the VFR/other LDM parameters from RU1 to RU2 form. Destination choice is the lowest in the structure, followed by classic/HSR choice, choice of public transport mode (rail, air or coach), choice between public transport and car, and finally frequency choice.

Table 5: Conversion of VFR/other LDM parameters from RU1 to RU2 form

RU1 specification		RU2 specification	
Utility parameters:		Lowest level lambda:	
Generalised time	-0.00330	λ_D	-0.00330
Structural parameters, working up structure:		Lambda parameters, working up structure:	
θ_{PT_D} / θ_{Rail} = $\theta_{RailSubModes\_D}$	0.89428	λ_R	-0.00295
θ_{PT_D}	0.72794	λ_{PT}	-0.00240
θ_{M_PT}	0.50087	λ_M	-0.00120
θ_{F_M}	0.51097	λ_F	-0.00062

(All lambdas give sensitivities to generalised time in minutes.)

The relative sensitivity to generalised time changes at the frequency level is lower in VFR/other compared to commute and, in particular, compared to business.

2.2 Trip rates by segment

In order to apply the XLDM model incrementally, it was necessary to calculate long-distance trip rates by purpose and segment. These trip rates are required in order to apply equation B14 given in Appendix A. In this equation, the zonal population by segment is inferred as the total trips in the segment divided by the mean trip rate for the segment. There are ten segments in total, defined by possible combinations of two car-ownership segments (non-car-owning, car-owning) and five household income bands:

- < £20,000 pa
- £20,000–40,000 pa
- £40,000–50,000 pa
- £50,000–75,000 pa
- > £75,000

The long-distance trip rates by purpose and segment have been calculated from analysis of weighted long-distance trip records from 2002–06 National Travel Survey (NTS) data. This dataset was one of the datasets used to estimate the LDM long-distance models. The trip rates, in long-distance trips per day, are summarised in Table 6.

Table 6: Long-distance trip rates by purpose and segment (trips per day)

Segment	Commute	Business	VFR/Other
NCO, < £20k pa	0.003137	0.004010	0.013877
NCO, £20–40k pa	0.003473	0.006865	0.019224
NCO, £40–50k pa	0.009597	0.010743	0.030530
NCO, £50–75k pa	0.009597	0.010743	0.030530
NCO, > £75k pa	0.009597	0.010743	0.030530
CO, < £20k pa	0.005836	0.009529	0.035622
CO, £20–40k pa	0.012524	0.016574	0.042662
CO, £40–50k pa	0.020394	0.022452	0.046881
CO, £50–75k pa	0.021049	0.031030	0.056094
CO, > £75k pa	0.031226	0.043807	0.068562

Note that for the top three NCO income bands trip rates have been calculated by aggregating over the three income bands, as the individual trip rates were influenced by small trip sample sizes and, as a result, trip rates were observed to decrease with income band. Aggregating the top three bands ensures that the trip rates used in the incremental application do not decrease with increasing income.

2.3 Description of spreadsheet

The XLDM incremental spreadsheet operates using the 406-district-level zoning system used in the LDM. This allows the spreadsheet to use the P/A base-trip matrices generated in the Phase 0 work directly without needing to aggregate to PLD zones. More importantly, it allows the LOS matrices output from the absolute version of the LDM model during the Phase 0 work to be used directly without needing to develop special averaging procedures to convert to the more aggregated PLD zoning system.

The XLDM incremental spreadsheet consists of the following components:

- inputs sheet, defining the input parameters for the model run
- LOS matrices for classic rail and HSR for each journey purpose[5]
- base-trip matrices, in P/A format
- output sheets by purpose and car ownership
- Visual Basic macros that implement the incremental model calculations.

The following subsections describe each of these components in turn.

2.3.1 Inputs sheet

The inputs sheet specifies:

- the lambda values presented in Section 2.1
- for commute and VFR/other, parameters from WebTAG that are used to determine values of time as a function of income band and purpose (values from Department for Transport, 2007, Section 11.4.4)
- the daily long-distance trip rates by purpose and segment presented in Section 2.2.

2.3.2 Level of service matrices

As part of the Phase 0 outputs, URS Scott Wilson supplied LOS matrices at the 406-zone level separately for each journey purpose for both classic rail and HSR. For other modes (car, air and coach) LOS has not been supplied because it is assumed to remain unchanged in the tests and so has no impact in the incremental model. The rail LOS matrices have been output from a specially modified version of the absolute version of the LDM model maintained by URS Scott Wilson. All costs are defined in pence, and all times are defined in minutes.

For commute and VFR/other, two tour LOS matrices have been supplied for classic rail and HSR:

- ‘money’ cost, including crowding penalty for classic rail, but not for HSR where no crowding is modelled

[5] The present version of the spreadsheet does not allow consideration of changes in LOS for other modes or even for classic rail.

- generalised time, including access and Passenger Demand Forecasting Handbook (PDFH) penalties for frequency and interchanges and, for VFR/other, the effect of the day-return bonus.

Costs are supplied separately from other generalised time components because their impact in generalised time units varies across the five income bands. For non-business travel, costs are converted into generalised time units using the WebTAG values of time that vary with income and distance (Department for Transport, 2007, Section 11.4.4). To calculate the value of time (VOT) for the first four income bands, the mid-point of the income band is assumed. For the top income band, a household income of £90,000 pa is assumed.

For business, separate weightings to convert the five components of classic rail and HSR tour LOS to generalised car time are applied:

- cost, including crowding penalty for classic rail only
- in-vehicle time
- frequency (trains per hour)
- access/egress times
- number of interchanges (for classic only, zero interchanges being assumed for HSR).

All HSR tests assume no fare premium. This means that if there is a crowding penalty applied to classic rail for a given Origin-Destination (OD) pair, the 'money' cost of HSR is *lower*. For business and VFR/other, the generalised time component includes the day-return bonus and a 64-minute reduction is applied to the generalised time if the return in-vehicle time is less than six hours.

For each OD pair and segment, the LOS matrices supplied for classic rail and HSR allow the generalised time associated with each mode to be calculated, and thus the generalised time difference between classic rail and HSR to be calculated.

2.3.3 Treatment of access/egress

In LDM, for classic rail, access/egress times represent a weighted average of access/egress times by car, other public transport modes and walk to reach a rail station within the zone, using observed times and shares from the 2004–06 NRTS data. No access/egress costs are included. The access/egress times are weighted by a factor of two when they are added to generalised time.

By contrast, generalised access/egress times to HSR represent access/egress by car and classic rail to the HSR network (which may be substantial) and do include access/egress costs, which are converted into generalised access/egress times using an appropriate value of time. In addition interchange and wait-time penalties that are not included in classic rail access/egress are included. HSR generalised access/egress times are *not weighted* when they are added to generalised time for commute and VFR/other, thus they effectively receive half the weighting of classic rail access/egress times. This approach has been adopted for consistency with the approach URS Scott Wilson has used to apply the LDM model in absolute form, ie it is part of the current standard specification of the LDM.

Table 7 compares the treatment of access/egress for classic rail and HSR. Appendix B presents a detailed note supplied by URS Scott Wilson that describes the approach used to model HSR access in more detail.

Table 7: Comparison of treatment of access/egress for classic rail and HSR

	Classic rail	HSR
Access modes represented	Other PT modes, car, walk	Classic rail, car
Source of access/egress times	Observed in NRTS data	Skimmed
Calculation of weighted access/egress times	Weighted using observed shares in NRTS data	Composite measure calculated using an access mode-choice parameter
Access costs included?	No	Yes
Inclusion of wait time and interchange penalties	No	Yes
Length of access/egress legs	Always within same zone	May be substantial in order to access HSR stations
Weighting when added to generalised time	2	1

The business model does not work with a generalised time formulation; instead a dedicated rail access time parameter is used. To achieve consistency with the treatment of access/egress time in commute and VFR/other, generalised access/egress times for HSR have been multiplied by a factor of 0.5 before they are multiplied by the access-time parameter in the model so that they are weighted at half the level of the classic rail values.

While performing detailed validation checks to compare the XLDM and XPLD results for specific P/A pairs, high HSR access/egress times were discovered for P/A pairs that involved access or egress in London. Further investigation indicated that high interchange penalties of 18 minutes were being applied (including tube transfers). These were resulting in HSR access/egress times that were unrealistically high relative to the access/egress times observed for classic rail for the same P/A pair. Therefore, the HSR LOS was recreated with the interchange penalty revised from 18 minutes to 5 minutes. At the same time, access times to the first station and from that last station for HSR journeys where access is by classic rail were given a weight of two, which ensures consistency with the weighting of access/egress legs to stations for classic rail as a main mode. This resulted in a second set of XLDM results, and all XPLD results have been obtained with the enhanced LOS. A priori, these second assumptions appear more reasonable and therefore, after testing reported below, they are used for the majority of the comparisons we have made. To summarise, results are presented for:

- *original* HSR LOS, with interchange penalties of 18 minutes, and no weighting on access time to the first station or egress from the final station for the classic rail access mode calculations
- *enhanced* HSR LOS, with interchange penalties of 5 minutes, and a weighting of two applied to access time to the first station and egress from the final station for the classic rail access mode calculations.

If the LDM were to be developed further, it would be worth revising the treatment of access/egress to specify an approach that gives greater consistency between classic rail and HSR. The improvements that could be made are discussed in detail in Appendix B. It is worth noting that the LDM was estimated from revealed preference data that includes classic rail only, and that HSR was incorporated in the structure at a relatively late stage in the model development in the expectation that further model development would be undertaken over time.

2.3.4 Base-trip matrices

Each of the base P/A trip matrices by purpose and segment that were output by the Phase 0 work are included in the spreadsheet, with a separate sheet used for each matrix. A consistent naming convention is used for each sheet so that each base matrix can be readily identified. Sheets are named 'PMS' where:

P is the purpose:

- W: work
- B: business
- O: VFR/other

M is the mode:

- A: air
- B: coach (B denotes bus and coach)
- C: car
- R: classic rail

S is the car ownership and household income segment:

1. NCO, < £20,000 pa
2. NCO, £20,000–40,000 pa
3. NCO, £40,000–50,000 pa
4. NCO, £50,000–75,000 pa
5. NCO, > £75,000 pa
6. CO, < £20,000 pa
7. CO, £20,000–40,000 pa
8. CO, £40,000–50,000 pa
9. CO, £50,000–75,000 pa
10. CO, > £75,000 pa

The commute and business models both have three modes available (air not being modelled for commute, coach not being modelled for business) and so have 30 base matrices each. The VFR/other model has all four modes available and so there are a total of 40 base matrices. Thus there are 100 base matrices in total.

2.3.5 Output sheets

Output sheets are produced that summarise the total number of trips predicted for HSR for each of the 406 production zones, and present the total HSR demand decomposed into:

- generation
- capture from car
- capture from air/coach
- capture from classic rail.

In addition, the total volume of redistribution for the production zone is computed. This is calculated for those destinations with HSR available in the logit version of HSR/classic rail choice, and for those destinations where HSR has lower generalised cost than classic rail in the minimum generalised cost HSR/classic rail choice version of the model (see Appendix A).

Each output sheet presents these results separately for the model with HSR/classic rail choice predicted using the existing logit approach and for the model with HSR/classic rail choice predicted using the minimum generalised cost approach. A total of six output sheets are defined for the possible combinations of the three journey purposes and the two car ownership segments (NCO, CO).

Six separate output sheets detail the total rail redistribution for each P/A pair, for each purpose and combination of logit and assignment HSR/classic rail choice. For logit HSR/classic rail choice, redistribution is calculated only for those attractions where HSR is available. For assignment HSR/classic rail choice, redistribution is calculated only for those attractions where the HSR generalised time is less than the classic rail generalised time. In all cases, the rail redistribution that is output is summed over the ten income and car ownership segments.

2.3.6 Visual Basic macros

The incremental model calculations are implemented using three Visual Basic macros, one for each journey purpose. Each macro follows the same overall structure.

A switch at the top of the macro code determines whether the HSR/classic rail choice is to be predicted using the logit model approach used in the absolute version of the LDM, or using the minimum generalised cost approach.

The next step is to read in the model parameters (the lambda values), the parameters that define the WebTAG VOT formulation for commute and VFR/other, the valuations of rail LOS components relative to car time for business and the mean trip rates by the ten segments.

The macro then begins a loop over the 406 production zones. For each production zone, the macro loops over the ten income and car-ownership segments. For each production zone and segment combination, the model in turn loops over the 406 possible attractions, calculating the generalised time for HSR and classic rail, allowing the generalised time difference to be calculated, which is defined only for those destinations for which HSR is available. Once the base trips as specified in the P/A trip matrices have been read in, the incremental model formulae can be applied.

Demand for HSR is decomposed into generation, capture from car, capture from air/coach and capture from classic rail, and is summed separately for NCO and CO segments for each production zone.

The final step for each production zone is to output the decomposed HSR demand to the output sheet for the purpose and car-ownership segment in question.

2.4 Validation

To validate the application of XLDM, the results from the version of the model with HSR/classic rail choice predicted using the logit approach have been compared with the results URS Scott Wilson obtains when applying the absolute version of the models (with HSR/classic rail choice predicted using the logit approach, which is standard). We would not expect the results to match exactly, as the approach used to infer the total trips made in each production zone in the incremental approach assumes constant trip rates across production zones, whereas in the absolute version of the model trip rates will vary according to the accessibility of the production zone. Nonetheless, the two sets of results are expected to correspond reasonably closely.

It is noted that these comparisons are based on the HSR LOS originally supplied by URS Scott Wilson, which assumes a penalty of 18 minutes per interchange, as this is the set of LOS URS Scott Wilson used to make its absolute model predictions.

Table 8: Validation of XLDM model for commute

	Generation	Car capture	Coach capture	Classic rail capture	Total HSR demand
XLDM	6,602	1,886	47	12,986	21,521
Real LDM	6,384	1,759	43	13,393	21,580
Difference	3.4%	7.2%	7.5%	-3.0%	-0.3%

Total HSR demand matches closely for commute, with a difference of just 0.3 percent. XLDM predicts slightly higher levels of generation, car capture and coach capture, and slightly lower classic rail capture, relative to the absolute version of the model.

Table 9: Validation of XLDM model for business

	Generation	Car capture	Air capture	Classic rail capture	Total HSR demand
XLDM	8,804	188	1,524	8,855	19,372
Real LDM	7,573	126	1,279	10,642	19,621
Difference	16.3%	49.2%	19.1%	-16.8%	-1.3%

XLDM predicts 1.3 percent fewer HSR trips compared with the absolute version, but higher levels of generation, air capture and in particular car capture compared with the absolute version of the model.

Table 10: Validation of XLDM model for VFR/other

	Generation	Car capture	Air/coach capture	Classic rail capture	Total HSR demand
XLDM	12,399	9,624	11,846	21,588	55,456
Real LDM	12,507	9,326	11,675	22,039	55,547
Difference	-0.9%	3.2%	1.5%	-2.0%	-0.2%

Total HSR demand matches to within 0.2 percent for VFR/other, and the predicted generation matches to within less than 1 percent. Car capture and air/coach capture are slightly higher in the incremental version of the model.

Overall it was concluded that the incremental and absolute applications of the LDM model were consistent. The differences in total HSR trips for business were higher than were expected. However detailed cross-checking of the incremental application code did not reveal any errors in the calculations.

CHAPTER 3 Incremental application of PLD

The incremental application of the PLD model follows the detailed procedure set out in Annex B of the brief, which is reproduced for completeness in Appendix A in this report. The incremental spreadsheet application of PLD is termed 'XPLD'.

Section 3.1 details the model parameters used in XPLD, and then Section 3.2 presents a comparison of the LDM and PLD model parameters to give insight into the relative sensitivities of the two models. Section 3.3 goes on to describe the spreadsheet that has been used to implement the PLD models in incremental form. Finally, Section 3.4 presents validation of the incremental results against the results Atkins obtains when applying PLD for the same 2008 HSR scheme.

3.1 Model parameters

The 2002 values of the PLD model parameters were specified in Table 8.1 of the February 2010 *Model Development Report* (Atkins, 2010a). Only the values for rail are required for the incremental application of the model, as only the impact of generalised cost differences for rail needs to be represented. The parameters relevant to rail are reproduced in Table 11.

Table 11: PLD model parameters, 2002 prices and values

	Commute	Business	VFR/other
Values of time (p/min)			
Rail IVT	12.6	51.2	13.7
Rail headway	5.9	27.9	10.3
Rail access/egress	18.9	66.6	18.4
Scaling parameters (1/p)			
Travel vs. no travel	0.000269	0.00017	0.000397
PT vs. highway	0.000808	0.000496	0.00119
Rail vs. air	No air demand	0.000681	0.00225

Source: Atkins, 2010a

For commute and VFR/other, the model is applied separately for no-car-available (NCA) and car-available (CA) segments. For commute, air is not modelled and therefore for the NCA segment all demand is rail captive. For business, it is assumed that all demand is made by CA persons in the HS2 modelling.[6] For VFR/other, air is modelled but it is only

6 Note, however, that the PLD does model business rail demand for the NCA segment. The decision to treat all business demand as CA in the HS2 modelling was taken in late 2009.

available to CA persons, and therefore NCA demand is rail captive. Table 12 summarises the availability of modes by purpose and car availability.

Table 12: PLD mode availability by purpose and car availability (HS2 modelling)

	Commute NCA	Commute CA	Business CA	VFR/other NCA	VFR/other CA
Rail	Available	Available	Available	Available	Available
Highway		Available	Available		Available
Air			Available		Available

These model parameters are used to calculate the generalised cost for classic rail and HSR using the following generalised cost formula (Atkins, 2010b):

$$GenCost = F + Cost_{AE} + (VOT * (IVT + Crowd)) + VOT_{AE} * AE + \frac{(VOT_H * W)}{F_W}$$
$$+ (7.16 + (0.066 * IVT)) * Board^{0.7}$$

where: *F* is the fare

$Cost_{AE}$ is the cost of access/egress

VOT is the value of rail in-vehicle time

IVT is the rail in-vehicle time

Crowd is the time spent in crowding

VOT_{AE} is the value of rail access/egress time

AE is the rail access/egress time

VOT_H is the value of rail headway

W is the wait time

F_W is the wait time factor (0.4)

Board is the number of boardings.

The PLD mode-choice model is applied as a trip model, and therefore the components of generalised cost that feed into this calculation are defined in trip, rather than tour, units.

For business and VFR/other, a distance damping factor is applied to the generalised cost differences, which is specified as the straight line distance in kilometres between origin and destination raised to the power of -0.1. No distance damping is applied for commuting.

Atkins has supplied the growth factors it has used to update the model parameters from 2002 to 2008 values. These growth factors were defined separately for work and non-work VOTs on the basis of growth in work VOTs specified in WebTAG in 2009. The work VOT growth is calculated first, and then the non-work VOT growth is calculated by raising the work VOT growth to the power of 0.8.

Table 13: Value of time growth factors

Range of years	Work VOTs	Non-work VOTs
2002–07	1.11694	
2007–08	1.023	
2002–08	1.142630	1.112562

The values of time in the model were increased by simply applying the growth in work VOTs to the business VOTs, and the growth in non-work VOTs to scale up the commute and VFR/other VOTs. To adjust the scaling parameters, the following relationship was applied (Atkins, 2010a):

$$\lambda_{2002} VOT_{2002} = \lambda_{2008} VOT_{2008}$$

where: λ_{2002} and λ_{2008} are the 2002 and 2008 values for the scaling parameters

VOT_{2002} and VOT_{2008} are the 2002 and 2008 values of time.

Thus the sensitivity of the lambda scaling parameters is reduced to compensate for the growth in VOT between 2002 and 2008. The 2008 values for the model parameters are reproduced in Table 14. These parameter values have been used for the PLD analysis presented in this chapter and the comparisons of XLDM and XPLD presented in Chapter 4.

Table 14: PLD model parameters, 2008 values in 2002 prices

	Commute	Business	VFR/other
Values of time (p/min)			
Rail IVT	14.018	58.503	15.242
Rail headway	6.564	31.879	11.459
Rail access/egress	21.027	76.099	20.471
Scaling parameters (1/p)			
Travel vs. no travel	0.000242	0.000145	0.000357
PT vs. highway	0.000726	0.000434	0.001070
Rail vs. air	No air demand	0.000596	0.002022

As noted above, the PLD mode-choice model is for trips, not tours, and therefore these lambda parameters are defined for trip, not tour, LOS.

It should be noted that Atkins confirmed at a meeting in London on 10 January 2012 that the adjustments to account for the increase in VOT from 2002 to 2008 had *not* been applied when it ran PLD for 2008. Therefore the additional PLD analysis presented in Chapter 5 does not use the parameter values given in Table 14; instead the values in 2002 values and prices presented in Table 11 are used.

3.2 Comparison of LDM and PLD model parameters

To provide a comparison of the relative sensitivity of the LDM and PLD models, the two sets of model parameters have been converted into units of generalised time for trips. The following tables compare the sensitivity parameters for the three purposes modelled.

Table 15: Comparison of commute model parameters, generalised time for trips

	LDM	PLD	LDM/PLD
λ_D	-0.01304	n/a	n/a
λ_R	-0.00995	n/a	n/a
λ_{PT}	-0.00359	n/a	n/a
λ_M	-0.00359	-0.01018	0.353
λ_F	-0.00257	-0.00339	0.759

The PLD values are higher in absolute terms, particularly for mode choice between car and public transport, which implies a higher sensitivity to cost changes for these responses.

Table 16: Comparison of business model parameters, generalised time for trips

	LDM	PLD	LDM / PLD
λ_R	-0.01082	n/a	n/a
λ_D	-0.00963	n/a	n/a
λ_{PT}	-0.00770	-0.03487	0.221
λ_M	-0.00437	-0.02540	0.172
λ_F	-0.00437	-0.00870	0.502

As with commute, the PLD values show greater sensitivity to cost changes for responses represented in both models.

Table 17: Comparison of VFR/other model parameters, generalised time for trips

	LDM	PLD	LDM / PLD
λ_D	-0.00660	n/a	n/a
λ_R	-0.00590	n/a	n/a
λ_{PT}	-0.00481	-0.03083	0.156
λ_M	-0.00241	-0.01630	0.148
λ_F	-0.00123	-0.00544	0.226

The story with VFR/other is consistent with the pattern observed for commute and business: the frequency, car versus public transport and public transport mode-choice decisions are more sensitive to cost changes in PLD.

3.3 Description of the spreadsheet

XPLD has been coded using the 406-district-level zoning system used in the LDM, rather than the 235-zone system used by Atkins for PLD. Making the incremental application of the model at the 406-zone level means that the P/A trip base matrices by segment output from the Phase 0 work can be used directly, as can the LOS matrices output from the LDM during the Phase 0 work.[7]

The XPLD spreadsheet follows the same structure as the LDM incremental spreadsheet, and consists of the following components:

- inputs sheet, defining the input parameters for the model run

[7] In principle, this change of zoning will cause a slight downwards bias in the elasticities of the model.

- LOS matrices for classic rail and HSR for each journey purpose
- base-trip matrices, in P/A format
- output sheets by purpose and car ownership
- Visual Basic macros that implement the incremental model calculations.

The following subsections describe each of these components in turn.

3.3.1 Inputs sheet

The inputs sheet defines the model parameters given in Table 14, and the distance-damping parameters that are applied for business and VFR/other.

3.3.2 Level of service matrices

In order to apply the PLD model in incremental form, LOS matrices were supplied by URS Scott Wilson for classic rail and HSR broken down into the following components for each journey purpose:

- cost, including crowding penalty for classic rail only
- in-vehicle time
- frequency (trains per hour)
- access/egress times
- number of interchanges (for classic only, zero interchanges being assumed for HSR).

The tour-based LOS supplied by URS Scott Wilson was converted into a trip-based LOS for use in XPLD. This LOS is equivalent to the LOS used in XLDM. The only difference is that in XLDM, for commute and VFR/other the in-vehicle time, frequency, access/egress times and numbers of interchanges components have been pre-processed into a generalised time matrix by URS Scott Wilson for application in XLDM.

For PLD, crowding in minutes is added to in-vehicle time, and then is converted into generalised cost using the VOT for in-vehicle time. In the LOS that has been used for this work, crowding in pence has been added to the cost of classic rail.

Section 2.3 presented a detailed explanation of how access/egress times to classic rail and HSR are treated in the LDM-based LOS matrices used in XPLD. An important difference between the LDM-based LOS matrices and the LOS used in real PLD is that in the LDM-based LOS, travel time on classic rail to access HSR services is counted as access time and is weighted accordingly. By contrast, in real PLD travel time on classic rail is weighted as equal to travel time on HSR when determining whether HSR will be used.

As Chapter 5 will illustrate, the differences in the treatment of access/egress to HSR between LDM and PLD have an important impact on the validation of XPLD and real PLD. They also have an important impact on the comparison of results between XLDM and XPLD – XLDM is designed to emulate a model that has been developed with LOS for classic rail and HSR taken from separate network models, whereas XPLD emulates a model with classic rail and HSR represented within a single rail network model which automatically ensures access to classic rail and HSR is treated consistently.

The PLD generalised cost formulation works with wait times, which are converted into headways by dividing by the weight time factor of 0.4. So a journey with an 8-minute wait time is equivalent to a 20-minute headway. The LDM-generated LOS used for this work uses frequencies rather than wait times. Frequencies in trains per hour have been converted into headways by calculating 60/frequency.

In PLD, both access costs and times should be represented in the generalised cost calculations for both HSR and classic rail. Thus the impact of access is under-represented when working with the LDM-based LOS: for classic rail because access costs are not represented and for HSR because the application of a factor of 0.5 reduces the impact of access costs.

To be fully consistent with PLD, separate access time and cost skims would be supplied for both HSR and classic rail, and the classic rail in-vehicle time component of HSR access would be distinguished from other components of access. Unfortunately it was not possible to supply access costs for classic rail, as they have not been defined in the rail assignment models currently used by LDM.

Table 18 summarises how each of the terms in the PLD generalised cost function has been applied using the LDM-generated LOS.

Table 18: Summary of application of XPLD using LDM-generated LOS

Generalised cost component	Differences between LDM-derived LOS and original PLD definitions
Fare	Consistent
Cost of access/egress	Only included for HSR, and note weighting
In-vehicle time	Consistent
Crowding	Added to fare rather than being defined in minutes
Access/egress time	Consistent, though note weighting applied to HSR
Headways	Derived from frequency rather than wait time
Boardings	Consistent

The key difference between the application of the model using LDM-generated LOS and the original PLD definitions is in the treatment of access/egress costs and times discussed above. Our understanding is that Atkins's experience from application of the PLD is that the model results are very sensitive to changes in access times and costs, and so this inconsistency is expected to lead to divergence between the results obtained from the incremental application of PLD in this work, and the results Atkins obtains.

3.3.3 Base-trip matrices

The base-trip matrices are identical to the P/A trip matrices used in XLDM, as described in Section 2.3. The definition of a long-distance trip in the base matrices is that the one-way distance is 50 miles or more.

The definition of a long-distance trip in PLD is more complex. The PLD demand data represent all car trips over 30km and air and rail trips of all distances. However excluded from this total are any trips made wholly within a PLANET zone. (Zone sizes vary considerably, for example North of Scotland is one zone while Greater London has seven.) Also excluded are trips made within the PLANET South or PLANET Midlands regions. (PLANET South includes all of the South East, East of England and South West.) This will exclude many trips (such as Bristol or Norwich to London and Inverness to Fort William) that are longer than 30km but made wholly within these regions or a zone.

The PLD zoning system has been deliberately designed to model within reasonable fidelity the likely routes of a North–South High-Speed Line while retaining sensible run times and data requirements. Trips within South and Midlands are modelled separately by PLANET South and Midlands while car trips of less than 30km are modelled as preloads to the highway network speed/flow curves.

In order to ensure consistency in trip definitions between XLDM and XPLD, and to use the LDM base matrices, it was decided to use the LDM definition of a long-distance trip for the incremental application of the PLD, rather than apply the more complex PLD definition.

Thus XPLD uses the PLD model parameters in 2008 values;[8] applies these parameters to LOS changes output from the LDM model to calculate changes in generalised cost; and then applies the changes in generalised cost to calculate changes in trips relative to the long-distance P/A trip matrices output from the LDM. The LDM definition of a long-distance trip has been used.

There are important differences between PLD and LDM in terms of the treatment of incomes and which modes are available for which car availability segments. The PLD does not include any income segmentation, and so the first step is to sum the LDM base matrices for each mode and purpose combination over the five income bands represented.

Another important difference between the PLD and LDM models is that car demand in PLD is only predicted for car available (CA) segments, whereas in LDM car demand is predicted for both the no-car and one-or-more-car segments. Furthermore, in PLD air demand is predicted only for CA segments, whereas in LDM air demand is predicted for both the no-car and one-or-more-car segments. Finally, coach demand is predicted in the LDM for commute and VFR/other travel, but is not predicted at all in the PLD.

To ensure that base-matrix demand for a given mode is not lost due to the different assumptions the two models make about the availability of modes according to car availability, modes available only in the CA segment in PLD were pivoted off the sum of demand in the no-car and one-or-more-car segments in the P/A trip base matrices output from LDM. Table 19 summarises where demand has been summed over no-car and one-or-more-car segments for each PLD purpose and mode combination. For example, in commute PLD predicts car demand only in the CA segment, so the base-matrix demand from the no-car and one-or-more-car segments in LDM has been summed to allow the PLD model to be applied incrementally for the CA segment to pivot off total car demand represented in the PLD commute base matrices.

8 As noted earlier, this assumption was subsequently revised and in the additional analysis presented in Chapter 5 PLD model parameters in 2002 values and prices have been used.

Table 19: Treatment of LDM base matrices by PLD purpose and car availability

		PLD car availability	
PLD purpose and mode		NCA	CA
Commute	Rail	0 cars	1+ cars
	Car	unavailable	Sum 0 cars and 1+cars
Business	Rail	unavailable	Sum 0 cars and 1+cars
	Car	unavailable	Sum 0 cars and 1+cars
	Air	unavailable	Sum 0 cars and 1+cars
VFR/other	Rail	0 cars	1+ cars
	Car	unavailable	Sum 0 cars and 1+cars
	Air	unavailable	Sum 0 cars and 1+cars

As coach is not modelled in the PLD, this component of LDM base-matrix demand is not included in XPLD.

3.3.4 Output sheets

Output sheets are produced that summarise the total number of trips predicted for HSR for each of the 406 production zones, and present the total HSR demand decomposed into:

- generation
- capture from car
- capture from air (not for commute)
- capture from classic rail

These components are calculated by summing over the attractions for which HSR is available for each production zone. It is noted that the PLD model does not include destination choice, so no results for rail redistribution are presented.

A separate output sheet is presented for each of the three journey purposes.

3.3.5 Visual Basic macros

Separate Visual Basic macros have been coded for the three journey purposes, each of which follows the same structure.

The macros start by reading in the model parameters for the purpose, specifically the values of time by component and the scaling parameters.

The macros then begin a loop over the 406 production zones. Next, for commute and VFR/other only, a loop over the car availability segments is begun. The code then loops over the 406 possible attraction zones, and calculates the difference in generalised cost between HSR and classic rail. If HSR is available, and the generalised time is lower than the classic rail generalised time, the code applies the incremental model calculations detailed in Appendix A of the P/A pair in question, otherwise the HSR demand for that P/A pair is zero.

Demand for HSR, decomposed into generation, capture from car, capture from air and capture from classic rail is summed over HSR-available attraction zones for each production zone. For commute and VFR/other these summations are made separately for NCA and CA segments.

The final step for each production zone is to output the decomposed HSR demand to the output sheet for the purpose and car-availability segment in question.

3.4 Validation

To validate XPLD, the results were compared with the results obtained when Atkins applied the same 2008 HSR scheme in real PLD.

Given the significant differences in the treatment of access/egress costs and times between Atkins's run and the incremental application using LDM-derived LOS and given our experience from applying the incremental models that they are highly sensitive to assumptions about access/egress times, these comparisons have been presented for two different treatments of access/egress costs and times:

- *Enhanced LOS*: for classic rail applying access/egress times only; for HSR where both access/egress times and costs are included as part of generalised access/egress time, using the enhanced LOS with reduced interchange penalties and a weight of two on station access/egress legs, and applying an overall weight of 0.5 to generalised access/egress time consistent with LDM
- *Test LOS*: as with the enhanced LOS, but with a 20 percent reduction applied to HSR generalised access/egress times to assess the sensitivity of the model predictions to assumptions about access/egress.

In addition to these differences in the treatment of access/egress times, the differences in the definition of a long-distance trip between PLD and LDM will also have an impact upon these comparisons, as will differences in the base-matrix totals between LDM and PLD.

Noting these caveats, the comparisons of HSR demand are presented in Table 20 to Table 22. For the real-PLD runs generated by Atkins:

- Generation is calculated as the net increase in trips between the base and with-HSR matrices.
- Car capture is calculated as the reduction in car trips between the base and with-HSR matrices.
- Total HSR demand is calculated from a select-line analysis.
- Classic rail capture is calculated as the net increase in rail trips between the base and with-HSR rail matrices, less the total HSR demand from the select-line analysis.

Table 20: Validation of XPLD model for commute

	Generation	Car capture	Classic rail capture	Total HSR demand
XPLD Enhanced LOS	1,431.3	850.0	10,595.6	12,876.9
XPLD Test LOS	2,765.9	1,534.9	13,714.9	18,015.8
Real PLD	455.0	2,492.0	10,072.0	13,019.0
Difference Enhanced LOS	214.6%	-65.9%	5.2%	-1.1%
Difference Test LOS	507.9%	-38.4%	36.2%	38.4%

The total volume of HSR demand predicted in the enhanced-LOS version of XPLD closely matches the results obtained by Atkins, and classic rail capture also matches quite well. However, the incremental model predicts significantly more generation, and significantly lower car capture, compared to the Atkins run.

A factor in the higher car capture observed for PLD is differences in the PLD and LDM base-matrix totals. For car, a masked comparison excluding all trips under 50 miles and those within the PLANET Midland and PLANET South areas reveals the LDM base matrices for car contain 144,000 trips whereas the PLD base matrices contains 409,000 trips. Therefore, changes in the probability of choosing car are applied to much higher car-trip totals in the Atkins run.

The test LOS run of the incremental model demonstrates a high sensitivity to HSR access/egress times, with an implied elasticity of total HSR demand to HSR access/egress time of -1.50.

Table 21: Validation of XPLD model for business

	Generation	Car capture	Air capture	Classic rail capture	Total HSR demand
XPLD Enhanced LOS	3,989.5	3,699.8	2,373.6	13,024.7	23,087.6
XPLD Test LOS	7,334.6	6,356.3	4,302.5	15,483.0	33,476.3
Real PLD	4,915.0	5,153.0	2,241.0	21,387.0	33,696.0
Difference Enhanced LOS	-18.8%	-28.2%	5.9%	-39.1%	-31.5%
Difference Test LOS	49.2%	23.4%	92.0%	-27.6%	-0.7%

XPLD predicts around 10,000 fewer HSR trips per day compared to the Atkins run. The major difference between the two sets of predictions is that the Atkins run predicts more classic rail capture.

If HSR access/egress times are reduced by just 20 percent, total HSR demand increases substantially so that it matches the Atkins total closely. The implied elasticity of total HSR demand to HSR access/egress time is -1.67, so the predicted demand for HSR is highly sensitive to the assumptions made about HSR access/egress times.

HSR access/egress time elasticity tests were also run for the LDM business models to provide a comparison with XPLD. The XLDM model with probabilistic HSR/classic rail choice has an elasticity of -0.73 and the XLDM model with minimum generalised cost HSR/classic rail choice has an elasticity of -1.01. So moving to minimum generalised cost increases the elasticity of the LDM to HSR access/egress times, but nonetheless the model is significantly less elastic than XPLD.

Table 22: Validation of XPLD model for VFR/other

	Generation	Car capture	Air capture	Classic rail capture	Total HSR demand
XPLD Enhanced LOS	3,010.7	3,983.7	1,600.5	17,069.2	25,664.1
XPLD Test LOS	6,277.9	8,115.6	3,771.2	24,431.7	42,596.4
Real PLD	12,115.0	7,567.0	2,489.0	57,170.0	79,341.0
Difference Enhanced LOS	-75.1%	-47.4%	-35.7%	-70.1%	-67.7%
Difference Test LOS	-48.2%	7.3%	51.5%	-57.3%	-46.3%

The incremental model predicts substantially lower HSR demand for VFR/other compared to the Atkins run, predicting around one-third of the Atkins HSR trip total. Comparison of the enhanced-LOS and test-LOS results demonstrates that predicted demand for HSR is highly sensitive to the assumptions made about HSR access/egress times, with an implied elasticity of -2.27.

Table 23: Validation of XPLD model, all purposes

	Generation	Car capture	Air capture	Classic rail capture	Total HSR demand
XPLD Enhanced LOS	8,431.5	8,533.5	3,974.1	40,689.5	61,628.6
XPLD Test LOS	16,378.3	16,006.8	8,073.6	53,629.6	94,088.4
Real PLD	17,485.0	15,212.0	4,730.0	88,629.0	126,056.0
Difference Enhanced LOS	-51.8%	-43.9%	-16.0%	-54.1%	-51.1%
Difference Test LOS	-6.3%	5.2%	70.7%	-39.5%	-25.4%

The overall level of demand predicted for HSR in the enhanced-LOS version of XPLD model is around half of that predicted in the Atkins run of the PLD model.

It is clear from the test LOS sensitivity test that the incremental model results are highly sensitive to the access/egress assumptions: a 20 percent reduction in generalised HSR access/egress time results in over 50 percent growth in total HSR demand. This result means that applying a 20 percent reduction in HSR access/egress times results in a substantial increase in the number of destinations for which HSR has lower generalised cost than classic rail.

Therefore, the different assumptions made to represent access/egress for classic rail and HSR in PLD and LDM are believed to be the main cause of the different levels of HSR demand predicted between XPLD and real-PLD runs. Other differences in the definition of LOS between the two models and differences between the LDM and PLD base matrices, both in terms of total demand and in the definition of trips included, will also play a role.

In Chapter 5, some revisions are made to XPLD and the comparisons of HSR demand to real-PLD figures are repeated.

CHAPTER 4 Comparison of model predictions

Throughout this chapter, three-way comparisons of model results are presented, summarising demand for HSR predicted by:

- the version of XLDM that predicts the HSR/classic choice using the existing logit model approach
- the version of XLDM that predicts the HSR/classic choice using the minimum generalised cost approach, but maintaining the parameters from the logit-model version
- XPLD that predicts the HSR/classic choice using the minimum generalised cost approach.

For each of these, demand for HSR has been predicted by applying the incremental models to base matrices predicted by the LDM. The LDM base matrices contain numbers of all-day P/A trips on an average day, and therefore demand for HSR is predicted on this basis.

Section 4.1 presents an analysis summarising the impact of improving the assumptions made for the calculation of the HSR generalised access/egress times on the predicted demand for HSR for the three incremental modelling approaches.

Section 4.2 presents an analysis comparing the three sets of incremental model results, both in total and separately by journey purpose, with a discussion of differences in the relative contributions to HSR demand of generation and mode capture between the three sets of results. It is noted that the generation response would include switching to or from short distance trips, which would be expected to be lower in the main PLD due to the different definition of long-distance travel.

Section 4.3 presents an analysis of the contribution of redistribution to the XLDM results, noting that destination choice is represented in LDM but not in PLD.

One of the key advantages of LDM is that it takes full account of the impact of income on generation, mode and destination choice. Section 4.4 presents an analysis for real LDM that summarises how the composition of HSR demand varies with income band.

Section 4.5 summarises the results from tests to determine the HSR fare elasticities for the three approaches.

Finally, Section 4.6 presents comparisons of XLDM and XPLD demand for specific production zones.

4.1 Impact of different HSR access/egress assumptions

The following tables illustrate the impact of different access/egress assumptions on HSR demand for the three modelling methodologies.

Table 24: Total HSR demand summed over purposes, original HSR LOS

	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM, probabilistic HSR/classic choice	27,804.5 28.9%	11,698.4 12.1%	13,416.6 13.9%	43,429.0 45.1%	96,348.4 100.0%
XLDM, min. gen. cost HSR/classic choice	11,424.5 13.0%	5,138.8 5.8%	6,491.5 7.4%	65,044.3 73.8%	88,099.1 100.0%
XPLD, min. gen. cost HSR/classic choice	8,941.7 14.3%	8,839.7 14.1%	3,876.7 6.2%	41,048.6 65.5%	62,706.8 100.0%

Table 25: Total HSR demand summed over purposes, enhanced HSR LOS

	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM, probabilistic HSR/classic choice	27,495.3 28.7%	11,660.7 12.2%	13,430.1 14.0%	43,099.4 45.0%	95,685.6 100.0%
XLDM, min. gen. cost HSR/classic choice	11,102.4 12.9%	5,101.4 5.9%	6,510.4 7.6%	63,389.9 73.6%	86,104.1 100.0%
XPLD, min. gen. cost HSR/classic choice	8,431.5 13.7%	8,533.5 13.8%	3,974.1 6.4%	40,689.5 66.0%	61,628.6 100.0%

The enhanced HSR LOS reduced the interchange penalties from 18 to 5 minutes, but applied a weight of two to the access to the first station and egress from the final station components of access/egress using classic rail. Comparing Table 24 and Table 25, it can be seen these changes have a minor impact on total HSR demand, with small reductions in total HSR demand in both the LDM and PLD runs. Therefore, the reduction in generalised times that follow from the revised interchange penalties have been offset by higher station access/egress times for classic rail. Note that this result does not indicate that the models are insensitive to changes in access/egress times – in fact the analysis presented in Section 3.3 demonstrated a high sensitivity for both XLDM and XPLD – but rather that that the net effect of the two changes cancels out.

Overall, the revisions to the HSR LOS have had a minor impact on HSR demand. Nonetheless, *a priori* the enhanced assumptions represent an improved treatment of HSR access/egress, and therefore all subsequent comparisons are based upon the enhanced HSR LOS.

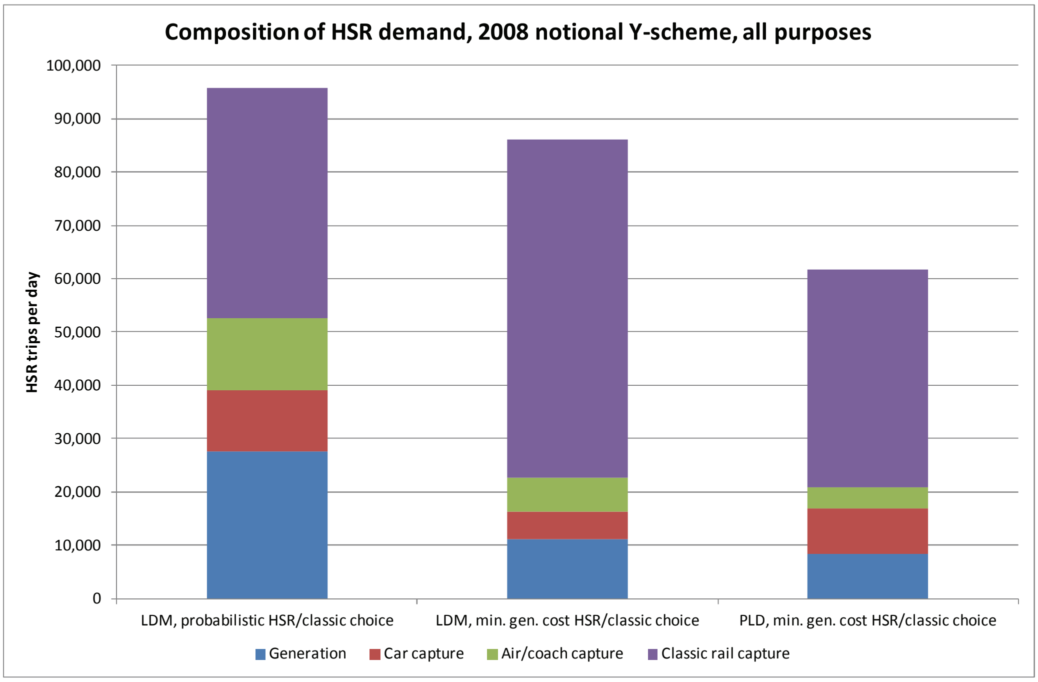
4.2 Comparisons of total demand

Table 26 and Figure 1 report the composition of HSR demand, using the enhanced HSR LOS assumptions, for the three modelling methodologies.

Table 26: Total HSR demand summed over purposes, enhanced HSR LOS

	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM, probabilistic HSR/classic choice	27,495.3 28.7%	11,660.7 12.2%	13,430.1 14.0%	43,099.4 45.0%	95,685.6 100.0%
XLDM, min. gen. cost HSR/classic choice	11,102.4 12.9%	5,101.4 5.9%	6,510.4 7.6%	63,389.9 73.6%	86,104.1 100.0%
XPLD, min. gen. cost HSR/classic choice	8,431.5 13.7%	8,533.5 13.8%	3,974.1 6.4%	40,689.5 66.0%	61,628.6 100.0%

Figure 1: Total HSR demand summed over purposes, enhanced HSR LOS



In the version of the LDM with probabilistic HSR/classic choice, just over one-quarter of HSR demand comes from generation, and over 40 percent comes from classic rail capture. Air/coach capture accounts for one-fifth of trips, and car capture represents just over 10 percent of demand.

When XLDM is run with the minimum generalised cost approach, total demand for HSR trips is reduced by around 10 percent. The proportion of HSR demand that comes from generation is reduced by more than half, and mode shifts from car and air/coach are also significantly reduced. These changes result from the fact that in the probabilistic approach, introducing HSR leads to an improvement in the logsum for the rail nest, and this always has a greater impact for higher-level choices than improving the attractiveness of a particular alternative in the minimum generalised cost approach. **These results illustrate that modelling HSR/classic rail choice using a minimum generalised cost approach instead of a probabilistic approach results in a significant change in the composition of HSR demand and indicates the need to recalibrate if the model of HSR/classic rail choice is changed.** It is noted that when PLD moved from a probabilistic HSR/classic rail choice to an assignment choice, no model recalibration was undertaken.

Comparing the composition of HSR demand between the XLDM probabilistic model and XPLD, it can be seen that the XLDM predicts significantly higher generation, and higher air/coach capture, relative to XPLD. Consequently the proportion of classic rail capture is significantly higher in XPLD.

Comparing the XLDM minimum generalised cost results with XPLD, we see greater similarities in the composition of demand, with 13–14 percent due to generation, and 66–74 percent due to classic rail capture. However, car capture is lower in percentage terms for XLDM. These differences are explored further in the purpose-specific comparisons presented in Table 28 to Table 30 and Figure 2 to Figure 4 below.

In terms of absolute levels of demand, HSR demand is significantly higher in the two XLDM versions compared with XPLD. Again, differences in total levels of demand are explored further in the purpose-specific comparisons given below.

4.2.1 Comparison with real-world examples of HSR

Before going on to present purpose-specific comparisons of the three models, it is useful to compare the composition of demand presented in Table 26 with the observed composition of HSR demand for five other European HSR corridors, using the values quoted by Preston (2009). While we would expect the composition of HSR demand to vary between the different corridors as a result of differences in geography and levels of competition from other modes, the comparison is nonetheless useful in setting the predictions of the three incremental models in context.

Our understanding is that the generation figures quoted by Preston include redistribution from other destinations, as well as generation of additional trips for the corridor in question, though Preston does not state this explicitly. In the XLDM numbers quoted above the generation figures do not include redistribution from other destinations, and XPLD does not model redistribution. Note that approximately 20 percent of total HSR demand predicted by the probabilistic HSR-choice version of LDM is between London and West Midlands productions and attractions. Additional HSR demand would be expected in this corridor for movements between the West Midlands and the South East.

Table 27: Composition of HSR demand in five existing HSR corridors

	Generation	Car capture	Air capture	Classic rail capture	Total
Paris–Lyons 430km	29%	11%	20%	40%	29%
Madrid–Seville 471km	50%	6%	24%	20%	50%
Madrid–Barcelona 630km	20%	10%	60%	10%	20%
Thalys	11%	34%	8%	47%	11%
Eurostar	20%	19%	49%	12%	20%
Average	26%	16%	32%	26%	26%

Source: Preston, 2009, Table 1

The composition of HSR demand in the Paris–Lyons corridor matches closely the composition of HSR demand predicted by the XLDM probabilistic model for the 2008 HSR Y-network. It is also noteworthy that the average proportion of generation predicted across these five corridors is 26 percent, in line with the prediction of the XLDM probabilistic model. Furthermore the average proportion of car capture is 16 percent, in line with the relatively low percentages predicted by the three models presented in Table 26.

Key differences between the demand composition in these five corridors and the demand predicted for the 2008 HSR Y-network are higher levels of air capture and lower levels of classic rail capture in the five corridors. In particular, for the longest (Madrid–Barcelona) air capture accounts for 60 percent of demand, much higher than the level of air capture predicted for the 2008 Y-network. However, in these corridors the journey length is significantly higher than for journeys between London, Birmingham, Manchester and Leeds.

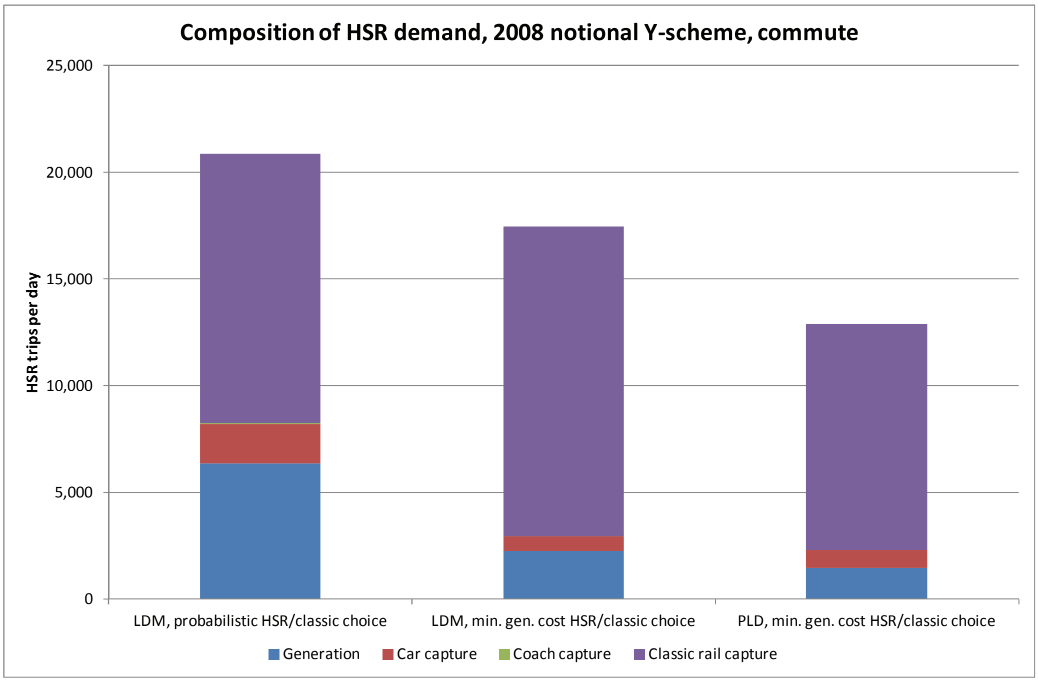
4.2.2 Purpose-specific comparisons

Below we present the model results by purpose.

Table 28: Commute HSR demand, enhanced HSR LOS

	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM, probabilistic HSR/classic choice	6,353.7 30.4%	1,819.3 8.7%	44.6 0.2%	12,655.6 60.6%	20,873.2 100.0%
XLDM, min. gen. cost HSR/classic choice	2,260.9 12.9%	666.5 3.8%	16.2 0.1%	14,518.9 83.1%	17,462.4 100.0%
XPLD, min. gen. cost HSR/classic choice	1,431.3 12.6%	850.0 7.2%	0.0 0.0%	10,595.6 80.2%	12,876.9 100.0%

Figure 2: Commute HSR demand, enhanced HSR LOS



The probabilistic version of XLDM predicts significantly higher generation than the XLDM and XPLD minimum generalised cost models. In the probabilistic LDM, generation accounts for 30 percent of HSR demand, compared to 13 percent in PLD. These differences follow from the fact that improving the HSR logsum has a greater impact on higher-level choices in the probabilistic HSR/classic rail choice version of XLDM.

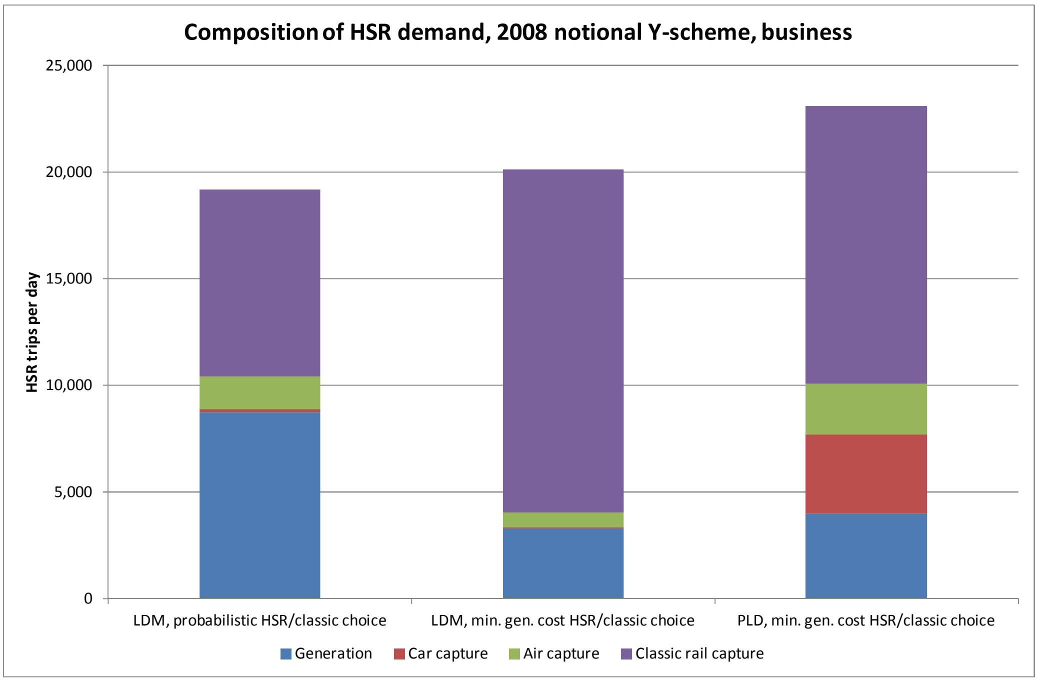
When the XLDM minimum generalised cost and XPLD runs are compared, while XLDM predicts more trips overall, the relative contributions of generation and classic rail capture are similar between the two models. Thus modelling HSR/classic rail choice using a minimum generalised cost approach, rather than using the probabilistic approach, has a significant impact on the composition of predicted HSR demand.

Reviewing the total levels of demand, it can be seen that both XLDM versions predict significantly higher demand for HSR than XPLD. The investigations in Section 3.4 suggest that the XPLD results are highly sensitive to changes in access/egress times, and therefore the use of the LDM-based access/egress information for XPLD is believed to underlie the differences in total commute demand.

Table 29: Business HSR demand, enhanced HSR LOS

	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM, probabilistic HSR/classic choice	8,708.9 45.4%	186.4 1.0%	1,510.7 7.9%	8,793.4 45.8%	19,199.4 100.0%
XLDM, min. gen. cost HSR/classic choice	3,267.9 16.2%	69.0 0.3%	666.7 3.3%	16,122.7 80.1%	20,126.3 100.0%
XPLD, min. gen. cost HSR/classic choice	3,989.5 17.3%	3,699.8 16.0%	2,373.6 10.3%	13,024.7 56.4%	23,087.6 100.0%

Figure 3: Business HSR demand, enhanced HSR LOS



The composition of HSR business demand varies considerably between the three models. In the probabilistic version of XLDM, 45 percent of demand is due to generation, 46 percent is due to capture from classic rail and switching from car is very low. These results follow from the structural parameters estimated in the LDM business model, which imply that frequency and main mode choice are equally sensitive to changes in utility, and that the choice between air and rail is significantly more sensitive than the choice between public transport modes and car.

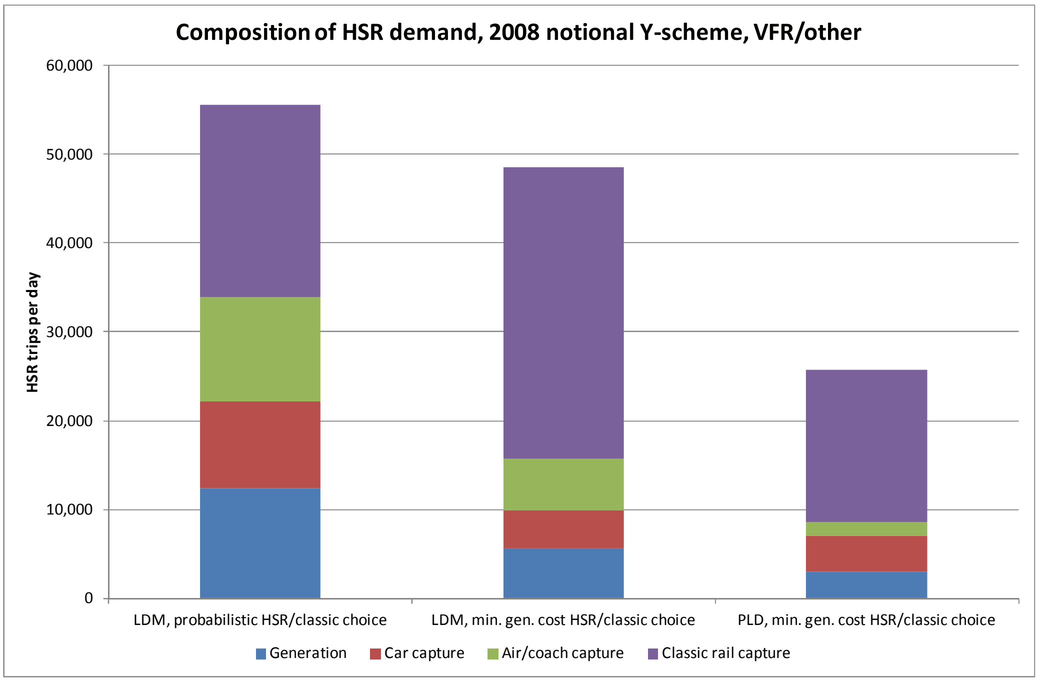
When XLDM is run with the minimum generalised cost approach, the proportion of HSR demand from generation is reduced substantially to 16 percent of total demand, similar to the proportion predicted in PLD. However, car and air capture remain low, and consequently classic rail capture accounts for 80 percent of the predicted demand, compared to 56 percent in PLD. As noted above, the low levels of car capture in XLDM follow from the value of the structural parameter for car versus public transport mode choice.

The total levels of HSR demand are reasonably consistent between the three models, with XPLD actually predicting slightly higher demand for HSR compared with the two XLDM versions.

Table 30: VFR/other HSR demand, enhanced HSR LOS

	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM, probabilistic HSR/classic choice	12,432.7 22.4%	9,655.1 17.4%	11,874.9 21.4%	21,650.3 38.9%	55,613.0 100.0%
XLDM, min. gen. cost HSR/classic choice	5,573.7 11.5%	4,365.9 9.0%	5,827.5 12.0%	32,748.3 67.5%	48,515.4 100.0%
XPLD, min. gen. cost HSR/classic choice	3,010.7 11.7%	3,983.7 15.5%	1,600.5 5.8%	17,069.2 67.0%	25,664.1 100.0%

Figure 4: VFR/other HSR demand, enhanced HSR LOS



It is noted that XPLD does not model any coach demand, whereas in XLDM the total coach demand is around three times as high as the total air demand. For this reason, the air/coach capture totals are expected to be higher for the two XLDM runs.[9]

9 Note that XLDM does not predict air and coach capture separately. However, when the real LDM is applied for the same 2008 HSR scheme, predicted coach capture is 9,192 trips, 3.7 times as high as the predicted air capture of 2,482 trips.

As with commute and business, the predicted proportion of HSR demand that comes from generation is highest in the probabilistic version of XLDM (22 percent). The probabilistic version of XLDM also predicts substantial contributions from car capture and air/coach capture, so that classic rail capture accounts for just under 40 percent of total HSR demand.

Running the XLDM version with the minimum generalised cost approach results in the proportion of HSR demand from generation halving, and similar reductions are seen in the car capture and air/coach capture shares. Consequently the share of HSR demand predicted from classic rail capture increases substantially, from 39 percent to 68 percent.

Comparing the XPLD results with those obtained from XLDM minimum generalised cost, it is noteworthy that the proportions of demand that come from generation and classic rail capture correspond closely, a pattern that was also observed for commuting. Car capture is higher in XPLD, whereas air/coach capture is lower as expected due to the omission of coach in XPLD.

The total volume of HSR demand predicted in the XLDM probabilistic version is significantly higher than that predicted by XPLD. The investigations in Section 3.4 suggest that the XPLD results are highly sensitive to the assumptions made about HSR access/egress times, with the VFR/other model most sensitive of all. Therefore, the use of the LDM-based LOS information for XPLD is believed to underlie the differences in total VFR/other demand.

4.3 Impact of redistribution in LDM

The LDM model incorporates destination choice, and therefore it is useful to examine the total volume of redistribution that results from the introduction of the HSR scheme. Redistribution has been calculated by eliminating the generation effect, and then calculating the changes in demand for HSR-available destinations summed across all modes. This allows demand for HSR to be decomposed into generation, redistribution from other destinations summed across all modes and pure mode switching from the same destination.

These calculations have been made separately for the probabilistic and minimum generalised cost versions of XLDM. However, the calculation gave implausibly high redistribution for the probabilistic version of the business model, and it was not possible to solve the issues in the calculations in the time available for completion of this work. Therefore redistribution results for this model are not presented.

Table 31: Commute HSR demand, redistribution effects

	Generation	Redistribution	Pure mode switching	Total HSR demand
XLDM, probabilistic HSR/classic choice	6,353.7 30.4%	5,029.7 24.1%	9,489.8 45.5%	20,873.2 100.0%
XLDM, min. gen. cost HSR/classic choice	2,260.9 12.9%	6,191.5 35.5%	9,010.1 51.6%	17,462.4 100.0%

Redistribution from other destinations accounts for 24–36 percent of total HSR demand for commute, and therefore is a significant effect. In the LDM commute model, destination choice is the lowest in the choice structure, and therefore is expected to be sensitive to generalised cost changes. It is noted that the majority of pure mode switching will be shifting from classic rail for the same P/A pair.

Table 32: Business HSR demand, redistribution effects

	Generation	Redistribution	Pure mode switching	Total HSR demand
XLDM, min. gen. cost HSR/classic choice	3,267.9 16.2%	4,314.4 21.4%	12,544.1 62.3%	20,126.3 100.0%

The contribution from redistribution in the minimum generalised cost version of the model is lower than that observed for commute, but is nonetheless a significant component of demand, with a greater contribution than generation. Given the low car and air capture totals for business in this model the majority of the redistribution effect will be shifts from classic rail for other destinations. Similarly the majority of pure mode switching is switching from classic rail for the same destination.

Table 33: VFR/other HSR demand, redistribution effects

	Generation	Redistribution	Pure mode switching	Total HSR demand
XLDM, probabilistic HSR/classic choice	12,432.7 22.4%	21,329.2 38.4%	21,851.1 39.3%	55,613.0 100.0%
XLDM, min. gen. cost HSR/classic choice	5,573.7 11.5%	19,995.5 41.2%	22,946.2 47.3%	48,515.4 100.0%

The redistribution effect is strongest in percentage terms in the VFR/other model, to the extent that in the probabilistic version of the model the effect is almost as strong as pure mode switching from the same destination. While the majority of redistribution will be from classic rail, the contributions from car, air and coach capture will be higher than for commute and business, as the levels of capture from these modes are largest in VFR/other.

These redistribution runs demonstrate that redistribution makes a significant contribution to total HSR demand in XLDM, accounting for 20–40 percent of total HSR demand. Redistribution is higher in the commute and VFR/other models, for which destination choice is the lowest level (most sensitive) choice, than in the business model, for which the HSR/classic rail choice is the lowest level choice.

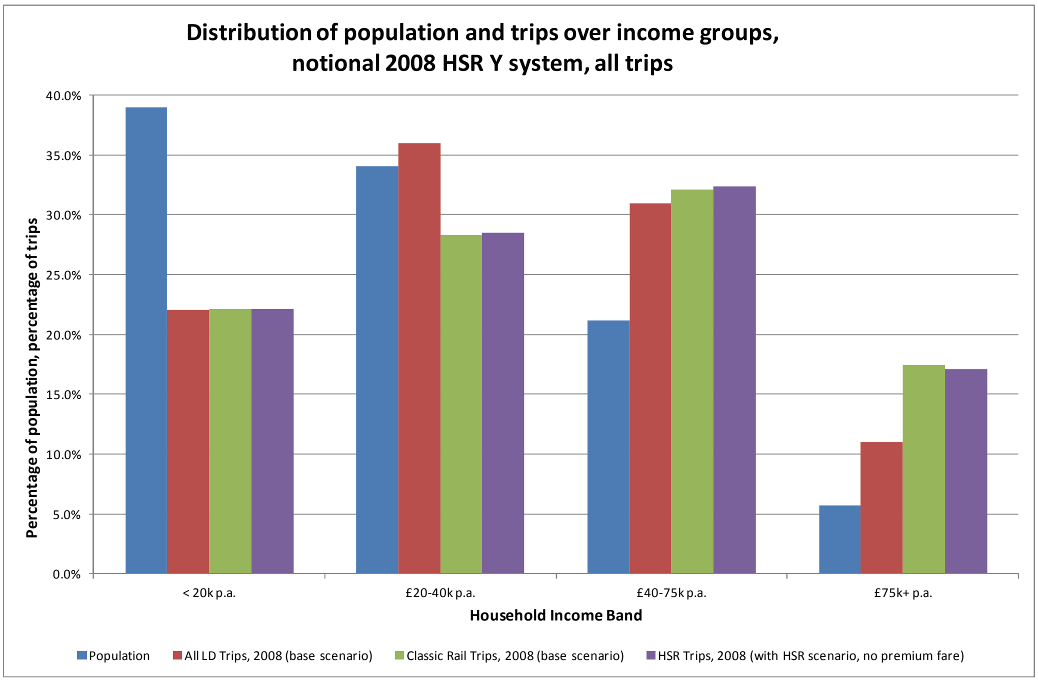
4.4 Composition of HSR demand by income band

The distribution of total HSR demand across income bands has been compared with:

- the distribution of the 2008 population as a whole
- the distribution of all long-distance trips across income bands
- the distribution of classic rail trips across income bands.

This information has been taken from a run of the real LDM for 2008 with the HSR Y-network scenario. This comparison is presented in Figure 5.

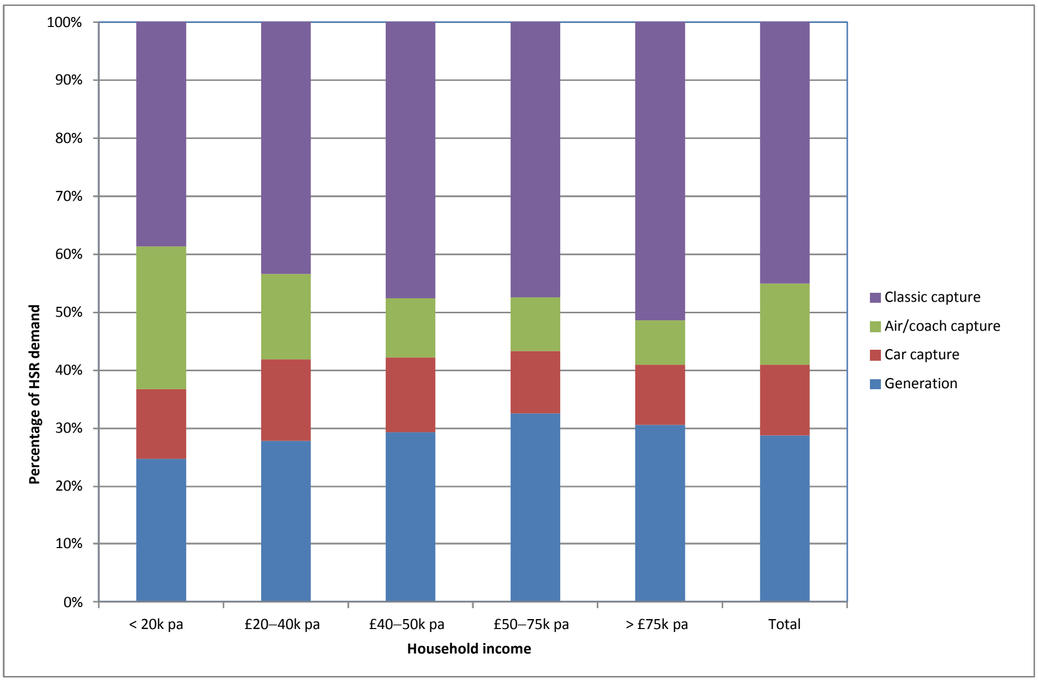
Figure 5: Distribution of population and long-distance trips over income bands



The comparison of the bars for population (blue) and all long-distance trips (red) clearly demonstrates that long-distance trips are much more likely to be made by higher income groups. The bars for classic rail (green) and HSR (purple) demonstrate that rail users have higher incomes on average than long-distance travellers as a whole. However, under the no-premium-fare assumption, there is no significant difference between the income profiles of classic rail and HSR users.

The composition of HSR demand across income bands is presented in Figure 6.

Figure 6: Composition of HSR demand across income bands



It can be seen that generation and classic rail capture shares increase with income band, whereas air/coach capture falls with income band, driven by a falling share for coach travel.

4.5 Elasticity to HSR fare

HSR fare elasticities have been obtained by applying a 10 percent increase to the HSR fare, and calculating the resulting reduction in HSR demand. The results are summarised in Table 34.

Table 34: HSR fare elasticities by model and purpose

Model	Purpose			
	Commute	Business	VFR/other	Total
XLDM, probabilistic HSR/classic choice	-1.12	-0.73	-1.55	-1.29
XLDM, min. gen. cost HSR/classic choice	-2.23	-1.22	-2.47	-2.14
XPLD, min. gen. cost HSR/classic choice	-6.52	-2.01	-6.42	-4.56

Our understanding is that PDFH recommends long-distance fare elasticities in the range -0.85 to -1.00 for corridors where rail is competitive relative to other modes (and lower in other cases), though as classic rail remains in place we would expect the HSR fare elasticities to be somewhat higher than the PDFH range. The values obtained for the probabilistic version of LDM straddle the PDFH range of values, and the pattern of inter-purpose variation is consistent with the fare elasticity tests made during the LDM model estimation stage, when business was observed to be the least elastic model to fare changes and VFR/other the most elastic.

When XLDM is run with a minimum generalised cost approach, the HSR fare elasticities increase substantially. Modelling HSR/classic rail choice on the basis on minimum generalised cost will introduce some lumpiness to the results, as some destinations that were previously assigned to HSR will shift to classic rail, and this reassignment effect leads to a significant increase in elasticity.

The elasticities observed for XPLD are very high for commute and VFR/other, more than double the LDM minimum generalised cost values. This result implies that there are a lot of P/A pairs where the generalised cost of HSR is only slightly higher than that for classic rail. With just a 10 percent increase in HSR fare, there is a substantial reduction in the number of P/A pairs for which HSR is chosen over classic rail, and therefore a substantial reduction in HSR demand. To confirm this explanation, changes in the number of destinations for which HSR is chosen were calculated. These are summarised in Table 35.

Table 35: XPLD HSR fare elasticity runs, changes in destinations chosen for HSR

	Commute	Business	VFR/other
Change in HSR demand	-46.3%	-17.4%	-45.8%
Change in destinations chosen for HSR	-22.7%	-7.8%	-28.8%

Assuming HSR demand is uniformly distributed over destinations, these results suggest that around half of HSR demand is lost due to reassignment to classic rail, but that another half is lost to mode choice for those destinations that are still chosen for HSR. This means that the mode-choice elasticity to HSR fare changes would be in excess of two, so that XPLD has a high sensitivity to fare changes.

Our understanding is that when Atkins tested the impact of premium fare assumptions in the HS2 modelling, it used distributed VOTs to avoid 'lumpy' assignments, where a lot of demand shifts to and from HSR in response to fare changes (Atkins, 2010a). This approach is consistent with the substantial changes in HSR-available destinations noted in Table 35, as using a distributed VOT would smooth the HSR/classic rail split in the assignment. Nonetheless, the results in Table 35 suggest that even with a smoothed assignment effect, the mode-choice elasticity would be in excess of two, and there would still be a (reduced) assignment elasticity, and therefore XPLD would retain a highly sensitivity to fare changes.

The two sets of XLDM elasticity runs demonstrate that modelling the HSR/classic rail choice on the basis of minimum generalised cost rather than using a choice model results in a substantial increase in the HSR elasticity due to reassignment. The results for XPLD, together with the tests of the sensitivity of HSR demand to HSR access/egress presented in Section 3.4, demonstrate that the predicted demand for HSR in XPLD is highly sensitive to the LOS assumptions made for HSR. On the basis of these results, it is suggested that sensitivity tests should be run for the full PLD HS2 model runs to assess the sensitivity of predicted HSR demand to changes in modelled HSR LOS.

4.6 Comparisons for specific production zones

In addition to the predictions of total HSR demand outlined in Section 4.2, comparisons have been obtained for three specific production zones, Birmingham, Bradford and Richmondshire in North Yorkshire, for travel to London attractions.

The comparison for the Birmingham production zone provides allows XPLD and XLDM demand to be compared for a production with relatively low access times to HSR, so that the demand comparisons are more strongly influenced by the journey-time savings between classic rail and HSR. The results for the Birmingham production zone can then be compared with those for the Bradford production zone, where access to HSR involves a short classic rail access journey to Leeds, and Richmondshire where a lengthy access journey is required to access HSR.

Table 36: Total HSR demand, Birmingham production zone to London attractions

Model	Purpose			
	Commute	Business	VFR/other	Total
XLDM, probabilistic HSR/classic choice	861	641	2,180	3,682
XLDM, min. gen. cost HSR/classic choice	1,005	819	1,565	3,390
XPLD, min. gen. cost HSR/classic choice	1,159	939	1,743	3,842

For the Birmingham production zone, with good access to HSR, the overall levels of HSR demand are reasonably consistent between XLDM and XPLD, with XPLD forecasting slightly higher demand overall. For commute and business, the minimum generalised cost models predict more demand for HSR, as for P/A pairs where HSR is more attractive than classic rail in generalised cost terms, all rail demand is forecast to use HSR. By contrast, in the probabilistic version of the model some classic rail demand will still be forecast.

Table 37: Total HSR demand, Bradford production zone to London attractions

Model	Purpose			
	Commute	Business	VFR/other	Total
XLDM, probabilistic HSR/classic choice	313	151	531	995
XLDM, min. gen. cost HSR/classic choice	368	185	568	1,121
XPLD, min. gen. cost HSR/classic choice	197	204	210	611

For the Bradford production zone, total HSR demand in XPLD is significantly lower than in XLDM for commute and VFR/other, and as a result the total demand is also lower. However, for business the XPLD results are slightly higher than those predicted in XLDM, consistent with the higher overall demand in XPLD for business compared to XLDM.

Table 38: Total HSR demand, Richmondshire production zone to London attractions

Model	Purpose			
	Commute	Business	VFR/other	Total
XLDM, probabilistic HSR/classic choice	26	15	37	78
XLDM, min. gen. cost HSR/classic choice	14	18	24	56
XPLD, min. gen. cost HSR/classic choice	29	19	17	65

Overall levels of demand from the Richmondshire production zone are significantly lower, as would be expected. The XLDM probabilistic model predicts the highest demand which would be expected because for P/A pairs where HSR has a low probability of being chosen compared to classic rail, the minimum generalised cost approach will assign all rail demand to classic rail.

These runs demonstrate the differences in the HSR demand predictions between the probabilistic and minimum generalised cost approaches for P/A pairs where HSR is more and less attractive relative to classic rail. There is some evidence that XPLD model predicts lower demand for VFR/other compared to the probabilistic version of the XLDM for P/A pairs where access is more difficult relative to classic rail.

CHAPTER 5 Additional PLD analysis

The analysis presented in Section 3.4 demonstrated significant differences between the levels of demand for HSR predicted by the spreadsheet application of PLD using LDM-derived LOS, termed 'XPLD' in this chapter, and the 'real' version of PLD run by Atkins. A meeting was held at HS2's offices on 10 January 2012, and at that meeting a number of additional analyses were agreed in order to understand better the differences between the XPLD and real-PLD forecasts for HSR.

In summary, the additional analyses that have been undertaken are:

- investigation of differences between the PLD and LDM rail cost skims
- a review of the performance of XPLD so that the classic rail versus HSR choice is determined on the basis of minimum generalised journey time (with fares having no impact), and with cost and parameter adjustments applied in a consistent fashion to real PLD
- investigation of the impact of multi-routing in real PLD, whereby demand is shared between classic rail and HSR for a given OD pair.

Outputs from the revised version of XPLD are used to inform all three components of this analysis, and so this chapter starts in Section 5.1 with a detailed explanation of the changes made to XPLD. Subsequent sections of the chapter present the three sets of analysis summarised above.

5.1 Revisions to XPLD

Following clarification from Atkins at the meeting on 10 January 2012, two changes were made to the treatment of costs and adjustments to the parameters for different model years to achieve consistency with the assumptions Atkins used when running PLD for 2008:

- costs in 2008 prices were deflated to 2002 prices for consistency with PLD
- the adjustment to the model parameters which had been made to take account of real growth in VOT between 2002 and 2008 were removed so that the PLD model parameters in 2002 values are now used (as specified in Table 11).

A key change made to the operation of XPLD was in how the choice between classic rail and HSR is determined. In real PLD, the choice between classic rail and HSR is made in the rail assignment on the basis of minimum generalised journey time (GJT), rather than on the basis of the generalised cost difference calculated for the application of the mode-choice model. Therefore XPLD has been modified so that the choice between classic rail and HSR is determined on the basis of minimum GJT, using the weights specified in the table below, rather than on the basis of the generalised cost difference calculated for application of the mode-choice model. It noted that when XPLD is applied, crowding effects are added to the cost term and as such do not contribute to GJT.

The GJT weightings used in the rail assignment were specified in Table 5.7 of the *Model Development Report* (Atkins, 2010a), which is reproduced in Table 39.

Table 39: PLD assignment model GJT parameters

Parameter	Value
Board penalty (minutes)	30
Wait-time factor	0.4
Wait-time weight	2.0
Access/egress-time weight	4.0
Board-time weight	1.0

The LDM-derived LOS does not specify boarding times separately, so these have not been included in the calculation of GJT for classic rail and HSR. The other parameters have been applied to the LDM-derived LOS to calculate classic rail and HSR GJT. If HSR has a non-zero in-vehicle time for a given P/A pair, and has a lower GJT than classic rail, then it is modelled as being chosen.

The high weight of 4 applied to access/egress time when calculating the GJT differences should be noted. In the XPLD results presented in Chapters 3 and 4, the choice of HSR was made on the basis of the difference in generalised cost calculated using the PLD mode-choice parameters presented in Table 14. In the PLD mode-choice parameters, access time is weighted by approximately 1.3 relative to in-vehicle time. Thus moving from minimum generalised cost to minimum GJT to determine the classic versus HSR choice substantially increases the weighting on access/egress time.

For P/A pairs for which HSR is chosen, the generalised cost difference between classic rail and HSR is calculated to feed into the mode-choice model. The calculation of the generalised cost difference has not been changed from the original version of XPLD described in Chapter 3. In particular, any differences in cost due to crowding on classic rail contribute to the calculation of the generalised cost difference.

The choice between HSR and classic rail in XPLD has been reformulated so that it is made on the basis of minimum generalised journey time, rather than minimum generalised cost. A key impact of this change is that access/egress times are now weighted by 4 in the GJT calculation, rather than by the 1.3 factor applied in the generalised cost calculations used in the mode-choice model. For P/A pairs for which HSR is chosen, the generalised cost difference between classic rail and HSR is calculated for input into the mode-choice model.

5.2 Comparison of PLD and LDM rail cost skims

Two sets of analyses have been undertaken to compare the PLD and LDM cost skims. First, a comparison of individual components has been made between PLD and LDM to investigate the similarities in the cost skims in the base case in which HSR is not present. Second, a detailed comparison has been made for six P/A pairs of the *differences* in the PLD and LDM cost skims that follow from the introduction of HSR.

5.2.1 Comparison of rail cost skims in the base case with no HSR

The LDM LOS is calculated as tour (two-way) LOS. To compare the LDM LOS with PLD, PLD LOS for the NCA segment has been extracted. In PLD the NCA segment works on an OD basis, and therefore the LOS for the movement from O to D has been added to the LOS for the movement from D to O so that LOS for both outward and return directions is calculated and can be compared with the tour-based LOS available from LDM.

The situation is more complex for access/egress time. In LDM, access/egress times for classic rail are calculated as a weighted average over car, walk and other public transport access modes. The relative weighting for each component is based on the access shares observed for the zone in NRTS data. For PLD, access is calculated separately for NCA, CA from home and CA to home segments. For this comparison, a weighted average access time for the P/A pair has been calculated over these three segments, weighting by the total volume of demand in each segment in the 2008 rail base matrices.

Cost skims have been compared for commute (which in LDM is modelled using an am-peak rail assignment model) and for VFR/other (which in LDM is modelled using an inter-peak rail assignment model). The PLD models all purposes using an all-day rail assignment model. All fares have been calculated in 2008 values and prices for these comparisons.

For commute, the comparison is based on the 22,444 P/A pairs where the LDM and PLD zoning maps one-to-one and where both models have a non-zero value for the rail skims. The comparison is presented in Table 40.

Table 40: Comparison of PLD and LDM commute rail skims

Component	PLD		LDM		Correlation
	Mean	Standard deviation	Mean	Standard deviation	
Fare (2008 values & prices)	4,198.1	2,310.3	5,878.3	3,055.7	0.770
In-vehicle time	440.0	200.8	412.0	188.3	0.962
Access/egress time	389.6	285.1	81.8	56.4	0.117
Frequency[10]	2.3	1.1	3.3	2.1	0.354
Interchanges	2.9	1.3	4.5	2.0	0.535

The mean fares in PLD are around 71 percent of the LDM values, but the individual values correlate reasonably well with the LDM values.[11] PLD fares are taken from EDGE

[10] For PLD, frequencies have been inferred from the first-wait times, and the wait-time factor of 0.4.

[11] Note that the LDM fare values include both the fare and a weighting for crowding in pence, but contribution of crowding to total commute costs is relatively small, typically 1–2 percent of the total cost.

(Exogenous Demand Growth Estimator) whereas the LDM values are based on LENNON data, with NRTS used to provide additional information regarding the correlation of ticket types with journey purposes and to inform the proportions of demand using specific stations. The EDGE-based values in PLD are noticeably lower than the LENNON-based values in LDM.

For in-vehicle time, the mean values correspond well between the two models, and the individual values are highly correlated.

Mean access/egress times are substantially higher in the PLD model, and the individual values correlate poorly. As the PLD values are more than four times higher than the LDM values, it was queried with Atkins whether they had been pre-weighted by a factor of four for application in the GJT calculation, but Atkins clarified that the values were not pre-weighted.

Mean service frequencies are higher in LDM, which may follow from the fact that they are from an am-peak model, and the mean number of interchanges is noticeably higher. In both cases, the two sets of values do not correlate closely at the OD level.

For VFR/other, there a total of 23,202 P/A pairs where the LDM and PLD zoning maps one-to-one and where both models have a non-zero values for the rail skims. The comparison is presented in Table 41.

Table 41: Comparison of PLD and LDM VFR/other rail skims

Component	PLD		LDM		Correlation
	Mean	Standard deviation	Mean	Standard deviation	
Fare (2008 values & prices)	4,571.9	2,052.3	7,607.5	4,031.8	0.900
In-vehicle time	435.9	198.7	416.1	189.5	0.959
Access/egress time	385.1	284.1	82.7	55.7	0.120
Frequency	2.2	1.1	2.7	1.1	0.468
Interchanges	2.8	1.3	4.1	1.7	0.545

The mean value for PLD fare skims is significantly lower than that for LDM, so EDGE is again giving significantly lower estimates of fare compared to the LENNON-based data used in LDM, but the two sets of skims do correlate well at the individual P/A pair level. Mean in-vehicle times match well, and the values correlate closely at the individual P/A pair level.

The story for access/egress time is the same as for commute, with mean values in PLD more than four times higher than the LDM values.

Mean frequencies match more closely than for commute, and correlate better at the individual P/A pair level, though LDM again has higher mean frequencies. The mean number of interchanges is again significantly higher in the LDM rail model.

In summary, mean rail in-vehicle times correspond well between the PLD and LDM rail models. Access/egress times appear to be substantially higher in PLD by a factor of more than four. Frequencies and numbers of interchanges are somewhat higher in the LDM models.

5.2.2 Comparison of cost skims when HSR is introduced

To investigate the impact of differences in the cost skims in more detail, six P/A pairs have been analysed in more detail to look at the impact of the differences between the PLD and LDM LOS. These P/A pairs have been selected using LDM zones where the LDM and PLD zoning maps one-to-one. The P/A pairs are detailed in Table 42. For PLD, skims have been extracted for the two CA segments. Mean values between the CA-to and CA-from segments are presented. The generalised cost calculations use an average of the values for the CA-to and CA-from segments, following exactly the calculation procedure set out in a spreadsheet supplied by Atkins. All costs are calculated in 2002 prices.

Table 42: Test P/A pairs

Production	LDM zone	PLD zone	Attraction	LDM zone	PLD zone
Birmingham	352	5	Leeds	396	105
Birmingham	352	5	Glasgow	203	37
Birmingham	352	5	Sunderland	140	189
Nottingham	79	139	Richmondshire	399	147
Nottingham	79	139	Glasgow	203	37
Sunderland	140	189	Milton Keynes	250	132

Commute

For commute, there is no base rail demand in PLD for the first three P/A pairs. This means there are no rail cost skims for these P/A pairs, and therefore the generalised cost difference that results when HSR is introduced cannot be calculated.

However, the skims can be compared for the final three P/A pairs. Yellow shading indicates that HSR would not be chosen for the P/A pair on the basis of minimum GJT, which is presented in Table 45 below.

Table 43: Comparison of skims, XPLD calculations, LDM-derived LOS, commute

	Base case, classic only						Skims from separate HSR Y-network					
P/A pair	Cost	Time	Access time	Frequency	Headway	Inter-change	Cost	Time	Access time	Frequency	Headway	Inter-change
Nottingham–Richmondshire	2,252.66	134.51	20.52	4.54	13.22	1.48	2,261.18	85.00	27.17	1.00	60.00	0.00
Nottingham–Glasgow	3,524.04	311.08	35.93	4.67	12.85	2.35	2,462.87	132.45	164.08	1.26	47.45	0.00
Sunderland–Milton Keynes	4,603.17	216.77	45.51	2.33	25.78	1.89	2,644.07	107.91	165.04	1.22	49.04	0.00

Table 44: Comparison of skims, PLD calculations, CA segment, commute

	Base case, classic only						With HSR Y-network					
P/A pair	Cost	Time	Access time	Frequency	Headway	Inter-change	Cost	Time	Access time	Frequency	Headway	Inter-change
Nottingham–Richmondshire	740.39	130.12	322.74		64.03	1.625	740.39	95.18	481.89		56.06	0.50
Nottingham–Glasgow	3,155.73	333.54	44.56		99.13	2.00	3,155.73	273.51	44.13		69.94	1.25
Sunderland–Milton Keynes	3,880.69	287.39	95.14		98.69	1.85	3,880.69	195.19	106.73		46.13	1.50

These LOS inputs give rise to the following differences in generalised cost and GJT for the classic rail only (C) and with HSR Y-network (H) cases. In XPLD the choice between classic rail and HSR is based on minimum GJT. If HSR has a lower GJT than classic rail (indicated by green shading of the GJT_H cell) then HSR is chosen.

Table 45: Generalised cost and journey time, XPLD calculations, LDM-derived LOS, commute

P/A pair	GC_C	GC_H	GJT_C	GJT_H
Nottingham–Richmondshire	4,686.8	4,430.7	301.5	271.7
Nottingham–Glasgow	8,789.3	8,097.1	565.6	856.7
Sunderland–Milton Keynes	8,813.2	7,963.3	506.2	837.3

Table 46: Generalised cost and journey time, PLD calculations, CA segment, commute

P/A pair	GC_C	GC_H	GJT_C	GJT_H
Nottingham–Richmondshire	9,423.4	11,696.8	1,551.07	2,112.58
Nottingham–Glasgow	9,801.5	8,457.3	681.06	573.46
Sunderland–Milton Keynes	10,710.2	9,115.0	832.41	733.99

In the XPLD case, higher access time skims for HSR mean that HSR is not chosen for the Nottingham–Glasgow or Sunderland–Milton Keynes P/A pairs. However in the PLD case, access times for these two OD pairs are similar in the base and with-HSR cases, and the comparison of in-vehicle times between the base and with-HSR-Y-network cases shows that HSR is used. For the Nottingham–Richmondshire P/A pair, the access/egress times for the CA-to segment change substantially between the base and with-HSR cases. As a result, the GJT for HSR is worse in the PLD calculations.

Differences in the values of access/egress times are key to the differences between the two sets of LOS inputs in the predictions of whether or not HSR will be chosen for each P/A pair.

Business

The skims for business are shown in the following Tables 47 and 48.

Table 47: Comparison of skims, XPLD calculations, LDM-derived LOS, business

	Base case, classic only						Skims from separate HSR Y-network					
P/A pair	Cost	Time	Access time	Frequency	Headway	Inter-change	Cost	Time	Access time	Frequency	Headway	Inter-change
Birmingham–Leeds	2,745.60	124.74	37.22	2.31	25.97	0.04	2,728.55	57.64	42.80	1.59	37.71	0.00
Birmingham–Glasgow	6,146.71	238.92	48.84	1.13	52.94	0.54	4,581.48	139.63	132.61	1.28	46.74	0.00
Birmingham–Sunderland	5,003.29	227.17	29.67	2.16	27.83	1.06	3,803.68	88.47	86.82	1.00	60.00	0.00
Nottingham–Richmondshire	3,941.68	140.14	20.83	4.42	13.58	1.45	3,893.48	85.00	24.02	1.00	60.00	0.00
Nottingham–Glasgow	5,937.98	315.42	33.35	4.03	14.87	2.43	4,479.42	129.32	151.52	1.20	49.82	0.00
Sunderland–Milton Keynes	8,276.20	236.54	45.51	2.67	22.50	1.63	5,341.55	112.94	138.06	1.36	44.11	0.00

Table 48: Comparison of skims, PLD calculations, CA segment, business

	Base case, classic only						With HSR Y-network					
P/A pair	Cost	Time	Access time	Frequency	Headway	Inter-change	Cost	Time	Access time	Frequency	Headway	Inter-change
Birmingham–Leeds	2,593.58	122.30	56.41		60.14	0.01	2,593.58	61.57	56.41		35.47	0.00
Birmingham–Glasgow	3,406.30	262.66	27.28		86.14	0.71	3,406.30	248.93	27.09		79.54	0.65
Birmingham–Sunderland	3,441.36	222.72	65.78		67.08	0.51	3,441.36	150.99	65.86		89.94	0.50
Nottingham–Richmondshire	1177.16	123.93	304.14		64.72	1.68	1177.16	68.38	303.74		34.31	0.50
Nottingham–Glasgow	3,291.87	338.29	42.53		105.19	1.90	3,291.87	270.36	42.53		68.56	1.25
Sunderland–Milton Keynes	4,852.48	262.10	101.10		74.94	1.30	4,852.48	206.78	96.56		72.47	1.50

From these LOS inputs the following generalised cost and GJT differences are calculated:

Table 49: Generalised cost and journey time, XPLD calculations, LDM-derived LOS, business

P/A pair	GC_C	GC_H	GJT_C	GJT_H
Birmingham–Leeds	13,719.3	10,570.5	325.6	289.0
Birmingham–Glasgow	25,559.1	24,348.1	522.7	737.5
Birmingham–Sunderland	21,475.1	17,512.0	429.8	513.7
Nottingham–Richmondshire	14,188.6	12,619.3	307.8	259.1
Nottingham–Glasgow	27,469.3	25,179.3	563.7	805.3
Sunderland–Milton Keynes	26,339.8	23,875.6	515.6	730.5

Table 50: Generalised cost and journey time, PLD calculations, CA segment, business

P/A pair	GC_C	GC_H	GJT_C	GJT_H
Birmingham–Leeds	15,316.3	11,067.7	383.51	345.62
Birmingham–Glasgow	23,603.1	22,171.9	491.90	470.39
Birmingham–Sunderland	23,888.9	19,252.2	584.73	531.49
Nottingham–Richmondshire	31,870.0	27,069.3	1,472.53	1,355.78
Nottingham–Glasgow	30,134.3	24,334.4	679.54	562.81
Sunderland–Milton Keynes	29,916.2	25,949.9	795.45	725.98

Using the LDM-derived LOS, HSR is chosen for only two P/A pairs where the slightly higher access times in the HSR network are offset by the substantial journey time savings. For the other four P/A pairs, access times in the with-HSR network cases are substantially higher than in the base case as they include access to the first HSR station by classic rail. Given the weighting of four that is applied to access time in the GJT calculation, these P/A pairs are not chosen.

By contrast, with the PLD LOS access times are almost identical between the base and with-HSR cases. This is because time spent on classic rail to get to HSR services is classified as rail in-vehicle time, rather than access time. On the basis of the reductions in in-vehicle time between the base and with-HSR cases, it is clear that HSR is used for at least five of the P/A pairs in the with-HSR case, and possibly for the Birmingham–Glasgow P/A pair as well.

Thus differences in the treatment of access times between the LDM and PLD LOS result in HSR being chosen for more P/A pairs when working with the PLD LOS.

VFR/other

The skims for VFR/other are shown in Tables 51 and 52.

Table 51: Comparison of skims, XPLD calculations, LDM-derived LOS, VFR/other

	Base case, classic only						Skims from separate HSR Y-network					
P/A pair	Cost	Time	Access time	Frequency	Headway	Inter-change	Cost	Time	Access time	Frequency	Headway	Inter-change
Birmingham–Leeds	2,174.66	124.74	37.22	2.31	25.97	0.04	2,167.26	56.45	44.93	1.53	39.34	0.00
Birmingham–Glasgow	4,611.31	238.92	48.84	1.13	52.94	0.54	3,523.71	137.85	186.25	1.23	48.67	0.00
Birmingham–Sunderland	3,904.77	227.17	29.67	2.16	27.83	1.06	2,863.35	85.51	116.07	1.08	55.44	0.00
Nottingham–Richmondshire	2,914.71	140.14	20.83	4.42	13.58	1.45	2,916.47	85.00	28.94	1.00	60.00	0.00
Nottingham–Glasgow	4,472.91	315.42	33.35	4.03	14.87	2.43	3,326.59	133.26	196.11	1.23	48.92	0.00
Sunderland–Milton Keynes	6,036.24	236.54	45.51	2.67	22.50	1.63	3,642.70	107.25	184.18	1.23	48.92	0.00

Table 52: Comparison of skims, PLD calculations, CA segment, VFR/other

	Base case, classic only						With HSR Y-network					
P/A pair	Cost	Time	Access time	Frequency	Headway	Inter-change	Cost	Time	Access time	Frequency	Headway	Inter-change
Birmingham–Leeds	1,789.04	131.64	46.23		57.88	0.061	1,789.04	61.57	45.83		35.47	0.001
Birmingham–Glasgow	2,583.95	257.33	27.28		81.96	0.81	2,583.95	248.90	27.09		79.69	0.65
Birmingham–Sunderland	2,324.19	221.88	71.43		71.89	0.51	2,324.19	150.99	71.51		89.94	0.50
Nottingham–Richmondshire	1,001.33	127.30	320.75		70.13	1.70	1,001.33	67.66	320.86		32.53	0.65
Nottingham–Glasgow	2,548.85	340.70	44.34		102.31	1.95	2,548.85	270.45	44.34		69.25	1.25
Sunderland–Milton Keynes	3,518.66	273.70	105.66		76.56	1.43	3,518.66	206.75	105.66		72.47	1.50

The differences in generalised cost and generalised journey time are:

Table 53: Generalised cost and journey time, XPLD calculations, LDM-derived LOS, VFR/other

P/A pair	GC_C	GC_H	GJT_C	GJT_H
Birmingham–Leeds	5,151.3	4,409.2	325.6	297.7
Birmingham–Glasgow	9,890.3	10,011.5	522.7	951.8
Birmingham–Sunderland	8,330.3	7,190.8	429.8	624.1
Nottingham–Richmondshire	5,663.4	5,504.8	307.8	278.8
Nottingham–Glasgow	10,200.1	9,948.9	563.7	986.8
Sunderland–Milton Keynes	10,875.9	9.622.7	515.6	913.1

Table 54: Generalised cost and journey time, PLD calculations, CA segment, VFR/other

P/A pair	GC_C	GC_H	GJT_C	GJT_H
Birmingham–Leeds	5,667.8	3,995.1	394.69	303.31
Birmingham–Glasgow	8,174.1	7,863.5	486.22	470.48
Birmingham–Sunderland	8,208.6	6,952.0	610.36	554.11
Nottingham–Richmondshire	10,013.9	8,508.4	1,547.40	1,426.63
Nottingham–Glasgow	10,217.4	8,445.2	688.43	570.72
Sunderland–Milton Keynes	10,817.6	9,592.7	830.35	762.38

The story for VFR/other is consistent with the pattern observed for these six P/A pairs in business. Working with the LDM-derived LOS, higher access times in the separate with-HSR network mean that HSR is chosen for only two of the six P/A pairs. However, with the PLD LOS access times change only marginally when HSR is introduced, and on the basis of the differences in in-vehicle time HSR is used for at least five of the six P/A pairs.[12]

In the LDM-derived LOS, HSR access times include access by classic rail and therefore give rise to higher access time differences relative to the without-HSR case compared with the differences calculated from the PLD LOS. As a result of the weighting of four applied to access time, HSR is much less likely to be chosen in XPLD for a given P/A pair.

5.2.3 Impact of supply-demand iteration on PLD cost skims

When XPLD is run, there is no iteration between supply and demand, whereas the PLD results are those obtained after 12 iterations between the assignment and mode-choice models. Therefore generalised cost differences have been calculated for the first and final mode-choice iterations to assess the impact of iteration on the PLD cost skims. Generalised cost differences between the base and with-HSR cases have been calculated for the 1st and 11th iterations. (Skims from the 11th iteration are used to apply the mode-choice model at the final 12th mode-choice iteration.) In all cases, the generalised cost differences are calculated for the final *assignment* iteration of the mode-choice iteration, because the LDM skims for the separate HSR Y-network model are from a converged assignment. Cost skims from the CA segments have been used for these calculations.

The results are presented in Table 55.

Table 55: Impact of supply-demand iteration on PLD generalised cost differences

	Commute CA			Business CA			Other CA		
	MC Iter 1	MC Iter 11	Change	MC Iter 1	MC Iter 11	Change	MC Iter 1	MC Iter 11	Change
Birmingham–Leeds	n/a	n/a	n/a	-5,043	-4,249	-15.75%	-1,672	-1,673	0.01%
Birmingham–Glasgow	n/a	n/a	n/a	-1,516	-1,431	-5.60%	-340	-311	-8.69%
Birmingham–Sunderland	n/a	n/a	n/a	-4,642	-4,637	-0.12%	-1,258	-1,257	-0.11%
Nottingham–Richmondshire	2,267	2,273	0.30%	-4,823	-4,801	-0.46%	-1,508	-1,505	-0.17%
Nottingham–Glasgow	-1,348	-1,344	-0.28%	-5,812	-5,800	-0.22%	-1,778	-1,772	-0.31%
Sunderland–Milton Keynes	-1,597	-1,595	-0.12%	-3,974	-3,966	-0.20%	-1,225	-1,225	0.02%

For the Nottingham–Richmondshire P/A pair, the generalised costs *increase* in the with-HSR case due to substantial increases in access/egress times for the to-home segment. In all

[12] For Birmingham to Glasgow there is only a small reduction in rail in-vehicle time from 257 minutes to 249 minutes. For other P/A pairs, much larger reductions are observed and therefore HSR is clearly used.

other cases, generalised cost differences are negative as generalised costs are lower when HSR is introduced.

For most P/A pairs, only slight reductions in the generalised cost difference are observed between the first and 11th mode-choice iterations, implying that supply-demand iteration does not have a significant impact on the predicted demand for HSR in the PLD model. However, for the Birmingham–Leeds P/A pair a significant reduction in the generalised cost difference is observed for business, and for Birmingham–Glasgow a significant reduction is observed for other.

Overall, the results suggest that predicted demand for HSR in PLD would be slightly higher if results from the first, rather than the final, mode-choice iteration were used.

5.3 Review of performance of XPLD

5.3.1 Impact on total demand

Following the changes to XPLD so that the model parameters were defined in 2002 values, 2008 fares were deflated to 2002 prices and the HSR choice was determined on the basis of minimum GJT rather than minimum generalised cost, XPLD was re-run, and the results compared with the results from real PLD. These comparisons are presented in the following tables.

Table 56: Validation of revised XPLD model, all purposes

	Generation	Car capture	Air capture	Classic rail capture	Total HSR demand
XPLD	4,978.5 13.8%	5,668.7 15.7%	1,958.5 5.4%	23,489.5 65.1%	36,095.1 100.0%
Real PLD	17,485.0 13.9%	15,212.0 12.1%	4,730.0 3.8%	88,629.0 70.3%	126,056.0 100.0%
Difference	-71.5%	-62.7%	-58.6%	-73.5%	-71.4 %

The total demand for HSR predicted in XPLD has decreased significantly as a result of moving to a minimum GJT choice between classic rail and HSR. As a result predicted HSR demand has fallen from half to under 30 percent of real-PLD HSR demand. The difference is driven by the weighting of four that is applied to access/egress times in the GJT formulation, compared to a weighting of approximately 1.3 that was applied to access/egress times in the earlier generalised cost version of XPLD.

Table 57: Validation of revised XPLD model, commute

	Generation	Car capture	Air capture	Classic rail capture	Total HSR demand
XPLD	426.5	321.7	0.0	2,634.4	3,382.6
	12.6%	9.5%	0.0%	77.9%	100.0%
Real PLD	455.0	2,492.0	0.0	10,072.0	13,019.0
	3.5%	19.1%	0.0%	77.4%	100.0%
Difference	-6.3%	-87.1%	0.0%	-73.8%	-74.0%

Table 58: Validation of revised XPLD model, business

	Generation	Car capture	Air capture	Classic rail capture	Total HSR demand
XPLD	1,825.7	1,748.8	601.3	4,430.9	8,606.7
	21.2%	20.3%	7.0%	51.5%	100.0%
Real PLD	4,915.0	5,153.0	2,241.0	21,387.0	33,696.0
	14.6%	15.3%	6.7%	63.5%	100.0%
Difference	-62.9%	-66.1%	-73.2%	-79.3%	-74.5%

Table 59: Validation of revised XPLD model, VFR/other

	Generation	Car capture	Air capture	Classic rail capture	Total HSR demand
XPLD	2,726.3	3,598.3	1,357.2	16,424.2	24,105.9
	11.3%	14.9%	5.6%	68.1%	100.0%
Real PLD	12,115.0	7,567.0	2,489.0	57,170.0	79,341.0
	15.3%	9.5%	3.1%	72.1%	100.0%
Differences	-77.5%	-52.4%	-45.5%	-71.3%	-69.6%

The results by purpose are consistent with the overall results, with total HSR demand predicted in XPLD at 25–30 percent of the levels predicted in the real PLD. Thus, the impact of access/egress times on reducing the predicted demand for HSR is consistent between purposes.

It is also possible to present the changes in total rail demand given by XPLD and real PLD. However, it should be noted that while the LDM data used in XPLD is restricted to trips with a one-way distance of 50 miles or more, in PLD the demand data includes rail trips of all distances (but excludes trips made wholly within a PLANET zone or within the PLANET South or PLANET Midlands regions), and therefore matrix totals are not directly comparable between the two.

Table 60: Comparison of total rail demand (trips)

	XPLD			Real PLD		
	Base	with HSR	% change	Base	with HSR	% change
Commute	95,213	95,961	0.8%	496,532	499,479	0.6%
Business	70,341	74,516	5.9%	109,944	122,253	11.2%
VFR/other	196,692	204,374	3.9%	340,210	362,381	6.5%
Total	362,246	374,851	3.5%	946,686	984,113	4.0%

For business and VFR/other, higher percentage growth in rail trips is observed in real PLD. For commute, the percentage growth is lower in PLD, but a lot of commute trips will be shorter trips that would not use HSR services.

5.3.2 Comparison of predicted demand for selected P/A pairs

Investigating differences in demand for selected P/A pairs overcomes the issue of differences in the definitions of trips included in the PLD and LDM base matrices, and therefore gives more insight into likely differences than differences in demand summed over the base matrices.

For commute, there was no demand in the PLD base matrices for the six selected P/A pairs. However, for business and VFR/other it is possible to compare base-matrix totals between PLD and LDM. For the purposes of this comparison it is assumed that PLD trips in the NCA segment are symmetric to allow OD trips to be converted to P/A format.

Table 61: Comparison of base-matrix demand for test P/A pairs, business (P/A trips)

	LDM base matrices (XPLD)			PLD base matrices			
PA pair	NCO	CO	Total	NCA	CA from	CA to	Total
Birmingham–Leeds	0.000	12.501	12.501	19.450	22.800	32.680	42.250
Birmingham–Glasgow	0.000	3.247	3.247	2.820	3.530	3.010	6.350
Birmingham–Sunderland	0.000	1.002	1.002	0.430	0.450	1.900	0.880
Nottingham–Richmondshire	0.000	0.185	0.185	0.230	0.300	0.820	0.530
Nottingham–Glasgow	0.000	0.624	0.624	0.370	0.370	0.410	0.740
Sunderland–Milton Keynes	0.000	0.154	0.154	0.010	0.070	0.020	0.080

Note that LDM base-matrix demand has been summed over NCO and CO segments, and applied to the CO segment only, and hence no NCO demand is presented.

For the key Birmingham–Leeds P/A pair, PLD demand is 3.4 times the LDM value, and demand is almost twice as high for the Birmingham–Glasgow P/A pair.

Table 62: Comparison of base-matrix demand for test P/A pairs, VFR/other (P/A trips)

	LDM base matrices (XPLD)			PLD base matrices			
PA pair	NCO	CO	Total	NCA	CA from	CA to	Total
Birmingham–Leeds	9.680	19.270	28.950	45.070	58.800	70.320	103.870
Birmingham–Glasgow	1.187	2.687	3.874	8.760	11.140	9.270	19.900
Birmingham–Sunderland	0.308	0.688	0.997	1.150	1.300	4.470	2.450
Nottingham–Richmondshire	0.086	0.189	0.275	0.670	0.900	2.360	1.570
Nottingham–Glasgow	0.089	0.206	0.295	1.260	1.320	1.360	2.580
Sunderland–Milton Keynes	0.051	0.109	0.160	0.040	0.190	0.050	0.230

The base-matrix totals are consistently higher in the PLD base matrices.

Overall, these six P/A pairs suggest base levels of rail demand are higher in the PLD base matrices than in the LDM base matrices used for this work (which are synthetic matrices, rather than the matrices used in pivoting, as the synthetic matrices can be segmented by income band).

It is also possible to sum total rail demand in the with HSR case for the six test P/A pairs. The following tables present this comparison for business and VFR/other. The HSR in XPLD? column of these tables highlights whether HSR is chosen for this P/A pair in XPLD.

Table 63: Comparison of total rail demand in the with-HSR case, business (P/A trips)

P/A pair	XPLD	HSR in XPLD?	PLD
Birmingham–Leeds	26.59	Yes	162.24
Birmingham–Glasgow	3.25	No	12.22
Birmingham–Sunderland	1.00	No	7.94
Nottingham–Richmondshire	0.10	Yes	3.23
Nottingham–Glasgow	0.62	No	6.46
Sunderland–Milton Keynes	0.15	No	0.27

Total rail demand in the with-HSR case is consistently substantially higher in PLD compared to XPLD. The PLD column demonstrates a significant increase in trips relative to the base-matrix values quoted in Table 61.

Table 64: Comparison of total rail demand in the with-HSR case, VFR/other (P/A trips)

P/A pair	XPLD	HSR in XPLD?	PLD
Birmingham–Leeds	41.89	Yes	320.12
Birmingham–Glasgow	3.87	No	36.56
Birmingham–Sunderland	1.00	No	12.35
Nottingham–Richmondshire	0.30	Yes	9.65
Nottingham–Glasgow	0.30	No	11.66
Sunderland–Milton Keynes	0.16	No	0.66

Total rail demand is again consistently significantly higher in PLD, and the PLD figures show a substantial growth in rail trips relative to the base-matrix values quoted in Table 62.

The test P/A pairs demonstrate significantly higher levels of base rail demand in PLD compared to the LDM synthetic base matrices used for this work. These differences contribute to higher total rail demand in PLD for P/A pairs where both XPLD and PLD predict demand for HSR.

5.4 Impact of multi-routing in PLD with-HSR assignment

In XPLD, the choice between classic rail and HSR is made on an all-or-nothing basis determined by minimum generalised cost. However, in PLD the use of HSR services is determined in assignment, and due to multi-routing it is possible that HSR is used for only a fraction of total demand between an OD pair. Where multi-routing occurs the XPLD spreadsheet will not be able to emulate real PLD.

5.4.1 Overall impact

To investigate the impact of multi-routing in PLD, Atkins supplied select link matrices that allow the proportion of total rail demand that uses HSR for a given OD pair to be determined. Two sets of analysis have been undertaken using these matrices, one for the business CA from home segment, and one for the VFR/other NCA segment.

For the business CA from home segment, of the 43,320 P/A pairs with non-zero base rail demand, 20,744 (47.9 percent) have at least some HSR demand. For these 20,744 P/A pairs, the proportion of total rail demand that uses HSR was calculated (PHSR), and then weighted distributions of these proportions were calculated.

Table 65: Distribution of HSR probabilities, business CA segment

		Frequency	Percent	Valid percent	Cumulative percent
Valid	PHSR < 0.1	1672	8.7	8.7	8.7
	0.1 <= PHSR < 0.5	3235	16.8	16.8	25.5
	0.5 <= PHSR < 0.9	3619	18.8	18.8	44.4
	PHSR >= 0.9	10687	55.6	55.6	100.0
	Total	19212	100.0	100.0	

For cases where PHSR < 0.1 or PHSR >= 0.9 it is reasonable to assume that the choice is close to an all-or-nothing choice between classic rail and HSR. However, where PHSR lies between 0.1 and 0.9 multi-routing has an important impact. For around one-third of weighted P/A pairs PHSR lies in the range 0.1 to 0.9, and for these P/A pairs XPLD and PLD would not be expected to be comparable.

For the VFR/other NCA segment, of the 41,054 OD pairs with non-zero base rail demand, 20,936 (51.0 percent) have some HSR demand. The proportions of total rail demand that uses HSR for these OD pairs has been calculated (PHSR) and a weighted distribution obtained, weighting by total rail demand for the OD pair.

Table 66: Distribution of HSR probabilities, VFR/other NCA segment

		Frequency	Percent	Valid percent	Cumulative percent
Valid	PHSR < 0.1	2526	11.0	11.0	11.0
	0.1 <= PHSR < 0.5	4427	19.2	19.2	30.2
	0.5 <= PHSR < 0.9	4522	19.6	19.6	49.8
	PHSR >= 0.9	11549	50.2	50.2	100.0
	Total	23025	100.0	100.0	

Just over 50 percent of weighted cases have PHSR >= 0.9, where it is reasonable to say this is equivalent to XPLD predicting that all rail demand will use HSR. However, for 38.8 percent of weighted cases PHSR lies in the range 0.1 to 0.9 and for these cases the PLD results would not be expected to correspond to XPLD.

5.4.2 Impact for six selected P/A pairs

The impact of multi-routing in real PLD on the six P/A pairs selected for analysis was investigated. For the Birmingham–Glasgow P/A pair, 49 percent of business HSR demand and 49 percent of other travel HSR demand was predicted to use HSR, and therefore multi-routing had an important impact. For the other six P/A pairs, all rail demand was predicted to use HSR, i.e. PHSR=1.

In real PLD, multi-routing between classic rail and HSR plays an important role in the predictions of demand for HSR. For P/A pairs where multi-routing occurs, XPLD will not be able to emulate the real-PLD results, as XPLD predicts HSR demand as an all-or-nothing choice.

CHAPTER 6 Detailed P/A pair analysis

The comparisons of XLDM and XPLD reported so far have been complicated by differences in the relative sensitivities to access and egress of the two models, and this has made it difficult to compare the two models on a consistent basis and make conclusions about their relative sensitivities.

Following discussions at the project steering meeting on the 20 February 2012, RAND Europe was commissioned to undertake additional analysis to look at predicted levels of demand for HSR for six specific P/A pairs. For each of the six P/A pairs we have tested the addition of an HSR service with 0-, 15- and 30-minute time savings (for a return journey) relative to classic rail for the P/A pair in question, with all other components of LOS, such as access/egress times and service frequency, assumed to be equal between classic rail and HSR.

By focusing on simple changes to in-vehicle time for particular P/A pairs, a direct comparison of the sensitivities of the XLDM and XPLD models could be made. The impact of these changes has been calculated for the continuous HSR/classic rail choice version of XLDM (XLDMC), for the assignment version of XLDM (XLDMA) and for XPLD.

The six P/A pairs that have been chosen are the six pairs that were selected for the analysis reported in Chapter 5:

- Birmingham–Leeds
- Birmingham–Glasgow
- Birmingham–Sunderland
- Nottingham–Richmondshire
- Nottingham–Glasgow
- Sunderland–Milton Keynes

The remainder of this chapter is structured as follows. Section 6.1 presents the top-level findings from these tests, flagging an important issue of a diversity benefit resulting from the introduction of HSR that explains differences between the level and composition of HSR demand predicted by XLDMC and XLDMA. Section 6.2 summarises the findings from the P/A comparisons for each model purpose.

These sections are supported by two appendices. Appendix C presents the additional theoretical investigations that we've undertaken in order to explain the difference between the XLDMC and XLDMA results. Finally, Appendix D presents the detailed results by P/A pair in full.

6.1 Top-level findings and issues raised

In running very simple tests, where we modelled the introduction of an HSR service giving a 0-, 15- or 30-minute advantage relative to classic rail for just one P/A pair we observed that:

1. XLDMA and XPLD give broadly similar results, with XPLD being more sensitive for generation and capture from modes other than rail, consistent with the comparison of the LDM and PLD parameter values reported in Section 3.2.
2. XLDMA gives somewhat larger classic capture than XLDMC, but XLDMC gives much larger mode shift and generation effects – investigations have focused on understanding these differences.
3. The larger mode shift and generation effects in XLDMC relative to XLDMA for commute and VFR/other also applies to business, but it works a little differently in the business model because of the structure of that model and we have focused on VFR/other in the analysis we have done to understand these differences.
4. The assignment models (XPLD and XLDMA) give zero benefit when HSR has the same time as classic rail – this is unreasonable in practice as there would be a frequency benefit and in many cases a benefit arising from diversity of access points and train timings.
5. Very detailed investigation for VFR/other shows that the main cause of the increased mode shift and generation in XLDMC is the ‘diversity benefit’ arising from the calculation of a logsum over HSR and classic rail, i.e. the addition of an alternative in the system. Appendix D explains how this diversity benefit arises terms of the incremental model calculations used to apply the model set out in Appendix A.
6. This diversity benefit is large when calculated in minutes, because of the very small lambda values in the model.
7. When applied for a full set of P/A movements, the differences are less extreme, because of the variation of the advantage given by HSR: in a number of important cases HSR has higher generalised cost than classic rail, but XLDMC still predicts that a minority of people will choose it.
8. The diversity benefit depends on the lambda value: essentially the benefit is up to a maximum of log 2 divided by the rail sub-mode choice lambda, giving approximately 0.7 * 340 ≈ 235 minutes or nearly 4 hours for VFR/other (for a tour).
9. The evidence for this lambda value comes from the stated-choice exercises which give the lambda for classic/HSR choice *relative* to PT mode choice, whereas the absolute values of the frequency, main mode, PT mode and destination choice lambdas come from revealed preference (RP) modelling.
10. We get very small lambda values in the RP models because we are modelling long-distance travel.

- Note that to get a time elasticity of about 1, we need to have lambda values such that lambda times the mean trip length is about 1, i.e. the estimated lambda values imply tour lengths of about 340 minutes, which seems reasonable. (This calculation is approximate but will give the correct order of magnitude.)
- Also note that we obtain 'reasonable' elasticities with these RP lambda values.

11 The issue is whether the rail sub-mode choice lambda should be much larger than the PT mode-choice lambda (or infinitely larger to make XLDMA correct) and there we rely on the SP – the theta value in question is 0.814, with a standard error of 0.053, i.e. the value is quite accurately determined.

- To keep the model reasonably simple the choice between HSR and classic has to be modelled with one model scale covering both cases where only the time is different and cases where there are differences in fare, access, interchange and time.

12 Note, however, that real PLD has some multi-routing and now it has a station-choice model with logsums in it that mirror to some extent what is happening in XLDMC and LDM

- The impact of a station-choice model, with choice over a number of stations, will introduce a logsum effect in PLD similar to the effect in LDM and XLDMC, but this is not present in XPLD and XLDMA.
- Diversity of access point is a real benefit. (You can go to the station nearest your O and D.)

These findings raise a more general question for modelling demand for HSR services. Should we expect additional demand resulting from the introduction of a new service, which is what happens in XLDMC? A key consideration here is model structure. One extreme is to treat HSR as a rail-route-choice alternative, to be modelled in the assignment. The other extreme is to treat it as a new public transport mode. XPLD and XLDMA take the former approach, which neglects all diversity (such as access stations, train timings, interchange etc.) and moreover does not account for the frequency effect of adding the HSR service. PLD allows for diversity in station choice. LDM (and XLDMC) has a classic rail/HSR nest, which leads to higher cross-elasticities between these alternatives than between them and the other PT modes. The extent of additional cross-elasticity is calibrated from the stated-choice data.

In the LDM model estimation, the classic rail/HSR lambdas were estimated relative to PT mode choice using stated-choice surveys, whereas the frequency, main mode, PT mode and destination choice lambdas were estimated from RP data, and the stated-choice and RP lambdas were only combined at the model implementation stage. A more rigorous approach would be to jointly estimate the lambdas together in a combined estimation procedure, which would give greater confidence in the sensitivity of the classic rail/HSR choice relative to the frequency, main mode, PT mode and destination choices.

6.2 Discussion of P/A pair results by purpose

The detailed results for the six P/A pairs and three purposes are presented in Appendix C. This section summarises the key points that emerge from analysis of the detailed results.

6.2.1 Commute

Comparison of XLDMC and XLDMA results highlights the following:

- XLDMC predicts substantial[13] levels of HSR demand when HSR offers no time improvement – this is due to the diversity benefit resulting from the introduction of HSR.
- This diversity benefit effect gives rise to substantial generation and car-, coach- and classic- rail-capture effects in XLDMC. The *additional* levels of generation, car capture and coach capture that result from moving from 0- to 15- and 30-minute time improveme*nt are sim*ilar in magnitude between XLDMC and XLDMA, but in XLDMC these are added to substantial contributions observed at zero minutes time improvement.
- In terms of classic rail capture, XLDMC shows higher total capture, indicating greater capture from other destinations relative to XLDMA.
- Because of the diversity benefit, HSR demand is consistently higher in XLDMC than XLDMA.

Comparison of XLDMA and XPLD results shows the following:

- Overall levels of HSR demand are consistent between the two models.
- This is because the main effect is HSR capture from the same P/A pair (shown by the XPLD classic rail capture for 15- and 30-minute improvements).
- In XLDMA, there is also some redistribution of classic rail trips from other P/A pairs that increases HSR demand.
- However, generation and car capture effects are lower in XLDMA. This is because the XPLD model is more sensitive to changes in costs for these effects (consistent with the comparison of the LDM and PLD parameters presented in Section 3.2).
- The net effect of these changes is slightly higher HSR demands in XLDMA.

6.2.2 Business

An important difference between business and the other two purposes is that in business the structure used for the continuous choice and assignment models is the same, because the classic rail/HSR choice is represented at the lowest level in real LDM. When we compare XLDMC and XLDMA results we observe the following:

- Again, there is substantial demand for HSR at 0-minute time improvement in XLDMC resulting from the diversity benefit.
- However, at 15- and 30-minute time improvements XLDMA predicts *higher* demand for HSR than XLDMC.
- This difference is driven by higher classic rail capture in XLDMA. In XLDMA all of the classic rail demand from the P/A pair is captured, and there is a small

[13] By substantial, we mean relative to the base rail demand for the P/A pair.

redistribution effect. However the XLDMC results show that at most 55–60 percent of classic rail demand from the P/A pair is captured.

Comparison of XLDMA and XPLD shows the following:

- Overall levels of demand for HSR are consistent between the two models.
- Generation effects are comparable between the two models.
- Car and air capture (for those P/A pairs where there is base air demand) is greater in XPLD, consistent with the greater sensitivity to main mode choice in PLD.
- Classic rail capture is slightly higher in XLDMA as there is some redistribution from other destinations.
- The net effect of these different effects is slightly higher HSR demands in XPLD.

6.2.3 VFR/other

In VFR/other (as in commute) the continuous-choice and assignment versions of XLDM use a different structure because in real LDM the classic rail/HSR choice lies above destination choice. Comparison of XLDMC and XLDMA results highlights the following:

- Once again, substantial demand for HSR at 0-minute time improvement in XLDMC resulting from the diversity benefit, with no demand predicted in XLDMA.
- This diversity benefit results in substantial generation and car, air/coach and classic rail capture in XLDMC at 0-minute time improvement.
- These effects from the diversity benefit mean that HSR demand is also higher in XLDMC relative to XLDMA for 15- and 30-minute time improvements
- However, classic rail capture in XLDMA is higher than in XLDMC for 15- and 30-minute time improvements because in XLDMA all demand from the P/A in question is captured.

Comparison of XLDMA and XPLD shows the following:

- Overall levels of demand are again consistent between the different models.
- Classic rail capture is slightly higher in XLDMA due to limited capture from other destinations.
- However, generation and car-capture and (for some P/A pairs) air-capture effects are higher in XPLD, consistent with the greater sensitivity to these response in PLD.

The comparison of XLDMC and XLDMA results demonstrated levels of generation and car- and air-capture up to 20 times higher in XLDMC in these simple P/A pair tests. However, when we ran for all P/A pairs with the actual 2008 classic and HSR LOS that was extracted from LDM by URS Scott Wilson during the Phase 0 work (the results reported in Section 4.2), these effects were around twice as high in XLDMC. To investigate this difference further, additional analysis was undertaken for the Birmingham production zone using the 2008 classic and HSR LOS from LDM.

Using the actual proportion of destinations served by HSR in the two models, and the mean generalised time saving HSR offers for these destinations (weighted by base rail demand) we calculated from the formulae presented in Appendix C the overall rail cost change in each model. These were different by a factor of 3.5, a difference consistent with the relative impact of generation and other mode capture in the aggregate results for the Birmingham production zone using the actual 2008 classic and HSR LOS.

There are two reasons why XLDMC generation, car capture and air capture are up to 20 times higher than XLDMA values in the simple P/A pair tests, but only 3.5 times higher when the models are run for all P/A pairs using the 2008 classic and HSR LOS from LDM. First, the proportion of destinations available to HSR is higher when working with the 2008 HSR LOS. Second, the mean generalised time savings resulting from the introduction of HSR are higher when working with the 2008 HSR LOS. Both of these effects work to reduce the difference between the XLDMC and XLDMA results.

CHAPTER 7 Conclusions and recommendations

Summary

Below we summarise the structure of the incremental applications of LDM and PLD, before going on to discuss the comparison between their predictions, additional PLD analysis and detailed analysis to compare the models at the P/A level.

Incremental application of LDM

The reduced-segmentation versions of the LDM frequency, mode and destination-choice models have been implemented in incremental form as an Excel spreadsheet that uses Visual Basic macros to implement the incremental model code. The incremental model, termed XLDM, predicts demand for HSR from P/A trip matrices split by mode, purpose and segment that are output from a base-year run of the LDM. Changes in generalised cost resulting from the introduction of HSR are calculated from LOS supplied from 2008 base-year runs of the LDM, with the 2008 base (without HSR) run used to output classic rail LOS, and the 2008 with HSR Y-network run used to output HSR LOS. All calculations are undertaken using the 406-district zoning system used in the LDM.

Two versions of XLDM model have been implemented. The first predicts HSR versus classic rail choice as a probabilistic choice, consistent with how the original LDM model was estimated and implemented. The second predicts the HSR versus classic rail choice on the basis of minimum generalised cost. The second implementation does not correct the parameters to take account of the different calculations that are made in the minimum generalised cost version and consequently the generation and mode-switch effects are always lower than in the choice-model version. If such a structure were to be used for forecasting, correction to the parameters would be required.

The total demand for HSR in 2008 predicted by the probabilistic version of XLDM has been compared to the HSR demand predicted by URS Scott Wilson when it applies the reduced-segmentation versions of the LDM models in absolute form. Total HSR trips match very closely for commute and VFR/other, and closely for business.

Incremental application of PLD

The PLD mode-choice models have also been implemented as an Excel spreadsheet containing Visual Basic macros to implement the incremental model code. The incremental application, termed XPLD, uses the PLD model parameters (in 2008 values), and applies these parameters to LOS changes output from the reduced-segmentation version of the LDM to calculate changes in generalised cost, and then applies the changes in generalised cost to calculate changes in trips relative to the long-distance P/A trip matrices output from the LDM.

Important implications of this approach are that changes are forecast relative to LDM, rather than PLD base-matrix totals and on the basis of changes in LOS taken from LDM rather than from PLD. The LDM base matrices use the simpler LDM definition of a long-distance trip as all trips greater than 50 miles in length, rather than the more complex definition used in PLD.

When XPLD is used to predict demand for HSR, total demand for HSR is around half the level Atkins predicts when it forecasts 2008 HSR demand for the Y-network in PLD, with the largest difference in trips between the two approaches observed for the VFR/other purpose. Tests demonstrated that the PLD-predicted demand for HSR was highly sensitive to the values of HSR generalised access/egress time, and so differences in the definition of LOS between LDM and PLD are judged to be a significant factor in the substantial difference in total HSR trips.

Comparison of XLDM and XPLD predictions

During detailed validation of the XLDM model, it was discovered that some of the assumptions regarding HSR generalised access/egress could be improved: specifically the interchange penalty was high and classic rail access/egress legs were not weighted in a consistent way with access/egress to classic rail in the classic rail network.

Enhanced HSR generalised access/egress LOS was generated with improved assumptions. This had only a minor impact on predicted demand for HSR in both XLDM and XPLD, with the effects of the two changes cancelling one another out, but nonetheless the enhanced LOS is taken to be a better definition and so was used for all subsequent comparisons.

The total demand predicted for HSR in a hypothetical 2008 situation is 96,700 trips per day in the XLDM probabilistic model, 86,100 in the XLDM minimum generalised cost model and 61,600 in XPLD. Checks for individual production zones suggest that XLDM and XPLD demands are reasonably consistent in production zones with good access to HSR, but that XPLD demand for VFR/other travel may be lower for production zones where access to HSR is more difficult.

In terms of the composition of HSR demand, the probabilistic version of LDM predicts significantly higher levels of generation than PLD, in particular for business. For all purposes, the LDM frequency response is more sensitive than PLD. It is noted that the LDM frequency parameters are estimated from observations of long-distance travel and include switching from shorter distances, whereas in PLD the frequency response is assumed to be one-third as sensitive as the next level choice in the structure, based on professional experience; it is not clear that the PLD parameters are specifically based on long-distance travel or are drawn from contexts in which destination-switching is excluded.

The sensitivity of the LDM business model to frequency changes is relatively high, so that the generation response comprises 45 percent of total demand. A recommendation from this study is that the model structure for the LDM business model is reviewed if further model development work is undertaken. This review should look for evidence from other HSR schemes on the proportion of HSR demand for business that comes from generation.

If the LDM model is applied using the minimum generalised cost approach for HSR/classic rail choice, the proportion of HSR demand from generation is significantly reduced, whereas the proportion of classic rail capture is significantly increased. Therefore **the choice of modelling approach for the classic rail versus HSR choice has a significant impact on the composition of the predicted demand for HSR.** It is noted that proportions of generation and classic rail capture in the minimum generalised cost version of LDM are in line with those predicted by PLD. The significant changes in the composition of demand observed for the LDM model indicate that the model should be recalibrated if the approach for modelling HSR/classic rail choice is revised to minimum generalised cost.

Analysis has been made to examine the role of redistribution in the LDM predictions, which is done by distinguishing HSR demand from generation, redistribution from other zones summed across all modes and pure mode capture from the same destination. **The analysis runs demonstrate that redistribution makes a significant contribution in the LDM model, accounting for 20–40 percent of total HSR demand.**

HSR fare elasticities have been run for all three sets of models, applying a 10 percent increase in HSR fare. **The elasticities in LDM are relatively high, with a total fare elasticity of -1.3. However, significantly higher elasticities are obtained if the LDM model is run with the minimum generalised cost approach, and the elasticities are higher still in PLD, with a total fare elasticity of -4.6.** This analysis demonstrates a significant reassignment effect to classic rail, but nonetheless the mode-choice fare elasticity is above two, demonstrating the predicted demand for HSR to be highly sensitive to the no-premium-fare assumption.

On the basis of the HSR access/egress time sensitivity tests and the HSR fare elasticity runs, **it is recommended that sensitivity tests should be run for the full PLD HS2 model runs to assess the sensitivity of predicted HSR demand to changes in modelled HSR costs and times.**

Additional PLD analysis

Following discussion at a technical meeting held on 10 January 2012 at HS2's offices, a series of additional analyses were run with the objective of understanding why the spreadsheet implementation of PLD (XPLD) predicts much lower levels of HSR demand than real PLD.

Comparison of the PLD and LDM rail cost skims in the base case without HSR demonstrated consistency in rail in-vehicle times. However, other components showed significant differences. In particular mean access/egress times are substantially higher in real PLD (given that the weighting of four was not applied we are not clear why this is the case), the PLD network skims have less frequent services; and the number of interchanges is substantially lower.

When the *difference* in cost skims that results from the introduction of HSR was calculated, the key difference was in access/egress times. In the with-HSR case, in PLD access to HSR services by classic rail forms part of rail in-vehicle time, whereas in the LDM-derived LOS access by classic rail forms part of access/egress time. Access/egress time is weighted by four in the GJT calculation that determines the choice between classic rail and HSR, and as a result in XPLD (which uses PLD-derived LOS) HSR is predicted for a lower proportion of P/A pairs, specifically P/A pairs where the access legs to HSR are short.

The impact of mode-choice iteration on the levels of demand predicted for HSR in PLD was investigated.[14] The results suggest slightly higher HSR demand would be obtained if results from the first, rather the final, mode-choice iteration were used. However, this effect appears to be small.

The operation of XPLD was revised following the technical meeting. The key change was to change the choice between classic rail and HSR to use GJT to mimic the calculation applied in the real-PLD rail assignment. This change has resulted in the total level of HSR demand predicted by XPLD falling further, from around half the real-PLD value to under 30 percent of the real-PLD value. This reduction follows from the high weighting of four applied to access/egress time in the GJT calculation.

Analysis of six test P/A pairs demonstrated significantly higher levels of base rail demand in PLD than in the LDM synthetic base matrices used for this work. The PLD base matrices are likely to be of higher quality than the synthetic LDM base matrices used in XPLD. These differences in base-matrix totals contribute to higher total rail demand in PLD for P/A pairs where both XPLD and PLD predict demand for HSR.

Multi-routing, whereby a proportion of rail demand between a P/A pair uses HSR at some point in the journey and a proportion uses classic rail for the entire journey, plays an important role in the real-PLD rail assignment. XPLD predicts demand for HSR as an all-or-nothing choice and so cannot emulate real-PLD behaviour for P/A pairs where multi-routing occurs. However, because the split in the multi-routing is balanced between cases with more and less than 50 percent of demand assigned to HSR, it is likely that the net effect of multi-routing is small.

It is our view that the different treatments of HSR between PLD and LDM, with HSR choice determined as an assignment choice within a single rail network in the former, and on the basis of completely separate HSR network with classic rail as an access mode in the latter, mean that it is not possible for XPLD to emulate the real-PLD results using the LDM-based LOS. If the LDM-based LOS were to be revised to achieve greater consistency in the treatment of access time between classic rail and HSR then a better correspondence XPLD and real-PLD predictions for HSR would be expected.

Finally, it should be emphasised that the issue of low predicted HSR demand relates to the application of LDM-based LOS in XPLD. The levels of demand predicted for HSR in the real version of LDM are much more consistent with those predicted in PLD.

Additional P/A pair analysis

Following discussion at the project steering group meeting on 20 February 2012 at HS2's offices, additional analysis was undertaken to compare the XLDM and XPLD models for individual P/A pairs. To facilitate comparison between the two models, these tests were

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[14] When PLD is run, there is an iteration between the mode-choice model, and the assignment models. Changes in the skims from the assignment models impact on the predicted mode choices, and so an iterative process is required in order to reach a point at which demand and supply levels are in equilibrium.

made assuming HSR was introduced for individual P/A pairs offering 0-, 15- and 30-minute time savings relative to classic rail.

Comparison of the continuous HSR/classic rail choice version of XLDM (XLDMC) and the assignment version of XLDM (XLDMA) demonstrated that XLDMC gives much larger mode-shift and generation effects. Detailed investigations to understand these differences showed the main cause of the increased mode-shift and generation effects to be the 'diversity benefit' that results from the addition of a new alternative when HSR is introduced into the LDM system.

The diversity benefit is large in minutes because of the small lambda values in the LDM, a consequence of the long tour lengths for long-distance travel. In XLDMA and XPLD there is no diversity benefit resulting from the introduction of HSR, despite the fact that there would be a frequency benefit and in many cases a benefit arising from diversity of access points.

The XLDMA and XPLD models gave broadly similar results, with demand for HSR dominated by capture from classic rail. XPLD is more sensitive for generation and capture from modes other than rail, but XLDMA gives higher rail capture due to some capture from other destinations.

Conclusions

The PLD results are much more sensitive to assumptions about HSR access/egress as well as to assumptions about fares and times, than are the results for the LDM. It seems that part of this higher sensitivity is due to the assignment approach used in PLD. **Our recommendation is that sensitivity tests should be run for the full PLD HS2 runs to test the sensitivity of HSR demand to changes in HSR fare and access. Specification of HSR access/egress in LDM should be reconsidered.**

The continuous (probabilistic) version of the HSR/classic rail choice used in LDM is preferred to the minimum generalised cost approach, as it gives lower and more plausible fare elasticities, and in general gives more plausible responsiveness to LOS changes. The minimum generalised cost approach is prone to giving 'lumpy' assignments for HSR, with relatively small changes in LOS sometimes resulting in significant volumes of demand-switching to classic rail.

The continuous (probabilistic) version of XLDM suggests that generation and redistribution effects form significant contributions to total HSR demand. But it is noteworthy that the predicted level of generation seems to be in line with experience from France and Spain. The business model gives a particularly high generation response, and if the LDM were to be developed further to inform the HS2 modelling, it is recommended that further investigations of model structure should be made for business. If it is judged, for other reasons, that an all-or-nothing approach is preferred, then the LDM model would require recalibration to take into account this assumption (because the model parameters were estimated assuming a classic rail/HSR choice structure). We note that PLD model parameters were also estimated assuming classic rail/HSR choice modelled with a logit formula, and the model parameters have not been recalibrated to reflect the move to an assignment classic rail/HSR choice, nor have the parameters been recalibrated to take account of the new station-choice model. We recommend that the PLD parameters should be recalibrated to take account of these two changes.

An important advantage of the LDM model is that it incorporates the impact of income on long-distance travel and demand for HSR. Evidence from NTS suggests that long-distance travel demand is highly correlated with income. Moreover, rail and HSR are more likely to be chosen by higher income groups, because of the lower price sensitivity of these travellers. With the current assumption of no premium fare for HSR, we would not expect the income distribution of HSR users to differ from that of classic rail users. **However, with a fare premium, the distribution of users will be different, and this difference will not be predicted in PLD.** LDM, which incorporates income information and price sensitivity as a function of income, demonstrates proportionately higher capture from coach for the lowest income bands, and proportionately higher capture from classic rail for the highest income bands. Use of the LDM to inform the HS2 modelling would allow such effects to be properly represented. **Moreover, LDM could quantify the distributional impacts of HSR.**

An important difference between the continuous (probabilistic) and assignment-choice versions of XLDM is the 'diversity benefit' that results from the introduction of HSR into the model structure. This effect results in substantial additional generation and mode capture effects in the continuous-choice version of XLDM. In the assignment version of XLDM, there is no diversity benefit resulting from the addition of HSR, despite the frequency benefit resulting from adding new services. **Further work is required to consider whether the high diversity benefit resulting from the introduction of HSR in the continuous-choice version of XLDM is appropriate.**

The structure of the models in the LDM should be considered again, perhaps through joint estimation using the RP and SP data together. This would allow the model structures that determine the relative sensitivities of the different choices to be reconsidered, and would provide more a rigorous basis for determining the sensitivity of the HSR/classic rail choice nest, in turn leading to a better estimation and understanding of the diversity benefit.

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APPENDICES

Appendix A: Specification of incremental model application

Introduction

Although the PLD and LDM demand models have been constructed in very different ways, they operate on similar zoning systems and demand segments. In addition, the hierarchical structures are similar. These considerations facilitate a detailed comparison of the output.

The proposal is to examine the forecast first round changes to demand, and the source/breakdown of those changes, for a small number of IJ pairs that would be affected by an HSR service. To avoid confusion according to future year growth, the comparison will be carried out for the current base year.

We adopt a pure 'incremental logit' [IL] approach, which is compatible with PLD, and should be closely compatible with LDM, even though the operation of the 'pivot' process is different. (LDM uses absolute pivot models – in other words it applies the results of an absolute model incrementally to the base – and this can give different results when base or forecast are zero or when large growth is predicted).

The assumption will be that the existing PLD ('assignment') methodology of allocating between classic and HSR on the basis of minimum generalised cost can be maintained. The LDM uses a logit model to allocate between classic and HSR rail. For the purpose of the comparison the LDM will be operated both on the logit basis and on the basis of minimum generalised cost. Any significant differences in response characteristics between these operations will be of interest.

We ignore journey purpose in what follows, but the investigations should be carried out separately for each of the three purposes – commuting, business, leisure/VFO, and for car-owning and non-car-owning segments. The LDM IL implementation also needs to be done separately for different income segments, but these will be combined for the purpose of comparison.

We use the notation I, J for zones, and c, a and r for respectively the modes car, air and rail. For each IJ to be examined, we require the base matrix by mode, which we write as $T_{IJ,m}$ where m = {c,a,r}. Since the PLD zoning system is somewhat more aggregate than LDM, we adopt the PLD system for the purpose of these tests. However, the base matrices from LDM (as described in Annex A) will be used for both models.

Essentially, the only cost change introduced to the system is that between the rail stations (eg London and Birmingham)*, which is converted to different cost changes ΔC_{IJr} at the IJ level. Because the LDM also involves a destination choice process, it will be helpful – for each 'production zone' I – to calculate the set {J} for which ΔC_{IJr} is significantly different from 0.

The LDM model hierarchy (omitting bus/coach and, at this stage, the classic rail/HSR choice nest for this exercise – but see below) can be described as follows:

{no travel, travel [car (dest), PT {air (dest), rail (dest) }] }

while the PLD model hierarchy can be described as follows:

{no travel, travel [car, PT {air, rail }] }

When HSR is introduced to the LDM, there are two possibilities for the choice component 'rail (dest)': we can either have

(i) rail (dest {classic, HSR}) or

(ii) rail {classic (dest), HSR (dest)}.

In the existing model, structure (i) is used for the business purpose, and structure (ii) for the commuting and VFO purposes. Note that if the choice between classic rail and HSR is to be based purely on minimum generalised cost, this corresponds with structure (i) for all purposes.

Both structures will need to be programmed for the IL version of LDM.

We now describe the implementation of these models based on a set of changes $\{\Delta C_{IJr}\}$, starting from the bottom of the structure. Note that there are different possible conventions for programming nested logit models (see for example Hensher & Greene, 2002†). Purely for the purposes of exposition, we adopt a particular version here in which the inclusive values (or 'logsums') are re-scaled at each level to generalised cost units. This is not necessarily compatible with the way in which the individual models have been formulated, nor is it a requirement for the contractor to adopt it. The contractor is, however, required to adopt a convention which is the same for both PLD and LDM models, and to agree that parameters used for each model are correct.

We assume a set of generalised cost parameters: λ^F at the highest level (travel, no travel), λ^M for the overall mode-choice level, λ^{PT} for the public transport mode-choice level, and, for LDM only, λ^D for destination choice and λ^R for the choice between classic rail and HSR. The relationships between the different λ parameters are compatible with the structural parameters "θ" (which must lie between 0 and 1), so that $\lambda^M = \lambda^F/\theta_{F\_M}$, $\lambda^{PT} = \lambda^M/\theta_{M\_PT}$. In addition, for LDM only, there are two possible structures for relating the λ^R, λ^D and λ^{PT} parameters (see below). Given the different model conventions, some effort will

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* NB for the purpose of the comparison, we are ignoring the 2nd round effects and the possibilities afforded by the increased capacity for classic rail

† Hensher D A & Greene W H (2002), Specification and Estimation of the Nested Logit Model: Alternative Normalisations, Transportation Research Part B (36) pp 1-17

be required to define these parameters, and they will need to be 'signed off' by the model authors. Note also that in PLD the scaling parameters λ are modified with distance (though the effect is small).

The specification below is written in mathematical terms, and is valid when, due to unavailability, the costs are effectively infinite. However, in programming this, it will naturally be necessary to make special arrangements to ensure that unavailable alternatives have a zero choice probability.

LDM

Destination choice (including choice of rail mode)

Since cost changes occur only for the rail mode, this can be confined to the rail mode. Two versions are required [(i) and (ii)], dependent on the location of the HSR/classic rail nest:

(i) Classic/HSR nest below destination choice

choice of HSR (H = HSR, C = Classic rail)

$$p_{H|IJr} = \frac{\exp\left(-\lambda^R.\left[C_{IJH} - C_{IJC}\right]\right)}{1+\exp\left(-\lambda^R.\left[C_{IJH} - C_{IJC}\right]\right)} \tag{B1}$$

Note that when HSR is not available for a particular IJ movement, the cost difference [C_{IJH} – C_{IJC}] is plus infinity, so that the share of HSR is zero. In addition, for the 'assignment' version of the structure, the probabilities can only be 0 or 1.

Hence we can calculate incremental 'composite' cost ΔC_{IJr} for the composite rail mode r, using the familiar 'logsum' formulation:

$$\Delta C_{IJr} = -1/\lambda^R.\ln\left(1+\exp\left(-\lambda^R.\left[C_{IJH} - C_{IJC}\right]\right)\right) \tag{B2}$$

For the assignment version, this becomes $\min(0,\left[C_{IJH} - C_{IJC}\right])$

Now for *destination choice* we have

$$p_{J|Ir} = \frac{T_{IJr}\exp\left(-\lambda^D.\Delta C_{IJr}\right)}{\sum_{J'} T_{IJ'r}\exp\left(-\lambda^D.\Delta C_{IJ'r}\right)} \tag{B3}$$

and $$T_{I*r}\exp\left(-\lambda^D.\Delta C_{I*r}\right) = \sum_{J'} T_{IJ'r}\exp\left(-\lambda^D.\Delta C_{IJ'r}\right) \tag{B4}$$

where $T_{I*r} = \sum_{J'} T_{IJ'r}$

Hence we can calculate incremental 'composite' cost ΔC_{I*r}, transforming Eq. A4 into the 'logsum' formulation:

$$\Delta C_{I*r} = -1/\lambda^D.\ln\left(\frac{\sum_{J'} T_{IJ'r}\exp\left(-\lambda^D.\Delta C_{IJ'r}\right)}{T_{I*r}}\right) \tag{B4'}$$

Note that we expect $\Delta C_{IJr} = 0$ for the majority of destinations J

For other modes (m = a, c) $\Delta C_{I*m} = 0$

(ii) Classic/HSR nest above destination choice (but below PT)

Destination choice (conditional on H or C)

In the base case, without HSR, we will have (non-incremental formulation)

$$p_{J|I,r=C} = \frac{A_J \exp\left(-\lambda^D.C_{IJr}\right)}{\sum_{J'} A_{J'} \exp\left(-\lambda^D.C_{IJ'r}\right)} \quad \text{(B5)}$$

When HSR is introduced, these destination proportions for classic rail will not change. However, we also require the corresponding destination proportions for HSR. These can be calculated 'incrementally', as follows:

$$p_{J|I,r=H} = \frac{T_{IJr} \exp\left(-\lambda^D.\left[C_{IJH} - C_{IJC}\right]\right)}{\sum_{J'} T_{IJ'r} \exp\left(-\lambda^D.\left[C_{IJ'H} - C_{IJ'C}\right]\right)} \quad \text{(B6)}$$

Note that for destinations where HSR is not available, $[C_{IJH} - C_{IJC}]$ is infinite, so that no trips will be allocated.

In the usual way, we can write

$$T_{I*r} \exp\left(-\lambda^D.\left[C_{I*H} - C_{I*C}\right]\right) = \sum_{J'} T_{IJ'r} \exp\left(-\lambda^D.\left[C_{IJ'H} - C_{IJ'C}\right]\right) \quad \text{(B7)}$$

where $T_{I*r} = \sum_{J'} T_{IJ'r}$

and hence $$\left[C_{I*H} - C_{I*C}\right] = -1/\lambda^D.\ln\left(\frac{\sum_{J'} T_{IJ'r} \exp\left(-\lambda^D.\left[C_{IJ'H} - C_{IJ'C}\right]\right)}{T_{I*r}}\right) \quad \text{(B7')}$$

Of course, if for a given origin HSR is not available for any destination, this will have the value zero.

choice of HSR (H = HSR, C = Classic rail)

$$p_{H|I*r} = \frac{\exp\left(-\lambda^R.\left[C_{I*H} - C_{I*C}\right]\right)}{1 + \exp\left(-\lambda^R.\left[C_{I*H} - C_{I*C}\right]\right)} \quad \text{(B8)}$$

Hence we can calculate incremental 'composite' cost ΔC_{I*r} for the composite rail mode r:

$$\Delta C_{I*r} = -1/\lambda^R.\ln\left(1 + \exp\left(-\lambda^R.\left[C_{I*H} - C_{I*C}\right]\right)\right) \quad \text{(B9)}$$

For other modes (m = a, c) $\Delta C_{I^*m} = 0$

PT choice

$$p_{r|I,PT} = \frac{T_{I^*r} \exp\left(-\lambda^{PT} . \Delta C_{I^*r}\right)}{\sum_{m \in PT} T_{I^*m} \exp\left(-\lambda^{PT} . \Delta C_{I^*m}\right)} \quad \text{(B10)}$$

and $$T_{I^*,PT} \exp\left(-\lambda^{PT} . \Delta C_{I^*,PT}\right) = \sum_{m \in PT} T_{I^*m} \exp\left(-\lambda^{PT} . \Delta C_{I^*m}\right) \quad \text{(B11)}$$

Hence calculate incremental 'composite' cost ΔC_{I^*PT}.

Mode choice

$$p_{PT|I} = \frac{T_{I^*,PT} \exp\left(-\lambda^{M} . \Delta C_{I^*,PT}\right)}{\sum_{m=c,PT} T_{I^*m} \exp\left(-\lambda^{M} . \Delta C_{I^*m}\right)} \quad \text{(B12)}$$

and $$T_{I^{**}} \exp\left(-\lambda^{M} . \Delta C_{I^{**}}\right) = \sum_{m=c,PT} T_{I^*m} \exp\left(-\lambda^{M} . \Delta C_{I^*m}\right) \quad \text{(B13)}$$

Hence calculate incremental "composite" cost $\Delta C_{I^{**}}$.

Travel choice

In the LDM, this is also formulated as a logit model. The IL version can be written:

$$p_{travel|I} = \frac{T_I . \exp(-\lambda^F \Delta C_I *)}{\left(N_I - T_I\right) + T_I . \exp(-\lambda^F \Delta C_I *)} \quad \text{(B14)}$$

where N_I is the total zonal population. For convenience, it will be assumed that base year trip rates can be assumed to have a value r constant across origin zones (though they will, of course, vary by segment). This allows N_I to be estimated as T_I / r.

Revised demand

Given these probabilities, we now 'go down the tree' calculating the revised demands T′:

$T'_{I^{**}} = N_I . p_{travel|I}$

$T'_{I^*,PT} = T'_{I^{**}} . p_{PT|I}$ $\qquad T'_{I^*c} = T'_{I^{**}} - T'_{I^*,PT}$

$T'_{I^*r} = T'_{I^*,PT} . p_{r|I,PT}$ $\qquad T'_{I^*a} = T'_{I^*,PT} - T'_{I^*r}$

Then, for structure (i):

$T'_{IJr} = T'_{I^*r} . p_{J|I,r}$ $T'_{IJH} = T'_{IJr} . p_{H|IJr}$ $\qquad T'_{IJC} = T'_{IJr} - T'_{IJH}$

while for structure (ii):

$T'_{I^*H} = T'_{I^*r} . p_{H|Ir}$ $\qquad T'_{IJH} = T'_{I^*H} . p_{J|I,r=H}$ and

$T'_{I^*C} = T'_{I^*r} - T'_{I^*H}$ $\qquad T'_{IJC} = T'_{I^*C} \,.\, p_{J|I,r=C}$

Note that for the other modes, the destination probabilities are unchanged: the demand only reflects the higher level loss of demand over all destinations.

Given this, we can partition the outcome between:

generation	$T'_{I^{**}} - T_{I^{**}}$
capture from car	$T_{I^*c} - T'_{I^*c}$
capture from air	$T_{I^*a} - T'_{I^*a}$
capture from classic rail	$T_{I^*C} - T'_{I^*C}$

Although it cannot be compared with PLD, it is also useful to calculate a measure of re-distribution from the model. This measure can be calculated by summing over modes to eliminate mode-choice effects, and applying an adjustment to total trips to eliminate the generation effect. This is calculated by applying the following calculation, summed over those destinations J benefitted by HSR (those with a positive HSR probability in the original LDM or those that chose HSR in the assignment LDM)*:

$T'_{IJ^*} \,(T_{I^{**}} / T'_{I^{**}}) - T_{IJ^*}$

The corresponding calculations for the PLD model are given below:

PLD

For the rail mode, if HSR is chosen, then $\Delta C_{IJr} = C_{IJH} - C_{IJC}$: otherwise $\Delta C_{IJr} = 0$. For other modes (m = a, c) $\Delta C_{IJm} = 0$.

PT choice

$$p_{r|IJ,PT} = \frac{T_{IJr}\exp\left(-\lambda^{PT}.\Delta C_{IJr}\right)}{\sum_{m\in PT} T_{IJm}\exp\left(-\lambda^{PT}.\Delta C_{IJm}\right)} \qquad \text{(B15)}$$

and $$T_{IJ,PT}\exp\left(-\lambda^{PT}.\Delta C_{IJ,PT}\right) = \sum_{m\in PT} T_{IJm}\exp\left(-\lambda^{PT}.\Delta C_{IJm}\right) \qquad \text{(B16)}$$

Hence calculate incremental 'composite' cost $\Delta C_{IJ,PT}$.

* Note that this represents an amendment to the calculation set out in Annex B of the proposal that was agreed by John Bates by email on 08/12/11.

Mode choice

$$p_{PT|IJ} = \frac{T_{IJ,PT}\exp\left(-\lambda^M.\Delta C_{IJ,PT}\right)}{\sum_{m=c,PT} T_{IJm}\exp\left(-\lambda^M.\Delta C_{IJm}\right)} \qquad \text{(B17)}$$

and $$T_{IJ*}\exp\left(-\lambda^M.\Delta C_{IJ*}\right) = \sum_{m=c,PT} T_{IJm}\exp\left(-\lambda^M.\Delta C_{IJm}\right) \qquad \text{(B18)}$$

Hence calculate incremental 'composite' cost ΔC_{IJ*}. This is used in the frequency formula given below.

Revised demand

Given these probabilities, we now 'go down the tree' calculating the revised demands T′:

$T'_{IJ*} = T_{IJ*} \exp(-\lambda^F. \Delta C_{IJ*})$

$T'_{IJ,PT} = T'_{IJ*} . p_{PT|IJ}$ $\qquad T'_{IJc} = T'_{IJ*} - T'_{IJ,PT}$

$T'_{IJr} = T'_{IJ,PT} . p_{r|IJ,PT}$ $\qquad T'_{IJa} = T'_{IJ,PT} - T'_{IJr}$

As before, we can partition the outcome between:

generation $T'_{IJ*} - T_{IJ*}$

capture from car $T_{IJc} - T'_{IJc}$

capture from air (coach) $T_{IJa} - T'_{IJa}$

If HSR is chosen for IJ, then T_{IJr} represents the capture from classic rail*.

For comparison with LDM, these results will need to be summed over destinations.

* This step represents a correction to the formula given in Annex B of the brief, that was agreed by John Bates by email on 23/11/11.

Appendix B: Station-access modelling in LDM

Introduction

This appendix describes how the term 'station-access cost' is used in the LDM. The term has a different meaning in the context of classic rail and HSR.

Rail-network model

Station access in the rail-assignment model is represented by centroid connectors. The physical (elapsed) time taken to travel to the station is coded on centroid connectors. This time is derived from NRTS data as an average access time by walk, car, bus and London Underground (in London only) weighted by the proportion of station users who arrive by each of these modes. These proportions are also derived from NRTS and calculated individually for each station modelled in LDM. The same procedure is applied to egress times. The physical times calculated for access and egress are summed into one variable and referred to as classic access time (CAT) throughout this note. Note that CAT represents physical (elapsed) time and there is no account taken of access/egress costs such as parking charges or bus fares.

The access/egress to/from stations (the centroid connectors) are fixed in the LDM rail assignment model. This means that the demand from a particular zone is always assigned to specific stations according to fixed proportions (also derived from NRTS), so that access (and egress) cost has no impact on the route choice. Therefore there is no need to apply any weights to access (and egress) during the assignment.

Once the assignment is complete CAT and other generalised cost components are skimmed along the multiple routes calculated by the assignment. This means that for each pair of zones, CAT is an average of all the routes allowed between these two zones. These routes depend on the stations used by the demand from a given zone (as reported in NRTS). The average CAT is therefore weighted by the fixed proportions of demand from that zone using each of the stations derived from NRTS (as described above).

AirHSL model

The LDM contains a bespoke spreadsheet route-choice model used to assign passengers to the Air and HSR networks. In both cases a station (or airport) access cost is calculated. This is a composite of highway and classic rail time and cost:

Rail_SAC = IVT + *ttif* * First_wait_time + Other_wait_time + *rail_ip* * Interchanges

+ **CAT** + (Crowding + Fare)/VOT

Highway_SAC = IVT + *hw_ip* + (Fuel_cost + Non_fuel_cost)/VOT

where *ttif* is a timetable irregularity factor penalising long waits

rail_ip is a penalty per interchange (including the final interchange to HSR)

hw_ip is a single penalty for the interchange from car to HSR

The current values used in LDM for these parameters are:

ttif = 1.15, *rail_ip* = 18mins, *hw_ip* = 36mins.

We note that the *hw_ip* parameter was not part of the original specification of LDM and has been added as a result of discussions and conclusions, which emerged in the course of the LDM–PLD comparison project.

Note that the CAT enters into the Rail_SAC unweighted.

At this point, all zones are tested to check which airports and HSR stations are deemed accessible from the zone. For airports the cut-off generalised access time (generalised time meaning time and cost converted into time) is between one and two hours, with individual values calibrated to match base-year demand data (number of passengers using each airport based on Civil Aviation Authority data). For HSR stations the cut-off highway generalised time is 100 minutes and the cut-off rail generalised time is 300 minutes to allow capturing longer connecting journeys by rail (such as for example the Glasgow to London journey with in interchange to HSR in Birmingham or Manchester).

If the airport or HSR station is accessible by both rail and highway, their respective generalised times (described above) enter a logit function to produce a composite surface/station-access cost (SAC). The spread parameter of the logit function is -0.1 and is the same as the spread parameter used for modelling of surface access in the DfT's SPASM model.

The calculation of SAC is undertaken for both access and egress. The route-choice model subsequently assigns the demand to available routes on the basis of air or HSR time and cost components and the SAC described above. After the assignment of demand to routes, the SAC alongside other generalised cost components is skimmed for each pair of zones. This means that for each pair of zones the SAC and the other air/HSR generalised cost components are an average of all chosen routes weighted by the proportions of demand between these two zones assigned to each route

Choice model

We now get to the LDM choice model. We have two sets of skims: the CAT representing access/egress times to/from classic rail stations and the SAC representing access/egress times to/from HSR stations. We also know that the CAT is an input into the calculation of the SAC.

For every pair of zones the choice model calculates a utility value for each mode. The classic rRail utility function includes a 2 * CAT term and the HSR utility includes a SAC term. Neither the SAC term nor the CAT term which forms part of it is weighted.

This is where a disparity occurs: the same value may enter both calculations (with the same meaning) but end up weighted by a different amount. For an extreme example consider a journey starting near London Euston and ending in Birmingham. Let's say the CAT is 15 minutes at both ends of the journey making a total of 30 minutes. The SAC is also 30 minutes as the same stations serve both classic rail and HSR (we'll ignore the logit calculation with Highway_SAC). However when the utilities are calculated we get[*]:

U_Classic_Rail = 2 * 30mins + IVT + PDFH_penalty + (Fare + Crowding)/VOT

U_HSR = 30mins + IVT + PDFH_penalty + Fare/VOT

So classic rail appears to be unfairly punished due to the way classic access time is weighted.

Changes for this project

In conjunction with RAND Europe we've experimented with improving the treatment of SAC (described as 'enhanced' HSR LOS in the main body of this report). The first important change we made was to change the definition of HSR SAC so that CAT is weighted by 2 for consistency with the treatment of CAT in Classic Rail, ie:

Rail_SAC = IVT + *ttif* * First_wait_time + Other_wait_time + *rail_ip* * Interchanges

+ 2 * CAT + (Crowding + Fare)/VoT

This means that classic access time enters all generalised cost/utility calculations with a weighting of 2.

At the same time we dropped the *rail_ip* to 5 minutes because the 18 minutes penalty was on review considered to be too high, especially in London where there are usually several interchanges. As demonstrated in Section 4.1 this seemed to have the effect of roughly cancelling out the change in the CAT weighting (they work in opposite directions) so overall there was little effect on the results.

Limitations

Although changing the weighting of the CAT has removed an inconsistency from the model to some extent there are still other limitations to the methodology. These are listed below in no particular order.

- HSR rail access cut-offs are very high to allow interlining from Scotland on classic rail. However this leaves the possibility of odd routings through the network (e.g. South West to London via Birmingham). The necessity to use very high cut-offs

[*] This is the formulation for commute and VFR/other. Business is a bit different as the access term has its own coefficient (-0.0110355) in the classic rail utility function. We divide this by 2 for HSR so that Rail_access is still weighted by 2 compared to HSR_access.

for interlining rail journeys and the discussion presented in this note highlight the issue of inconsistent treatment of access cost for classic rail and HSR services. The inconsistency originates from the initial historic assumption made in Phase 0 of the development of LDM that HSR as a mode is likely to be more akin to air rather than rail (particularly for the longest possible journeys such as London to Scotland). Further development of the understanding of the most likely effects of HSR (such as the abstraction of demand primarily from rail) and further detail of how the development of the HSR network in the UK is currently planned (such as integration with rail – part high-speed/part classic network running, close proximity or the same location of HSR and classic stations, the possibility of interchanges between the two and phased implementation over relatively short stretches of the route) point at HSR being an improvement in the rail service rather than an explicit new mode of travel. In the light of this, it would be logical to amend the treatment of HSR access costs and treat the access journey by rail as part of HSR journey (clearly with an interchange between the two). For example, the rail access in-vehicle time would then form part of the overall improved rail in-vehicle time comprising time spent in classic rail and HSR. The CAT would then be the only generalised costs component treated as access cost. It would also be treated in the same way for both classic and high-speed journeys. The apparent inconsistency in the treatment of access costs would then be addressed.

- Route choice lambdas may be too high for HSR (and possibly air as well).

- HSR access costs (SAC) include rail fares, but they don't allow for the possibility of through-ticketing. For example a journey from Kent to Glasgow may be costed as follows:

  SAC fare (Kent to London + Manchester to Glasgow)
  + HSR fare (London to Manchester)

- A detailed analysis needs to be undertaken of the access logit split between highway and rail. This would reveal which airports/HSR stations are mainly accessed by car and which by rail.

Appendix C: The diversity benefit in XLDMC

This discussion is based on the appendix to the Phase 2 Brief and the equation numbers (where given) correspond to those in Appendix A this report. The calculations set out here used the incremental formulae that apply to the commute and VFR/other purposes.

XLDMC (continuous HSR/classic rail choice)

Dropping the subscript for the origin, the cost difference between HSR and classic rail is calculated over destinations as:

$$[C_{*H} - C_{*C}] = -1/\lambda_D.\log\left(\frac{\sum_{J'} T_{J'r}\exp(-\lambda_D.[C_{J'H} - C_{J'C}])}{T_{*r}}\right) \qquad \text{(B7')}$$

Suppose that a fraction p of total rail demand in the base matrix goes to zones served by HSR and that HSR is better than classic rail for all of those destinations by δ minutes. Then demand for other destinations disappears from B7′ and we get (in minutes)

$$[C_{*H} - C_{*C}] = -1/\lambda_D.\log(p.\exp(\lambda_D\delta)) = -\delta - 1/\lambda_D.\log(p)$$

The total improvement in rail cost is given by:

$$\Delta C_{*r} = -1/\lambda_R.\log(1 + \exp(-\lambda_R.[C_{*H} - C_{*C}])) \qquad \text{(B9)}$$

ie:

$$\begin{aligned}\Delta C_{*r} &= -1/\lambda_R.\log(1 + \exp(\lambda_R.[\delta + 1/\lambda_D.\log(p)])) \\ &= -1/\lambda_R.\log\left(1 + p^{\lambda_R/\lambda_D}.\exp(\lambda_R\delta)\right)\end{aligned}$$

Even if $\delta = 0$, as p increases the improvement increases until it reaches $log(2)/\lambda \approx 235$ minutes, which is a large amount. When p is small, this increase will be smaller (about 3 minutes when p is 1 percent), but still significant. So the continuous-choice model is telling us that the introduction of HSR gives a benefit which depends on the proportion of destinations served, even when there is no service advantage over classic rail. This is the diversity benefit.

Note that λ_D is comparatively unimportant in this calculation: the key variable is λ_R.

XLDMA (assignment HSR/classic choice)

In the assignment versions, the total improvement in rail cost is calculated directly by:

$$\Delta C_{*r} = -1/\lambda_D . \log\left(\frac{\sum_{J'} T_{J'r} \exp\left(-\lambda_D . \Delta C_{J'r}\right)}{T_{*r}}\right) \qquad \text{(B4')}$$

ie, in this case:

$$\Delta C_{*r} = -1/\lambda_D . \log\left(1 - p + p \exp \lambda_D \delta\right)$$

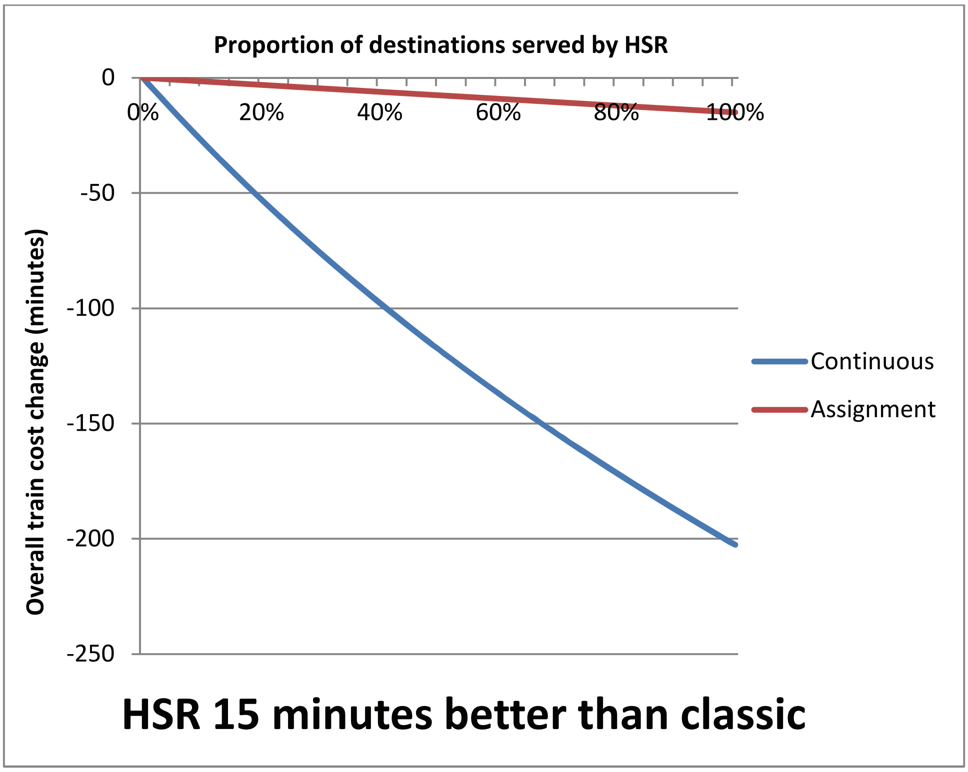
When p and $\lambda_D \delta$ are small, this is approximately $p\lambda_D\delta$. That is, in the assignment version (since increased frequency is not modelled) there is no bonus from having a second alternative that is equivalent to classic rail – HSR has to be better to get any benefit. In this case it is λ_D that is the key variable.

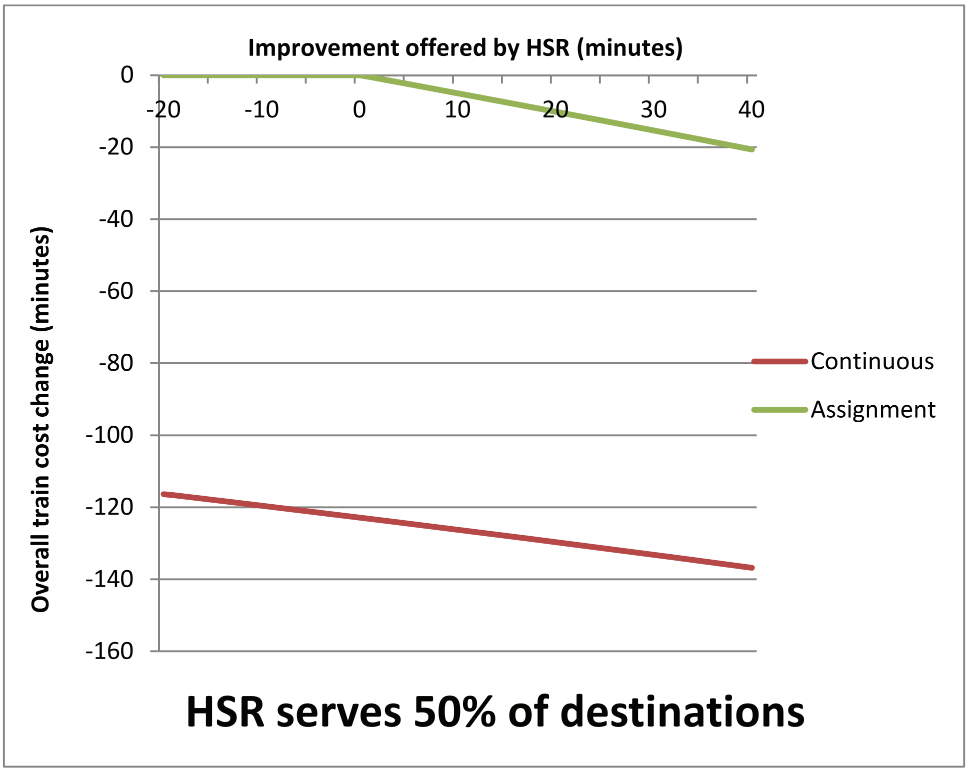
Comparison of XLDMC and XLDMA

A comparison of the impact of HSR on the total rail mode is shown in the two graphs below, the first showing how rail cost (and therefore mode-switch and generation) varies with the proportion of destinations served by HSR, assuming a 15-minute advantage for HSR to every destination served. The second graph shows how the rail cost change varies with the HSR advantage, assuming that HSR serves 50 percent of destinations.

The second graph illustrates why in the single P/A pair tests, XLDMC predicts much higher generation and mode-capture relative to XLDMA – only a single destination is served by HSR in our tests and so the proportion of destinations served (*p*) is close to zero. It also illustrates that, in XLDMC, HSR demand is predicted when HSR offers no time-saving relative to classic rail, whereas in XLDMA no demand is predicted in this case.

These graphs assume illustrative values for the lambda parameters.





Appendix D: Detailed P/A pair results

Commute

Birmingham–Leeds

0 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	8.657	2.447	0.066	22.684	33.853
	25.6%	7.2%	0.2%	67.0%	100.0%
XLDM (assignment)	0.000	0.000	0.001	0.000	0.001
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	9.322	2.634	0.071	24.404	36.431
	25.6%	7.2%	0.2%	67.0%	100.0%
XLDM (assignment)	0.214	0.061	0.002	11.588	11.864
	1.8%	0.5%	0.0%	97.7%	100.0%
XPLD	0.283	0.451	0.000	10.765	11.499
	2.5%	3.9%	0.0%	93.6%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	10.037	2.836	0.076	26.252	39.202
	25.6%	7.2%	0.2%	67.0%	100.0%
XLDM (assignment)	0.450	0.127	0.003	12.494	13.075
	3.4%	1.0%	0.0%	95.6%	100.0%
XPLD	0.586	0.931	0.000	10.765	12.282
	4.8%	7.6%	0.0%	87.6%	100.0%

Birmingham–Glasgow

0 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.792	0.223	0.006	2.102	3.123
	25.4%	7.1%	0.2%	67.3%	100.0%
XLDM (assignment)	0.000	0.000	0.001	0.000	0.001
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.853	0.240	0.006	2.264	3.364
	25.4%	7.1%	0.2%	67.3%	100.0%
XLDM (assignment)	0.009	0.003	0.000	0.501	0.513
	1.8%	0.5%	0.0%	97.7%	100.0%
XPLD	0.012	0.021	0.000	0.465	0.498
	2.5%	4.2%	0.0%	93.4%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.920	0.259	0.007	2.439	3.624
	25.4%	7.1%	0.2%	67.3%	100.0%
XLDM (assignment)	0.019	0.005	0.000	0.540	0.565
	3.4%	1.0%	0.0%	95.6%	100.0%
XPLD	0.025	0.043	0.000	0.465	0.533
	4.8%	8.1%	0.0%	87.2%	100.0%

Birmingham–Sunderland

0 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.212	0.060	0.002	0.561	0.834
	25.4%	7.2%	0.2%	67.3%	100.0%
XLDM (assignment)	0.000	0.000	0.001	0.000	0.001
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.228	0.064	0.002	0.605	0.899
	25.4%	7.2%	0.2%	67.3%	100.0%
XLDM (assignment)	0.002	0.000	0.000	0.088	0.091
	1.8%	0.5%	0.0%	97.7%	100.0%
XPLD	0.002	0.004	0.000	0.082	0.088
	2.5%	4.3%	0.0%	93.2%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.246	0.069	0.002	0.651	0.968
	25.4%	7.2%	0.2%	67.3%	100.0%
XLDM (assignment)	0.003	0.001	0.000	0.095	0.100
	3.4%	1.0%	0.0%	95.6%	100.0%
XPLD	0.004	0.008	0.000	0.082	0.095
	4.7%	8.4%	0.0%	86.9%	100.0%

Nottingham–Richmondshire

0 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.170	0.048	0.001	0.452	0.672
	25.3%	7.2%	0.2%	67.3%	100.0%
XLDM (assignment)	0.000	0.000	0.001	0.000	0.001
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.183	0.052	0.001	0.487	0.724
	25.3%	7.2%	0.2%	67.3%	100.0%
XLDM (assignment)	0.002	0.000	0.000	0.092	0.094
	1.8%	0.5%	0.0%	97.7%	100.0%
XPLD	0.002	0.004	0.000	0.085	0.091
	2.5%	4.3%	0.0%	93.2%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.198	0.056	0.001	0.525	0.780
	25.3%	7.2%	0.2%	67.3%	100.0%
XLDM (assignment)	0.004	0.001	0.000	0.099	0.104
	3.4%	1.0%	0.0%	95.6%	100.0%
XPLD	0.005	0.008	0.000	0.085	0.098
	4.7%	8.4%	0.0%	86.9%	100.0%

Nottingham–Glasgow

0 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.081	0.023	0.001	0.215	0.319
	25.3%	7.1%	0.2%	67.4%	100.0%
XLDM (assignment)	0.000	0.000	0.001	0.000	0.001
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.087	0.025	0.001	0.232	0.344
	25.3%	7.1%	0.2%	67.4%	100.0%
XLDM (assignment)	0.001	0.000	0.000	0.035	0.035
	1.8%	0.5%	0.0%	97.7%	100.0%
XPLD	0.001	0.002	0.000	0.032	0.035
	2.5%	4.5%	0.0%	93.0%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.094	0.026	0.001	0.250	0.371
	25.3%	7.1%	0.2%	67.4%	100.0%
XLDM (assignment)	0.001	0.000	0.000	0.037	0.039
	3.4%	1.0%	0.0%	95.6%	100.0%
XPLD	0.002	0.003	0.000	0.032	0.037
	4.7%	8.8%	0.0%	86.5%	100.0%

Sunderland–Milton Keynes

0 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.041	0.012	0.000	0.109	0.163
	25.3%	7.4%	0.2%	67.1%	100.0%
XLDM (assignment)	0.000	0.000	0.001	0.000	0.001
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.044	0.013	0.000	0.118	0.175
	25.3%	7.4%	0.2%	67.1%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.022	0.022
	1.8%	0.5%	0.0%	97.7%	100.0%
XPLD	0.001	0.001	0.000	0.020	0.022
	2.5%	4.5%	0.0%	93.0%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Coach capture	Classic rail capture	Total
XLDM (continuous)	0.048	0.014	0.000	0.127	0.189
	25.3%	7.4%	0.2%	67.1%	100.0%
XLDM (assignment)	0.001	0.000	0.000	0.024	0.025
	3.4%	1.0%	0.0%	95.5%	100.0%
XPLD	0.001	0.002	0.000	0.020	0.024
	4.7%	8.7%	0.0%	86.5%	100.0%

Business

Birmingham-Leeds

0 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	4.715	0.092	0.559	6.173	11.539
	40.9%	0.8%	4.8%	53.5%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic Rail capture	Total
XLDM (continuous)	5.098	0.100	0.604	6.652	12.454
	40.9%	0.8%	4.9%	53.4%	100.0%
XLDM (assignment)	0.415	0.008	0.049	12.961	13.433
	3.1%	0.1%	0.4%	96.5%	100.0%
XPLD	0.509	0.920	0.000	12.501	13.930
	3.7%	6.6%	0.0%	89.7%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	5.512	0.108	0.653	7.165	13.439
	41.0%	0.8%	4.9%	53.3%	100.0%
XLDM (assignment)	0.860	0.017	0.102	13.455	14.434
	6.0%	0.1%	0.7%	93.2%	100.0%
XPLD	1.075	1.931	0.000	12.501	15.507
	6.9%	12.5%	0.0%	80.6%	100.0%

Birmingham–Glasgow

0 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	1.224	0.026	0.144	1.612	3.006
	40.7%	0.9%	4.8%	53.6%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	1.324	0.028	0.155	1.738	3.245
	40.8%	0.9%	4.8%	53.6%	100.0%
XLDM (assignment)	0.107	0.002	0.013	3.367	3.489
	3.1%	0.1%	0.4%	96.5%	100.0%
XPLD	0.124	0.108	0.243	3.247	3.721
	3.3%	2.9%	6.5%	87.3%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	1.431	0.030	0.168	1.873	3.502
	40.9%	0.9%	4.8%	53.5%	100.0%
XLDM (assignment)	0.223	0.005	0.026	3.497	3.751
	5.9%	0.1%	0.7%	93.2%	100.0%
XPLD	0.262	0.227	0.512	3.247	4.248
	6.2%	5.4%	12.0%	76.4%	100.0%

Birmingham–Sunderland

0 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	0.378	0.008	0.045	0.498	0.929
	40.7%	0.8%	4.8%	53.6%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	0.409	0.008	0.048	0.537	1.003
	40.8%	0.8%	4.8%	53.5%	100.0%
XLDM (assignment)	0.033	0.001	0.004	1.040	1.078
	3.1%	0.1%	0.4%	96.5%	100.0%
XPLD	0.041	0.063	0.045	1.002	1.151
	3.5%	5.5%	3.9%	87.1%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	0.442	0.009	0.052	0.579	1.082
	40.9%	0.8%	4.8%	53.5%	100.0%
XLDM (assignment)	0.069	0.001	0.008	1.080	1.158
	5.9%	0.1%	0.7%	93.2%	100.0%
XPLD	0.085	0.132	0.093	1.002	1.313
	6.5%	10.0%	7.1%	76.4%	100.0%

Nottingham–Richmondshire

0 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	0.070	0.002	0.007	0.093	0.171
	40.7%	0.9%	4.0%	54.4%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	0.075	0.002	0.007	0.101	0.185
	40.7%	0.9%	4.0%	54.3%	100.0%
XLDM (assignment)	0.006	0.000	0.001	0.192	0.199
	3.1%	0.1%	0.3%	96.6%	100.0%
XPLD	0.008	0.014	0.001	0.185	0.207
	3.7%	6.8%	0.2%	89.3%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	0.082	0.002	0.008	0.108	0.200
	40.8%	0.9%	4.0%	54.3%	100.0%
XLDM (assignment)	0.013	0.000	0.001	0.200	0.214
	5.9%	0.1%	0.6%	93.3%	100.0%
XPLD	0.016	0.029	0.001	0.185	0.231
	7.0%	12.5%	0.4%	80.1%	100.0%

Nottingham–Glasgow

0 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	0.235	0.005	0.023	0.315	0.578
	40.6%	0.9%	4.0%	54.5%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	0.254	0.006	0.025	0.339	0.624
	40.7%	0.9%	4.0%	54.4%	100.0%
XLDM (assignment)	0.021	0.000	0.002	0.648	0.671
	3.1%	0.1%	0.3%	96.6%	100.0%
XPLD	0.026	0.020	0.057	0.624	0.727
	3.6%	2.8%	7.8%	85.8%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM(continuous)	0.275	0.006	0.027	0.366	0.674
	40.8%	0.9%	4.0%	54.3%	100.0%
XLDM (assignment)	0.043	0.001	0.004	0.673	0.721
	5.9%	0.1%	0.6%	93.4%	100.0%
XPLD	0.053	0.042	0.116	0.624	0.835
	6.4%	5.0%	13.9%	74.7%	100.0%

Sunderland–Milton Keynes

0 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	0.070	0.001	0.017	0.083	0.170
	40.8%	0.8%	9.7%	48.7%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	0.074	0.001	0.018	0.088	0.181
	40.9%	0.8%	9.8%	48.5%	100.0%
XLDM (assignment)	0.006	0.000	0.001	0.184	0.191
	3.1%	0.1%	0.7%	96.1%	100.0%
XPLD	0.006	0.011	0.005	0.154	0.176
	3.5%	6.4%	2.7%	87.4%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air capture	Classic rail capture	Total
XLDM (continuous)	0.079	0.002	0.019	0.093	0.192
	40.9%	0.8%	9.9%	48.4%	100.0%
XLDM (assignment)	0.011	0.000	0.003	0.189	0.203
	5.4%	0.1%	1.4%	93.1%	100.0%
XPLD	0.013	0.023	0.009	0.154	0.200
	6.5%	11.7%	4.7%	77.1%	100.0%

VFR/other

Birmingham–Leeds

0 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	9.756	7.218	8.593	22.892	48.459
	20.1%	14.9%	17.7%	47.2%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	10.196	7.543	8.980	23.921	50.640
	20.1%	14.9%	17.7%	47.2%	100.0%
XLDM (assignment)	0.264	0.195	0.233	29.722	30.414
	0.9%	0.6%	0.8%	97.7%	100.0%
XPLD	0.736	0.934	0.000	28.950	30.619
	2.4%	3.0%	0.0%	94.5%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	10.656	7.884	9.384	24.995	52.919
	20.1%	14.9%	17.7%	47.2%	100.0%
XLDM (assignment)	0.541	0.400	0.478	30.532	31.951
	1.7%	1.3%	1.5%	95.6%	100.0%
XPLD	1.514	1.932	0.000	28.950	32.396
	4.7%	6.0%	0.0%	89.4%	100.0%

Birmingham–Glasgow

0 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	1.615	1.218	1.390	3.831	8.054
	20.1%	15.1%	17.3%	47.6%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car Capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	1.688	1.273	1.453	4.004	8.419
	20.1%	15.1%	17.3%	47.6%	100.0%
XLDM (assignment)	0.035	0.027	0.030	3.978	4.070
	0.9%	0.7%	0.7%	97.7%	100.0%
XPLD	0.091	0.097	0.187	3.874	4.249
	2.1%	2.3%	4.4%	91.2%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	1.765	1.331	1.519	4.185	8.800
	20.1%	15.1%	17.3%	47.6%	100.0%
XLDM (assignment)	0.072	0.055	0.062	4.088	4.277
	1.7%	1.3%	1.5%	95.6%	100.0%
XPLD	0.190	0.205	0.393	3.874	4.663
	4.1%	4.4%	8.4%	83.1%	100.0%

Birmingham–Sunderland

0 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	0.480	0.361	0.414	1.138	2.394
	20.1%	15.1%	17.3%	47.5%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	0.502	0.378	0.433	1.190	2.503
	20.1%	15.1%	17.3%	47.5%	100.0%
XLDM (assignment)	0.009	0.007	0.008	1.024	1.047
	0.9%	0.7%	0.7%	97.7%	100.0%
XPLD	0.024	0.033	0.009	0.997	1.063
	2.3%	3.1%	0.9%	93.8%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	0.525	0.395	0.453	1.244	2.616
	20.1%	15.1%	17.3%	47.5%	100.0%
XLDM (assignment)	0.019	0.014	0.016	1.052	1.101
	1.7%	1.3%	1.5%	95.6%	100.0%
XPLD	0.050	0.069	0.019	0.997	1.135
	4.4%	6.1%	1.7%	87.8%	100.0%

Nottingham–Richmondshire

0 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	0.132	0.101	0.128	0.297	0.659
	20.1%	15.4%	19.5%	45.1%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	0.138	0.106	0.134	0.311	0.689
	20.1%	15.4%	19.5%	45.1%	100.0%
XLDM (assignment)	0.003	0.002	0.002	0.282	0.289
	0.9%	0.7%	0.8%	97.6%	100.0%
XPLD	0.007	0.009	0.000	0.275	0.292
	2.4%	3.2%	0.0%	94.4%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air/Coach Capture	Classic rail capture	Total
XLDM (continuous)	0.144	0.111	0.140	0.325	0.720
	20.1%	15.4%	19.5%	45.1%	100.0%
XLDM (assignment)	0.005	0.004	0.005	0.290	0.304
	1.7%	1.3%	1.6%	95.4%	100.0%
XPLD	0.014	0.019	0.000	0.275	0.309
	4.6%	6.3%	0.0%	89.1%	100.0%

Nottingham–Glasgow

0 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	0.141	0.109	0.135	0.317	0.701
	20.0%	15.5%	19.2%	45.2%	100.0%
XLDM (assignment)	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car Capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	0.147	0.114	0.141	0.332	0.733
	20.0%	15.5%	19.2%	45.2%	100.0%
XLDM (assignment)	0.003	0.002	0.003	0.303	0.310
	0.9%	0.7%	0.8%	97.6%	100.0%
XPLD	0.007	0.008	0.015	0.295	0.325
	2.1%	2.4%	4.6%	90.8%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	0.154	0.119	0.147	0.347	0.766
	20.0%	15.5%	19.2%	45.2%	100.0%
XLDM (assignment)	0.006	0.004	0.005	0.311	0.326
	1.7%	1.3%	1.6%	95.4%	100.0%
XPLD	0.015	0.017	0.032	0.295	0.359
	4.1%	4.6%	8.9%	82.3%	100.0%

Sunderland–Milton Keynes

0 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	0.074	0.058	0.095	0.144	0.371
	20.1%	15.6%	25.5%	38.9%	100.0%
XLDM (assignment)	0.000	0.000	0.001	0.000	0.001
	n/a	n/a	n/a	n/a	n/a
XPLD	0.000	0.000	0.000	0.000	0.000
	n/a	n/a	n/a	n/a	n/a
15 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	0.078	0.061	0.099	0.151	0.388
	20.1%	15.6%	25.5%	38.9%	100.0%
XLDM (assignment)	0.001	0.001	0.002	0.164	0.168
	0.9%	0.7%	1.1%	97.4%	100.0%
XPLD	0.004	0.005	0.004	0.160	0.174
	2.2%	3.0%	2.6%	92.2%	100.0%
30 minutes time improvement					
Model	Generation	Car capture	Air/coach capture	Classic rail capture	Total
XLDM (continuous)	0.081	0.063	0.103	0.158	0.406
	20.1%	15.6%	25.5%	38.9%	100.0%
XLDM (assignment)	0.003	0.002	0.004	0.168	0.177
	1.7%	1.3%	2.1%	94.8%	100.0%
XPLD	0.008	0.011	0.009	0.160	0.188
	4.2%	5.8%	4.8%	85.1%	100.0%