Mott MacDonald

Options for Phase Two of the High Speed Rail Network

PLANET Forecasting Model - Model Development Report PfMv3

July 2013
HS2 Limited

mvaconsultancy

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Eland House
Bressenden Place
London SW1E 5DU

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1. Introduction

1.1 Background

In March 2010, the Government published a report by High Speed Two (HS2) Limited which provided a business case including detailed recommendations for the design of a high speed rail route between London and the West Midlands. This business case was appraised using the PLANET Long Distance Framework, known in this document as the PLD Framework, originally developed during 2009, with additional improvements augmenting the framework in 2010.

HS2 Ltd has continued to commission work on the London-West Midlands scheme, resulting in revised forecasts being published in March 2011 and January 2012. These revised forecasts involved some minor technical adjustments to the PLD Framework and changes as a result of revised economic assumptions underpinning the forecasts. The January 2012 forecasts included a re-base of the PLD Framework from 2007/2008 to 2010/2011[1], and a major update to all of the demand and supply assumptions in the framework.

In parallel to these updates, HS2 Ltd commissioned demand forecasting and modelling advice to support the extension of the high speed rail project to Leeds and Manchester. This work used as a starting point the modelling and appraisal framework developed for the London-West Midlands scheme. It was recognised that the PLD Framework, in its state of development at the time, was unsuitable for analysing the extensions to Manchester and Leeds because it was unable to model local rail journeys and detailed station locations north of the West Midlands. In order to develop a modelling framework suitable for a robust appraisal of the Leeds and Manchester extensions, HS2 Ltd commissioned enhancements to the model. The key changes were to the station choice model and the interaction between the strategic model and regional rail models. During the application of the framework, the need for enhancements to the functionality was identified; such enhancements have since been incorporated. To distinguish this model from the PLD Framework, it became known as the Planet Framework Model (PFM).

The final stage in the model development programme was to bring together the changes made to the PLD Framework used for the London-West Midlands work, which primarily related to updated demand and representations of supply, and the changes made to the PFM model into a single version of the PFM model. All data, analysis and maps relate to work undertaken prior to August 2012.

1.2 Purpose of Report

The purpose of this report is to document the changes made to the PLD Framework in order to develop PFM, a modelling framework suitable for the robust appraisal of the Leeds and Manchester extensions. It explains the need for changes and the reasons for the approach taken, as well as detailing the updates, additions and changes made.

Except for a broad overview of the PFM's functionality, this report does not repeat information already provided in the existing documentation of the individual models or the PLD Framework. The relevant sections provide a list of documents from which such information can be obtained.

1 Note that the PLD Framework model and PfM represent financial years. In some documentation, the 2007/2008 model is referred to as 'the 2008 model'.

Procedures, parameters and other aspects of the Framework not mentioned in this report have been left unchanged.

1.3 Layout of Report

The report is structured as follows:

- **Section 2: Model Versions -** provides a summary of relevant background information for the PLD Framework model and provides a summary of the updates needed to create the PFM.
- **Section 3: Model Functionality -** details the changes made to the functionality to create the PFM.
- **Section 4: Station Choice Model -** present details of the station choice model.
- **Section 5: Supply Updates -** details the updates to the supply.
- **Section 6: Base Year Validation -** provides details of the validation of the base year model.
- **Section 7: Scheme Appraisal -** presents updates to the appraisal processes.

The report is supplemented by a number of appendices:

- **Appendix A: Glossary of Terms -** provides a list of abbreviations and a glossary of terms.
- **Appendix B: Model Versions -** provides further details of the different versions of the model.
- **Appendix C: Preload Transfer Process -** provides a worked example of the preload transfer process
- **Appendix D: Station Choice Model -** contains a copy of the full station choice model documentation
- **Appendix E: HS2 Service Specification -** presents the optimised service specification included in the final version of PFM v3.0
- **Appendix F: Released Capacity Specification -** presents the released capacity specification included in the final version of PFM v3.0

2. Model Versions

2.1 Overview

During the HS2 programme of work, a number of variants of both the PLD Framework and PFM have been developed. These different versions have different model architecture and functionality and, in some cases, changes to the input forecasts of demand and supply.

The following section presents an overview of the structure of the model that formed the starting point for model development, together with an overview of the changes incorporated in each of the models. The overview is summarised in Table 2.1. Details of the changes in the PLD Framework are also included, as a number of these have been incorporated in the PFM. A more detailed summary of each of these model changes is included in **Appendix B.**

2.2 The PLD Framework

The PLD Framework was used as the basis for the Phase One (London-West Midlands) appraisal work. The original PLD Framework model was used to present the appraisal and forecasts in March 2010. Two further versions of the model were subsequently developed: one to support the Public Consultation in February 2011 and the other to support the revised economic case published in January 2012.

2.2.1 Constituent models of the PLD Framework

The first version of the PLD Framework consisted of three PLANET models: Planet Long Distance (PLD), Planet South (PS) and Planet Midlands (PM), and a spreadsheet-based Heathrow access model (ADM). All of these models have been adapted to operate as part of the PLD framework model.

Full details of the PLD Framework are included in Model Development Report, Atkins, February 2010.

PLANET Long Distance (PLD)

Based on the previously existing PLANET Strategic Model (PSM), this model represents long-distance, or strategic, movements across the mainland United Kingdom for road, rail (including high speed rail) and air. PLD is an all-day model (16-hour) and includes assignment, incremental mode-choice and trip generation functions.

A station choice model (SCM) is included to represent the potential for passengers travelling between the West Midlands and London to choose between a number of origin and destination stations, and recognises that the choice of stations is inter-related.

As PLD is an all-day model, it is unable to represent peak-period service conditions, in terms of increased frequencies, passengers or crowding. In order to represent these effects, the regional models (PS and PM), which are AM peak-period models, are used.

For use as part of the PLD Framework, PLD explicitly excludes demand in the following areas:
- trips wholly within London/south-east and south-west (represented in PS);
- trips wholly within the Greater Birmingham area (represented in PM); and
- trips to/from Heathrow airport (represented in the ADM).

PLANET South and Planet Midlands

PS and PM are AM peak-period rail models covering the 3-hour period between 0700 and 1000. They are used principally for modelling the London and South East and the West and East Midlands rail networks, respectively. They use an elasticity-based approach to represent the change in demand caused by changes in service specification, crowding or fares.

Airport Demand Model

Airport travellers have different demand response characteristics that are distinct from most passengers. As the proposed alignment for HS2 includes close linkages with Heathrow Airport, it was deemed necessary to specifically model trips to and from Heathrow in detail. As such, a separate spreadsheet approach was adopted.

2.2.2 PLD Framework February 2011 Update

Revised forecasts and a revised business case for the London-West Midlands scheme were presented in February 2011 for the public consultation. These forecasts resulted from:

- a number of functional improvements and corrections to the modelling framework;
- changes to the station choice model to correct certain anomalies and improve the model's accuracy;
- inclusion of the impacts of revised economic growth forecasts and changes to Government policy; and
- changes to the appraisal process.

Note that some of the technical improvements were short-term solutions (e.g. changes to the station choice model) and would not be included in the PFM. Changes to demand and the appraisal process would be carried forward to the PFM model. Further details of these updates can be found in Appendix B, Section B.3.

2.2.3 PLD Framework January 2012 Update

For the revised economic case in January 2012 a comprehensive programme of additional work was undertaken to improve the robustness of the modelling and the appraisal and update assumptions underlying the forecasts, to reflect political and economic changes. This additional work focused on updating the base year models to represent 2010, and updating future-year forecasting assumptions. The following changes were incorporated in the model:

- Base-year demand for all of the PLD Framework models (PLD, PS and PM) and all modes (air, rail, highway) was updated to 2010/2011.
- The base-year networks and costs for all modes and models were updated to 2010/2011.
- Future-year demand has been updated for all models and modes based on the latest economic forecasts.
- Future supply (rail services, air services and highway) has been changed based on the latest information available from the DfT.
- Minor functional changes have been incorporated to take account of the updated supply and demand data, and to make minor corrections to model functionality.

Further details of these updates can be found in Appendix B, section B.4.

2.3 The Planet Forecasting Model (PFM)

The development of the PFM was originally driven by a wish to enhance the existing modelling framework to better model the extended network from the West Midlands to Manchester and Leeds. Subsequently, further enhancements to the modelling framework were identified through application of the framework, and a series of updates to the economic forecasts that underlie demand have occurred, which ultimately needed incorporating into the PFM.

The starting point for the PFM was the March 2011 version of the PLD Framework model. There have been two major updates to the PFM. PFM version 2 (v2.0) incorporates changes to the station choice models and interaction between strategic and local models, together with some further minor changes. PFM version 3 (v3.0) is based on PFM v2, with some further changes to the model architecture, changes to the interface to PLANET South and updates to the model to include the demand and supply updates contained in the January 2012 version of the PLD Framework.

2.3.1 PFM Version 2

It was recognised that, in its current form, the PLD Framework was not suitable for analysing the extensions to Manchester and Leeds because of the limitations in the modelling of local rail journeys and station locations in the existing framework. Subsequently, HS2 Ltd issued two briefs to develop the modelling framework to address some of the above requirements. PFM v2.0 incorporated the following changes:

- PLANET Midlands in its entirety;
- PLANET North – a regional model covering the north of England integrated into the PLD framework; and
- a revised Station Choice Model covering all stations into the framework.

A small number of technical adjustments have been necessary to address issues identified during the application of the model.

Further details of the development of PFM v2.0 are included in Appendix B, Section B.6.

2.3.2 PFM Version 3

The key developments from PFM v2.0 to PFM v3.0 were:
- further enhancements to model functionality to improve model performance;
- a revised base year of 2010
- revised future-year demand and supply assumptions, consistent with the January 2012 version of the PLD Framework, and
- Further development of HS2 service specification and released capacity service specification

Further details of the development of PFM v3.0 are included in Appendix B, Section B.7.

Table 2.1: **Summary of Model Versions**

Version	Comments	Documentation
PLD Framework 2010	**Demand and Supply** Base Year 2007/2008 **Functionality** ■ PLD ■ cut down PM ■ PS ■ SCM covering London and Birmingham ■ ADM	Atkins - Model Development Report, A Report for HS2, February 2010
PLD Framework February 2011	**Demand and Supply** Base Year 2007/2008 Forecasts based on economic forecasts included in Office for Budget Responsibility official budgetary forecast, June 2010 **Functionality** ■ As PLD Framework 2010 ■ Improvements to SCM ■ Revisions to interaction between PLD and PS ■ Misc. technical adjustments	WS Atkins - Modelling and Appraisal Updates and their impact on the HS2 Business Case - A Report for HS2 December 2010 MVA-Mott MacDonald - Model Development and Baseline Report (This Report includes some further work undertaken by Atkins not documented in above report) April 2011
PLD Framework January 2012	**Demand and Supply** Base Year 2010/2011 Forecasts based on economic forecasts included in Office for Budget Responsibility official budgetary forecast, November 2011 **Functionality** As PLD Framework Feb 2011 with the following changes: ■ Revised DM and DS service coding ■ Improved Birmingham and Manchester connectivity ■ Revised preload and wormhole factors ■ Misc. technical adjustments	MVA, Mott MacDonald and Atkins - Model Development and Baseline Report HS2 London-West Midlands Report for HS2 Ltd March 2012
PFM Version 2.0	**Demand and Supply** Base Year 2007/2008 Forecasts as PLD Framework February 2011 **Functionality** As PLD Framework Feb 2011 with the following changes: ■ PN added ■ Expanded PM added ■ Modified preload process for PM and PN ■ Revised SCM covering whole of UK ■ Adjustments to model architecture to improve stability	
PFM Version 3.0	**Demand and Supply**	

Version	Comments	Documentation
	Base Year 2010/2011 Forecasts as PLD Framework January 2012 **Functionality** As PFM Version 2 with the following changes: ■ Optimised HS2 service spec. ■ Optimised released capacity spec. ■ Revised preload transfer process PM to PLD ■ Minor upgrades to SCM	

3. Model Functionality

3.1 Introduction

A series of alterations and improvements have been introduced to the PFM to provide an enhanced modelling framework, in order to better model the extended HS2 network between the West Midlands and the north of England. As the focus of the model development is a better representation north of Birmingham, a large proportion of the development work has focused on improving both the representation of local demand and supply in the north of England and the addition of a new station choice model to model the choices in these regions.

The key enhancements to the model functionality are:

- the introduction of the Planet North (PN) regional model into the PLD framework;
- the expansion of the geographical representation of the PM regional model; and
- the addition of a new station choice model covering the whole country.

In implementing these changes, a number of new or modified processes and structural changes to the model are required. This provided the opportunity to enhance some existing processes. In particular, the enhancements to the model include:

- the need for a revised control matrix procedure to allocate demand to individual models;
- changes to the preload transfer processes between individual models; and
- the requirement for a separate rail assignment databank in PLD with a station zoning system to incorporate the Station Choice Model.

In addition to these structural changes, we also implemented a number of other changes to improve elements of the PFM. These include:

- resetting of demand; and
- model stability.

All of these changes are described below. The changes to the station choice model are detailed in Chapter 4.

3.2 Representation of local supply and demand

The PLD zoning structure is fairly aggregated outside London, with zones typically representing districts at the most granular level, rising to groups of districts as distances from London increase. As PLD is a strategic model, many services are not represented explicitly. However, the demand carried by these services can be significant in an HS2 context in respect of:

- Local demand on long-distance services (eg, Birmingham International to Birmingham New Street);
- The impact on capacity and patterns of movement on local services when long-distance service patterns change.

The existing PLD Framework has regional models covering the South (PS) and the Midlands (PM). However, the PM model in the PLD Framework is a cut-down version of the full PM model, focused on the immediate Greater Birmingham area. There is no regional model covering the East Midlands and the North. Therefore, in order to more accurately reflect the interaction between local and long-distance services in the wider Midlands area and the North of England, a regional model or models covering these areas was required. To address this, PFM extends the functionality in PLD to incorporate:

- An extended version of PM (AM 3-hour peak period), covering the West and East Midlands.
- A version of PLANET North (AM 3-hour peak period), covering the North, including Liverpool, Manchester, Sheffield and Leeds.

3.2.1 Planet Midlands

PM was originally adapted for use within the PLD Framework by cutting back the geographic scope of the model to the immediate greater Birmingham area. For the extensions to Leeds and Manchester, the geographic area of interest is wider; therefore, the whole of the PM model has been incorporated within PFM. The PM network and transit lines were initially unaltered when integrated into PFM. However, the PLD network was altered to accommodate the full PM network. For more details about this process, see section 3.2.3.

3.2.2 Planet North

PN is a 'sister' model to PM, in that it was developed side by side with PM. The models share development history, functionality and data sources. The geographic coverage of PN is centred on the M62 corridor – Liverpool, Manchester, Leeds and Sheffield.

As in PM, all rail service coding has been updated to 2010/2011 and the latest assumptions in regard to future service specifications. These updates are consistent with the January 2012 version of the PLD Framework.

The PN network was unaltered when integrating into PFM. However, the PLD network was altered to accommodate the full PN network. For more details about this process, see section 3.2.3.

3.2.3 Modifications to PLD to incorporate Revised Regional Models

Ideally, the integration of PLD and the regional models requires identical networks between the regional and PLD models. This greatly facilitates the preload demand transfer mechanism. In the case of PM and PN, the PLD network has been altered to incorporate all of the links in the regional models and to ensure that the node numbers between the models matched. Transit lines in PLD have been updated so that they run correctly on the revised network; additional transit lines have been added where relevant.

Although the preload process has been updated in PS, no further modifications have been made to the PLD network in the area covered by PS. **Figure 3.1** shows the additional network coded into PLD in order to ensure that it is identical to the regional models for the areas that the regional models are focused.

Figure 3.1: Additional PLD network in PFM

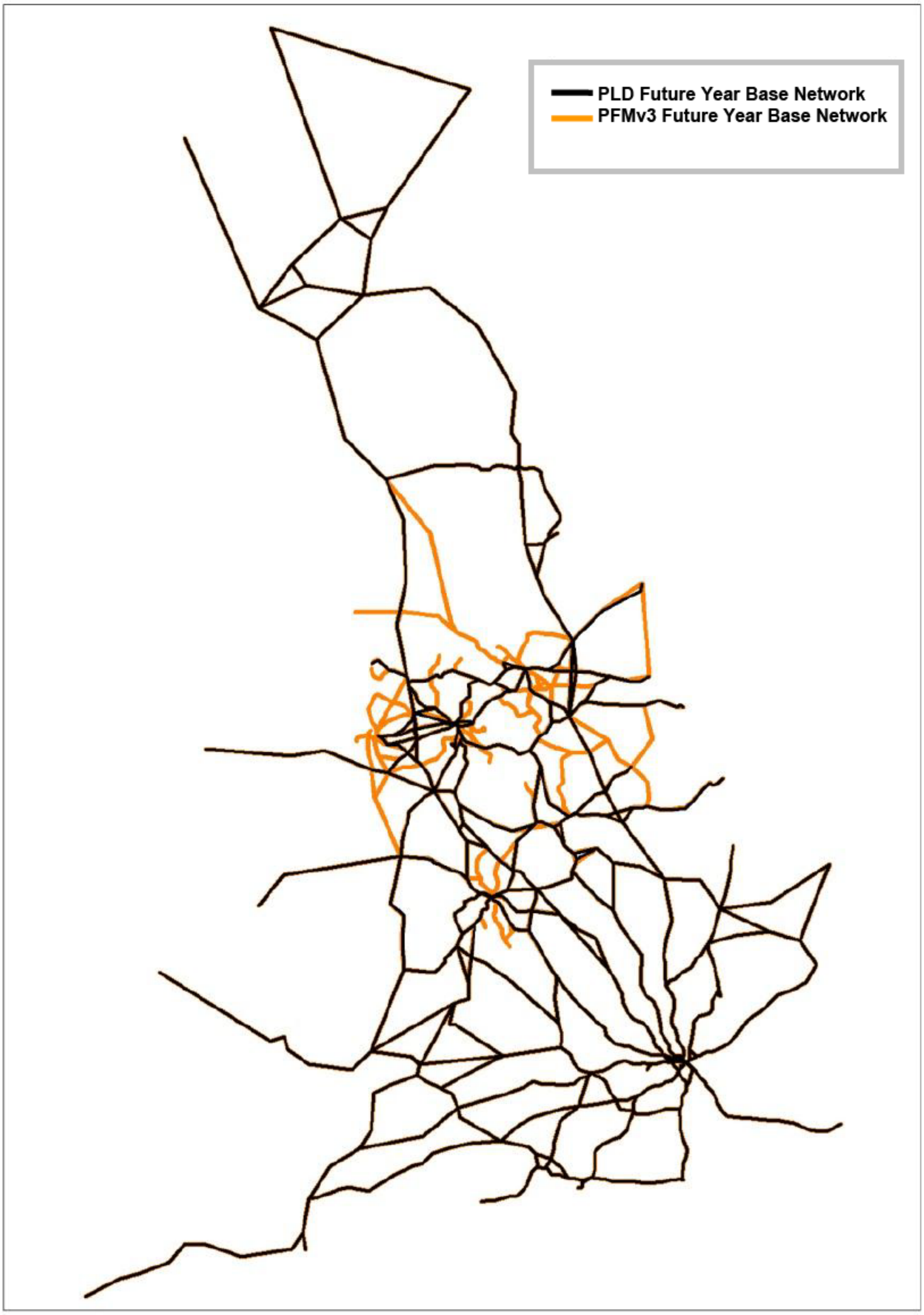
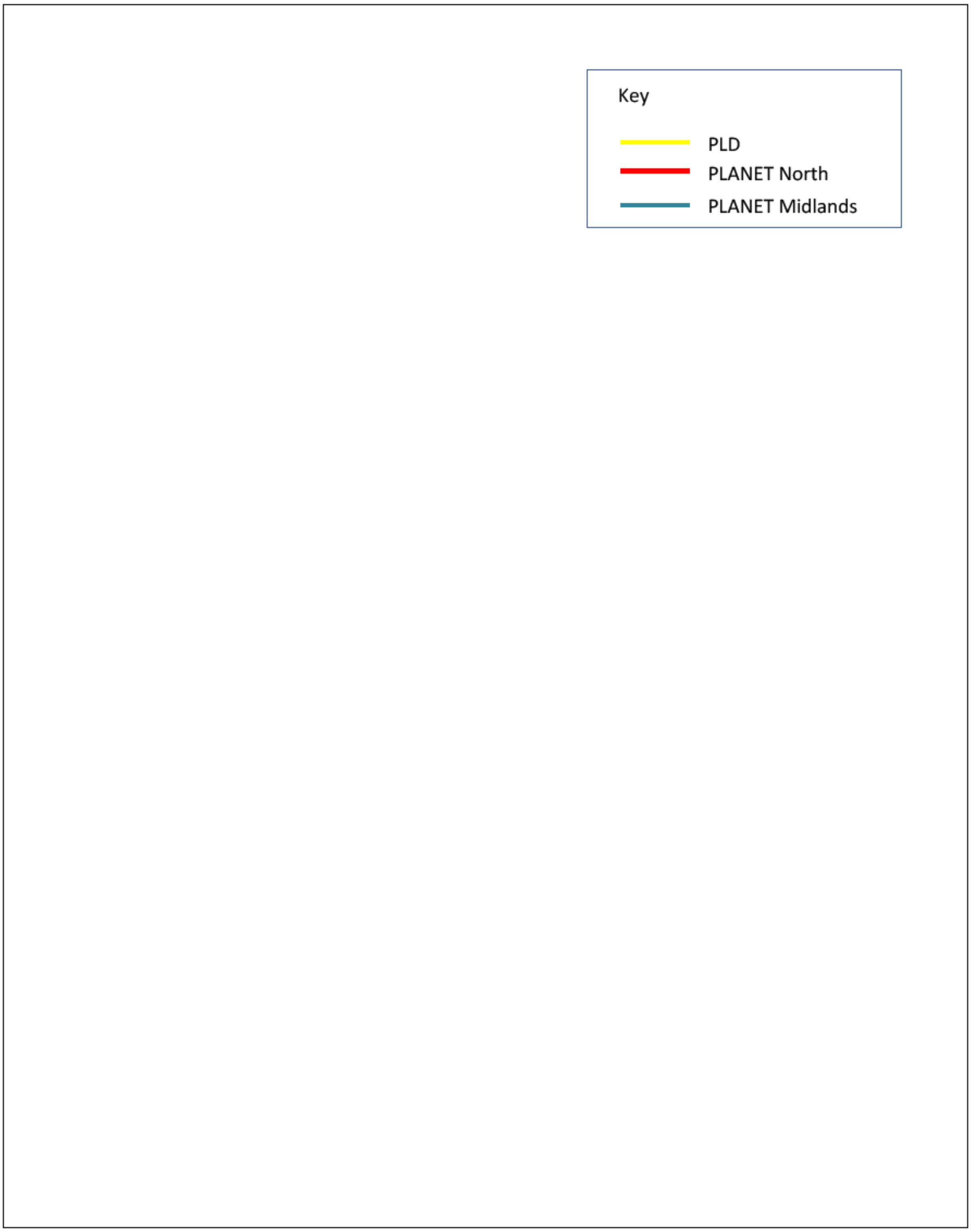


Figure 3.2 provides a geographic representation of where the PLD network has been updated and the areas where PLANET North and PLANET Midlands network have been used for the update.

Figure 3.2: Source of PLD Rail Network in PFM



Following the integration of the PM and PN networks into PLD, a number of minor changes were made to the PLD network as follows:

- East Midlands Parkway station has been added into PLD and PM (future-year models only); and
- Meadowhall Parkway station has been added into PLD and PM (future-year models only).

A number of transit lines in PLD have been updated so that they run correctly on the revised network (or added, where relevant, if not included in PLD previously). These lines are as follows:

- Northern Trains: Leeds-Carlisle
- Northern Trains: Leeds-York
- Northern Trains: Manchester Victoria-Clitheroe
- Northern Trains: Manchester Victoria-Blackburn
- Northern Trains: Sheffield-Leeds (via Barnsley)
- Northern Trains: Sheffield-Huddersfield
- Northern Trains: Manchester Piccadilly-Chester

3.3 The Control Matrix

The key to integrating the regional and long distance models into PFM is to determine whether a given movement should be modelled in PLD, PS, PM or PN. Demand for a particular movement should only be included in only one of the models, i.e. in PLD or one of the regional models. Demand matrices for each model are initially provided covering all movements. The control matrices (i.e. the indicator matrix that determines whether demand is represented in PLD or the regional models) determine which movements to retain in each model, and remove demand for non-selected movements.

In the PLD Framework, the differentiation was simpler, as it was possible to trace a clear boundary between the PS model area of influence and the rest of the UK. Furthermore, the PM element of the framework was within a relatively small area around Birmingham. PFM examines multiple areas of interest in both PM and PN and therefore requires a more comprehensive approach to determining which movements are appraised from each model.

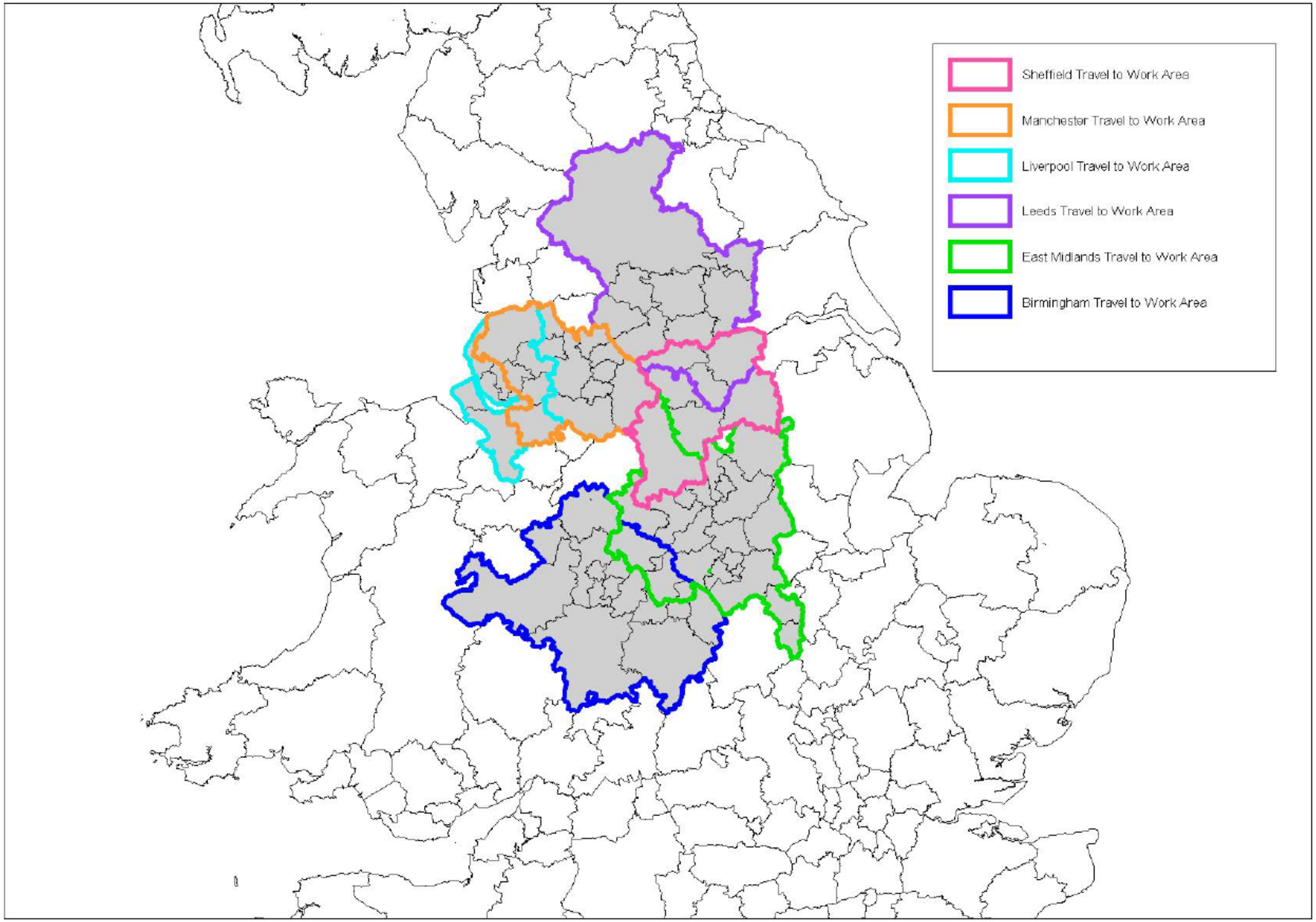
For example, Stafford to Manchester movements are best represented in PLD, so we remove demand for this movement from PN. This demand is therefore represented in PN as a preload on the route, coming from the modelling in PLD. On the same route, we would expect to represent movements between Stockport and Manchester in PN. These would be assigned in the normal way within PN, on top of the preloaded PLD demand. Conversely, the resultant PN assigned demand on Stockport-Manchester flows provides the basis of preloads into the PLD model.

When choosing the model within which the demand for a particular movement resides, there are two elements to consider: the travel to work (TTW) area for the major conurbations of interest and local trips using key strategic corridors.

It is important to represent movements within each TTW area in the appropriate regional model. The TTW areas that we use in the model are based on the Department for Transport (DfT) TTW area definitions that were defined to encompass the hinterland of an urban centre, from which it could be reasonably expected that people commute to the urban centre. Figure 3.3 shows the TTW areas. Trips wholly within each individual TTW area are modelled within the appropriate regional Planet model (i.e. Birmingham and East Midlands in PM, the remainder in PN).

Figure 3.3 shows that a number of the TTW areas overlap. For example, zones in the eastern section of the Liverpool TTW area are also in the western section of the Manchester TTW area. Therefore, the control matrix must be built carefully, so as to exclude from the PLD demand matrices only those origin-destination zone pairs that constitute local trips.

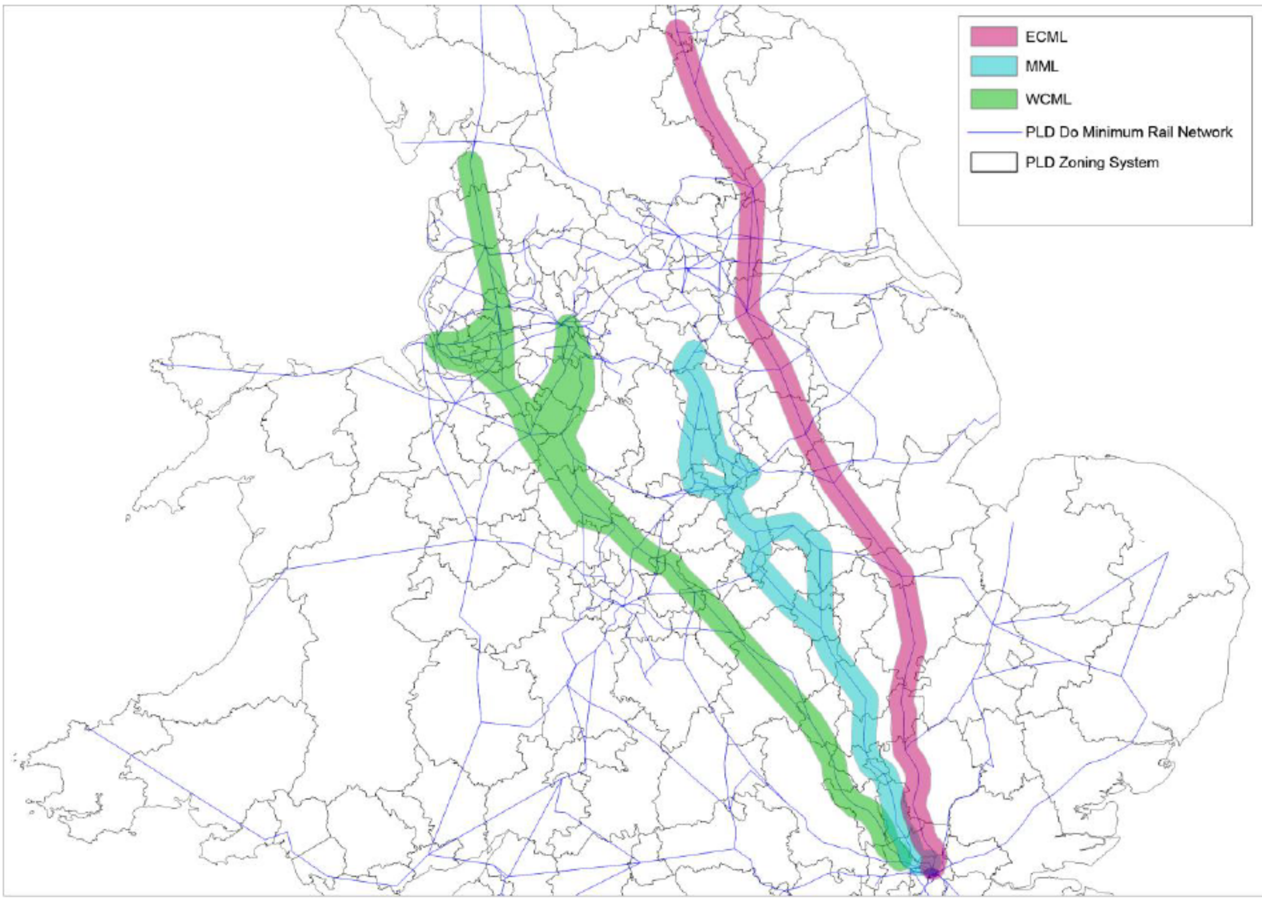
Figure 3.3: PLD Travel to Work Areas



It is also important to ensure that local trips along the key rail corridors affected by HS2 are captured and modelled in the regional models. The three key corridors are the West Coast Main Line (WCML), Midland Main Line (MML) and East Coast Main Line (ECML), shown in **Figure 3.4**. Along each of these rail corridors, the control matrix ensures that local trips are modelled in PM or PN as appropriate. Local trips have been defined as trips between adjacent zones along the key corridors. This ensures that, for example, demand from Crewe to Warrington is included in PN, but demand from Crewe to Preston is modelled in PLD.

The Control Matrix was initially developed for the PLD zoning system. Correspondences to PM and PN were used to derive control matrices for the regional models. This approach ensures that no demand is represented in both PLD and a regional model, and that all movements have a defined model within which to reside.

Figure 3.4: Key Corridors



3.4 Highway Model Update

For consistency in approach with the rail matrices, we apply the revised Control Matrix to the highway demand matrices. This is to ensure that the highway demand which is subject to the mode choice and trip generation calculations in PLD has the same geographic coverage as the applicable rail demand.

This results in a reduction in the highway matrix, particularly in the north of England. However, it is important to maintain the correct traffic volume levels on the highway network, as these volumes determine the correct journey time on links through the application of volume/capacity calculations. This, in turn, ensures that realistic generalised journey times are modelled for highway movements. This is not an issue in the regional models, as they do not model highway travel as a mode.

Therefore, the preloads that are applied to the highway network are recalculated. The recalculation ensures that the total traffic (assigned and preloaded) for the base model is equal in the PLD Framework and in PFM. This ensures consistency with the previous PLD Framework and maintains realistic levels of delay in the highway network. In future years, the highway preloads are grown using the same factors used to grow the highway demand matrices, so that future-year levels of delay are fully reflected.

The highway model was otherwise unchanged, except for the addition of two centroid connectors to link the highway network with revised parts of the rail network, namely:
- North Yorkshire-Harrogate. Added highway link to Harrogate; and
- Ribble Valley-Clitheroe. Added highway link to Clitheroe.

3.5 Transfer of Demand between PLD and Regional Models

3.5.1 Overview

There is a sub-set of services in each model that are represented in the other models (known as 'mixed' services, which may carry long-distance as well as local demand). The long-distance trips are 'native' to PLD, while the short-distance trips are 'native' to the regional models. To produce an accurate model of the demand on a particular service and to capture crowding effects in each model more fully, both the long and short-distance demand is required. This requires the transfer of flows from PLD to the regional models and from the regional models to PLD. These are transferred via preloads.

In simple terms, the process for identifying and transferring preloads between the models relies on two manual processes:
- the identification of the sections of track (links) where preloads are required; and
- the identification of the train services (transit lines) which carry both 'local' and long-distance demand on those track sections.

This process enables these transit lines to be included in the preload process only on the applicable links, even if the transit lines traverse more than one preload area. This becomes even more crucial as preloads are included for short-distance movements along strategic corridors, as well as in urban areas.

The use of preloads offers certain benefits, particularly the ability to display demand data within the modelling framework at both a link[2] and segment[3] level, enabling detailed analysis of service loadings.

2 In the rail model, a link represents a section of train track on which transit lines (train services) run.

There is also a tangible linkage between the models, which enables an element of transparency of model-to-model transfer of demand. The overall concept of using preloads is common practice in transport modelling.

Technically, it is feasible to match individual services in PLD and the regional models in order to pass actual demand directly to the correct service in the other model. However, the services modelled in PLD and the regional models are not necessarily consistent. For example, services may run only outside the AM peak period and therefore would not be included in the regional models. Conversely, service patterns and utilisation may be different in the AM peak when compared to an all-day model. Furthermore, the process of coding transit lines using Network Rail CIF files leads to inconsistent service numbering between PLD and the regional models, so direct matching of services is not straightforward. As a result, such a detailed approach is complex and labour-intensive.

The preload transfer process included in the original PLD Framework model is a simplified process with a number of steps that could be enhanced to deliver greater robustness, particularly as the extent and potential influence of model preloads increases significantly when increasing the scope of PM and incorporating PN into PFM.

The key issues with the existing process are as follows:

- Although preloads are generated at a segment level, they are aggregated and transferred between models at a link level. Preloads are then factored back from link level to transit line segment level by a measure of headway only. Significantly, this means that the preloads applied in the crowding process in each constituent model are applied to in-scope transit lines, taking no account of relative journey time, stopping patterns or origin/destination. This results in particular discrepancies within PLD, such as long-distance services being allocated preloads for local trips from stations where the long-distance service passes through, but does not stop. This implies that the calculated preload on some services may be unrealistic.
- The process of transferring preloads between all-day PLD flows and the AM peak period regional models is simple. To take some account of 'tidal' flows within the regional model, the directional flows in the regional model are combined to create a single two-way flow, and are factored before transfer to PLD.
- Demand is passed between the 'from' and 'receiving' model on a 'per train' basis. However, if the number of trains in the 'receiving' model differs significantly from the number of trains in the 'from' model, the preload demand is effectively factored by the ratio of services in the 'receiving' model and the 'from' model. This is a particularly significant issue where service frequency in the peak period differs significantly from the all-day service frequency.

A further disadvantage of the preload process is that transit lines must be manually identified for inclusion in the preload process in both PLD and the regional models. This can make the model cumbersome to update. The issue is worse when we expand the application of the preload process to the three separate sub-models.

There are further complications to continuing this method of preloads around the inclusion of more than one area of interest within the PN and PM models, and the implications of long-distance services which traverse more than one of the areas of interest where preloads are to be modelled. The application of the

3 In the rail model, a segment represents a specific transit line (train service) on a specific link.

preload mechanism presents difficulties when services pass through more than one principal urban centre (Manchester, Leeds etc). Many long-distance transit lines traverse more than one urban centre, but may not fulfil the criteria for a 'mixed' service in each of those areas, or indeed each corridor traversed in a specific urban centre.

To address the above concerns, we developed a revised approach to calculating preloads. It more accurately represents the preloads and hence crowding impacts on individual services at particular locations within both PLD and the regional models.

This revised approach is detailed below and has been used for the transfer of demand between PS, PM, PN and PLD, both for local demand being passed to PLD and for long-distance demand being passed to the regional models. Note that the exception to this is the method for passing relevant long-distance demand from PLD to PS through the "wormhole" mechanism. This is different from the preload mechanism and has been retained in the PFM.

3.5.2 Adopted Approach

Step 1: Identify links/services

The first stage in the revised preload process is to define which train services (transit lines) and which links should be included within the subset of links and services where preloads should be defined.

Firstly, the links that are within the core areas of the regional models are identified. In PM and PN, these are largely within the TTW areas (e.g. Manchester to Stoke-on-Trent). Links in PS are defined as those on strategic corridors (e.g. the WCML). This is because services that are not on strategic corridors will not be carrying long-distance demand. This shows that choice of links and services are inter-related.

Secondly, the subset of services which are eligible to be used in the preload process is defined. These services must to be able to transport strategic demand and local demand. Therefore, the service needs to:

- have rail service origin and rail service destination in different TTW areas (for strategic demand criteria, i.e. if they were both in the same area, the control matrix would mean all demand would be modelled in the designated regional model); and
- have at least two stops in a given TTW area (for local demand included in regional model to be able to make use of service).

Step 2: Group services into packets

The process of producing the transit lines from CIF files for PLD and the regional models leads to many distinct service specifications within the PLANET models, many of which are slight variations in stopping pattern or timings, rather than substantially different services. Therefore, it makes sense for the preload process to group similar services in order to smooth out the transfer process. For example, an off-peak service that is included in PLD but not in the regional models may have a stopping pattern that is very different from that of a service running in the AM peak. This should not be grouped with the AM peak services when transferring demand to the regional model.

Therefore, services are grouped together in PLD and regional models, if they are similar in terms of the stations at which they call and the markets for which they cater. These groupings are known as 'packets' of services. The adoption of the packet approach removes the reliance in the PLD Framework model upon headway to apportion preload demand. This enables preload allocations to take account of journey times, stopping patterns and individual services.

Step 3: Calculate total two-way flows for each packet on each link

This section uses transferring demand between PN and PLD as an example.

The PN model exports the demand by segment - that is, the demand on a given link for a given service - to the preload spreadsheets. The total demand on a link by user-designated 'packet' is calculated by direction in the spreadsheet. The demand is also calculated in the opposite direction for each link.

The demand by packet is exported to PLD. Within PLD, this demand is reallocated to individual segments by packet using headway of service. As the packets are defined as being a suitable match between the models, this produces a more realistic preload in the PLD.

Step 4: Convert between time periods

As PLD is an all-day model and all of the regional models are AM peak-period models, factors are required to convert between time periods, both AM peak-period to all-day and all-day to peak-period. To transform peak flows to all-day and vice versa, demand profiles from MOIRA[4] have been used to create suitably robust factors.

Factoring demand is important, as demand profiles vary considerably in the course of a day. For example, consider demand on long-distance West Coast services to and from Manchester. Long-distance demand on the WCML is heavily skewed towards London in the early morning and a corresponding return peak in the late afternoon/early evening. Demand on these services modelled in PLD is balanced in both directions, as the PLD model is an all-day model. When transferring long-distance demand on these services from PLD to the regional model (PN, in this case), demand profiles become important because in the AM peak period covered by PN, long-distance demand on services to London is much higher than on services from London.

Conversely, local demand using the same long-distance services also requires factoring when transferred from PN to PLD. AM peak flows modelled in PN (such as Stockport-Manchester or Macclesfield to Manchester) are heavily biased towards Manchester in the AM peak, but for inclusion in the all-day PLD such flows are directionally balanced and should be factored before transfer to PLD.

The factoring mechanism allows for factors converting PM, PN and PS AM peak demand (local short-distance flows) to PLD all-day demand to be disaggregated by train operating companies (TOCs). However, our analysis of local demand using MOIRA data suggests that there is little variation between TOCs. Therefore a factor of 2.67 is applied to all TOCs in the PM and PN areas, while in the PS area a factor of 3.2 was found to be more appropriate. This factor converts two-way AM peak segment flows to an all-day segment flow (thereby ensuring preloads in PLD are directionally balanced). Note that the 'segment flow' is the flow on a link for a specific service.

[4] MOIRA is the standard industry tool designed to predict how changes to the planned timetable will affect passenger demand and revenue.

The factor to convert PLD demand to regional model demand varies by the type of movement of the transit line, as there are strong tidal flows into London in the AM peak. As such, factors are provided for Non-London, To London and From London services, as shown in **Table 3.1**. These factors are used to apply directionality to the PLD to PM and PN regional model preloads. An alternative 'wormhole' approach is used in the PS area.

Table 3.1: All-Day to Peak-Period Conversion Factors

Direction	Factor
Non-London	0.22
To London	0.34
From London	0.05

Source: MOIRA demand profiles

3.5.3 Consistency between networks

Ideally, the preload methodology relies on networks for those corridors where preloads are to be applied being consistent between PLD and the regional models. For PM and PN, the PLD network has been modified to make it consistent with the regional models (see section 3.2.3).

The PS network is much more extensive in terms of coverage than the PLD network, and the node numbers between the two models do not always match. It was not considered beneficial or desirable to integrate a lot of additional network coding into PLD, as this would introduce unnecessary complexity and might adversely affect run times.

In order to allow the preload process to work, the node numbers that did not match were altered in the PS-to-PLD preload spreadsheet before the preload calculation, to ensure that the right links matched up. An additional complication occurred when, in PS, a number of stations are represented by 'exploded' nodes – for example, where the northbound services call at one node and the southbound services call at another. In general, this does not occur in PLD. This issue was addressed by modifying the link correspondence tables in the PS-to-PLD preload spreadsheet.

A worked example of the preload transfer process is included in **Appendix C**.

3.6 Additional Functionality Improvements

3.6.1 Resetting of Demand

In the PLD Framework, the 'Do Something' model run is an iterative process between assignment and demand model calculation. For each of these iterations, the assignment model is run (including station choice model) to produce cost skims for the demand model. In turn, the demand model is run to recalculate mode split, trip generation and suppression, and thus produce revised demand matrices to be reassigned.

The initial demand input to this process is the 'Do Minimum' demand. After each iteration of the assignment/demand model, the outturn demand becomes the input demand for the next iteration. In the PLD framework model, demand was incorrectly reset to the 'Do Minimum' demand at the third and sixth iteration of this process. This was caused by not running through the full demand model at these iterations. In PFM this has been addressed, so that the demand is not reset at these iterations.

Figure 3.5 and **Figure 3.6** show the impact of these changes. **Figure 3.5** shows the link demand at selected locations for each iteration of the assignment/demand model, with and without the resetting of demand.**Figure 3.6** shows the change in overall change in rail passenger kilometres between successive iterations of the demand model- assignment model loops, again with and without the resetting of demand. These outputs were derived from an intermediate test databank, used specifically to check this issue. As such, the figures are indicative, rather than pertaining to a particular scheme.

In both figures, 'Existing' refers to the PLD Framework results and 'Revised' refers to the results from the model with the removal of the demand resetting.

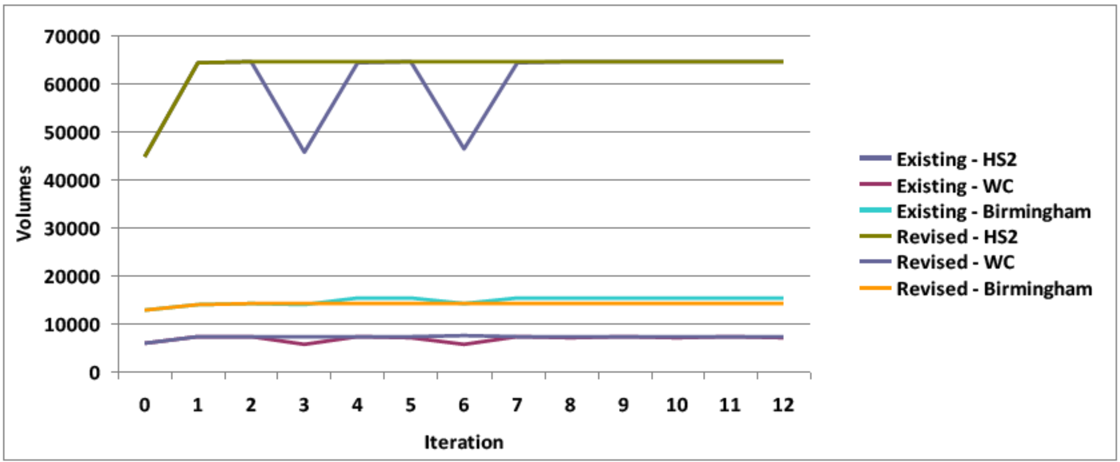
Figure 3.5 shows the demand for:

- HS2 – The HS2 link between Euston and Old Oak Common;
- Birmingham – the WCML link between Coventry and Birmingham (nearest to Birmingham New Street), as this showed the largest discrepancy between Existing and Revised runs; and
- WC – The WC link from Nuneaton to Rugby, chosen because this is consistently the most variable link in terms of rail demand at the latter stages of the model run.

Figure 3.5 shows that in the existing situation, the demand on HS2 is considerably lower in the third and sixth iterations than in all iterations (excluding the starting point). This is the exhibition of the 'resetting of demand'. It is also clear that this does not happen in the revised model.

It is worth noting that the effect is pronounced for the HS2 link. This could be expected, as this is the fundamental change between 'Do Minimum' and 'Do Something' networks – in particular, the effects of the elasticity calculations on demand. The effect is also noticeable on the WC link.

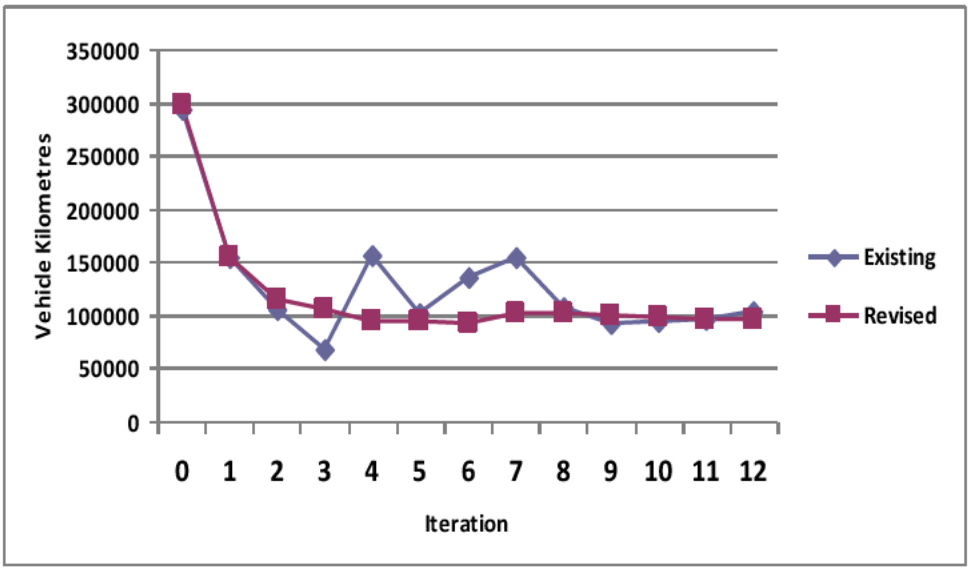
Figure 3.5: Link Flow Changes



Similarly, **Figure 3.6** shows that in the existing situation, there are significant changes in total rail kilometres between iteration of the demand assignment models. These changes start to reduce at around the 10th iteration. The resetting of demand increases the time required to achieve stable outputs from the model.

The results indicate that, with the changes implemented, both the link flow changes and changes in total rail passenger kilometres are much more stable between successive iterations. Although not ultimately affecting the final outturn results, it has an impact on the number of iterations that are required to obtain stable results.

Figure 3.6: Change in passenger km in final assignment iteration by scenario



3.6.2 Model Stability

Stability issues have been observed in earlier work on the London-West Midlands scheme. These issues were not directly related to the model architecture, having more to do with the high level of demand on the network compared to available supply. This was particularly evident in areas of the model where there was high intra-regional demand but no regional model, and hence where supply was restricted to strategic services (e.g. in the north of England and parts of Scotland).

This was addressed by adding additional local services into the PLD rail network, known as shadow services. The incorporation of PN and expansion of PM have addressed some of these issues; however, there are still areas outside the core area of interest where shadow services are required (e.g. in Scotland, around Glasgow and Edinburgh).

Stability of demand and supply are not automatically monitored in all elements of a model run, since the model architecture (as implemented at present) does not report this. Both the main PLD rail assignment and the loops between the assignment and mode choice model run for a fixed number of iterations. For each of the sub-models, individual assignment convergence statistics are produced; these statistics are also reproduced for the final PLD scenario rail assignment. A number of measures have been implemented to monitor stability and convergence of the model. These are calculated for the PFM between assignment/demand iterations at the end of a model run:

- In the PFM, the overall change in total rail passenger kilometres across the whole network (percentage and/or absolute) between the last two (or more) assignment/demand iterations is calculated.
- Modelled flows along key routes in successive model assignment/demand iterations are monitored to ensure that there are no significant differences. Changes in two-way demand at important locations on the West Coast, East Coast, Midland Main Line and High Speed Line between the last two scenarios (model, not assignment iterations) are calculated. Network-wide plots are also produced to illustrate the stability of the rail assignment. WebTAG 3.10.4 (para 1.5.3) recognises that some models use stability statistics such as maximum percentage changes in flows between iterations.

- To demonstrate that network costs converge, the change in overall generalised journey time by demand segment across the whole network (percentage and/or absolute) between the last two (or more) scenarios has been calculated.

To reduce the likelihood of instability in the model, the number of iterations in the PLD rail transit assignment has been increased from 10 to 20. Although this increases the run time, it provides greater confidence in the stability of the model.

3.7 Integration of SCM within PFM

A considerable number of changes were required in order to integrate the SCM into the existing PLD architecture, especially as the relationship between SCM and PLD is not one-directional.

The SCM requires station-to-station transit times from PLD; however, the structure of the PLD Framework means that this data cannot be readily extracted, as skims are produced on a zone-to-zone basis. Therefore, in a process similar to the PN and PM model architecture, it was necessary to split the PLD model into two databanks: a Demand databank known as 'PLD_demand' and an Assignment databank known as 'PLD_assign'.

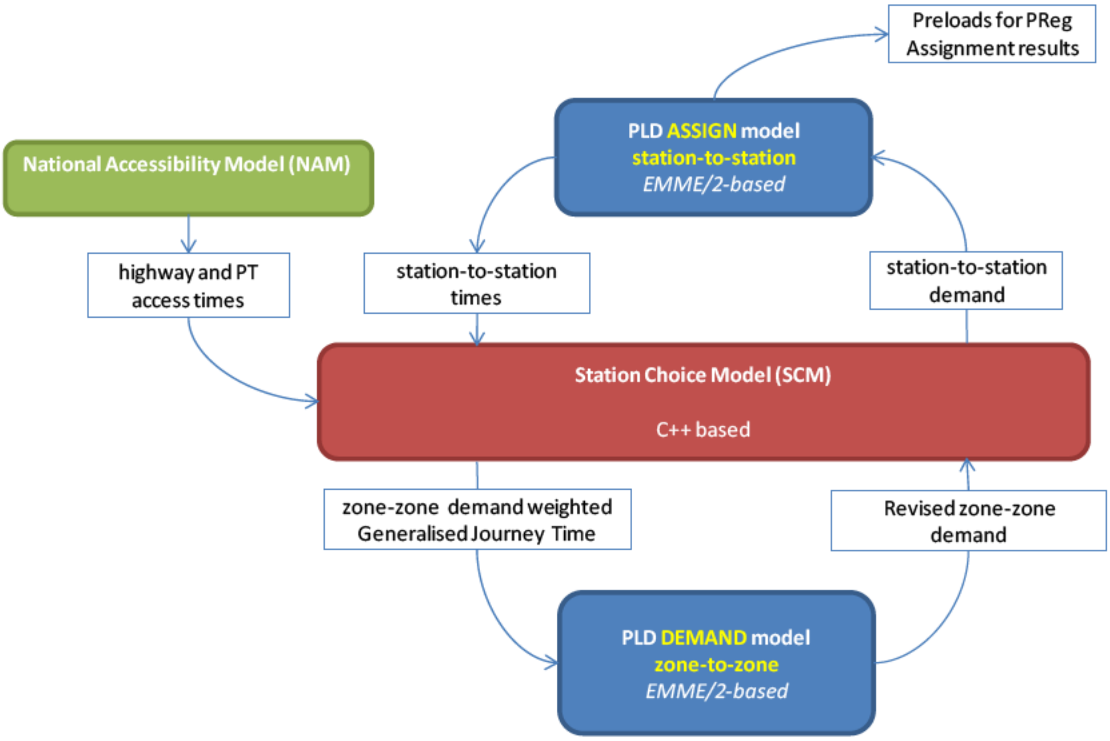
The Demand databank operates at the PLD geographical zone level and includes the air and highway assignments and the overall demand model. The Assign databank operates at the station-to-station zone level and is used for the strategic rail assignments. The Assign databank consists of the network and transit lines, with a zone system based on stations included in PLD. It operates to a dimension of 225 zones, which represent all of the original strategic stations designated within PLD, plus a set of additional dummy station zones, which can be brought into use to represent new stations. The SCM then passes data between the PLD Assign and Demand databases.

The requirements of the SCM during a model run are as follows:

- The SCM requires the station-to-station generalised cost information (in order to get this, a rail assignment must be carried out in PLD);
- The SCM requires a PLD zone-to-PLD zone demand matrix, derived from the PLD DEMAND matrix (the SCM uses NRTS data or gravity model outputs to disaggregate demand from a PLD zone-to-PLD zone demand matrix to an mzone-to-mzone demand matrix);
- The PLD Assign model requires as an input a station-to-station demand matrix for assignment, so that crowding effects correctly reflect the station choices calculated by the SCM;
- The PLD Demand model requires, as an input skim, matrices at the PLD zone level, so that the demand model can calculate changes to overall demand levels based on the more accurate access/egress costs provided by the Station Choice model, and the other full-journey costs calculated at a station-to-station level in PLD; and
- The regional models require representation of local rail access trips carried out on rail services that are not represented in PLD, but are implicitly undertaken as a local access mode within the SCM to access a strategic rail station for a long-distance rail journey. The SCM can estimate this demand should it be needed to fit into the PLANET regional model demand matrices.

Figure 3.7 provides an overview of how the EMME databanks interact with the SCM and which data is passed between the models.

Figure 3.7: Integration of Station Choice Model within PFM



In the first instance, assignments are run with a dummy demand to produce station-to-station transit times, which consist of rail in-vehicle time (excluding crowding time), auxiliary transit time, total wait times and boardings. This data is augmented by highway and PT access times taken from the National Accessibility Model (NAM). From this data, the SCM produces zone-zone weighted generalised journey time matrices, which are fed into PLD.

The demand model carries out air and highway assignments, derives generalised journey time matrices for these modes, then carries out a mode choice and trip generation calculation to produce revised rail demand matrices. These matrices are fed through the SCM in order to produce revised station-to-station demand matrices.

In turn, the station-to-station demand matrices are fed into the Assign databank, where revised rail assignment takes place. The outputs from this assignment are used to update the preload values for the Planet Regional models and for reporting purposes if no further iterations of the model are required.

Therefore, there are a series of dependencies between each model. To create a stable modelling framework, each sub-model must be run in a certain order so that the requisite data can be passed over to the other sub-models. To ensure an acceptable level of stability between the models, this process must be run a number of times.

Furthermore, the SCM is fulfilling a number of separate functions, to do with passing data between the Assign and Demand databanks (and their zone systems), as well as carrying out the Station Choice process. In order to reduce overall run times and to produce consistent final results in the assign and demand databanks, the SCM is run in one of three modes:

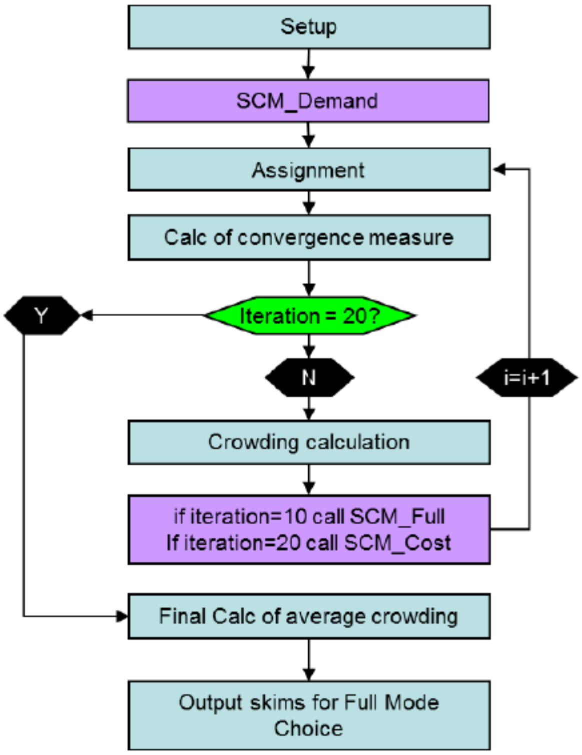
1. **Demand run (Mode 1 or SCM_Demand).** This splits a given PLD-PLD demand matrix to a Station-Station demand matrix, without recalculating the station-to-station split. Instead, it uses the previously calculated version. This should be used before the assignment when we are expecting only small changes in the full model cost elements.

2. **Cost run (Mode 2 or SCM_Cost).** This calculates a revised PLD-PLD cost matrix from the station-station cost matrix, without recalculating the change in m-zone to station shares. This should be used before a full mode choice calculation, if there are not significant changes to the station-to-station costs. This allows the cost and demand matrices to be consistent prior to a full mode choice calculation.

3. **Full model run (Mode 0 or SCM_Full)**. Incorporating Demand and cost calculations.

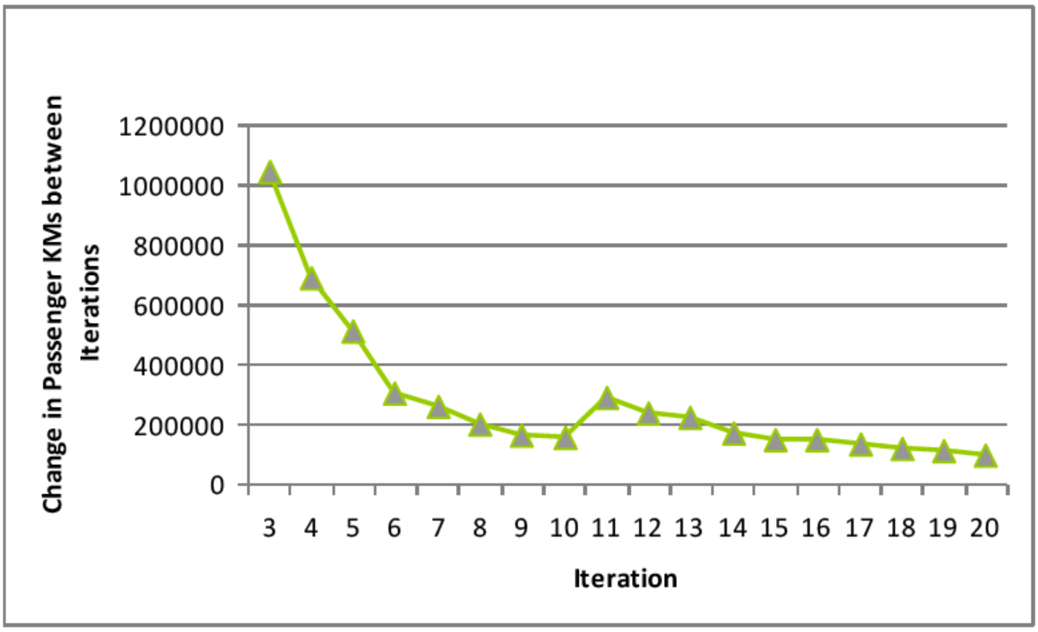
This necessitates altering the assignment process in PLD, and the resultant iteration of the rail assignment and calls to the SCM in a 'Do Something' test are shown in **Figure 3.8**. Note that, for the first iteration of the 'Do Something' model, the initial call to SCM_Demand is replaced by SCM_Full. This also applies to the 'Do Minimum' where, in addition, the calls to SCM_Demand and SCM_Cost are not deemed necessary (apart from a final call to SCM_Cost at the end of the 'Do Minimum' process, to provide final skims).

Figure 3.8: Assignment and Station Choice procedure in a test 'Do Something' run of PFM



This requires more assignment loops to achieve a satisfactory level of stability. This is because, when called in its full form, the Station Choice Model recalculates station choice and hence the demand matrix being assigned, and interrupts convergence towards equilibrium, due to the changes that it elicits. This is shown in **Figure 3.9**, which shows the change in passenger km at each assignment in PLD. This shows the change for iterations 3 to 20. The impact of the full station choice model run at iteration 10 can be clearly seen.

Figure 3.9: Integration of SCM within PFM



Therefore, when integrating the SCM, we considered it important to increase the number of assignment iterations to account for the additional variation introduced by the effect of the SCM. Furthermore, it is important to call only the SCM cost model in the last assignment iteration, so that the demand and all the component costs are as consistent as possible when being submitted to the mode choice model.

3.8 Access Leg Integration

The SCM provides the forecast of access/egress demand between mzone and station by highway/PT main mode. The PT demand includes local rail access/egress. To provide a representation of the increased level of crowding on the local models due to the access/egress journeys, the demand for local rail access/egress should ideally be fed back from the SCM to the local models.

PFM has the capability to include these access and egress trips with the modelled demand. This was done so that the long-distance passengers, not included within regional models assigned demand that use local rail for the access/egress leg of their journey, could be included in the models and contribute to crowding effects. However, this demand also contributes to the revenue calculations in the regional models, meaning that there is a degree of double counting of revenue (as these trips are accounted for, revenue-wise, within PLD). We have taken a conservative approach and not included the impact of access and egress trips because of the additional revenue impacts. The processes set up to incorporate access/egress demand are outlined below.

The SCM models the access/egress demand as an aggregate PT mode without a further sub-mode split. To isolate the rail access/egress demand from the aggregate PT demand, we hypothesised that the proportion of rail access with respect to all PT access is a function of the access distance and the station type.

NRTS data was extracted to provide the required proportions. **Table 3.2** shows the proportion of rail access from all PT access by access distance and station type (conurbation, parkway and other). As expected, the longer the access distance, the higher the proportion of rail access. There is also a higher proportion of rail access for stations in conurbations.

Table 3.2: NRTS proportion of rail access by access distance and station type

Access distance	Conurbation	Parkway	Other
<1km	0.5%	0.0%	0.1%
1-2km	1.1%	0.0%	0.1%
2-5km	9.0%	2.6%	1.1%
5-10km	26.7%	7.1%	6.5%
10-15km	66.3%	27.0%	31.6%
15-20km	81.4%	67.2%	52.6%
20-30km	92.0%	77.6%	75.2%
>=30km	93.5%	86.8%	82.6%
All distance	20.8%	13.2%	10.1%

The proportions in **Table 3.2** are used in the SCM to establish the rail access/egress demand for feedback to the local models, with the exception of those cells that are less than 1%, which are suppressed. Thus, no transfer of rail access/egress demand to the local models occurs where access distance is less than 1km for all station types, or access distance is less than 2km for parkway and other station types.

One of the outputs from the SCM are matrices, per purpose, of rail passengers that use the designated local rail station to a strategic rail station to access long-distance rail services. These ‘SCM access trips’ have the local station as an origin, and the strategic rail station as a destination. The ‘SCM egress trips’ have the strategic rail station as an origin, and the local station as a destination. Matrices are produced for PS, PM and PN, each trip appearing in only one of these regional models. These matrices are output as EMME format text input files.

4. Station Choice Model

4.1 Introduction

In isolation, PLD is not ideal for forecasting station choice. This is partly because the relatively large geographic zones are not always detailed enough to differentiate between different station locations in a given urban area, and partly because the existing rail assignment does not adequately represent the spread of station choices that are made for any given movement, often resulting in an 'all or nothing' choice. Taken in combination, these issues do not provide the requisite level of sensitivity to station choice when there is more than one realistic option. This can be particularly important when assessing the location of new stations.

To address the above issues, a station choice model (SCM) was included in the PLD Framework to represent the potential for passengers travelling between the West Midlands and London to choose between a number of origin and destination stations. It was recognised that choices of stations are inter-related. To provide access times to the stations in question, PRISM was used in the West Midlands and RAILPLAN in Greater London. However, this station choice model was limited to those geographical areas and was therefore not suitable for assessing the wider network, including the areas covered by the extensions of HS2 to Leeds and Manchester. A new, dedicated SCM has therefore been developed and included in PFM, replacing the existing model. This chapter provides an overview of how the new SCM operates.

Further details on the application of the SCM are available in Appendix D.

4.2 Overview of SCM

The SCM comprises three main components:

- Observed NRTS data was adopted for key HS2 locations and a gravity model was developed for non-key areas and where there was insufficiently robust NRTS data;
- A discrete choice model, which provides the basic model engine, and,
- A DOS-based user interface.

The SCM disaggregates the PLD zonal demand into finer geographic zones and models the choice of station/route using a logit model approach. The logit SCM is carried out outside the PLD regime, but takes inputs from PLD and feeds outputs back into PLD.

The SCM requires knowledge of the station-to-station trip costs, wait time, in-vehicle time and the number of interchanges. This information (from the PLD assignment) is combined with the access and egress costs derived from the National Accessibility Model (NAM), for each origin zone in the SCM to each potential origin station and for each destination zone in the SCM to each potential destination station. This information is provided for each feasible combination of origin and destination station pair to enable the SCM to apportion demand from origin and destination zone to an origin and destination station using a logit-based formulation.

4.2.1 Geographic coverage

The SCM considers the same geographic area as PLD, but adopts a finer zoning system for the core area of interest, broadly covering North West England, Yorkshire, West Midlands, East Midlands and Greater London.

For the core area outside London, the SCM operates at the Middle Layer Super Output Area (MSOA) level, whereas Transport for London's Railplan zoning system[5] is used for the Greater London area.

For the rest of Britain, the PLD zoning system is retained.

The above zonal disaggregation results in 3,962 zones, referred to as mzone in SCM terminology. The mzone system comprises 2,608 MSOA zones, 1,211 Railplan zones and 143 'PLD zones'. A link between the 3,962 mzones and the 235 PLD zones is maintained, such that data at mzone level can be aggregated to provide outputs at PLD zone level.

Figure 4.1 below shows the SCM's mzone coverage.

4.2.2 Journey segments

PLD's rail matrices represent origin-to-destination travel[6]. There are nine journey segments distinguishing the journey purposes and car availability:

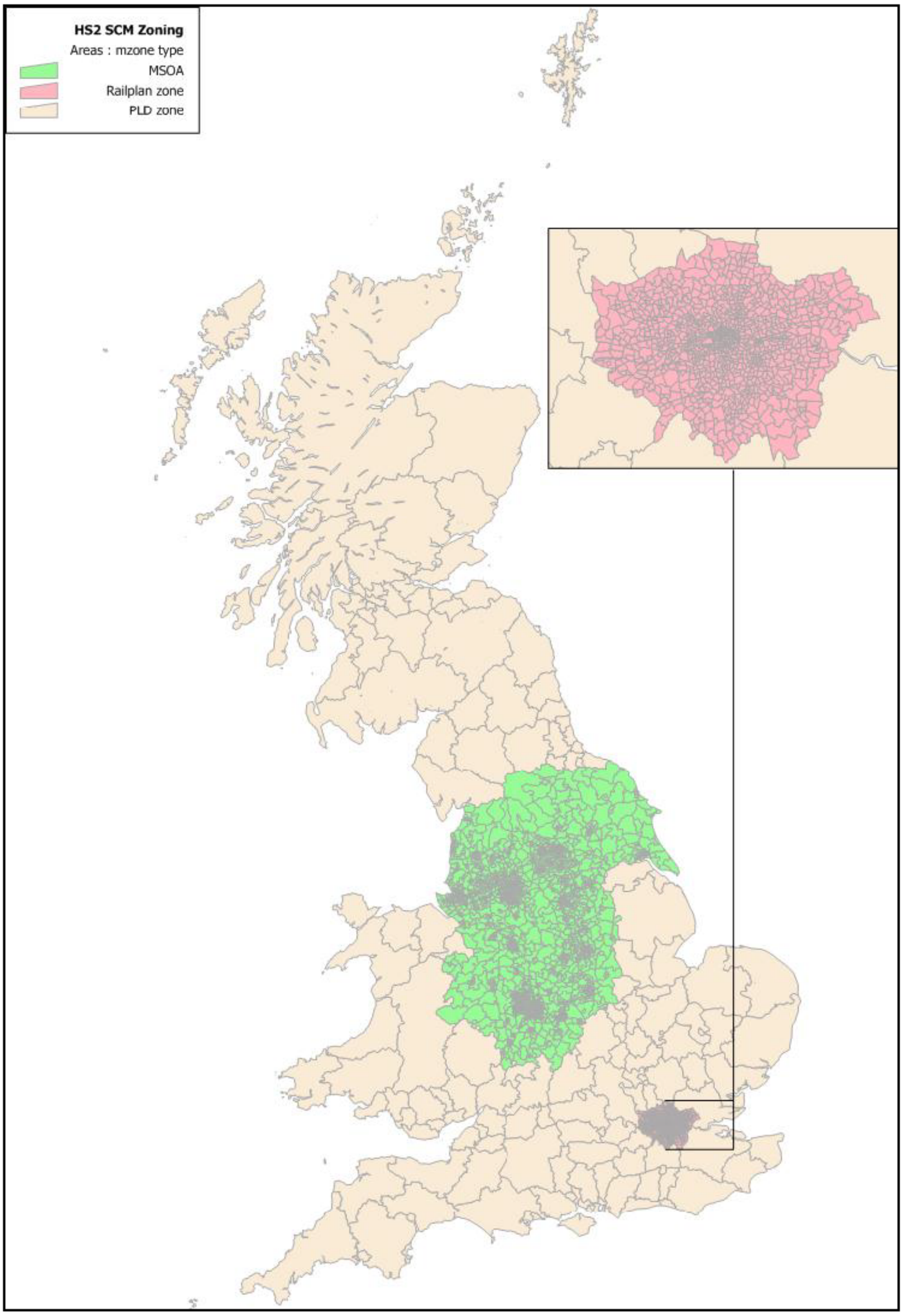
- business car available from origin (thus, origin is the production end);
- business car available to destination (thus, destination is the production end);
- business car not available;
- leisure/other car available from origin;
- leisure/other car available to destination;
- leisure/other car not available;
- commuting car available from origin;
- commuting car available to destination; and
- commuting car not available.

The SCM also considers these nine journey segments. Model estimations and application are carried out by journey segment.

[5] Railplan 4 zoning is used. It comprises a total of 1,571 geographic zones, including 1,211 zones in the GLA.

[6] The origin-destination matrices were obtained by summing the LENNON/NRTS production-attraction matrices and the transpose of these (i.e. attraction-production matrices). However, by retaining information on car availability, the key attribute (for station access) of production and attraction matrices is preserved.

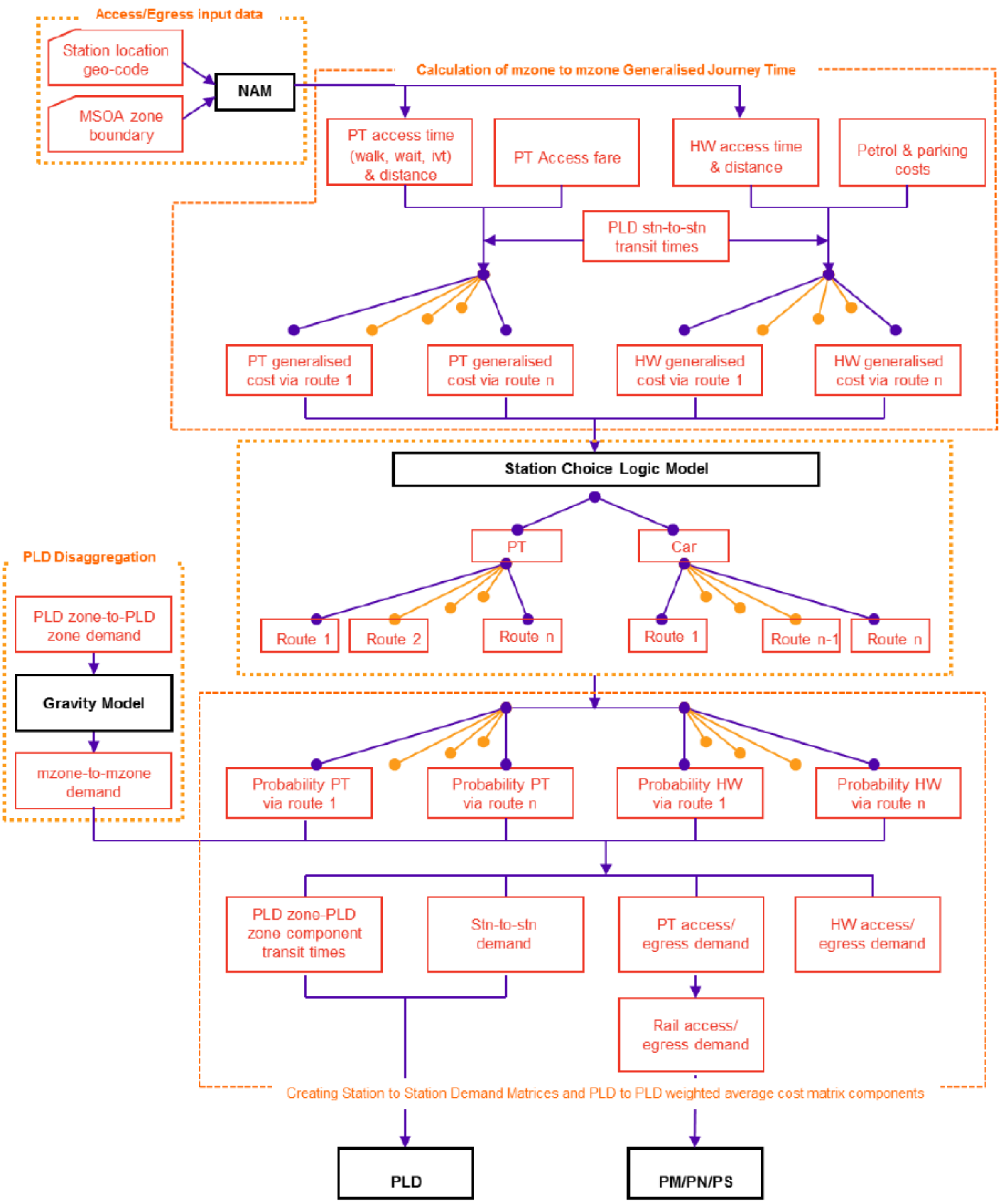
Figure 4.1: SCM zone coverage



4.2.3 Model structure

Figure 4.2 shows the SCM model structure. The model operates separately for each journey segment.

Figure 4.2: SCM model structure



The

structure of the model consists of the following components:

- Access/Egress Input data: This data is prepared from NAM and is a key input to the model.
- PLD Disaggregation: PLD zone-to-PLD zone demand is disaggregated to mzone-to-mzone demand using NRTS data for key areas of the model or a gravity model for the remaining areas.
- Calculation of mzone-to-mzone Generalised Journey Time (GJT): The model works on the basis of mzone-to-mzone movements and comparing all of the station-to-station options. To do this, the entire generalised cost (the access GJT, the mainline rail GJT component between the stations and the egress GJT) is calculated.
- Station Choice Logic Model: Using this cost information, the probability of using PT or highway as the access or egress mode is calculated. (Highway is only available at one end of the journey for car available purposes). The probability of using each station-to-station movement is then calculated separately for PT and highway.
- Calculating station-to-station demand and PLD-to-PLD weighted average cost components: The final step of the process is to apply the probabilities calculated in the station choice logic model to produce station-to-station demand matrices. As PLD zone-to-PLD zone cost components are required for the PLD demand model, the station-to-station costs are averaged using the demand to produce PLD zone-to-PLD zone weighted components. The sum of the PLD zone-to-PLD zone cost components is equal to the composite cost.

4.3 Calibration of the SCM

The logit model behind the SCM is the engine used to allocate trips probabilistically across the available station, route and access mode options. The logit model is based on random utility theory. This asserts that when faced with a choice of competing travel alternatives, an individual will choose that option which yields the greatest utility (see, for example, Koppelman and Baht 2006[7]). Here, utility is taken to be determined by the generalised journey time for the whole journey and the attractiveness of the option.

Model estimations were carried out using the statistical estimation software Biogeme v1.88.

4.3.1 Model assumptions

The SCM logit model makes the following assumptions:

- Access at the London end is calculated assuming PT costs, and London end trips are assigned to the PT access mode. This is a simplifying assumption and essentially means that highway and PT access costs are assumed to be the same;
- Highway or taxi access trips are not excluded, but would need to be calculated outside the model using suitable assumptions;
- The highway option is unavailable to the 'car not available' segments - this is supported by estimation results of the access mode choice model described in section 4.3.3;
- There will be no trip generation or suppression as a result of introducing new options, except insofar as doing so influences the overall cost of long-distance travel;
- Access/egress PT fares are distance-based, with an additional fixed fare component; the fixed fare and the fare per unit distance are inputs for the model;

[7] Bhat, C.R., Govindarajan, A. and Pulugurta, V., 1998. Disaggregate attraction-end choice modeling: formulation and empirical analysis. *Transportation Research Record,* 1645, 60–68.

[8] http://transp-or.epfl.ch/page63023.html (Bierlaire, 2003).

- petrol costs are also distance-based, with the petrol cost per unit distance as an input for the model; and
- parking cost will be an input for the station, taken from indicative one-day parking.

4.3.2 Calibration Data

National Rail Travel Survey (NRTS) data was used for model estimations. NRTS is an on-mode paper-based survey designed to obtain the pattern of rail passenger travel. Raw survey data has been expanded to match station counts.

NRTS data for long-distance rail journeys (>50 miles) provided the "observed" data (i.e. the revealed preference) for model estimations. A subset of this data where there is a choice of station/route to use from a particular zone, travelling to/from London, was used.

Access/egress costs were obtained from the National Accessibility Model (NAM). NAM is the model used by the Department for Transport (DfT) to calculate travel times to essential services (the Core Accessibility Indicators[9]). The same modelling approach was adopted to obtain access times between MSOA zones and stations for HS2 station choice modelling outside London. The routing algorithm allows a maximum highway distance of 200 km and a maximum public transport access time of 120 minutes.

NAM used the public transport network and service pattern from the National Public Transport Data Repository (NPTDR[10], 31 October 2009) database of transport services, and the highway network from Ordnance Survey Integrated Transport Network (ITN). To better reflect highway travel times, Trafficmaster ITN link speed data provided by the DfT was used for modelling the highway access times.
The outputs from NAM were:

- highway access time (in minutes);
- public transport access time - walk time (in minutes);
- public transport access time - wait time (in minutes);
- public transport access time - in-vehicle time (in minutes); and
- access distance (in metres).

Output data from NAM is deficient in the following areas:

- DfT's Trafficmaster data included the whole of England and only a small part of Wales and Scotland. Typical link speeds by road type were used for access journey time calculations for areas where Trafficmaster data was unavailable (Motorways 100kph, A roads 70kph, B roads 60kph and minor roads 50kph).
- public transport timetable data for Scotland was not as comprehensive as the English equivalent; thus, lower accuracy was expected of the public transport access times for Scotland.
- current travel times were used in the NAM modelling (although manual adjustments can be made to reflect future year networks).

We made the following modifications to the National Accessibility Model (NAM) data:

- to avoid very short highway times (20 seconds is in the NAM data for one flow), we added 10 minutes to all highway times; this reflects getting into car, parking and getting to station;

[9] http://www.dft.gov.uk/pgr/statistics/datatablespublications/ltp/
[10] http://www.nptdr.org.uk/

- For distances of up to 1km, the walking option is assumed instead of public transport. The walk times came from NAM data and are based on a walk speed of 4.8km/h;
- For trips longer than 1km, we have created a boarding penalty for public transport access that varies according to distance, starting from 5 minutes and increasing up to 30 minutes. This highest penalty is equivalent to the boarding penalty in the assignment part of the PLD model and is applied for trips over 30km. For trips of less than 30km, the boarding penalty is calculated by linear interpretation. The boarding penalty is added to the public transport in-vehicle times;
- 10 minutes have been added to PT wait time to allow for the initial wait time that has not been included in the NAM dataset;
- We have checked the access times from high NRTS demand zones to stations of interest with Transport Direct, the national journey-planning website, to ensure that they are sensible; where required, manual adjustments have been made. The stations for which we adjusted Public Transport (PT) access times include Manchester Piccadilly, Manchester Airport, Warrington Bank Quay, Runcorn, Wigan North Western, Stockport, Macclesfield, Sheffield, Meadowhall, Nottingham, Derby, York and Leeds;
- To balance station choice and mode choice, an adjustment was made on the car access costs in key areas of interest, such as Manchester, Liverpool, Sheffield and the East Midlands. Introducing different Alternative Specific Constants (ASCs) for different types of station and different purposes would be the recommended way of addressing the issue. However, due to time constraints and the additional run times that this would incur, it was deemed appropriate to adjust the highway access times to the stations affected based on the relationship between demand and access costs: this has an identical effect on demand as adjusting ASCs.
- In addition, we adjusted the journey times for the PLD zones in the East Midlands to take account of the introduction of a Red Arrow bus service between Derby and Nottingham and the commitment to an extension of the NET services in Nottingham. We calculated the expected journey times for the new services and compared them to the NAM data. We then used the lowest value of the two in the data file. We looked at all of the zones with NET or Red Arrow stops, together with the neighbouring zones. We included walk time as well as the expected in-vehicle times to calculate the journey time using the Red Arrow and additional NET services.

In London, Transport for London's public transport model, Railplan, was used to provide generalised cost of access between Railplan model zones and stations. Railplan adopts the following weighting factors for components of access times:

- walk time: 2.0
- wait time: 2.5
- in-vehicle time: 1.0

Following an exercise to recalibrate the model with adjusted NAM data we found that the following weights gave a better fit, and therefore use these in the model:

- walk time: 1.0
- wait time: 2.0
- PT in-vehicle time: 1.0
- HW in-vehicle time: 2.0

4.3.3 Model estimations

Model estimation for the London end was carried out separately (as it was expected that travel behaviour in London would be notably different from the rest of Britain). The results of the London estimations are reported below. The following paragraphs focus on the model estimations for non-London access/egress.

Non-London access/egress

Two model formulations were considered:

- a two-step estimation involving an access/egress mode choice model and a separate station/route choice model, with an implicit nested logit assumption of station/route choice above the mode choice; and
- a simultaneous nested logit model with mode choice in the upper nest and station/route choice in the lower nest.

The results of the first formulation suggested that the scaling parameter for the mode choice model was lower than the scaling parameter for the station/route choice model. This implies that station/route choice exhibits a greater sensitivity to changes in utility than access mode choice. Therefore, the model formulation in the second bullet is the preferred model structure.

The model estimation for access mode choice also suggested that, for the 'car not available' segment, the access time parameter was close to zero for car with a significant negative highway modal constant - meaning that, for the 'car not available' segment, access is all PT. 'Taxi' was assigned to PT in the NRTS data.

We then proceeded with the second model formulation, with mode choice in the upper nest and station/route choice in the lower nest. As we used only long-distance rail journey to/from London from NRTS for the calibration, there is no need to include access/egress in London as part of the estimation - it is the essentially same for all choices; the utility functions for a particular route i, by highway and by PT, were established as follows:

$U_{hw,route\ i} = \beta \times (GJT_{hw,access/egress(non\text{-}London)} + GJT_{rail,route\ i}) + \alpha_{conurbation} \times Dummy_{conurbation} + \alpha_{parkway} \times Dummy_{parkway} + \alpha_{other} \times Dummy_{other}$

$U_{pt,route\ i} = \beta \times (GJT_{pt,access/egress(non\text{-}London)} + GJT_{rail,route\ i})$

where

$GJT_{hw,access/egress(non\text{-}London)}$ is the GJT of access/egress by highway for the non-London end (in minutes)

$GJT_{pt,access/egress(non\text{-}London)}$ is the GJT of access/egress by PT for the non-London end (in minutes)

$GJT_{rail,route\ i}$ is the GJT of the long-distance rail journey (in minutes)

$Dummy_{conurbation}$ is a dummy variable indicating whether the origin/destination station at the non-London end is a conurbation-type station (1 if true; 0 otherwise)

$Dummy_{parkway}$ is a dummy variable indicating whether the origin/destination station at the non-London end is a parkway-type station (1 if true; 0 otherwise)

$Dummy_{other}$ is a dummy variable indicating whether the origin/destination station at the non-London end is neither a conurbation-type station nor a parkway-type station (1 if true; 0 otherwise)

β is the scale parameter for the SCM (i.e. model coefficient associated with the GJT)

$\alpha_{conurbation}$ is the highway modal constant for a conurbation-type station

$\alpha_{parkway}$ is the highway modal constant for a parkway-type station

α_{other} is the highway modal constant for other station types

It was expected and confirmed that different types of station corresponded to very different propensities to use car access. We considered three types of station: centre of conurbation, parkway and other (which made up the majority).

Model estimations were undertaken by journey purpose. The results are summarised in Tables 4.1 to 4.3 below for those segments with car available. (By definition, this relates only to the production end of the trip.)

The GJTs for highway and PT are calculated as the composite costs of travelling by each of the different routes (station pairs). This is calculated as:

$$\frac{1}{\mu}\ln\left(\sum_{i}\exp\left(\mu\, GJT_{routei}\right)\right)$$

The spread parameter μ (in minutes) is defined as θ*β where θ is the next parameter estimated - see below.

Table 4.1: SCM nested logit model - business journeys

Name	Value	Std err	t-test	p-value
Scale parameter (β)	-0.0336	0.002	-15.85	≈ 0
hw modal constant - conurbation (αconurbation)	1.1	0.082	13.40	≈ 0
hw modal constant - parkway (αparkway)	2.34	0.145	16.13	≈ 0
hw modal constant - other (αother)	1.49	0.048	30.91	≈ 0
Nesting parameter (□)	1.67	0.111	14.94	≈ 0
Null Log-Likelihood	-10873			
Final Log-Likelihood	-6856			
Adjusted rho-square	0.369			

Table 4.2: SCM nested logit model - leisure journeys

Name	Value	Std err	t-test	p-value
Scale parameter (β)	-0.0209	0.002	-8.55	≈ 0
hw modal constant - conurbation (αconurbation)	1.04	0.191	5.48	≈ 0
hw modal constant - parkway (αparkway)	2.39	0.262	9.13	≈ 0
hw modal constant - other (αother)	1.70	0.149	11.41	≈ 0
Nesting parameter (□)	2.39	0.296	8.07	≈ 0
Null Log-Likelihood	-4151			
Final Log-Likelihood	-2760			
Adjusted rho-square	0.334			

Table 4.3: SCM nested logit model - commuting journeys

Name	Value	Std err	t-test	p-value
Scale parameter (β)	-0.0441	0.003	-14.94	≈ 0
hw modal constant - conurbation (αconurbation)	3.61	0.349	10.33	≈ 0
hw modal constant - parkway (αparkway)	4.38	0.252	17.40	≈ 0
hw modal constant - other (αother)	3.70	0.202	18.29	≈ 0
Nesting parameter (□)	1.44	0.114	12.64	≈ 0
Null Log-Likelihood	-5131			
Final Log-Likelihood	-3064			
Adjusted rho-square	0.402			

Overall, the models provide a good fit to the data (rho-square greater than 0.3 for all three purposes, which is good for discrete choice modelling) with coefficients that have intuitively correct signs and which are statistically significant. The nesting parameters which are all significantly greater than 1.0 conform to economic theory required for the nested logit structure.

We also see a clear pattern that highway access/egress is the most preferred for parkway-type stations, and is least preferred for stations in conurbations (with the exception of commuting trips where conurbation and other stations have comparable highway modal constants). This indicates a need for accurate definitions of the station types, as this can have a large impact on the level of car usage for access and the choices of stations that 'car available' passengers will have.

The effective scale parameter at the bottom nest, which is the product of the estimated scale parameter and the nesting parameter, is approximately -0.06 for all three purposes. The comparability of the effective scale parameters estimated independently by journey purpose gives credibility to the estimation results.

The 'no car available' segment only uses the PT Model following the finding that people without a car were using PT.

London access/egress

As mentioned above, model estimation for the London end was carried out separately using observed demand data of movement to/from London where station choice exists at the London end. Unfortunately, there are no inter-city flows where there is a choice of station that is not also significantly affected by the train service or fare; we therefore had to use South East flows. The following three key movements were considered:

- London to/from East Croydon/Brighton (choice of London Bridge, Victoria, etc.);
- London to/from south-west London (choice of Waterloo or Vauxhall); and
- London to/from the south-east (choice of Charing Cross, Cannon Street, etc.)

It is worth noting that these are relatively short-distance journeys. This means that the estimated parameter for the rail in-vehicle time component may not be directly applicable for long-distance rail journeys modelled in SCM. We consider the best estimates of the time coefficient associated with the long-distance rail GJT were those reported above (see Tables 4.1 to 4.3).

Railplan data provided by Transport for London was used for model estimations. The Railplan dataset provides the generalised access times between Railplan model zone and selected station locations.

NRTS demand for the three key movements identified above was used. For example, for a respondent reporting a journey from Waterloo to Wimbledon, the utilities associated with the two station alternatives would be:

$$U_{Waterloo} = \alpha \times Access_{Waterloo} + \beta \times IVT_{Waterloo-Wimbledon}$$

$$U_{Vauxhall} = \alpha \times Access_{Vauxhall} + \beta \times IVT_{Vauxhall-Wimbledon}$$

where α is the parameter associated with the access times, and β is the parameter associated with rail IVT, which is not transferred to the station choice model due to the characteristics of the short-distance rail journeys used in the calibration.

Model estimations were carried out by journey purpose (Business, Leisure and Commuting) and also for all purposes combined. The estimations produced access time parameters ranging between -0.13 to -0.17, depending on journey purpose. For all purposes combined, the parameter was estimated at -0.157. The estimated value by journey purpose, taking into account +/- two standard errors, did not appear to be significantly different from the overall value of -0.157. Thus, for the London end, a scale parameter of -0.157 was used in the SCM for all purposes (see Table 4.4).

Table 4.4: SCM logit model for the London end - All purposes

Parameter	Value	Std err	t-test	p-value
α (Access)	-0.157	0.006	-27.89	≈ 0
β (rail in-vehicle time)	-0.0287	0.00878	-3.26	≈ 0
Null Log-Likelihood	-174555			
Final Log-Likelihood	-105648			
Adjusted rho-square	0.395			

Although we used trips to and from London to calibrate how passengers choose the non-London station that they travel to/from, we use the model parameters for station choice outside of London for all long-distance trips, whether these were to/from London or to/from other places.

4.3.4 Rail access/egress trips to local models

The SCM provides the forecast of access/egress demand between mzone and station by highway/PT main mode. The PT demand includes local rail access/egress. To provide a representation of the increased level of crowding on the local models due to the access/egress journeys, the demand for local rail access/egress can be fed back from the SCM to the local models.

The SCM models the access/egress demand as an aggregate PT mode without a further sub-mode split. To isolate the rail access/egress demand from the aggregate PT demand, we hypothesised that the proportion of rail access with respect to all PT access is a function of the access distance and the station type.

NRTS data was extracted to provide the required proportions. Table 4.5 shows the proportion of rail access from all PT access by access distance and station type (conurbation, parkway and other). As expected, the longer the access distance, the higher the proportion of rail access. There is also a higher proportion of rail access for stations in conurbations.

Table 4.5: NRTS proportion of rail access by access distance and station type

Access distance	Conurbation	Parkway	Other
<1km	0.5%	0.0%	0.1%
1-2km	1.1%	0.0%	0.1%
2-5km	9.0%	2.6%	1.1%
5-10km	26.7%	7.1%	6.5%
10-15km	66.3%	27.0%	31.6%
15-20km	81.4%	67.2%	52.6%
20-30km	92.0%	77.6%	75.2%
>=30km	93.5%	86.8%	82.6%
All distance	20.8%	13.2%	10.1%

The proportions in Table 4.5 are used in the SCM to establish the rail access/egress demand for feedback to the local models, with the exception of those cells that are less than 1%, which are suppressed. Thus, no transfer of rail access/egress demand to the local models occurs where access distance is less than 1km for all station types or access distance is less than 2km for parkway and other station types.

4.3.5 Calibration of Gravity Model

For key HS2 locations, the distribution of productions and attractions was based on observed long-distance (over 50km) trips, by purpose, in NRTS. A gravity model was used to fill in places that are not key HS2 locations or where NRTS data was not considered robust enough.

The gravity model is used to distribute PLD zonal demand into MSOA zone level for the core area of the HS2 SCM outside London. The SCM operates at the MSOA level for the core area, with the exception of London where Railplan zone is used, whilst the non-core area is kept at the 'PLD zone' level.

The gravity model was calibrated separately for the production and the attraction end, using NRTS data for long-distance travel. For **production end**, the gravity model has been estimated so that the demand for a given MSOA zone is dependent on the population, income or number of high-level managerial jobs, access time and the presence of competing stations. The following model was estimated:

$$V_{zi} = K_x P_z Y_z^{\beta_Y} T_{zi}^{\beta_T} S_{zi} W_z^{\beta_W}$$

Where:

i relates to a station
z relates to an MSOA
x relates to a PLD zone
P = population at MSOA from Office of National Statistics (ONS) mid-year estimates
Y = income at MSOA from ONS model-based income estimates
T = access time from NAM
W =number of high-level managerial jobs from ONS 2001 census data
Ks = constants specific to each PLD zone
S_{zi} is the share of demand from MSOA zone z using station i

β_Y is elasticity with respect to income
β_T is elasticity with respect to access time
β_W is elasticity with respect to high-level managerial jobs

Model calibration was undertaken using R. We estimated the parameters for production separately for each purpose. For commuting, business and home-based leisure, we found that income and access time gave the best fit in estimating the distribution of trips. For non-home leisure, we found that the best model consisted of the number of high-level managerial jobs and access time. The estimation results are provided in Table 4.6.

Table 4.6: Gravity model estimates - production end

	Estimate	Std. Error	t value
Business			
βY (income)	1.651	0.04729	34.9
βT (access time)	-1.831	0.03054	-60.0
Leisure – home based			
βY (income)	1.489	0.05283	28.2
βT (access time)	-1.578	0.03062	-51.5
Leisure - non-home based			
BW (high-level managerial jobs)	0.9276	0.008959	103.5
βT (access time)	-0.7694	0.02375	-32.4
Commuting			
βY (income)	-2.023	0.03107	-65.1
βT (access time)	1.489	0.05283	28.2

The model estimates are of the expected sign and magnitude. They are statistically significant at the 95% level (t-stats well above 2.0).

We used the proportion of non-home-based leisure trips and home-based leisure trips from NRTS data to create an average distribution of trips for leisure passengers.

For the **attraction end**, a separate gravity model was calibrated, assuming demand for a given MSOA zone is dependent on the high-level managerial jobs, access time and the presence of competing stations. The following model was estimated in R:

$$V_{zi} = K_x W_z^{\beta_W} T_{zi}^{\beta_T} S_{zi}$$

Where:

i relates to a station
z relates to an MSOA
x relates to a PLD zone
W = high-level managerial jobs at MSOA from 2001 Census
T = access time from NAM

Ks = constants specific to each PLD zone
S_{zi} is the share of demand from MSOA zone z using station i
β_w is elasticity with respect to workplace population
β_T is elasticity with respect to access time

Calibration was carried out by journey purpose. Table 4.7 show the model estimates for business, leisure and commuting respectively.

Table 4.7: Gravity model estimates - attraction end

	Estimate	Std. Error	t value
Business			
βW (high-level managerial jobs)	1.744	0.02467	70.7
βT (access time)	-0.3389	0.03815	-8.9
Leisure			
βW (high-level managerial jobs)	0.6799	0.008585	79.2
βT (access time)	-1.197	0.03134	-38.2
Commuting			
βW (high-level managerial jobs)	0.9726	0.009739	99.9
βT (access time)	-2.167	0.04013	-54.0

All estimates are of the expected sign. It seems reasonable that the ordering of the elasticities to managerial jobs, from the most sensitive to the least sensitive, is business, commuting and then leisure, as we would expect the most business trips to be made by those in high-level managerial jobs.

A wide range of other formulations were tested, including resident population and retail floorspace for leisure attraction, commercial/industrial floorspace for business/commuting, and a logit-based model instead of the above gravity model approach. These did not produce as robust parameter estimates as the above and in some cases did not converge.

As noted previously, the gravity model has been applied only to places that are not key HS2 locations. For key HS2 locations, the distribution of productions and attractions was based on observed long-distance (over 50km) trips, by purpose, in NRTS. The PLD zones where NRTS data was used are Birmingham, Leicester, Derby, Nottingham, Sheffield, Leeds, Macclesfield, Stockport, Manchester and Warrington.

The gravity model is applied once for the non-key PLD zones to obtain the distribution factors to obtain MSOA level demand (as a proportion of the PLD zone it is in), for the SCM, for each purpose separately for origin and destination end trips. These distribution factors are then retained as static inputs to the SCM.

The gravity model is not used for the London end - Railplan demand matrices are used to apportion the PLD zonal demand for the London zones (including Heathrow and Hillingdon) to the corresponding Railplan zones.

4.4 Structure of the SCM

4.4.1 Model Inputs

Public transport and highway access times and distances between mzone and stations are obtained from the National Accessibility Model (NAM). NAM is run once to provide the required access times/distances inputs. The outputs from NAM are used as a set of static inputs to the SCM.

Various input assumptions are made about PT fares and petrol and parking costs for highway access. Together with the access times/distances from NAM, generalised cost of access/egress between mzones and stations are calculated. The user needs to decide which stations are available to which PLD zone (and consequently which mzone). A maximum of 15 stations can be defined for each PLD zone. Advice on setting up these 'catchment areas' is given below.

PLD provides the station-to-station transit times. These include rail in-vehicle time, rail auxiliary transit time, total wait times and the total number of boards. Other rail time components between individual station pairs are also read into the SCM for calculating the demand-weighted PLD zone-to-PLD zone equivalents which are required for PLD's mode choice model. These PLD transit time matrices change for each PLD run and are thus considered as "dynamic" inputs to the SCM. When the SCM is first run as part of the PLD model run, a set of cost matrices are used which have been produced by an assignment of a station-to-station unit demand matrix.

4.4.2 SCM Stations and Catchment Areas

Potential station options for each 'PLD zone' are defined as an input to the SCM. This definition feeds through to give the list of stations available to each mzone.

The station choice model catchment areas have an important role in determining the demand using each station. There is a potential overlap for PT access which, for any mzone, could be included in the catchment area of a station of interest or be required to access a closer PLD station to make the rest of the access journey within the PLD model.

It is difficult to set rules for the definition of catchment areas and some level of judgement is required; however, the following principles were followed. In key areas, particularly where HS2 are considering several different station locations, catchment areas were examined individually to best match the observed behaviour using NRTS/MOIRA, or discussions with local stakeholders.

4.4.3 Active Stations in London

The concept of 'active' stations dates back to the development of the original PSM model. In developing the strategic network model, it was not feasible or desirable (given the network coverage) to include all railway stations in the model. Therefore, the following criteria were used to select stations for inclusion in the model:

- all principal stops on north/south medium-distance and long-distance services; and
- In all other parts of the network, ensure that there is generally one strategic station to one strategic zone

This resulted in approximately 200 active stations. With the move to having a national dedicated SCM, the 'one zone, one station' relationship is no longer needed, so some amendments have been made possible (without the need to alter the 235 zones). As a result, some new stations have been added (e.g. East Midlands Parkway) and some detail has been removed where it is not necessary. Initial versions of the SCM included a large number of active stations in London. To improve performance of the logit model for the relevant choice set for long-distance rail travel towards the Midlands and North of England, this was restricted to the 'north-facing' termini, as these are the most relevant to the 'station choice' of HS2 and alternative rail services. The London stations active in the SCM are:

- Euston;
- King's Cross;
- St Pancras;
- Marylebone;
- Heathrow;
- Old Oak Common; and
- Paddington.

4.4.4 Highway Access

Highway access is assumed to cover the area up to 60 minutes away from the station, except where there is a larger station within that catchment area – for example, Wigan and Warrington should not include the area beyond Preston. This exception was made to prevent passengers from driving past a main station offering similar services within the station choice model. It is recognised that this is a necessary simplifying assumption and there will be certain locations where trips would in fact drive by if the further station had better accessibility.

New HS2 stations should be set up using these same principles. Consideration needs to be given to the dominance of a station in connection with the other HS2 stations in the area.

4.4.5 Public Transport Access

Public transport catchment areas should be much smaller than those for highway. In principle, passengers should only be allowed to access the rail network via their local station.

The classic rail network in PLD is best placed to determine the PT access if rail is involved. Where there is a local station within the PLD model, this should form the focus for PT trips.

The PT catchment area in the SCM is generally only used for classic rail where the local station is not in PLD or where there is light rail or bus access.

It is possible for PT access to be available from selected mzones (not necessarily all) within the PLD zone.

Every mzone must have at least one PLD station to which PT access is permitted.

4.4.6 Calculation of Generalised Journey Times

The SCM calculates the whole-journey GJTs between mzone pairs for each available route (i.e. origin station to destination station) option. Table 4.8 illustrates how the whole-journey GJTs are obtained for different car availability segments for a particular route (i.e. individual station pair).

Table 4.8: Calculation of whole-journey GJT by journey segment

Journey segment	Option	Access cost		Rail transit cost	Egress cost	
		pt	hw		pt	Hw
car available from origin	Pt	√		√	√	
car available from origin	Hw		√	√	√	
car available to destination	Pt	√		√	√	
car available to destination	Hw	√		√		√
car not available	Pt	√		√	√	
car not available	Hw					n/a

4.4.7 Station Choice Logit Model

The SCM is a nested logit model with station/route choice below the car/pt mode choice nests. This nested logit form allows for the fact that some travel alternatives are more closely related than others, with travel choices at the bottom of the hierarchy exhibiting a greater sensitivity to changes in utility than those at the top.

The SCM calculates, for each origin and destination mzone pair, the probabilities of travel via a specific route by highway and PT access/egress separately. We thus obtain the overall station choice probabilities.

These choice probabilities are applied to the demand matrices to obtain the station-to-station demand.

4.4.8 PLD Disaggregation

PLD provides the PLD zone-to-PLD zone demand to the SCM. Within the SCM regime, the PLD zonal demand is disaggregated to the mzone level to give mzone-to-mzone demand matrices. Whilst the PLD zonal demand is dynamic (i.e. it may vary between PLD runs), the disaggregation factors are static to the SCM, obtained using observed NRTS data for key HS2 locations and a gravity model approach for non-key locations as described in Section 4.3.5. This process outputs station-to-station demand matrices.

4.4.9 Composite cost vs. average cost & minimum cost

A point worthy of consideration is the computation of an 'average' GJT across the available choice sets (including mode and station/route options) for each mzone-to-mzone pair. Gerard Whelan's review of the Station Choice Model for London to Birmingham noted that:

- an arithmetic average is the simplest method, but can sometimes lead to counter-intuitive results in which the introduction of a new station can lead to an increase in the overall access time;
- the logsum is the most appropriate measure of economic benefit when using a demand model belonging to the Generalised Extreme Value (GEV) class of models. Its specification guarantees that the addition of a new alternative to a choice set, no matter how inferior, will generate a positive benefit to the decision-maker; and
- the minimum generalised time ignores the fact that demand is likely to be distributed across choice alternatives and instead assumes that everyone chooses the option with the lowest generalised time.

Given that the current SCM follows a nested logit structure, the logsum approach is the most appropriate way to compute the composite generalised journey times on theoretical grounds.

The aggregation of whole-journey GJT from mzone level to PLD zone level is a simple, demand-weighted average function, as we are summing the choices made by different groups of individuals.

4.5 Summary

The objective of the SCM is to forecast the demand for high speed services at different locations. The SCM disaggregates the PLD zonal demand into finer geographic zones and models the choice of station/route, including access mode, using a logit model approach. The SCM operates in conjunction with the PLANET Long Distance Model (PLD).

The discrete choice SCM adopts a nested logit model structure, with mode choice in the upper nest and station/route choice in the lower nest. The SCM is estimated to data from National Rail Travel Survey (NRTS), with access times and distance obtained from the National Accessibility Model (NAM).

The logit model shows a good fit to the data, has statistically significant coefficients with correct signs and plausible magnitudes, incorporates taste variation by journey purpose and has a sensible nesting structure to account for correlations between choice alternatives.

The logit model is combined with a combination of observed NRTS data for key HS2 locations and the outputs from gravity models for non-key HS2 locations, estimated using NRTS data by productions and attractions. The gravity models are used to allocate PLD zonal demand to constituent SCM mzones.

The logit model and gravity model applications are incorporated in a DOS-based application tool and used to provide aggregate forecasts of market shares for alternative station/route options and access/egress mode splits.

5. Supply Updates

5.1 Overview

In general, demand and supply included in the PFM is consistent with that included in the January 2012 version of the PLD Framework. There have been a small number of further updates to supply and demand; these are outlined in this section. In addition, the demand for PM and PN in PFM v2 was generated in a different way to that included in PFM v3, as there was not an appropriate donor model available at the time. This is briefly outlined in this section.

5.2 HS2 Service Specification

The HS2 service specification for the London-West Midlands scheme has previously gone through a process of refinement, and the specification included in the PFM model remains as that included in the January 2012 Economic Report.

The service specification for the extension to Leeds and Manchester has undergone refinement as part of work looking at the extensions to Leeds and Manchester. This includes service patterns, station locations and service stopping patterns. Further details of the refinement of the HS2 service specification are included in the Demand and Appraisal report. The final HS2 specification for the extensions is included in Error! Reference source not found..

5.3 Released Capacity Specification

The released capacity specification included in the assessment of the HS2 proposals between London and the West Midlands issued in January 2012 provided one view of a possible use of the capacity freed up by HS2. Released capacity changes were focused on the West Coast and London Midlands corridors between London and the West Midlands. However, this specification was designed on the basis of assumptions about future service patterns that were consistent with modelling undertaken in February 2011.

For the extensions to Leeds and Manchester, no additional assessment of released capacity was undertaken, and the released capacity assumptions included were identical to the London-West Midlands proposals. This means that there was no released capacity on other corridors (e.g. the East Coast Main Line (ECML) between London and Scotland and the Midland Main Line (MML) between London and Sheffield). In addition, released capacity on the West Coast Main Line (WCML) was restricted to changes between London and the West Midlands, with no further changes north of Birmingham.

The PFM version of the model has been used to refine the released capacity specification for the extensions to Leeds and Manchester. This work has indicated several opportunities to improve the service specification modelled, offering further benefits and improving connectivity between different locations, particularly for shorter distance trips.

For the London-West Midlands option, released capacity changes still focuses on the WCML and London Midland corridors. These changes are in line with the most up-to-date view of future service specifications without HS2. All other TOCs remain unchanged from the ‘Do Minimum’ scenario.

For the extensions to Leeds and Manchester, the released capacity specifications for the WCML and London Midlands remain as for the London-West Midlands. Further released capacity changes have been made to the MML, ECML and Cross Country services, as well as some Northern services and local train services in the East Midlands. All other TOCs remain unchanged from the 'Do Minimum scenario'. Full details of the final released capacity specification are shown in Error! Reference source not found. **Error! Reference source not found.**. The development of the released capacity specification is reported in the Demand and Appraisal Report.

6. Base-Year Validation

6.1 Background

Previously, the HS2 model framework base-year validation was presented in the HS2 Model Development and Baseline Report, London-West Midlands, April 2012 (covering the January decision).

Subsequently, a series of changes have been made to the modelling framework, as described in this report. These include model updates affecting the Station Choice Model, preload mechanisms, Airport Demand Model, and framework enhancements including the expansion of PLANET Midlands coverage and the integration of PLANET North.

All relevant changes have been applied to the base-year model so that their impact on base-year rail passenger flow validation can be assessed. This model is known as the PFM base-year model. This Chapter presents a summary of this assessment.

6.2 Model Stability

Assignment convergence outputs from the last 20 iterations of transit assignment of the final network scenario of PLD for the base-year model are shown in **Table 6.1**. Note that, as this is a base-year model run, other stability analysis is not presented.

Table 6.1: PLD Rail Assignment Summary Statistics

Last 20 Iterations	Total Passenger km ('000)	Change in Total Passenger km Absolute ('000)	Change in Total Passenger km Percentage (%)
0	67,094		
1	67,127	3,950	5.88%
2	67,163	1,295	1.93%
3	67,142	454	0.68%
4	67,128	274	0.41%
5	67,120	172	0.26%
6	67,120	130	0.19%
7	67,114	106	0.16%
8	67,110	87	0.13%
9	67,106	68	0.10%
10	67,103	65	0.10%
11	67,101	54	0.08%
12	67,099	52	0.08%
13	67,101	40	0.06%
14	67,099	48	0.07%
15	67,097	35	0.05%
16	67,096	30	0.04%
17	67,094	33	0.05%
18	67,093	26	0.04%
19	67,092	25	0.04%
20	67,094	28	0.04%

This demonstrates a good level of stability of the model.

6.3 PLD Rail Assignment Validation

It is normal practice to validate transport models by checking whether they accurately represent the current situation – for PLD, this would be to check that the assignment gives the current demand by train service. Where possible, this should be done using independent data. However, to provide the best possible calibration of PLD, the data we used in matrix building included the majority of available data, and certainly the most reliable data. As a result, undertaking a detailed validation of PLD is challenging, as alternative sources of data are likely to be less robust.

Of the data sources available, MOIRA represents one of the best, although it is not strictly independent (as both PLD and MOIRA draw their data from LENNON, the rail industry ticket sales data). It does, however, represent a valuable model validation check.

Guards counts data represents a further data source, and unlike MOIRA, it is an independent data source; however, these data are likely to be less accurate than the LENNON data used to create PLD. As with MOIRA, these data provide a useful validation cross check of PLD.

Emme/2 has been used to output assigned transit segment volumes for the PFM base-year model. Results of the validation across screenlines are presented in **Table 6.2** to **Table 6.29** below, along with a comparison of the results of the previous January 2012 validated base-year model. The only changes between these two models are the functionality updates implemented in PFM. It should be noted that direct comparisons in terms of observed and modelled flows cannot be made between the current model and the February 2011 base model, as they each represent different base years – the February 2011 model was a 2007/2008 base year, whereas the PFM and January 2012 models have a base year of 2010/2011. However, comparisons came be made about the level of validation. Where there are no entries in the tables for a particular link or model version, this is caused by a lack of either observed data or compatible modelled flow.

Each link on a screenline has been designated as a 'Pass' or 'Fail' to indicate whether it meets the WebTAG validation guidance of being within 25% of observed on each modelled link flow. Note that in some locations, validation has been undertaken by TOC and does not represent total link flow. Screenlines are also labelled as a 'Pass' or 'Fail' to show if they meet WebTAG validation guidance of being within 15% of the screenline observations as a whole.

London Termini Validation

Figure 6.1: London Termini Screenlines

Figure 6.1 above shows the screenline for three London termini – Euston, St. Pancras and King's Cross. The validation data are calculated for long-distance TOCs only. There are two sources of data at these locations – MOIRA and Guards' counts. The available data are a useful check against the assigned flows on each TOC, but are incomplete in terms of other TOCs operating from the same stations. This potentially implies that if data for a particular TOC do not match, it will not be clear whether the overall loading on the link is incorrect, or whether the balance between TOCs in that corridor is incorrect.

Mott MacDonald

Table 6.2 shows the validation of the modelled flows against the Guards' counts. As can be seen, the modelled flows on long distance WCML services at Euston are higher than observed Guards' counts, whilst flows at St. Pancras are lower. The different modelled flows on these routes mean that the PFM model now performs better than the January 2012 model on the St. Pancras outbound link, but worse on the Euston inbound link. The differences are relatively small, and have no impact on the overall validation of the screenline.

Table 6.3 shows London termini screenline validation against MOIRA data. The Guards' counts show an all-day balanced flow, whilst MOIRA suggests directionally imbalanced demand allocations to MML and ECML. It should be noted that the PLD demand matrices are balanced by direction, i.e. demand from zone A to B is equal to demand in the opposite direction. MOIRA 'counts' do not take account of crowding - important for Central London trains. Comparison of the performance of the PFM model against the January 2012 PLD Framework shows a significant improvement on the King's Cross links, but over-assignment at Euston, The net effect is better validation than the January 2012 model at a screenline level.

Overall, the model appears to validate well for long distance trains, just outside the Planet South boundary (**Table 6.4** to **Table 6.7**). The PFM model achieves similar levels of validation as the January 2012 PLD Framework model across the Peterborough and Bedford screenlines. Within this boundary there are problems of allocations to the right TOC – the tables only consider flows, and counts, from strategic TOCs, not local ones (London Midland at Euston, Thameslink/FCC at St. Pancras, First Capital Connect at King's Cross). Most models will tend to produce passenger interchanges to save small journey times, and the model may be predicting more changes between TOCs than actually occur. The PS validation (shown later) is more relevant when considering the calibration at London terminals.

Table 6.2: London Termini Screenline - Counts

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	Guard Count (2007/08)	Total Count (2010)	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
West Coast Main Line	Euston	Outbound	19,124	27,097	24805	5,681	30%	Fail	30,624	3,526	13%	Pass	33,504	6,407	24%	Pass
		Inbound	18,717	27,123	24752	6,035	32%	Fail	31,191	4,068	15%	Pass	34,942	7,819	29%	Fail
Midland Main Line	St Pancras	Outbound	12,975	14,558	12181	-794	-6%	Pass	10,767	-3,791	-26%	Fail	11,502	-3,056	-21%	Pass
		Inbound	12,307	13,896	11872	-435	-4%	Pass	10,639	-3,257	-23%	Pass	11,221	-2,675	-19%	Pass
East Coast Main Line	King's Cross	Outbound	15,106	17,129	16984	1,878	12%	Pass	14,326	-2,803	-16%	Pass	18,817	1,687	10%	Pass
		Inbound	14,025	16,882	18174	4,149	30%	Fail	14,953	-1,929	-11%	Pass	18,168	1,287	8%	Pass
Total		**Outbound**	**47,205**	**58,784**	**53,970**	**6,765**	**14%**	**Pass**	**55,717**	**-3,067**	**-5%**	**Pass**	**63,823**	**5,039**	**9%**	**Pass**
		Inbound	**45,049**	**57,900**	**54,798**	**9,749**	**22%**	**Fail**	**56,783**	**-1,117**	**-2%**	**Pass**	**64,331**	**6,431**	**11%**	**Pass**

Table 6.3: London Termini Screenline - MOIRA Flows

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
West Coast Main Line	Euston	Outbound	22,281	28,739	24,805	2,524	11%	Pass	30,624	1,885	7%	Pass	33,504	4,765	17%	Pass
		Inbound	23,079	28,537	24,752	1,673	7%	Pass	31,191	2,654	9%	Pass	34,942	6,405	22%	Pass
Midland Main Line	St Pancras	Outbound	12,993	17,542	12,181	-812	-6%	Pass	10,767	-6,775	-39%	Fail	11,502	-6,040	-34%	Fail
		Inbound	14,321	15,344	11,872	-2,449	-17%	Pass	10,639	-4,705	-31%	Fail	11,221	-4,123	-27%	Fail
East Coast Main Line	King's Cross	Outbound	19,775	21,180	16,984	-2,791	-14%	Pass	14,326	-6,854	-32%	Fail	18,817	-2,363	-11%	Pass
		Inbound	17,829	17,654	18,174	345	2%	Pass	14,953	-2,701	-15%	Pass	18,168	514	3%	Pass
Total		**Outbound**	**55,049**	**67,461**	**53,970**	**-1,079**	**-2%**	**Pass**	**55,717**	**-11,744**	**-17%**	**Fail**	**63,823**	**-3,638**	**-5%**	**Pass**
		Inbound	**55,229**	**61,535**	**54,798**	**-431**	**-1%**	**Pass**	**56,783**	**-4,752**	**-8%**	**Pass**	**64,331**	**2,796**	**5%**	**Pass**

Table 6.4: Peterborough North Screenline

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
East Coast and Open Access	Peterborough	Northbound	-	16,820	-	-	-	-	16,533	-287	-2%	Pass	18,922	2,102	12%	Pass
		Southbound	-	16,637	-	-	-	-	16,381	-256	-2%	Pass	18,247	1,610	10%	Pass
Total		**Northbound**	-	**16,820**	-	-	-	-	**16,638**	**-182**	**-1%**	**Pass**	**18,922**	**2,102**	**12%**	**Pass**
		Southbound	-	**16,637**	-	-	-	-	**16,451**	**-186**	**-1%**	**Pass**	**18,247**	**1,610**	**10%**	**Pass**

Table 6.5: Peterborough South Screenline

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
East Coast and Open Access	Peterborough	Northbound	-	19,052	-	-	-	-	17,288	-1,764	-9%	Pass	20,041	989	5%	Pass
		Southbound	-	19,040	-	-	-	-	16,826	-2,214	-12%	Pass	19,313	273	1%	Pass
Total		**Northbound**	-	**19,052**	-	-	-	-	**17,396**	**-1,656**	**-9%**	**Pass**	**20,041**	**989**	**5%**	**Pass**
		Southbound	-	**19,040**	-	-	-	-	**16,895**	**-2,145**	**-11%**	**Pass**	**19,313**	**273**	**1%**	**Pass**

Table 6.6: Bedford North Screenline

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
Midland Main Line	Bedford	Northbound	-	10,244	-	-	-	-	9,868	-376	-4%	Pass	8,744	-1,500	-15%	Pass
		Southbound	-	10,301	-	-	-	-	9,891	-410	-4%	Pass	8,799	-1,502	-15%	Pass
Total		**Northbound**	**-**	**10,244**	**-**	**-**	**-**	**-**	**10,118**	**-126**	**-1%**	**Pass**	**8,744**	**-1,500**	**-15%**	**Pass**
		Southbound	**-**	**10,301**	**-**	**-**	**-**	**-**	**9,684**	**-617**	**-6%**	**Pass**	**8,799**	**-1,502**	**-15%**	**Pass**

Table 6.7: Bedford South Screenline

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
Midland Main Line	Bedford	Northbound	-	12,732	-	-	-	-	10,812	-1,920	-15%	Pass	10,868	-1,864	-15%	Pass
		Southbound	-	11,991	-	-	-	-	10,783	-1,208	-10%	Pass	10,852	-1,139	-9%	Pass
Total		**Northbound**	**-**	**12,732**	**-**	**-**	**-**	**-**	**11,063**	**-1,669**	**-13%**	**Pass**	**10,868**	**-1,864**	**-15%**	**Pass**
		Southbound	**-**	**11,991**	**-**	**-**	**-**	**-**	**10,576**	**-1,415**	**-12%**	**Pass**	**10,852**	**-1,139**	**-9%**	**Pass**

Validation for Midlands Screenlines

Figure 6.2 shows the location of the South of Midlands screenlines, and **Figure 6.3** the location of the North of Midlands screenlines. **Table 6.8** and **Table 6.9** show the validation for the South of Midlands screenlines, and **Table 6.10** and **Table 6.11** the validation for the North of Midlands screenlines.

Figure 6.2: South of Midlands Screenlines

Figure 6.3: North of Midlands Screenlines

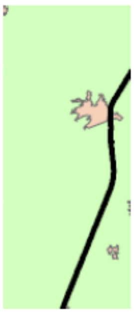


Table 6.8: South of Midlands Upper Screenline Results

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
West Coast	Milton Keynes	Northbound	24,445	27,067	23,227	-1,218	-5%	Pass	29,601	2,534	9%	Pass	32,494	5,427	20%	Pass
		Southbound	24,397	27,462	22,991	-1,406	-6%	Pass	30,189	2,727	10%	Pass	33,942	6,480	24%	Pass
Chiltern	Bicester North	Northbound	2,730	4,020	3,245	515	19%	Pass	2,981	-1,039	-26%	Fail	2,672	-1,348	-34%	Fail
		Southbound	2,651	4,095	3,166	515	19%	Pass	3,032	-1,063	-26%	Fail	2,768	-1,327	-32%	Fail
Cross Country	Oxford	Northbound	3,882	4,343	2,967	-915	-24%	Pass	4,506	163	4%	Pass	4,390	47	1%	Pass
		Southbound	3,957	4,265	3,129	-828	-21%	Pass	4,077	-188	-4%	Pass	4,189	-76	-2%	Pass
Total		**Northbound**	**31,057**	**35,430**	**29,439**	**-1,618**	**-5%**	**Pass**	**37,088**	**1,658**	**5%**	**Pass**	**39,557**	**4,127**	**12%**	**Pass**
		Southbound	**31,005**	**35,822**	**29,286**	**-1,719**	**-6%**	**Pass**	**37,298**	**1,476**	**4%**	**Pass**	**40,899**	**5,077**	**14%**	**Pass**

Table 6.9: South of Midlands Lower Screenline Results

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
West Coast	Milton Keynes	Northbound	29,483	28,397	24,888	-4,595	-16%	Pass	30,124	1,727	6%	Pass	33,895	5,498	19%	Pass
		Southbound	29,433	28,537	24,598	-4,835	-16%	Pass	30,677	2,140	7%	Pass	35,331	6,794	24%	Pass
Chiltern	Bicester North	Northbound	3,647	5,209	3,769	122	3%	Pass	3,152	-2,057	-39%	Fail	3,893	-1,316	-25%	Fail
		Southbound	3,668	5,275	3,621	-47	-1%	Pass	3,178	-2,097	-40%	Fail	3,902	-1,373	-26%	Fail
Cross Country	Oxford	Northbound	3,535	4,165	3,320	-215	-6%	Pass	4,611	446	11%	Pass	3,441	-724	-17%	Pass
		Southbound	3,328	3,538	3,464	136	4%	Pass	4,213	675	19%	Pass	3,320	-218	-6%	Pass
Total		**Northbound**	**36,665**	**37,771**	**31,977**	**-4,688**	**-13%**	**Pass**	**37,888**	**117**	**0%**	**Pass**	**41,229**	**3,458**	**9%**	**Pass**
		Southbound	**36,429**	**37,350**	**31,683**	**-4,746**	**-13%**	**Pass**	**38,067**	**717**	**2%**	**Pass**	**42,553**	**5,203**	**14%**	**Pass**

Table 6.10: North of Midlands Upper Screenline

		Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
Crewe	Northbound	8,270	13,402	9,894	1,624	20%	Pass	15,599	2,197	16%	Pass	14,290	888	7%	Pass
	Southbound	8,103	13,835	9,524	1,421	18%	Pass	16,256	2,421	18%	Pass	14,213	378	3%	Pass
Stoke	Northbound	7,229	8,292	7,701	472	7%	Pass	8,843	551	7%	Pass	8,599	307	4%	Pass
	Southbound	7,466	8,003	8,431	965	13%	Pass	8,139	136	2%	Pass	8,515	512	6%	Pass
Total	**Northbound**	**15,499**	**21,694**	**17,595**	**2,096**	**14%**	**Pass**	**24,441**	**2,747**	**13%**	**Pass**	**22,889**	**1,195**	**6%**	**Pass**
	Southbound	**15,569**	**21,838**	**17,955**	**2,386**	**15%**	Fail	**24,395**	**2,557**	**12%**	**Pass**	**22,728**	**890**	**4%**	**Pass**

Table 6.11: North of Midlands Lower Screenline Results

		Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
Crewe	Northbound	8,727	13,156	10,360	1,633	19%	Pass	13,635	479	4%	Pass	14,530	1,374	10%	Pass
	Southbound	8,544	13,455	9,627	1,083	13%	Pass	14,310	855	6%	Pass	14,103	648	5%	Pass
Stoke	Northbound	7,772	8,825	8,378	606	8%	Pass	9,427	602	7%	Pass	9,084	259	3%	Pass
	Southbound	7,953	8,564	8,906	953	12%	Pass	8,751	187	2%	Pass	9,019	455	5%	Pass
Total	**Northbound**	**16,499**	**21,981**	**18,738**	**2,239**	**14%**	**Pass**	**23,062**	**1,081**	**5%**	**Pass**	**23,614**	**1,633**	**7%**	**Pass**
	Southbound	**16,497**	**22,019**	**18,533**	**2,036**	**12%**	**Pass**	**23,061**	**1,042**	**5%**	**Pass**	**23,122**	**1,103**	**5%**	**Pass**

At the South of Midlands screenlines there is a general deterioration in the flow validation in PFM compared to the January 2012 model; however, both models achieve the same levels of validation compared to WebTAG validation criteria. Both models pass the WebTAG criteria for the West Coast and Cross Country routes, and at the screenline level. Both models are under-assigned on the Chiltern route, with the issue worsening to a minor degree in the PFM model. There is an imbalance between the WCML (which is over-assigned) and Chiltern, resulting in a failure to meet WebTAG validation criteria at Bicester North in both models. This imbalance can be seen on both directions of flow. As at Euston, this suggests that the model over-allocates passengers to WCML instead of Chiltern for long-distance trips. As previously commented, we believe this is because PLD does not take account of fares when assigning routes (Chiltern fares are generally slightly lower than WCML).

For the north of Midlands screenlines, the PFM model comfortably achieves the WebTAG levels of acceptable validation.

North of England Screenlines

The North of Midlands screenlines (shown previously) give an indication of the quality of the validation at various points between London/Birmingham and Manchester/Liverpool/Glasgow (i.e. the West Coast route). To show validation for routes to Leeds/York/Newcastle/Edinburgh, screenlines were also examined for the North of England on the East Coast route. Routes to Manchester, Leeds and Preston are validated as a key indication of the results of extending the coverage of the model in the North. Note that modelled data is unavailable for various northern links in the February 2011 2007/2008 base model due to significant changes to the rail network. There are two screenlines in the Doncaster area, lower and upper, as shown in **Figure 6.4** below. Results are presented in **Table 6.12** and **Table 6.13** below.

Figure 6.4: Doncaster Screenlines

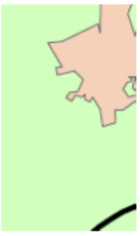


Table 6.12: Doncaster Upper Screenline Results

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route	Sta ion	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
Cross Country	Doncaster	Northbound	0	1,534	-	-	-	-	1,945	411	27%	Fail	2,022	488	32%	Fail
		Southbound	0	1,769	-	-	-	-	2,037	268	15%	Pass	2,132	363	21%	Pass
East Coast and Open Access	Doncaster	Northbound	13,364	15,101	14,967	1,603	12%	Pass	14,551	-550	-4%	Pass	15,315	214	1%	Pass
		Southbound	13,318	15,418	15,527	2,209	17%	Pass	14,781	-637	-4%	Pass	15,370	-48	0%	Pass
Total		**Northbound**	**13,364**	**16,635**	**14,967**	**1,603**	**12%**	**Pass**	**16,497**	**-138**	**-1%**	**Pass**	**17,337**	**702**	**4%**	**Pass**
		Southbound	**13,318**	**17,187**	**15,527**	**2,209**	**17%**	**Fail**	**16,818**	**-369**	**-2%**	**Pass**	**17,502**	**315**	**2%**	**Pass**

Table 6.13: Doncaster Lower Screenline Results

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
Cross Country	Doncaster	Northbound	0	1,731	-	-	-	-	2,064	333	19%	Pass	1,789	58	3%	Pass
		Southbound	0	2,393	-	-	-	-	2,315	-78	-3%	Pass	2,099	-294	-12%	Pass
East Coast and Open Access	Doncaster	Northbound	13,442	15,611	16,036	2,594	19%	Pass	15,469	-142	-1%	Pass	16,601	990	6%	Pass
		Southbound	13,151	15,526	15,811	2,660	20%	Pass	15,476	-50	0%	Pass	16,398	872	6%	Pass
Total		**Northbound**	**13,442**	**17,342**	**16,036**	**2,594**	**19%**	**Fail**	**17,533**	**191**	**1%**	**Pass**	**18,391**	**1,049**	**6%**	**Pass**
		Southbound	**13,151**	**17,919**	**15,811**	**2,660**	**20%**	**Fail**	**17,791**	**-128**	**-1%**	**Pass**	**18,496**	**577**	**3%**	**Pass**

At both of the Doncaster screenlines there are some differences in the level of validation at individual locations; however, both PFM and the January 2012 achieve the same levels of validation compared to WebTAG validation criteria. The Doncaster Upper screenline, whilst struggling to differentiate between TOCs at this location, nevertheless meets WebTAG criteria for the screenline.

Newcastle screenlines are shown in **Figure 6.5**, with results in **Table 6.14** and **Table 6.15**.

Figure 6.5: Newcastle Screenlines

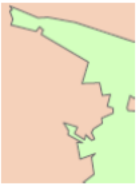


Table 6.14: Newcastle Upper Screenline Results

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route	Sta ion	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
Cross Country	Newcastle	Northbound	0	3,645	-	-	-	-	3,671	26	1%	Pass	3,929	284	8%	Pass
		Southbound	0	3,619	-	-	-	-	3,477	-142	-4%	Pass	3,771	152	4%	Pass
East Coast	Newcastle	Northbound	6,177	6,505	7,245	1,068	17%	Pass	7,159	654	10%	Pass	7,287	782	12%	Pass
		Southbound	5,900	6,818	7,603	1,703	29%	Fail	7,321	503	7%	Pass	7,552	734	11%	Pass
Total		**Northbound**	**6,177**	**10,150**	**7,245**	**1,068**	**17%**	**Fail**	**10,830**	**680**	**7%**	**Pass**	**11,216**	**1,066**	**11%**	**Pass**
		Southbound	**5,900**	**10,437**	**7,603**	**1,703**	**29%**	**Fail**	**10,798**	**361**	**3%**	**Pass**	**11,323**	**886**	**8%**	**Pass**

Table 6.15: Newcastle Lower Screenline

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route	Sta ion	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
Cross Country	Newcastle	Northbound	0	1,685	-	-	-	-	1,873	188	11%	Pass	2,044	359	21%	Pass
		Southbound	0	1,593	-	-	-	-	1,781	188	12%	Pass	1,892	299	19%	Pass
East Coast	Newcastle	Northbound	3,978	4,611	4,535	557	14%	Pass	4,558	-53	-1%	Pass	4,477	-135	-3%	Pass
		Southbound	3,845	4,726	4,781	936	24%	Pass	4,671	-55	-1%	Pass	4,574	-152	-3%	Pass
Total		**Northbound**	**3,978**	**6,296**	**4,535**	**557**	**14%**	**Pass**	**6,431**	**135**	**2%**	**Pass**	**6,521**	**225**	**4%**	**Pass**
		Southbound	**3,845**	**6,319**	**4,781**	**936**	**24%**	Fail	**6,451**	**132**	**2%**	**Pass**	**6,466**	**147**	**2%**	**Pass**

The screenlines at Newcastle also show consistency in validation between PFM and the January 2012 PLD Framework. As can be seen, all TOC flows meet the WebTAG validation guidance of being within 25% of observed on the modelled link flows, and within 15% of the screenline as a whole. There is a slight deterioration in the lower Cross Country link, though the absolute change is minor.

Table 6.16: Manchester South Screenline

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
West Coast Main Line	Manchester Piccadilly	Northbound	4,232	7,268	-	-	-	-	8,422	1,154	16%	Pass	6,796	-472	-6%	Pass
		Southbound	4,328	7,757	-	-	-	-	8,938	1,181	15%	Pass	7,184	-573	-7%	Pass
Cross Country	Manchester Piccadilly	Northbound	2,274	2,657	-	-	-	-	3,947	1,290	49%	Fail	3,315	658	25%	Pass
		Southbound	2,753	2,872	-	-	-	-	3,611	739	26%	Fail	3,166	294	10%	Pass
East Midlands Trains	Manchester Piccadilly	Northbound	1,727	1,916	-	-	-	-	2,348	432	23%	Pass	2,031	115	6%	Pass
		Southbound	1,411	2,067	-	-	-	-	2,365	298	14%	Pass	2,194	127	6%	Pass
TransPennine	Manchester Piccadilly	Northbound	1,289	1,623	-	-	-	-	1,544	-79	-5%	Pass	1,366	-257	-16%	Pass
		Southbound	1,362	1,669	-	-	-	-	1,742	73	4%	Pass	1,418	-251	-15%	Pass
Arriva Trains Wales	Manchester Piccadilly	Northbound	771	964	-	-	-	-	1,602	638	66%	Fail	985	21	2%	Pass
		Southbound	1,093	1,169	-	-	-	-	2,240	1,071	92%	Fail	1,084	-85	-7%	Pass
Total		**Northbound**	**10,293**	**14,428**	-	-	-	-	**17,863**	**3,435**	**24%**	Fail	**14,493**	**65**	**0%**	**Pass**
		Southbound	**10,947**	**15,534**	-	-	-	-	**18,896**	**3,362**	**22%**	Fail	**15,045**	**-489**	**-3%**	**Pass**

Table 6.17: Manchester West Screenline

Route / Strategic TOC	Station	Direction	Observed: MOIRA 2007/08	Observed: MOIRA 2010/11	February 2011 Base: PLD Model (Modelled)	February 2011 Base: Difference	February 2011 Base: % Difference	February 2011 Base: Pass / Fail	April 2012 Consult. Base: PLD Model (Modelled)	April 2012 Consult. Base: Difference	April 2012 Consult. Base: % Difference	April 2012 Consult. Base: Pass / Fail	PFMv3 Base: PLD Model (Modelled)	PFMv3 Base: Difference	PFMv3 Base: % Difference	PFMv3 Base: Pass / Fail
East Midlands Trains	Manchester Piccadilly	Eas bound	1,540	1,748	-	-	-	-	2,406	658	38%	Fail	2,122	374	21%	Pass
		Westbound	1,468	1,720	-	-	-	-	2,462	742	43%	Fail	1,834	114	7%	Pass
Arriva Trains Wales	Manchester Piccadilly	Eas bound	1,630	1,756	-	-	-	-	2,246	490	28%	Fail	1,532	-224	-13%	Pass
		Westbound	1,664	1,812	-	-	-	-	2,464	652	36%	Fail	1,855	43	2%	Pass
TransPennine	Manchester Piccadilly	Eas bound	5,357	8,187	-	-	-	-	7,308	-879	-11%	Pass	6,909	-1,278	-16%	Pass
		Westbound	5,644	7,069	-	-	-	-	7,566	497	7%	Pass	6,970	-99	-1%	Pass
Total		**Eastbound**	**8,527**	**11,691**	-	-	-	-	**11,960**	**269**	**2%**	**Pass**	**10,563**	**-1,128**	**-10%**	**Pass**
		Westbound	**8,776**	**10,601**	-	-	-	-	**12,492**	**1,891**	**18%**	**Fail**	**10,659**	**58**	**1%**	**Pass**

Table 6.18: Manchester East Screenline

Route / Strategic TOC	Station	Direction	Observed: MOIRA 2007/08	Observed: MOIRA 2010/11	February 2011 Base: PLD Model (Modelled)	February 2011 Base: Difference	February 2011 Base: % Difference	February 2011 Base: Pass / Fail	April 2012 Consult. Base: PLD Model (Modelled)	April 2012 Consult. Base: Difference	April 2012 Consult. Base: % Difference	April 2012 Consult. Base: Pass / Fail	PFMv3 Base: PLD Model (Modelled)	PFMv3 Base: Difference	PFMv3 Base: % Difference	PFMv3 Base: Pass / Fail
TransPennine	Manchester Piccadilly	Eas bound	5,542	6,614	-	-	-	-	7,765	1,151	17%	Pass	7,495	881	13%	Pass
		Westbound	5,405	6,690	-	-	-	-	8,723	2,033	30%	Fail	8,076	1,386	21%	Pass
Ashton-under-Lyne	Manchester Victoria	Eas bound	1,532	2,212	-	-	-	-	2,413	201	9%	Pass	1,592	-620	-28%	Fail
		Westbound	1,645	2,161	-	-	-	-	3,001	840	39%	Fail	1,666	-495	-23%	Pass
Calder Valley	Manchester Victoria	Eas bound	3,040	3,678	-	-	-	-	3,983	305	8%	Pass	2,844	-834	-23%	Pass
		Westbound	2,975	3,697	-	-	-	-	3,885	188	5%	Pass	2,894	-803	-22%	Pass
Total		**Eastbound**	**10,114**	**12,504**	-	-	-	-	**14,160**	**1,656**	**13%**	**Pass**	**11,930**	**-574**	**-5%**	**Pass**
		Westbound	**10,025**	**12,548**	-	-	-	-	**15,609**	**3,061**	**24%**	**Fail**	**12,635**	**87**	**1%**	**Pass**

Overall, the PFM model shows a good level of validation on the Manchester South screenline. All of the individual links that make up the screenline are within the acceptable levels set out in WebTAG criteria. We can see that in comparison to the January 2012 model, the PFM provides a better representation of modelled rail flows in this area; the increased detail in the North of England in PFM results much better representation of rail trips.

The validation of PFM on the Manchester East and West screenlines suggests a weakness in route choice (where certain routes are over-assigned and others are under-assigned), although overall the flows across the screenline are accurate. Again, the screenline level validation shows the greater accuracy of PFM over the January 2012 base model. In the case of Manchester West, this is also highly apparent on a link level.

Table 6.19: Leeds East Screenline

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
Cross Country	Leeds	Eas bound	2,319	2,354	-	-	-	-	1,664	-690	-29%	Fail	2,085	-269	-11%	Pass
		Westbound	2,427	2,049	-	-	-	-	1,802	-247	-12%	Pass	2,136	87	4%	Pass
TransPennine	Leeds	Eas bound	5,370	5,880	-	-	-	-	7,227	1,347	23%	Pass	5,852	-28	0%	Pass
		Westbound	5,493	5,912	-	-	-	-	7,674	1,762	30%	Fail	6,098	186	3%	Pass
Northern	Leeds	Eas bound	1,379	1,605	-	-	-	-	1,310	-295	-18%	Pass	1,912	307	19%	Pass
		Westbound	1,277	1,453	-	-	-	-	710	-743	-51%	Fail	1,778	325	22%	Pass
Total		**Eastbound**	**9,185**	**9,839**	-	-	-	-	**10,272**	**433**	**4%**	**Pass**	**9,894**	**55**	**1%**	**Pass**
		Westbound	**9,197**	**9,414**	-	-	-	-	**10,186**	**772**	**8%**	**Pass**	**10,012**	**598**	**6%**	**Pass**

Table 6.20: Leeds South Screenline

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
East Coast	Leeds	Northbound	4,413	5,537	-	-	-	-	5,406	-131	-2%	Pass	5,203	-334	-6%	Pass
		Southbound	4,732	5,565	-	-	-	-	5,406	-159	-3%	Pass	5,297	-268	-5%	Pass
Cross Country	Leeds	Northbound	3,249	3,856	-	-	-	-	3,055	-801	-21%	Pass	2,641	-1,215	-32%	Fail
		Southbound	3,310	3,537	-	-	-	-	3,191	-346	-10%	Pass	2,824	-713	-20%	Pass
Total		**Northbound**	**7,662**	**9,393**	-	-	-	-	**8,461**	**-932**	**-10%**	**Pass**	**7,844**	**-1,549**	**-16%**	**Fail**
		Southbound	**8,041**	**9,102**	-	-	-	-	**8,597**	**-505**	**-6%**	**Pass**	**8,120**	**-982**	**-11%**	**Pass**

Table 6.21: Leeds West Screenline

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
TransPennine	Leeds	Eas bound	7,704	9,102	-	-	-	-	8,880	-222	-2%	Pass	9,925	823	9%	Pass
		Westbound	7,857	9,228	-	-	-	-	9,326	98	1%	Pass	10,540	1,312	14%	Pass
Calder Valley (Nor hern)	Leeds	Eas bound	6,436	6,536	-	-	-	-	7,819	1,283	20%	Pass	7,002	466	7%	Pass
		Westbound	6,562	6,195	-	-	-	-	6,647	452	7%	Pass	6,613	418	7%	Pass
Total		**Eastbound**	**14,139**	**15,638**	-	-	-	-	**16,699**	**1,061**	**7%**	**Pass**	**16,928**	**1,290**	**8%**	**Pass**
		Westbound	**14,419**	**15,423**	-	-	-	-	**15,972**	**549**	**4%**	**Pass**	**17,153**	**1,730**	**11%**	**Pass**

The Leeds East screenline exhibits a good level of validation and a significant improvement over the January 2012 base model. Previously, three links failed to meet the WebTAG criteria; whereas in the updated PFM model, all links pass.

The validation of the Leeds South screenline in PFM has deteriorated compared to the January 2012 model. The under-assignment on the reported routes has increased, resulting in the screenline failing the WebTAG criteria in the northbound direction, though only by 1%. Leeds West validates well in both models.

Table 6.22: Preston North Screenline

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
West Coast Main Line	Preston	Northbound	1,984	4,867	-	-	-	-	6,319	1,452	30%	Fail	6,072	1,205	25%	Pass
		Southbound	2,106	4,762	-	-	-	-	6,564	1,802	38%	Fail	6,510	1,748	37%	Fail
TransPennine	Preston	Northbound	2,769	4,395	-	-	-	-	2,540	-1,855	-42%	Fail	2,404	-1,991	-45%	Fail
		Southbound	2,743	4,538	-	-	-	-	2,407	-2,131	-47%	Fail	1,928	-2,610	-58%	Fail
Total		**Northbound**	**6,089**	**9,262**	-	-	-	-	**8,859**	**-403**	**-4%**	**Pass**	**8,477**	**-785**	**-8%**	**Pass**
		Southbound	**6,154**	**9,300**	-	-	-	-	**8,971**	**-329**	**-4%**	**Pass**	**8,438**	**-862**	**-9%**	**Pass**

Table 6.23: Preston South Screenline

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	Station	Direction	MOIRA 2007/08	MOIRA 2010/11	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail	PLD Model (Modelled)	Difference	% Difference	Pass / Fail
West Coast Main Line	Preston	Northbound	2,791	5,946	-	-	-	-	8,075	2,129	36%	Fail	7,037	1,091	18%	Pass
		Southbound	2,933	5,579	-	-	-	-	7,143	1,564	28%	Fail	6,994	1,415	25%	Fail
TransPennine	Preston	Northbound	3,031	4,008	-	-	-	-	4,493	485	12%	Pass	3,315	-693	-17%	Pass
		Southbound	2,977	4,298	-	-	-	-	4,546	248	6%	Pass	3,552	-746	-17%	Pass
Total		**Northbound**	**7,299**	**9,954**	-	-	-	-	**12,568**	**2,614**	**26%**	**Fail**	**10,351**	**397**	**4%**	**Pass**
		Southbound	**7,288**	**9,877**	-	-	-	-	**11,689**	**1,812**	**18%**	**Fail**	**10,545**	**668**	**7%**	**Pass**

The Preston North screenline suggests unbalanced choice between TOCs in PFM, where West Coast is under-assigned and TransPennine is over-assigned. This pattern is also evident in the January 2012 base, and in both models does not adversely affect the overall validation of the screenline.

The Preston South screenline shows a significant improvement in PFM over the January 2012 model. Although there appears to be a TOC choice imbalance in PFM (as in the North screenline), the overall impact on the screenline is a validation level within WebTAG criteria – a notable improvement over the January 2012 model which failed in both directions due to over-assignment of trips.

Table 6.24: Long-Distance TOCs Guard Count Results

			Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Strategic TOC	**Station**	**Direction**	**Guard Count 2007/08**	**Guard Count 2010/11**	**PLD Model (Modelled)**	**Difference**	**% Difference**	**Pass / Fail**	**PLD Model (Modelled)**	**Difference**	**% Difference**	**Pass / Fail**	**PLD Model (Modelled)**	**Difference**	**% Difference**	**Pass / Fail**
East Coast	Leeds	Southbound Dep.	-	5,467	-	-	-	-	5,406	-61	-1%	Pass	5,297	-170	-3%	Pass
	Newcastle	Southbound Dep.	-	6,533	-	-	-	-	7,336	803	12%	Pass	7,552	1,019	16%	Pass
Virgin Trains	Birmingham New St	Southbound Dep.	-	8,601	-	-	-	-	8,924	323	4%	Pass	9,811	1,210	14%	Pass
		Northbound Arr.	-	9,515	-	-	-	-	8,646	-869	-9%	Pass	9,556	42	0%	Pass
	Manchester Piccadilly	Southbound Dep.	-	6,980	-	-	-	-	8,938	1,958	28%	Fail	7,184	204	3%	Pass
		Northbound Arr.	-	7,481	-	-	-	-	8,661	1,181	16%	Pass	6,954	-526	-7%	Pass
	Liverpool Lime St	Southbound Dep.	-	2,441	-	-	-	-	2,293	-148	-6%	Pass	2,418	-23	-1%	Pass
		Northbound Arr.	-	2,592	-	-	-	-	2,636	44	2%	Pass	2,232	-360	-14%	Pass
East Midlands Trains (MM services)	Sheffield	Southbound Dep.	-	3,131	-	-	-	-	3,193	62	2%	Pass	2,555	-576	-18%	Pass
		Northbound Arr.	-	3,565	-	-	-	-	3,042	-523	-15%	Pass	2,373	-1,192	-33%	Fail
	Nottingham	Southbound Dep.	-	3,399	-	-	-	-	3,702	303	9%	Pass	3,226	-173	-5%	Pass
		Northbound Arr.	-	3,879	-	-	-	-	3,481	-398	-10%	Pass	3,204	-675	-17%	Pass
	Leicester	Southbound Dep.	-	9,260	-	-	-	-	9,769	509	6%	Pass	8,569	-691	-7%	Pass
		Northbound Arr.	-	10,540	-	-	-	-	9,762	-778	-7%	Pass	8,430	-2,110	-20%	Pass
Total by TOC	**East Coast**	**Southbound Dep.**	-	**12,000**	-	-	-	-	**12,809**	**810**	**7%**	**Pass**	**12,849**	**849**	**7%**	**Pass**
	Virgin Trains	**Southbound Dep.**	-	**18,021**	-	-	-	-	**19,740**	**1,719**	**10%**	**Pass**	**19,413**	**1,391**	**8%**	**Pass**
		Northbound Arr.	-	**19,587**	-	-	-	-	**19,923**	**336**	**2%**	**Pass**	**18,742**	**-845**	**-4%**	**Pass**
	East Midlands Trains	**Southbound Dep.**	-	**15,790**	-	-	-	-	**16,256**	**466**	**3%**	**Pass**	**14,349**	**-1,441**	**-9%**	**Pass**
		Northbound Arr.	-	**17,984**	-	-	-	-	**16,760**	**-1,224**	**-7%**	**Pass**	**14,007**	**-3,977**	**-22%**	**Fail**

Validation has also been undertaken on modelled flows on a selection of long-distance TOCs at various station locations. These flows are compared against Guard Counts; the results are shown in Table 6.24. Generally, the validation between PFM and the January 2012 model is consistent. Validation at Manchester is significantly improved when comparing to the Guard Count data, as well as MOIRA flows as seen in Tables 6.16 to 6.18. There are notable deteriorations in PFM around Leicester and Sheffield (northbound arrivals) which underline a general under-assignment across most links. The net effect is a relatively minor change in the screenline level validation, with the East Midlands northbound arrival validation now outside the WebTAG limits.

PLANET South, Midlands and North Assignment Validation

For Planet South, results of validation at Central London stations are presented in Table 6.25. Levels of validation for the screenline remain within WebTAG criteria on individual links, with the exception of Marylebone, and at a screenline level the validation passes the acceptable criteria. There is very little change between the PFM and January 2012 models, which is to be expected as the majority of the development work between the models focuses on PLD and the north.

Table 6.25: PLANET South Validation Flows (0700 -1000 arrivals in Central London)

	Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Route / Count Point	Green Book (PIXC) Counts 2007	New Counts 2010/11	PS Framework	Difference	% Difference	Pass / Fail	PS Framework	Difference	% Difference	Pass / Fail	PS Framework	Difference	% Difference	Pass / Fail
Great Western Main Line (Paddington)	22,973	28,275	21,486	-1,487	-6%	Pass	22,508	-5,767	-20%	Pass	22,776	-5,499	-19%	Pass
Chiltern Main Line (Marylebone)	10,222	11,546	7,763	-2,459	-24%	Pass	7,311	-4,235	-37%	Fail	7,260	-4,286	-37%	Fail
West Coast Main Line (Euston)	17,256	22,603	18,737	1,481	9%	Pass	19,751	-2,853	-13%	Pass	19,667	-2,936	-13%	Pass
Midland Main Line (St Pancras)	23,543	23,144	23,828	285	1%	Pass	27,388	4,244	18%	Pass	27,144	3,999	17%	Pass
East Coast Main Line (Finsbury Pk)	32,752	35,939	32,238	-514	-2%	Pass	32,800	-3,140	-9%	Pass	33,010	-2,929	-8%	Pass
Total	**106,746**	**121,508**	**104,052**	**-2,694**	**-3%**	**Pass**	**109,757**	**-11,751**	**-10%**	**Pass**	**109,857**	**-11,651**	**-10%**	**Pass**

Planet Midlands validation results are shown in Table 6.26 below. Validation is significantly improved on the previously problematic Solihull to Birmingham New Street Corridor, though the scale of this flow actually means the screenline level improvement is comparatively small. The other links are very similar between PFM and the January 2012 model, and validate within the WebTAG criteria.

Table 6.26: Planet Midlands Validation Results (0700-1000 to Birmingham New Street)

	Observed		February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Corridor From	Observed Flow 2007/08	New Flows 2010/11	PM Framework	Difference	% Difference	Pass / Fail	PM Framework	Difference	% Difference	Pass / Fail	PM Framework	Difference	% Difference	Pass / Fail
West Coast Main Line (Coventry Corridor)	4,228	4,851	3,738	-490	-12%	Pass	4,985	135	3%	Pass	4,612	-239	-5%	Pass
Solihull Corridor to New St (Long-distance TOCs)	311	421	109	-202	-65%	Fail	134	-287	-68%	Fail	387	-34	-8%	Pass
West Coast Main Line (Wolverhampton Corridor)	4,647	5,959	4,765	118	3%	Pass	6,868	909	15%	Pass	6,649	690	12%	Pass
All Corridors	**9,186**	**11,230**	**8,612**	**-574**	**-6%**	**Pass**	**11,987**	**757**	**7%**	**Pass**	**11,648**	**418**	**4%**	**Pass**

PLANET North validation results are presented in Tables 6.27 to 6.29 for the first time, and there are no comparable figures for either the February 2011 or January 2012 models as PLANET North was not included in the framework in these versions.

Validation at Manchester is generally good, with only one link falling outside of the WebTAG criteria. This very localised inaccuracy is offset by under-assignment at other Manchester termini, with the overall result being a very good level of validation at the screenline level.

The Leeds validation shows two links that fail to meet WebTAG criteria, though Ilkley is only marginally over the acceptable limit. Overall validation of the screenline does pass the WebTAG criteria.

The Sheffield screenline validates within the WebTAG limits. Within the screenline we can see that there is sensitivity between route choice, affecting the link level validation of Hope Valley and Woodhouse corridors. Although the percentage difference from observed appears high, the absolute values using this corridor are small.

Table 6.27: PLANET North Validation Results (Manchester)

	Observed	February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Corridor	New Flows 2010/11	Model Flow	Difference	% Difference	Pass/Fail	Model Flow	Difference	% Difference	Pass/Fail	Model Flow	Difference	% Difference	Pass/Fail
Stockport	6,379	-	-	-	-	-	-	-	-	6,301	-79	-1%	Pass
East Lines	3,876	-	-	-	-	-	-	-	-	4,819	943	24%	Pass
Airport	1,886	-	-	-	-	-	-	-	-	1,533	-353	-19%	Pass
Piccadilly sub-total	12,141	-	-	-	-	-	-	-	-	12,662	521	4%	Pass
Deansgate	6,431	-	-	-	-	-	-	-	-	5,576	-856	-13%	Pass
Oxford Rd sub-total	6,431	-	-	-	-	-	-	-	-	5,576	-856	-13%	Pass
Salford Central	1,918	-	-	-	-	-	-	-	-	3,200	1,282	67%	Fail
Rochdale	1,744	-	-	-	-	-	-	-	-	1,637	-107	-6%	Pass
Ashton	1,225	-	-	-	-	-	-	-	-	1,064	-161	-13%	Pass
Victoria sub-total	4,887	-	-	-	-	-	-	-	-	5,901	1,014	21%	Pass
All Corridors	**23,459**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**24,139**	**680**	**3%**	**Pass**

Table 6.28: PLANET North Validation Results (Leeds)

	Observed	February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Corridor	New Flows 2010/11	Model Flow	Difference	% Difference	Pass/Fail	Model Flow	Difference	% Difference	Pass/Fail	Model Flow	Difference	% Difference	Pass/Fail
Wakefield Westgate	**2,951**	-	-	-	-	-	-	-	-	**3,440**	**489**	**17%**	Pass
Woodlesford	1,766	-	-	-	-	-	-	-	-	726	-1,040	-59%	Fail
Dewsbury	3,835	-	-	-	-	-	-	-	-	4,357	522	14%	Pass
Halifax	2,545	-	-	-	-	-	-	-	-	2,709	164	6%	Pass
Shipley	3,449	-	-	-	-	-	-	-	-	3,212	-237	-7%	Pass
Ilkley	2,197	-	-	-	-	-	-	-	-	1,646	-551	-25%	Fail
Harrogate	2,251	-	-	-	-	-	-	-	-	1,760	-491	-22%	Pass
Garforth	4,337	-	-	-	-	-	-	-	-	3,904	-434	-10%	Pass
All Corridors	**23,331**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**21,753**	**-1,578**	**-7%**	**Pass**

Table 6.29: PLANET North Validation Results (Sheffield)

	Observed	February 2011 Base				April 2012 Consult. Base				PFMv3 Base			
Corridor	New Flows 2010/11	Model Flow	Difference	% Difference	Pass/Fail	Model Flow	Difference	% Difference	Pass/Fail	Model Flow	Difference	% Difference	Pass/Fail
Meadowhall	3,637	-	-	-	-	-	-	-	-	3,006	-631	-17%	Pass
Hope Valley	726	-	-	-	-	-	-	-	-	1,014	288	40%	Fail
Woodhouse	552	-	-	-	-	-	-	-	-	333	-219	-40%	Fail
Chesterfield	**1,774**	-	-	-	-	-	-	-	-	**1,822**	**48**	**3%**	Pass
All Corridors	**6,689**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**6,175**	**-514**	**-8%**	**Pass**

6.4 Validation Summary

Overall, the PFM model exhibits an acceptable level of validation across the vast majority of links. The functionality development that has occurred between the January 2012 model and PFM has had a positive impact on the whole. Validation levels are either consistent or improved, with only a very small number of links deteriorating in accuracy.

In conclusion, we believe that the model represents a reasonable representation of observed travel patterns in the base year and is suitable as a basis for developing forecasts.

In most cases, the model accurately assigns demand to the appropriate train services. However, in some cases there are differences from the estimates in MOIRA and/or the Guards' counts data. This is to be expected, as models will always be better in some areas than others. In general, where the PLD model differs from other data sources, these are:

- outside of the core areas of interest (i.e. the proposed HS2 scheme alignment);
- where significant amounts of local demand are modelled outside PLD (by PLANET South / Midlands). In these locations, an improved level of validation is observed when the models (PLD and the relevant regional model) are considered together;
- where fare differential may be affecting choice of route (although the total level of demand across these routes is more robust); and
- where MOIRA predicts flow patterns that are unlikely to be observed in reality (e.g. where flows differ substantially by direction).

Overall, the updated PFM model performs as well as, and in some cases significantly better than, the January 2012 model.

The changes made to the base-year model have had a notable impact on modelled passenger volumes. The functionality updates have improved validation in key areas such as Manchester, while remaining largely consistent with the January 2012 Consultation base model in other areas. There are a small number of screenline flows where the validation has deteriorated, although their scale and overall impact is negligible.

The differences are as expected given the scale of modifications to the model – in other words, they are in the geographical areas where most changes were made. This is particularly noticeable in comparisons with the February 2011 2007/2008 base model.

The model exhibits a good level of stability.

No model of this size and complexity will produce a perfect validation. On the WebTAG criteria being examined, the validation is good. The key corridors and areas of interest validate to within the levels outlined in the criteria. The functionality changes made to the model have proved successful in improving validation and – just as importantly – have had no significant negative impacts.

Validation of the model is difficult due the limitations in the coverage and quality of the data we compare against and the need to make inferences related to data at adjacent locations. As stated above MOIRA and Guards' counts are a useful check against the assigned flows on each TOC, but only provide data for some operators which means if the comparison is poor it is difficult to determine if the link loading or TOC allocation is incorrect. Under-modelling of flows on ECML and MML does not appear to be due to long-distance demand (and this has to be our principle focus) as the comparison of Bedford and Peterborough shows (above Tables 6.4 to 6.7). This just illustrates how we need to use the data we have intelligently, all-day data is particularly scarce.

There are also limitations associated with the pre-load process (but we note the transfer process has been improved and has enhanced the validation in the v2 and v3 models particularly with respect to the screenlines in the north). The preloads are included in the flows reported in Planet Long Distance model but there are a number of weaknesses in the way that these intra-regional trips are represented in the Long Distance model. The preload process is designed to add regional demand and crowding to the Long Distance model but is not intended or sufficiently detailed to contribute to a detailed PLD validation as this would require a much more onerous matching process. Firstly the flows are sourced from AM peak models only and converted into 16-hour equivalents, furthermore these factors are not TOC or corridor specific so levels of commuting activity are not differentiated between operators. Secondly the transfer is between 'packets' of services (for modelling convenience) so the pre-loads are distributed between available services in the 'packet', this is necessarily simplistic and is based on a on the number of trains per hour. – this does not lend itself to detailed validation.

7. Scheme Appraisal

7.1 WebTAG Appraisal

A number of changes have been made to the WebTAG appraisal to reflect refinements to the appraisal process and development of the scheme. These are outlined below.

7.1.1 Price Base and Present Value Year

In February 2011 the appraisal had been given in 2009 price levels discounted to 2009. The main change made to the appraisal was to update it to 2011 values, discounted to 2011.

This clearly has no effect on demand figures. Revenue and economic benefits and many costs are adjusted by a factor that represents inflation. Construction costs are changed to the best estimates made at 2011 price levels. In addition, slight changes to discounting affect all costs, benefits and revenues, with two fewer years of discounting at 3.5%. The year at which the discount rate falls from 3.5% to 3% is changed from 2040 to 2042.

The changes to the appraisal process had only small impacts on the benefit to cost ratio, although the net present values (NPVs) of all elements are altered by the changes in price level and discount year by a factor of 13.6%.

7.1.2 Other Changes to the Appraisal

Further changes were made to the appraisal to ensure consistency with the scheme definition and the demand and revenue forecasts:

- the cap year is 2034 – no further growth in demand, fares or costs;
- the second forecast year is 2034; and
- 'value of time' growth is adjusted to reflect the gross domestic product (GDP) forecasts used for the rail demand forecasts – this continues to grow beyond the cap year.

7.1.3 Value of Time

Growth in the value of time is linked to changes in income (measured through per capita GDP growth). As GDP forecasts have been revised, values of time have been recalculated. Forecast values of time (VOT) annual percentage growth rates for working and non-working time originated from WebTAG 3.5.6 Table 3b and Office for Budgetary Responsibility GDP growth rate forecasts (July 2011).

Table 7.1 gives details of the growth rate indices that have been used in the appraisal. Also provided in this table are the equivalent Consultation values used, which are slightly higher than those used for the January 2012 Economic Case.

Table 7.1 Growth in Values of Time Index for Business and Leisure PLD (2002=100)

Year	Segment	January 2012 Economic Case Value of Time Growth (real)	Consultation Value of Time Growth (real)
2026	Business	1.39	1.41
	Other	1.30	1.32
2037	Business	1.66	1.73
	Other	1.50	1.55

7.1.4 Appraisal Period

The appraisal period for the London-West Midlands scheme is 60 years, with an opening year of 2026. For the Y network the appraisal period has changed to 67 years with an opening year of 2033. The appraisal of the Y network comprises:

- seven years of benefits from 2026 to 2033 for the London-West Midlands scheme.
- 60 years of benefits for the extension to Leeds and Manchester, from an opening year of 2033.

7.1.5 Carbon and Noise Benefit Changes

The economic appraisal has been updated to include the calculation and valuation of carbon benefits and noise benefits in line with WebTAG guidance.

7.1.6 Scheme Costs and Operating Costs

Scheme costs and operating costs included in the appraisal have been updated as more details of the scheme have developed. These take account of more detailed designs of scheme and route, change in the service specification for HS2 and change in the released capacity specification.

7.1.7 Revenue Calculation in Regional Models

Two adjustments have been made in the appraisal template that affected the revenue calculations in the regional models. These related to fares assumptions where indirect tax factors and real growth in fares were double-counted.

7.2 Wider Economic Impacts Assessment

The principles behind the calculation of Wider Economic Impacts (WEIs) remain unchanged. The only difference is the use of revised input data on cost and time of travel. The WEIs are also updated to 2011 prices, discounted to 2011.

Appendices

Appendix A. Glossary of Terms

A.1. List of Acronyms

ADM - air demand model

BCR - benefit to cost ratio

CAA - Civil Aviation Authority

DfT - Department for Transport

ECML - East Coast Main Line

GDP - gross domestic product

MML - Midland Main Line

MSOA - Middle Layer super Output Area

NAM - national accessibility model

NPV - net present value

NRTS - National Rail Travel Survey

PFM - PLANET Forecasting Model

PLD - PLANET Long Distance

PM - PLANET Midland

PN - PLANET North

PS - PLANET South

PSM - PLANET Strategic Model

PT - public transport

SCM - station choice model

TOC - train operating company

TTW - travel to work

VOT - value of time

WCML - West Coast Main Line

A.2. Glossary of Terms

active station – A railway station included in PLD or the SCM.

air demand model – A spreadsheet-based mode choice model used to forecast access mode for passengers at Heathrow airport.

auxiliary transit time – Time for initial access or final egress from railway station or between intermediate stations (excluding wait time).

control matrix – The indicator matrix that determines whether demand is represented in PLD or the regional model.

EMME – The transport modelling software package used for the PFM.

link – In the rail model, a link represents a section of train track that has transit lines (train services) running on it.

MOIRA – The rail industry standard tool designed to predict how changes to the planned timetable will affect passenger demand and revenue.

packet – Grouping of services in PLD or regional models that are similar in terms of stations called at and markets catered for.

PLANET forecasting model - The overall modelling framework developed to assess HS2.

PLANET Long Distance – The strategic model covering rail/air and highway modes, incorporating assignment and demand model functions.

PLANET Midland – A rail network model covering the Midlands, representing the AM peak time period.

PLANET North – A rail network model covering the north of England, representing the AM peak time period.

PLANET South – A rail network model covering the south of England, representing the AM peak time period.

preload - The representation of passenger demand from PLD in the regional models (and visa versa). Stored at segment level.

segment – In the rail model, a segment represent a specific transit line (train service) on a specific link.

station choice model - A probabilistic model that forecast the choice of origin and destination station for origin destination movements

transit line – In the rail model, a transit line is the representation of a train service.

Appendix B. Model Versions

B.1. Overview

During the HS2 programme of work, a number of variants of both the PLD Framework and PFM have been developed. These versions have different model architecture and functionality and, in some cases, changes to the input forecasts of demand and supply.

Atkins originally developed the PLD Framework model, which was used to present the appraisal and forecasts for the London-West Midlands scheme. Mott MacDonald subsequently developed two further versions of the model, one to support the public consultation in February 2011 and the other to support the revised economic case published in January 2012. The primary changes in February 2011 were an update to the forecasts in response to revised economic forecasts and some minor technical revisions to the model. The changes in January 2012 were more substantial, including a re-base of the base-year model to 2010 and a complete update of the demand and supply assumptions, plus a small number of minor technical changes.

The starting point for the PFM was the March 2011 version of the PLD Framework model. There have been two major updates to the PFM. PFM version 2 (v2) incorporates changes to the station choice models and interaction between strategic and local models, together with some further minor changes. PFM version 3 (v3) is based on PFM v2 with some further changes to the model architecture, the interface to PLANET South and updates to the model to include the demand and supply updates contained in the January 2012 version of the PLD Framework.

An overview of the structure of the model that formed the starting point for model development is presented in the following sections, together with the changes incorporated in each of the models. Details of the changes in the PLD Framework are also included, as a number of these changes have been incorporated in the PFM.

B.2. The PLD Framework

The PLD Framework was used as the basis for the London-West Midlands appraisal work. Atkins developed the PLD Framework to assess the case for HS2. The key functional requirements of the forecasting framework were:

- *The ability to develop passenger demand forecasts for a variety of high speed rail options serving different destinations with a range of journey times and service frequencies. The demand impacts should take into account shift from existing rail services as well as mode shift from air and highway modes and impacts on trip frequency and generation;*
- *Specific representation of the interaction between local and long-distance passengers on long-distance services where they serve both markets, particularly on Wolverhampton/Birmingham to London services which also serve the local Coventry to Birmingham and Milton Keynes to London markets;*
- *Understanding the impacts of passengers across the existing rail network re-routeing to take advantage of faster journey times on HS2 services for part of their journey;*
- *Service options for re-using capacity created on the existing network, including enhanced London/Birmingham suburban and inter-regional services;*

- *Demand and economic impacts of different high speed rail station locations, including provision of parkway stations in the Birmingham and London areas and impact on local transport networks through access trips to the high speed rail stations; and*
- *Specific examination of the market for high speed rail access to Heathrow Airport, taking into account the different behaviour of people making airport access trips*
  (Model Development Report, Page 8, Atkins, February 2010).

Full details of the PLD Framework are included in Model Development Report, Atkins, February 2010.

B.2.1. Constituent models of the PLD Framework

The PLD Framework as at January 2012 consisted of three PLANET models – Planet Long Distance (PLD), Planet South (PS) and Planet Midlands (PM) and a spreadsheet-based Heathrow access model. The station choice model embedded within PLD uses RAILPLAN and PRISM model outputs as inputs, but these models are not run as part of the PLD Framework.

PLANET Long Distance (PLD)

Based on the previously existing PLANET Strategic Model (PSM), this model provides representation of long-distance, or strategic, movements across mainland UK for road, rail (including high speed rail) and air. PSM was developed in 2002 for (what was then) the Strategic Rail Authority (SRA). Initially, it was intended to be used to assess the SRA High Speed Line Study and potential upgrade schemes for the ECML.

PLD is an all-day (16-hour) model which carries out highway, rail and air assignments in order to generate generalised costs for each mode and purpose (business, leisure, commuting) and for ‘car available/not available’. Incremental mode-choice and trip generation calculations are based on the generalised cost in order to provide new demand matrices in a test run.

The rail model includes representation of:
- The disbenefit of crowding (a perceived increase in journey time);
- different behaviour by journey purpose and car availability in terms of crowding, access costs and fares (not part of assignment);
- station access for the leg in question; and
- service frequency, stopping patterns, wait and interchange times.

For use as part of the PLD Framework, PLD explicitly excludes demand in the following area:
- trips wholly within London/South East and South West (represented in PLANET South);
- trips wholly within the Greater Birmingham area (represented in PLANET Midlands); and
- trips to/from Heathrow (represented in the Airport Demand Model (ADM)).

Rail demand was original derived from the rail industry’s LENNON (ticket sales data) for 2007/8, subsequently updated to 2010/2011 (see section 2.2.3), and National Rail Travel Survey data (2005/6). For more details see the Model Development Report (Section 5.2, Atkins, February 2010).

A number of services represented in PLD are affected by demand that is represented in the regional models. Therefore, a ‘preload’ mechanism is included to enable crowding effects to be accurately portrayed on long-distance services that are used by ‘local’ passengers. These passengers are not subject to routeing or demand response effects within PLD, essentially constituting a fixed demand as ‘preload flows’ extracted from the relevant regional model (Planet South or Planet Midlands) for relevant services.

A station-choice model is included to represent the potential for passengers travelling between the West Midlands and London to choose between a number of origin and destination stations. It recognises that station choices are inter-related. In order to provide access time data to the stations in question, PRISM is used in the West Midlands and RAILPLAN in Greater London.

The highway model includes representation of long-distance movements for the same strategic movements as represented in the rail model. The highway network is used to calculate station and airport access times for both rail and air models, for 'car available' legs.

Speed-flow curves are used to represent congestion on the network. Representations of junction delays are not included. Demand has been updated to a 2010/2011 base for the PLD Framework.

The air model within PLD covers most domestic air services in the UK mainland and includes representation of the following:

- Demand for domestic flights (not inter-lining)
- Fare/frequency/wait and journey time
- Car access/egress to/from airports

PLANET South (PS)

PS is an AM peak-period rail model covering the three-hour period between 0700 and 1000. It is used principally for modelling the London and South East rail network. It uses an elasticity-based approach to represent the change in demand caused by changes in service specification, crowding or fares, for example.

PS was adapted for use within this framework by removing the strategic, or long-distance, demand that is represented in PLD. This strategic demand is represented in PS by using a 'wormhole' process which feeds PLD origin-destination demand data into PS, so that the strategic demand can find the quickest and least crowded route to the final destination via the PS assignment process. These trips are subject to demand responses and changing costs via the mode choice process in PLD; however, they are not subject to the same demand responses in PS (which relies on elasticity-based responses to changing costs).

Local demand that is subject to elastic demand responses in PS may use long-distance services that are also represented in PLD. This demand is represented in PLD via a "preload" mechanism. Flows between the models are adjusted to reflect AM peak-period demand levels in the regional models and 16-hour demand in PLD.

PLANET Midlands (PM)

PM is an AM peak-period rail model covering the three-hour period between 0700 and 1000. It is similar in functionality to PS, but covers the West Midlands and East Midlands rail network. It was developed in 2009 for the DfT. Like PS, it uses an elasticity-based approach to represent the change in demand caused by changes in service specification, crowding or fares, for example.

The model is centred on Birmingham, but includes detailed representation of the East Midlands (Leicester, Derby and Nottingham).

The model includes local and long-distance services across this area. PM incorporates a Station Choice Model, which has been implemented using two zone systems. One is based on a geographic zone system incorporating the 1,146 zones. The second zoning system allows the assignment to be made on a station-to-station basis. There are 259 'station' zones for assignment purposes.

PM was adapted for use within the PLD Framework by cutting back the geographic scope of the model to the immediate Greater Birmingham area, where only local movements are included in the PM demand matrices and are subject to demand responses. PM includes local and long-distance services, so to represent the long-distance demand within PM, a preload process is used to pass demand from PLD to PM and vice versa. Flows between the models are adjusted to reflect AM peak-period demand levels in the regional models and 16-hour demand in PLD.

Airport Demand Model

Airport travellers have different demand response characteristics from most passengers. As the proposed alignment for HS2 includes close linkages with Heathrow, it was deemed necessary to model trips to and from Heathrow in specific detail. A separate spreadsheet-based approach (developed by SKM, which partnered Atkins in the PLD Framework development) is employed to model airport access for trips to and from Heathrow. This ADM is a mode-choice model based upon LASAM (SKM's London Airports Surface Access Model, developed for BAA). To capture HS2's impact on trips to and from the airport, there is an interface between the ADM and PLD. Generalised cost skims from PLD are fed into the ADM to calculate revised mode shares for trips to and from Heathrow and the resulting changes in demand by mode (highway, rail and air) are imported back into PLD.

Interaction of the models in the PLD Framework

PLD provides a representation of long-distance, or strategic, movements in the UK for rail, road and air. It is an all-day model. Therefore, it is unable to represent peak-period service conditions, in terms of increased frequencies, passengers or crowding. In order to represent these effects, the regional models (PLANET South and PLANET Midlands), which are AM peak period models, are utilised.

It is important to ensure that trips are not subject to demand responses in more than one model. Long-distance demand should reside within PLD with the local demand in the Planet Regional Models. However, there are rail services that cater to both long-distance and local trips. This necessitates passing demand between regional models and PLD, so that realistic crowding levels are included in both models. This is carried out in two different ways for the PLD-PS interface:

- Wormhole process: For demand that is passed from PLD to PS, a series of select link matrices are extracted from PLD at the boundary between PLD and PS. These are converted to the PS zoning system, factored to account for the difference between AM peak-period and all-day demand, and assigned to the PS network. This has the advantage of enabling long-distance demand to be assigned realistically on the more detailed PS network. However, it should be noted that this demand is not subject to demand responses in PS, but through the crowding mechanism it will affect the demand responses for 'local' trips within PS.

- Preload process (PS): The wormhole process is feasible because a clear boundary can be drawn at the perimeter of PS whereby the select link process can capture the relevant strategic demand from PLD. This approach is impossible for passing local demand from PS back to PLD; therefore, a "preload" approach is required. This approach requires the identification of both the services which can transport a mix of long-distance and local trips, and the links where the mix of long-distance and local trips are relevant, and passes the demand on a segment basis[11] from PS through to PLD.

The PLD-PM interface relies solely on the preload process in both the PLD to PM and the PM to PLD directions.

The relationships between the sub-models in the PLD Framework necessitate sequential running of the models to allow passengers on long-distance services to be passed between sub-models and vice versa.

The model can be run in 'Base' or 'Test' mode, where 'Base' refers to the 'Do Minimum / without HS2' scenario and 'Test' refers to the 'Do Something/With HS2' scenario. As each model operates iteratively (i.e. changes in demand and mode share are driven by changes in the travel costs for each mode), the Test case represents the impact of a change relative to the Base case. Before running the model in Test mode, a compatible Base model run is required.

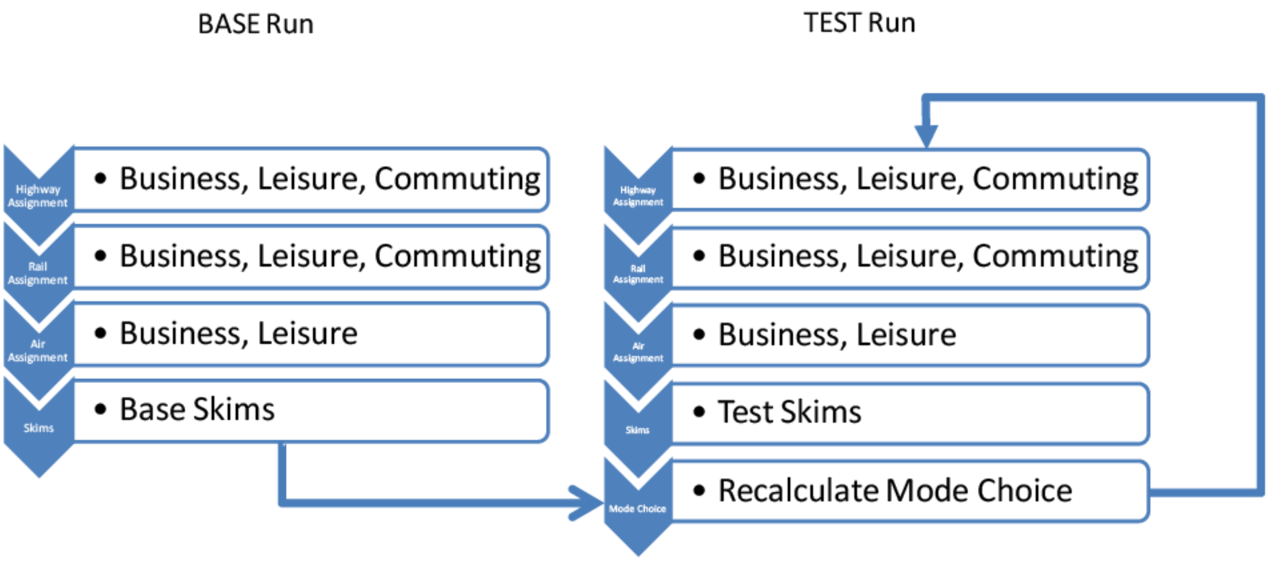
The Base mode operates with fixed demand: the mode choice and generation functionality is switched off in PLD and the elasticity functionality is switched off in regional models. The 'Base' mode is used for future year model runs, to produce the base case around which options can be tested.

The 'Test' mode builds on the 'Base' mode, with the final run of Regional models with elasticity switched on and PLD with mode choice and generation also enabled.

11 A "segment" is a transit line attribute in emme2 and refers to an individual transit line on a specific link.

Figure B.1 shows the process diagrammatically.

Figure B.1: PLD Framework January 2012



B.3. PLD Framework February 2011 Update

Revised forecasts and a revised business case for the London-West Midlands scheme were presented in February 2011 for the London-West Midlands public consultation. These forecasts resulted from changes to the modelling framework, revised economic forecasts and updated scheme appraisal. The following is a summary of the elements of the model that were enhanced.

The following technical adjustments were made to the model:
- improvements to model stability through changes to the do-minimum scenario;
- revision of interaction between PLD and PS;
- updates to the Heathrow ADM;
- changes to behavioural values of time; and
- corrections to coding of certain rail services on the WCML

A number of changes were made to the station choice model to correct certain anomalies and improve the accuracy of the model. These included:
- the application of behavioural weighting to London local leg benefits;
- the removal of double weighting of local leg time transferred to PLD;
- the application of local leg times and station shares on a production/attraction basis, rather than O/D;
- the revision of London local leg costs for London-West Midlands movements;
- the addition of West Midlands local leg costs to non-London movements;
- the calibration of the parameter controlling users' sensitivity to generalised cost; and
- adjustments to access times to reflect the relative ease of interchange at Old Oak Common compared to Euston.

The February 2011 model updates incorporated the impact of revised economic growth forecasts and changes to Government policy. This required the following changes to the model:
- an update to demand matrices to reflect revised short and medium-term economic growth forecasts (changes in demand meant that the demand cap year changed to 2043);

- changes to rail fares to reflect the impact of the Government's policy on regulated rail fares (RPI+3% for three years);
- the use of DfT's unconstrained air demand forecast, rather than constrained for GB internal air demand; and
- revised forecasts for Heathrow throughput for the ADM to reflect change in Government airport expansion policy.

The following changes were incorporated into the appraisal process:
- the inclusion of 'business - no car available' rail benefits;
- the revision of weightings of generalised journey cost components; and
- the change to the value of time.

Note that some of the technical improvements were short-term solutions (e.g. changes to the station choice model) and would not be included in the PFM. Changes to demand and the appraisal process would be carried forward to the PFM model. Full details of these changes can be found in the following reports:

- WS Atkins Modelling and Appraisal Updates and their impact on the HS2 Business Case - A Report for HS2 December 2010
- MVA-Mott MacDonald Model Development and Baseline Report April 2011

B.4. PLD Framework January 2012 Update

For the revised economic case in January 2012, a comprehensive programme of additional work was undertaken to improve the robustness of the modelling and appraisal and update assumptions underlying the forecasts to reflect political and economic changes. This additional work was focused on updating the base-year models to represent 2010/2011, future-year demand to reflect the latest economic forecasts and future-year supply to reflect the latest information. All the updates to the base-year and future-year demand and supply would be carried forward into the PFM.

Base-year demand for all of the PLD Framework models (PLD, PS and PM) was updated to 2010/2011. For PLD, rail, air and highway demand was updated. The most significant of these updates was the change to rail demand, which was updated using data from the rail industry's ticket sales database, LENNON, to represent the financial year 2010/11. Air demand matrices were updated using the latest observed data. Highway demand was updated by applying growth factors to the existing demand matrices.

The base-year networks and fares were also updated. Rail service transit lines were updated based on the Summer 2010 timetable. Air services were updated using CAA punctuality statistics for October 2010, supplemented with data on regional services sourced from airline and airport websites. The highway networks were updated to include any highway schemes that opened between October 2007 and October 2010 that could be represented in the PLD network (based on Highways Agency/DfT data). Rail fares and air fares were also updated to observed 2010 levels.

Future-year demand has been updated for all models and modes based on the latest economic forecasts. Rail demand has been updated based on the latest economic forecasts using growth factors derived from

EDGE[12]. Highway demand was grown using information from TEMPRO version 6.2. For GB internal air demand, factors reflecting the central case scenario of the DfT's latest UK aviation forecasts (August 2011) were used.

Future rail supply has been changed based on updated assumptions on future rail services without HS2 as a result of increased information and Government commitment to additional rail enhancement schemes. Future-year air networks were developed using the DfT's aviation model. For the highway network, the previous list of schemes that had been provided by the DfT was reviewed against the Highways Agency's current programme, with the revised list of schemes reflecting new scheme completions and the removal of withdrawn schemes.

A number of other minor changes were required to the framework in order to account for the updated supply and demand data and to make a minor correction to model functionality. These included:

- Preload Factors – factors to be applied when long-distance passenger flows are transferred from the peak-period regional models to the all-day PLD have been updated;
- Wormhole Factors – factors to convert all-day PLD flows crossing the PLANET South cordon to peak period for use in PS were recalculated using the new 2010/11 demand in PLANET South and PLD;
- Birmingham Connectivity – modelling of the interconnectivity between Birmingham International and Birmingham Interchange (HS2) and between New Street and Curzon Street has been improved;
- Manchester Connectivity – modelling of the interconnectivity between Manchester stations has also been improved;
- Functional Changes – minor adjustments were made to model macros and batch files to reflect the use of new base and forecast years.

The model updates are detailed in the Model Development and Baseline Report, April 2012, including comparisons with the earlier 2007 base.

B.5. The PLANET Forecasting Model (PFM)

The development of the PFM was originally driven by the desire to enhance the existing modelling framework to better model the extended network from the West Midlands to Manchester and Leeds. The objectives and requirements were defined in a series of briefs from HS2 Ltd.

Subsequently, further enhancements to the modelling framework have been identified through application of the framework, and a series of updates to the economic forecasts underlying demand have occurred which ultimately needed incorporating into the PFM.

In developing the current version of PFM, an interim version was developed, known as PFM v2. The development of this interim version is outlined below. The remainder of the report refers to the current version of PFM (PFM v3).

12 EDGE is the DfTs rail exogenous growth-forecasting model.

B.6. PFM Version 2

It was recognised that, in its current form, the PLD Framework was unsuited to analysing the extensions to Manchester and Leeds because of the limitations in the modelling of local rail journeys and station locations in the existing framework. The requirements for PFM were defined as:

- *Analysing the demand and appraising the benefits of high speed rail links between London, Birmingham, the East Midlands, Sheffield, Leeds and Manchester. This includes being able to optimise service patterns between different locations (including for non-London passenger flows);*
- *Advising on the potential for classic-compatible services (i.e. those using both high speed and classic networks for parts of a journey) that may run beyond Manchester and Leeds;*
- *Advising on the implications of different station locations in or around key cities along the line of route. This should include, as a minimum, Manchester, Leeds, Sheffield and the East Midlands (including Derby, Nottingham and Leicester). This must be of a sufficient geographical resolution to enable different options both within and around each location to be compared;*
- *Advising on the potential uses of capacity that high speed rail may free up on the classic network, both for short and long-distance services on the WCML, ECML and MML;*
- *Identifying any crowding issues in PLD, in either the base case or 'do-something', that may be caused by short-distance passengers being falsely assigned to long-distance services. This issue is particularly relevant on the ECML, WCML (north of Birmingham) and MML, where we suspect there may be issues with too much demand on long-distance services.*
- *Being as consistent as possible with the existing PLD, so that the appraisal of HS2 between London and West Midlands and the extensions to Leeds and Manchester are consistent. This means that, as far as possible, the business case of the "day 1" network between London and the West Midlands should remain stable.*

Subsequently, HS2 Ltd issued two briefs to develop the modelling framework to address some of the above requirements, the first brief concentrated on expanding the model framework to include PLANET North and PLANET Midlands in its entirety. The second brief developed a revised SCM for PLD and provided the combination of the two elements.

The development brief for the development of an enhanced PLD, with better representation of local services in the North, stated:

- *We require that either PLANET North or an equivalent local model be integrated into the PLD framework in a similar way to which PLANET South and PLANET Midlands have been integrated.*
- *Any changes to the underlying data or parameters in PLD are out of scope; and*
- *The development work under this work package is purely related to resolving the issues of modelling local rail trips*

The development brief for understanding demand impact of different station locations stated:

We… require analysis on station locations that will:

- *be able to distinguish between possible station locations in each of these areas and understand the different demand and benefits of each location;*
- *identify interactions between station catchment areas (such as between Leeds and Manchester or East Midlands and Sheffield);*
- *identify the accessibility of different modes and the likely modal split of passengers accessing each location option, and to enable some high-level analysis of the likely impacts on crowding/congestion on the local network;*

- *be of sufficient geographical resolution to allow HS2 Ltd to effectively distinguish between different locations within and around each city option – particularly the difference between locations in a city centre against those in the outskirts of an urban area;*
- *understand the likely impacts on local transport networks;*
- *assess the impacts of serving regional airports. The most important of these will be Manchester, although East Midlands and potentially Leeds/Bradford may also be of interest. We wish to understand the number of airport users who may wish to use HS2 to get to or from the airport as a result of easier accessibility. Bidders are also invited to suggest what analysis might be undertaken to look at how the airports markets might change and develop as a result of high speed connectivity.*

Combined, the work carried out under these briefs constitutes the model development carried out to develop the PFM.

B.6.1. Supply and Demand

Demand

Future-year demand for all models and all modes of transport in PFM v2 is consistent with the demand included in the February 2011 version of the PLD Framework. As there is no Planet North in the PLD Framework and the coverage of Planet Midlands is very different compared to the PFM, a process to update the demand in these models to be compatible with the February 2011 version of the forecasts had to be developed.

Supply

The representation of supply in PFM v2 was initially consistent with the February 2011 version of the PLD Framework. This includes the 'do minimum', the HS2 service specification and the released capacity specification.

As there is no PLANET North in the PLD Framework model, services were derived from the PLANET North model. Note that the geographical representation of supply in PLANET South is consistent in both models.

The PFM v2 model has subsequently been used to refine both the HS2 service specification and the released capacity specification; the final version of PFM v2 incorporates these changes.

B.6.2. Other Technical Changes

A small number of technical adjustments have been necessary to address issues identified during the application of the model. These were as follows:

- **Modelled years** – The modelled year and value of time and fares were changed to be consistent with the March 2011 version of the PLD Framework.
- **Station connectivity** – The connectivity between city-centre stations in both Manchester and Birmingham has been improved to address weaknesses in the existing model.
- **Model stability** – Adjustments have been incorporated into the model architecture to improve model stability.

B.7. PFM Version 3

PFM v3 is a development of PFM v2. The key changes going from PFM v2 were:

- further enhancements to model functionality to improve model performance;
- revised base year of 2010;
- revised future-year demand and supply assumptions consistent with the January 2012 version of the PLD Framework; and
- Further development of HS2 service specification and released capacity service specification

B.7.1. Enhancements to model functionality

The key enhancements to the model functionality were:

- the preload transfer interface updated between PS and PLD to be consistent with other regional models. (Note that the process between PLD and PS remains a wormhole process.)
- minor upgrades to the station choice model, including adjustments to London stations.

B.7.2. Updates from January 2012 version of PLD Framework

All of the updates included in the January 2012 version of PLD Framework model were incorporated in PFM v3. In addition, for PLANET North, revised rail service coding and revised 2010 rail demand matrices have been incorporated.

As the PLD Framework does not include PN, separate PN demand matrices were specifically developed for PFM v3 using the EDGE forecasting process.

Appendix C. Preload Transfer Process – Worked Example

C.1. Worked Example

A set of spreadsheets have been developed to automatically transfer demand from one model to another using VBA coding to import the extracted demand, calculate the preloads for the 'destination' model and export the data to an EMME-friendly format.

Segment data is extracted from the 'from' model in the format shown in **Figure C.1**. This data is from the PM model, which extracts the segment demand for business, leisure, commuting (segment data attribute names @vlbiz, @vllei, @vlcom) as well as headway. Segment data from PLD also includes disaggregation by car availability and production/attraction.

Figure C.1: Sample of Segment Data for Preload Mechansim

	A	B
1	line	inode
2	AW101-	91
3	AW101-	91
4	AW101-	91
5	AW101-	91
6	AW101-	91
7	AW101-	91
8	AW101-	91

Each spreadsheet contains the following data to enable the preload mechanism to transfer the correct demand:

- a list of links that are within areas applicable for preloads, such as urban areas or strategic corridors;
- a list of transit lines and associated packets for both the 'from' model and the 'to' model; and
- Factors to transform peak flows to all-day and vice versa.

This approach produces preload demand by segment, for reading into the 'to' model. Note that disaggregated demand by purpose and car availability is not fed through this process. This is not an issue because the preloads are not subject to demand responses.

Figure C.2 provides an example of the preload mechanism from PM to PLD for one packet (PMCH01A)[13], followed by an explanation of the calculations.

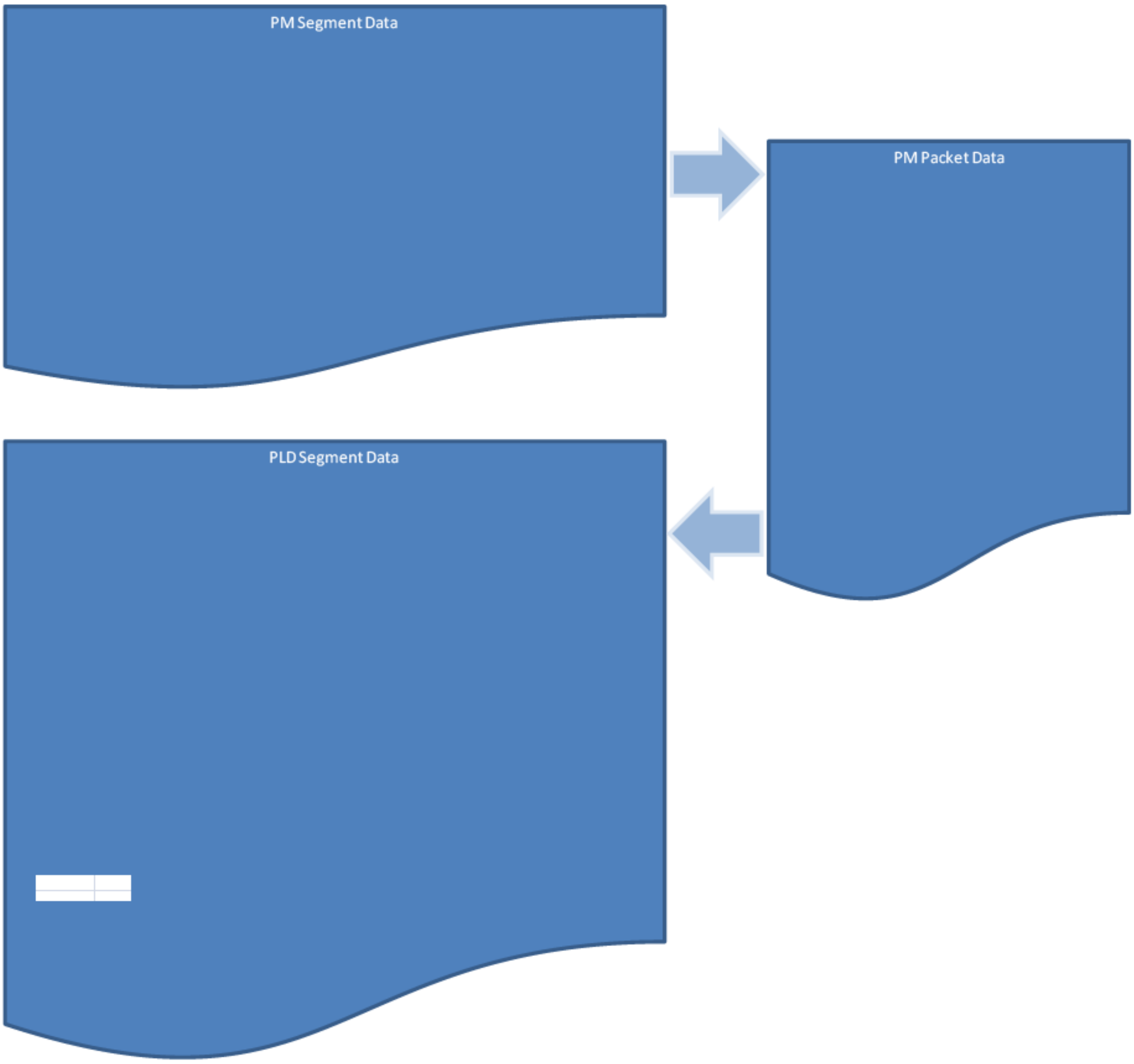
The following steps are carried out in the calculation of the PMCH01A packet:

- Step 1 – extract total demand for each segment (from PM model), including the reverse direction.
- Step 2 – calculate total demand for each segment by packet (PM model), including the reverse direction (581.8 and 361.0 respectively).
- Step 3 – extract headway for each segment by packet (PLD) (grey area in "PLD Segment Data") and calculate total number of trains on the PLD segment (31).

[13] Preload_PM_to_PLD_DS.xls, from final iteration of PFMv2_31_AA_3010.

- Step 4 – factor to transform packet demand to the relevant time period (average of the packet flow and the reverse packet flow[14]) - not shown in the diagram but is 2.67*(581.8+361.0)/2=1258.7.
- Step 5 – reallocate demand for each segment (using headway of service to weight the demand in the packet) – column labeled PLD Segment Preload.

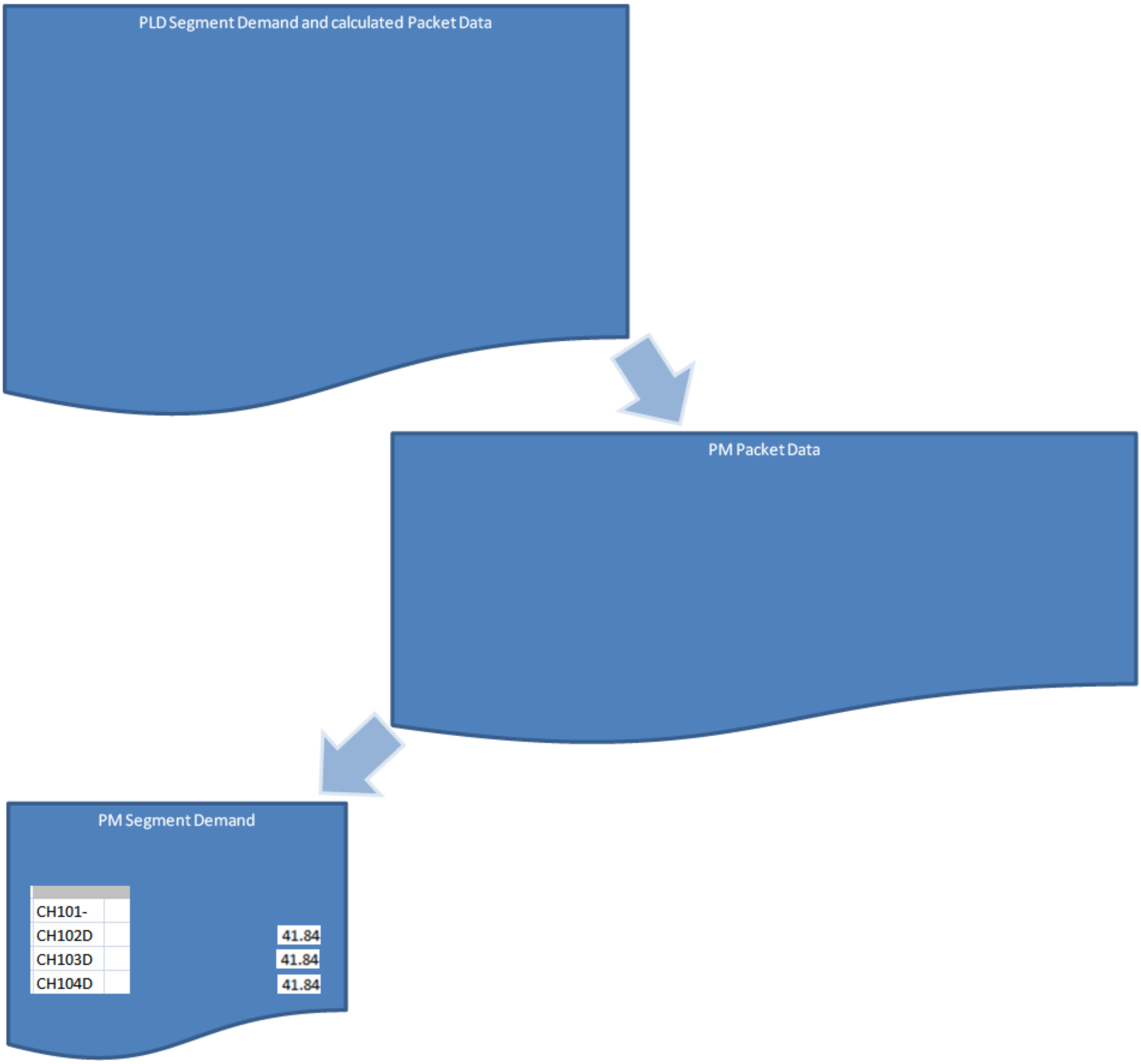
Figure C.2: PM to PLD Preload Mechanism Example



[14] Note that the average of the two flows is a simplification. It is poss ble to calculate the demand based on the 'blueness' factor, which weights the demand based on the directionality of the demand in PM. This has not been implemented yet, as it is a considerably more complex process

Similarly, **Figure C.3** provides an example of the preload mechanism from PLD to PM for the same packet as above (PMCH01A)[15], followed by an explanation of the calculations.

Figure C.3: PLD to PM Preload Mechanism Example



The following steps are carried out in the calculation of the PMCH01A packet:

- Step 1 – Extract total demand for each segment from PLD model.
- Step 2 – Calculate total demand and number of trains per packet for each segment (760.1 and 31, respectively).

[15] Preload_PM_to_PLD_DS.xls, from final iteration of PFMv2_31_AA_3010

- Step 3 – Extract headway for each segment by packet (PM model) (grey area in "PM Packet Data") and calculate total number of trains on the PM packet (4).
- Step 4 – For each PM segment, multiply packet demand by the relevant factor shown in Table 4.1, multiply by trains per segment and divide by trains per packet (using headway of service to weight the demand in the packet), so for CH101- the PM segment preload is: 760.6*0.22*1/4 = 41.84 (in this example, the demand is distributed evenly for each service, as the headway is the same for each).

Appendix D. Station Choice Model

D.1. SCM Operation Modes

The model was originally planned to carry out both the function of producing the station-to-station demand matrices and the average weighted PLD zone-to-PLD zone cost matrices. The SCM must be run twice during each iteration of the PLD model, which makes the run time of the SCM critical to the run time of the PLD model. As the proportion of passengers using each mzone-to-station-to-station-to-mzone will change only when there are new station-to-station cost skims, it was decided to produce model versions that use the proportions produced from a full SCM model run to either carry out the disaggregation of demand or the aggregation of cost functions to reduce PLD model run times without affecting the convergence of the PLD model.

The SCM can therefore be run in three modes:

- Full mode (0) – calculates the full generalised journey times (including access and egress costs), demand shares from the logit model and station-to-station demand and a file of PLD zone-to-PLD zone demand shares;
- Demand mode (1) – uses the file of PLD zone-to-PLD zone demand shares to distribute PLD zone-to-PLD zone demand to station-to-station demand; and
- Cost mode (2) – uses the file of PLD-to-PLD demand shares and PLD-to-PLD access/egress cost data to aggregate the station-station cost skims to PLD zone-to-PLD zone cost skims.

The SCM has to be run in full mode initially to produce the files needed for the demand mode and cost mode versions. The demand mode and cost mode SCM modes run significantly quicker than the full mode. This has meant that two output text files essential to running in demand mode and cost mode must be output from the full mode run of the SCM:

- PLD zone-to-PLD zone demand mode shares by purpose; and
- PLD zone-to-PLD zone access/egress costs by purpose.

The SCM is constructed as a Win32 console application. The executable file is compiled using MS Visual C++ 2008 SP1. It works in a standard Windows environment with the run time components of Visual C++ Libraries installed.

The model is run by entering the command

```
SCM x
```

Where x is 0, 1 or 2 depending on the mode in which it is to be run. If the x is omitted, the model is run in full mode.

D.2. SCM model Outputs

As well as the station-to-station demand matrices, the SCM also calculates rail access/egress demand for feedback into PLANET Midlands, PLANET North and PLANET South. The rail access/egress demand is estimated as certain fixed proportions of PT access/egress. The rail proportion factors differ by access distance and station type, and are described in more detail in Section 3. It should be noted that these outputs from the SCM have not been used because of how benefits from regional PLANET model are calculated.

By default, the SCM outputs:

- station-to-station demand matrices (for PLD);
- demand-weighted PLD-to-PLD component transit times (rail in-vehicle times, auxiliary transit times, total wait times, total boardings, rail-only boardings, rail additional crowded rail fares) for PLD;
- rail access/egress demand for the local models (PLANET Midlands, PLANET North and PLANET South), represented in station zone-to-station zone formats compatible with the local models;
- PLD zone-to-PLD zone demand mode shares by purpose; and
- PLD zone-to-PLD zone access/egress costs by purpose.

The last two outputs files are required for running the SCM in demand and cost modes.

In addition, the SCM can output the following for diagnostic purposes:

- PLD zone-to-station access demand, total and by access mode;
- Station-to-PLD zone egress demand, total and by egress mode;
- mzone-to-station access demand, total and by access mode;
- Station-to-mzone egress demand, total and by egress mode;
- PLD zone-to-PLD zone demand by available station pair; and
- PLD zone-to-PLD zone access egress cost by purpose and
- mzone-to-station generalised cost of access by mode.

N.B. These are not exported by default to reduce run time.

D.3. SCM Application

The SCM application tool is the user-end interface for running the SCM. It is compiled using MS Visual C++ 2008 SP1. It works in a standard Windows environment with the run time components of Visual C++ Libraries installed.

The SCM application tool reads in a set of input files which include the model parameters, the PLD zone to SCM mzone distribution split (i.e. outputs from the gravity models), PLD zonal demand and station-to-station transit time matrices. Some of these input files are static inputs to the SCM and are formatted as tab-separated text files. Others are dynamic inputs to the SCM, generated in each PLD run, and are formatted as EMME files with a .311 extension.

The SCM application tool processes the input data, and outputs a set of text files, as defined by the user. Some of these output files are fed back into PLD and thus are formatted as EMME files; the rest are optional output files mainly for diagnostic purposes, formatted as tab-separated text files.

Details of the input and output files and how the SCM application tool is executed in practice are provided in the *Information note IN11 Station Choice Model User Guide*. This section will focus on the processes behind the SCM application.

D.4. Processes behind the SCM Application

The following paragraphs provide a step-by-step walk-through of the processes in the SCM application tool.

Step 1: Reads in a set of input parameters which defines the model parameters and the required set of output files for the SCM run.

In Full Mode

Step 2: Reads in the definition of the stations available to each PLD zone. A maximum of 15 stations is allowed for each PLD zone to allow for a reasonable set of station options while maintaining a reasonable run time. A count is made of the number of stations defined for each PLD zone. This is the same number of stations available for each mzone, as there is a one-to-one relationship between mzone and PLD zone.

Step 3: Reads in the PLD zone to SCM mzone distribution.

Step 4: Reads in station-specific attributes for all stations considered in the SCM. There are 225 stations in total, including both key classic stations, HS2 stations and allowing for further stations. The total number of stations (225) is a constant in the code and changing it requires the code to be recompiled. Increasing the number of stations will increase the mode run-time.

Step 5: Reads in mzone to station access times and distances (outputs from NAM). The stations that are available to each mzone should be compatible with the definition under the PLD zone to station lookup (step 2). Due to the large number (and implied matrix size) of PLD zones, mzones and stations, there is no direct file linking all three of these relationships together. The PLD zone to SCM mzone distribution file (step 3) sets the one-to-one relationship between mzone and PLD zone. The mzone to station access time and the PLD to station lookup file (step 2) set up the relationships to the station. The ordering of the stations in both files must be the same for each mzone and their respective PLD zone.

Having read in the access distance between mzone and station, the generalised cost of access by highway and by PT is calculated, and the proportion of rail access with respect to all PT access determined for each mzone and station pair.

Step 6: Reads in mzone to local model station zone lookup. When activated this is used for passing the rail access/egress trips back to PLANET North, PLANET Midlands and PLANET South to provide some representation of crowding as a result of local rail access/egress.

Step 7: Sets counter i to 1 for the first journey segment (Para 2.6); a total of nine journey segments need to be processed.

Step 8: Read in PLD zonal demand for the i^{th} journey segment.

Step 9: Read in station-to-station component transit times for the i^{th} journey segment. The generalised journey time for the long-distance rail journey between each station-to-station pair is calculated from its component times.

Step 10: PLD zonal demand is distributed to the mzone level to obtain mzone-to-mzone demand for the i^{th} journey segment.

Step 11: For each origin mzone and destination mzone pair, the available station-to-station pairs (i.e. routes) are determined.

Step 12: Calculate the utilities of travel between the O-D mzone pair by highway and by PT access/egress, taking into account the GJTs of access, egress and the long-distance rail journey. If the origin/destination mzone is in London, highway access/egress is set as 'not available' accordingly; in this case all car availability trips are forced to use the PT accessibility data.

Step 13: Calculate the composite costs of the whole journey separately for the highway option and for the PT option; from this, the probabilities of choosing highway and PT are determined.

Step 14: Calculate the composite costs of the whole journey (logsum of the highway and PT options for the O-D mzone pair). This is the most efficient place for it to be calculated and it is stored for Step 18.

Step 15: Calculate the probabilities of choosing individual station-to-station pair options, conditional upon the highway option and the PT option respectively. These are summed to obtain the probabilities of choosing the individual station-to-station pairs.

Step 16: Calculate the demand choosing individual station-to-station pairs from the probabilities from Step 15 and mzone-to-mzone demand from Step 10.

Step 17: Aggregate mzone-level demand to PLD zonal level for outputs. Station-to-station demand across all O-D mzone pairs are also summed for outputs.

Step 18: mzone-level whole-journey composite GJT (from Step 14) is aggregated as a demand-weighted average to obtain PLD zone-to-PLD zone whole-journey composite GJT.

Step 19: PLD zone-to-PLD zone rail component GJT (rail in-vehicle time, rail auxiliary transit time, wait time, total boardings, etc.) are computed as a demand-weighted average from the station-to-station component GJT (for the complete PLD zone to mzone to station to station to mzone to PLD zone set).

Step 20: PLD zone-to-PLD zone auxiliary transit time is calculated. This takes into account the station-to-station auxiliary transit time, as well as the access and egress times. This method of calculation is used to ensure that the total GJT is the composite cost of the whole journey. The former is calculated as the demand-weighted average of the station-to-station component of the rail-leg auxiliary transit time (and hereafter referred to as PLD-to-PLD walk time). The latter is calculated as:

PLD-to-PLD access egress time
= (PLD-to-PLD whole journey GJT (Step 19)
- (PLD-to-PLD rail ivt) - 4 × (PLD-to-PLD walk time (Step 20))
- 2 × (PLD-to-PLD total wait time) - 30 × (PLD-to-PLD total boardings)

PLD-to-PLD auxiliary transit time
= (PLD-to-PLD walk time) + (PLD-to-PLD access egress time)/4

Step 21: Produces output files for the i^{th} journey segment as required. Rail access/egress demand are calculated, mapped to the local model station zones and exported.

Step 22: Reset the demand matrices to zero (to prepare for calculations for the next journey segment).

Step 23: Set i equals to i+1 for the next journey segment.

Step 24: Repeat Step 8 to Step 23 until i is greater than 9 (for the last journey segment).

Step 25: Output the access GJT by mode (hw/pt) if required.

Step 26: With flag 42 (output_PLDstn_stnPLD_demand) turned on outputs PLD-station-station-PLD demand share files to the appropriate file.

In 'Demand' Mode

Step D2: Reads the PLD-station-station-PLD demand share file.

Step D3: Reads the PLD zone-to-PLD zone matrix files.

Step D4: Calculates the station-to-station demand matrices by multiplying the PLD zone-to-PLD zone demand by the relevant PLD-station-station-PLD demand shares.

Step D5: The station-to-station demand matrices are output.

Step D6: If the appropriate output flags are on the 'PLD zone' to station access demand totals and the 'station to PLD' zone egress demand are produced.

In 'Cost' Mode

Step C2: Reads the PLD-station-station-PLD demand share file.

Step C3: Reads in the PLD-PLD access egress cost text file. This file needs to have been created first during a full mode SCM run with flag 39, output_PLDPLD_AccessEgress, turned on.

Step C4: Reads in the station-station cost files.

Step C5: The station-to-station cost skim files are converted to PLD zone-to-PLD zone cost skim files by summing the multiplication of the station-to-station costs with the PLD-station-station-PLD demand shares. In addition this step uses the PLD to PLD access egress text file to calculate the PLD-to-PLD GJT. (This file is also created in a full mode SCM run with flag 39, output_PLDPLD_AccessEgress, is turned on.)

Step C6: The PLD zone-to-PLD zone skim files are output. In this process the PLD access egress costs are added to the PLD-to-PLD walk costs, so they are included in the GJT that the PLD mode share model used.

In addition, the following checks are made:

- If there is no PLD-to-PLD demand, the calculation of station-to-station demand is put to 0 alongside composite cost data;
- If a station is a 'key SCM' station, then mzone-to-station-to-mzone movements are permitted. For example, if Toton station is not defined as a 'key SCM' station, it would be possible for someone travelling from Derby to Nottingham to access Toton station from Derby and then make an egress trip to Nottingham without having made a rail trip, whereas we would wish to force it to use the rail network. We cannot outlaw all of these trips, as in places like Scotland or Wales, where the PLD rail network is poorly defined – it may be the only reasonable way of getting between two mzones. The 'key SCM' stations are therefore defined in the StnAttributes file; and
- Whilst all zones with defined access to a PLD/mzone are assumed to have highway access, PT access can be turned off by setting the PT parameter in the accesscost file to 0.

The SCM is complete following the above steps. In practice, the SCM application tool can be executed as a stand-alone application or in conjunction with PLD, where it is run in each iteration of the PLD framework.