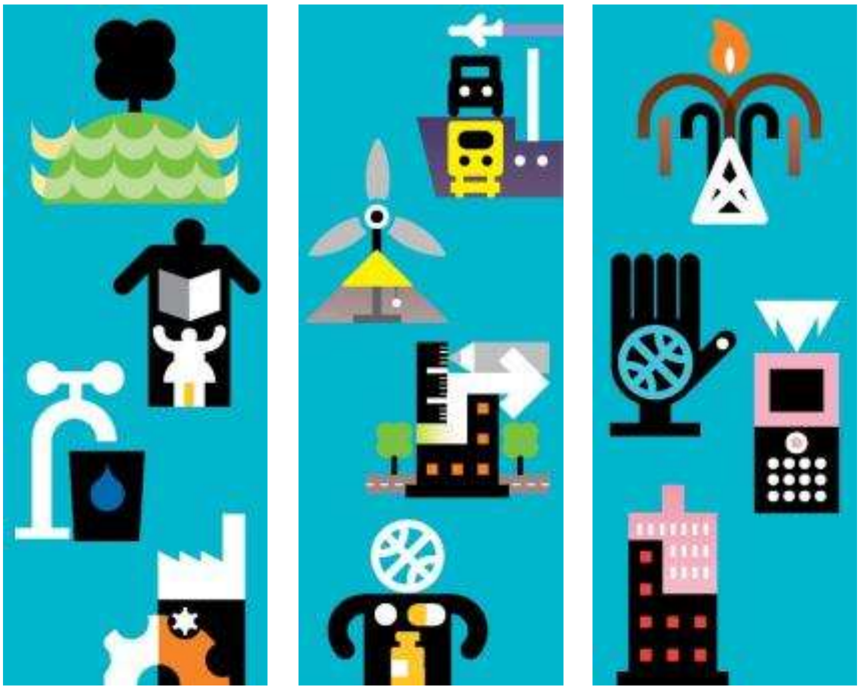

PRIISM Local Model Validation Report

September 2014

PRISM Management Group

Mott MacDonald

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1	10/09/14	Stacey Luxton Mike Oliver Jevgenija Guliajeva Nick Taylor	Tim Slater (Centro, PT sections) Mike Oliver	Philip Old	First issue	

Contents

Executive Summary

Background

The West Midlands' Policy Responsive Integrated Strategy Model (PRISM) is a multi-modal disaggregate demand model of the West Midlands Metropolitan Area. The model comprises separate highway and Public Transport (PT) assignment models linked together with a demand model. PRISM was originally developed to represent a 2001 base and was later rebased to 2006. Mott MacDonald was commissioned by the PRISM Management Group (PMG) to undertake a comprehensive update and to produce updated highway and public transport models for a 2011 base year. This report documents the development of the 2011 base year models, including the variable demand model.

Key Features

The highway models represent an average weekday for three time periods; the AM average hour from 0700 to 0930, the IP average hour from 0930 to 1530 and the average PM hour from 1530 to 1900. Four user-classes are modelled; Car Work, Car Non Work, LGV and HGV. The models use an equilibrium assignment procedure that incorporates detailed junction modelling and blocking back within the Area of Detailed Modelling.

The PT models represent an average weekday for three time periods; the AM average hour from 0700 to 0900, the IP average hour from 1000 to 1200 and the average PM hour from 1600 to 1800. Three user-classes are modelled; "Fare", "No Fare" and PLANET Long Distance. The assignment methodology makes use of the headway based assignment and parameters provided in the VISUM software.

The demand model consists of the following three main components: the Population Model, the Travel Demand Model and the Final Processing Model. The outcome of these three processes is a set of revised demand matrices for assignment in the HAM and PTAM. These new matrices include responses to cost changes in the assignment model.

Data Collection

A comprehensive data collection exercise was undertaken in the development of the models. Data collected included Road Side Interviews, household travel surveys, public transport user surveys, GPS data including TrafficMaster and INRIX, NAVTEQ, automatic and manual traffic counts and journey time data.

Model Development

The 2011 base year highway and public transport networks were developed based on the existing networks. Junction coding within the Area of Detailed Modelling was reviewed and updated based on aerial photography, the Integrated Transport Network (ITN), NAVTEQ and consultation with the PMG. The zoning system was also updated, allowing for the disaggregation of certain zones to allow for finer distribution of demand and for consistency with the PT assignment model. The services within the public transport model were updated based on ATCO-CIF data.

Model Calibration and Validation

The prior trip matrices were assigned to the highway and public transport networks and comparisons of the outputs were made to observed data. A matrix estimation process was then undertaken for different user-classes. Matrix estimation is a process whereby non-zero matrix cell values are adjusted so that modelled flows better match observed. The estimated matrices were then assigned to the networks and compared against observations to assess the level of validation and additionally for highway compared against observed journey times.

Individual comparisons show that the models produce base year traffic flows and passenger demand consistent with those observed. Trip length distribution comparisons show that matrix estimation has had little effect on mean trip lengths.

The response of the PRISM variable demand model to changes in car fuel cost, public transport fares and car journey time is realistic, albeit slightly outside the recommended WebTAG ranges in some cases. The relative elasticities within each test between demand segments is also realistic, suggesting PRISM is a robust model for forecasting the travel demand patterns of the West Midlands population.

The calibration process produced a model that closely fits observed link traffic flow and journey time observations.

1 Introduction

1.1 Overview

The Policy Responsive Integrated Strategy Model (PRISM) is a multi-modal disaggregate demand model of the West Midlands Metropolitan Area. The model comprises both a highway and a public transport assignment model linked with a demand model. The client is the seven Metropolitan districts of the West Midlands, the Highways Agency and Centro.

PRISM was originally developed to represent a 2001 base year and was later rebased to 2006. Mott MacDonald has been commissioned to develop a 2011 base year model.

This Local Model Validation Report (LMVR) describes the development of the PRISM Refresh 2011 base year highway assignment model in detail, and presents the level of validation achieved against observed traffic flow and journey time data. Other PRISM Refresh reports of relevance are:

- PRISM Refresh Technical Note 1: Zoning (Mott MacDonald, June 2012)
- PRISM Refresh Technical Note 3: Highway Network Build (Mott MacDonald, December 2012)
- Data collection:
  - PRISM Surveys 2011: Household Travel Survey (Mott MacDonald, November 2012)
  - PRISM Surveys 2011: Public Transport (Mott MacDonald, November 2012)
  - PRISM Surveys 2011: Roadside Interviews (Mott MacDonald, November 2012)
  - PRISM Surveys 2011: Urban Centres (Mott MacDonald, November 2012)
- PRISM Demand Model:
  - PRISM 2011 Base: Mode-Destination Model Estimation (RAND Europe, 2014)
  - PRISM 2011 Base: Frequency and Car Ownership Models (RAND Europe, 2014)
  - PRISM 2011 Base: Demand Model Implementation (RAND Europe, 2014)

The highway assignment models have been developed in accordance with the Department for Transport (DFT) online Transport Analysis Guidance (WebTAG) http://www.dft.gov.uk/webtag and the Highways Agency (HA) Design Manual for Roads and Bridges (DMRB) Volume 12, as well as Mott MacDonald internal Best Practice guidelines.

1.2 Uses of the Model

1.2.1 Scenarios and Interventions

PRISM was originally designed in 2001 and since its development in 2004 it has been used for a wide range of applications. This has included support for the assessment of local development plans, major scheme business cases, local models and as a database of travel and transport information. As a database of travel movements, PRISM has provided input to more local models, including microsimulation.

As in the past, it is intended that future transport and land use planning projects in the West Midlands that require modelling support will use PRISM, either as the database of network detail, planning data or travel demand patterns, or as a fully functional tool. The database may be more useful for smaller scale studies, for which cordoned networks and/or matrices can be generated for the years 2011, 2021 and 2031, whilst the full model specification becomes more relevant when forecasting the impacts of strategic transport schemes or substantial land use changes in the future.

1.2.2 Key Design Considerations

PRISM is the Strategic Transport Model for the West Midlands. The model's geographical area, modal representation, functional responsiveness and segmentation have been designed to reflect the intended uses of the model which are:

- To support development of local and regional transport and land use policies.
- To support Major Scheme Business Cases.
- To provide network inputs and consistent demand forecasts for local studies.
- To be a database of travel demand data in the West Midlands Region.
- To provide the Highways Agency with a robust regional modelling tool for projects and programmes in the West Midlands.

The model's design focuses on the above objectives, also recognising the investment in the original model in 2001, consistency with results and assumption previously made, and constraints imposed by software and reducing funding budgets.

As part of the consultations of the PRISM Management Group (PMG) it was decided that a new unified Public Transport model should be created alongside the PRISM HAM and that the PT model should be made by taking elements from two previous models; the Centro 2005/2008 PT Model and the PRISM 2006 PT Model. Where previously the models were used separately and could feed into each other the 'Unified' model can be used separately by the relevant parties.

This provides many benefits:

- The ability for parties to work separately, removing errors that occur from the exchange of data between parties and between both models;
- Greater accuracy of skims and route choice throughout the model;
- Provision for Centro to use larger networks with a wider coverage;
- A more detailed zoning system which means that users are fed more accurately onto the network than previously; and
- The ability for more than one party to work together on the model.

2 Highway

2.1 Model Standards

2.1.1 Model validation criteria and acceptability guidelines

For all elements of highway assignment validation, the validation criteria and acceptability guidelines used are as stated in TAG Unit 3.19, except where noted.

2.1.1.1 Trip matrix validation

For trip matrix validation, the measure used was the percentage difference between modelled flows and observed counts. The criterion and acceptability guideline for screenline flows are defined in Table 2.1.

Table 2.1: The acceptability guidelines for trip matrix validation

Criteria	Acceptability guideline
Differences between modelled flows and counts should be less than 5% of the counts	All or nearly all screenlines

Source: WebTAG Unit 3.19 (M3.1, Section 8.3.18 and 3.2.5)

Differentiations are made between the following types of screenlines:

- Roadside interview
- Other screenlines used in matrix calibration
- Independent validation

2.1.1.2 Link flow validation

For link flow validation, the measures used were:

- The GEH statistic, which incorporates both relative and absolute errors; and
- The absolute and percentage difference between modelled flows and observed counts

The TAG Unit3.19 criteria and acceptability guidelines for link flows are defined in Table 2.2.

Table 2.2: The WebTAG 3.19 acceptability guideline for individual link flow validation

Criteria	Description of criteria	Acceptability guideline
1	GEH <5 for individual flows	>85% of cases
2	Individual flows within 100 vehicles/hour of counts for flows less than 700 vehicles/hour	>85% of cases
	Individual flows within 15% of counts for flows from 700 to 2700 vehicles/hour	>85% of cases
	Individual flows within 400 vehicles/hour of counts for flows more than 2,700 vehicles/hour	>85% of cases

Source: WebTAG

The above application of the above criteria to the PRISM Refresh Highway networks has been modified so that counts with lower observed traffic volumes are given a greater acceptance range (provided in Table 2.3). The main justification for using greater ranges for lower counts is that PRISM is strategic in nature; it does not model important local effects such as pedestrian crossings, cyclists, effects of stopping bus services, increased frontage development and small / numerous side-roads. Also, the zoning system is coarse in some areas, so the loading of trips onto the network is approximate. Taking these two aspects into account, PRISM should not be expected to produce modelled traffic flows that are as close to observed traffic counts for roads with low traffic flows as for roads with higher traffic flows.

Table 2.3: The modified WebTAG 3.19 acceptability guideline for individual link flow validation

Criteria	Description of criteria	Acceptability guideline
1	GEH <5 for individual flows	>85% of cases
2	For counts less than 250 vehicles/hour flows do not exceed 350 vehicles/hour	>85% of cases
	Individual flows within 100 vehicles/hour of counts for flows from 350 to 700 vehicles/hour	>85% of cases
	Individual flows within 15% of counts for flows from 700 to 2700 vehicles/hour	>85% of cases
	Individual flows within 400 vehicles/hour of counts for flows more than 2,700 vehicles/hour	>85% of cases

Source: WebTAG

2.1.1.3 Journey time validation

For journey time validation, the measure used is the percentage difference between modelled and observed journey times, subject to an absolute maximum difference. The criteria and acceptability guideline for journey times are defined in Table 2.4. WebTAG Unit 3.19 indicates that journey time routes should be between 3km and 15km.

Table 2.4: The acceptability guideline for journey time validation

Criteria	Acceptability guideline
Modelled times along routes should be within 15% of surveyed times (or 1 minute, if higher)	>85% of cases

Source: WebTAG

2.1.2 Convergence Criteria

The highway assignment models use a procedure that includes an equilibrium assignment with blocking back and Intersection Capacity Analysis (ICA). Measures of convergence monitored during assignment are provided in Table 2.5.

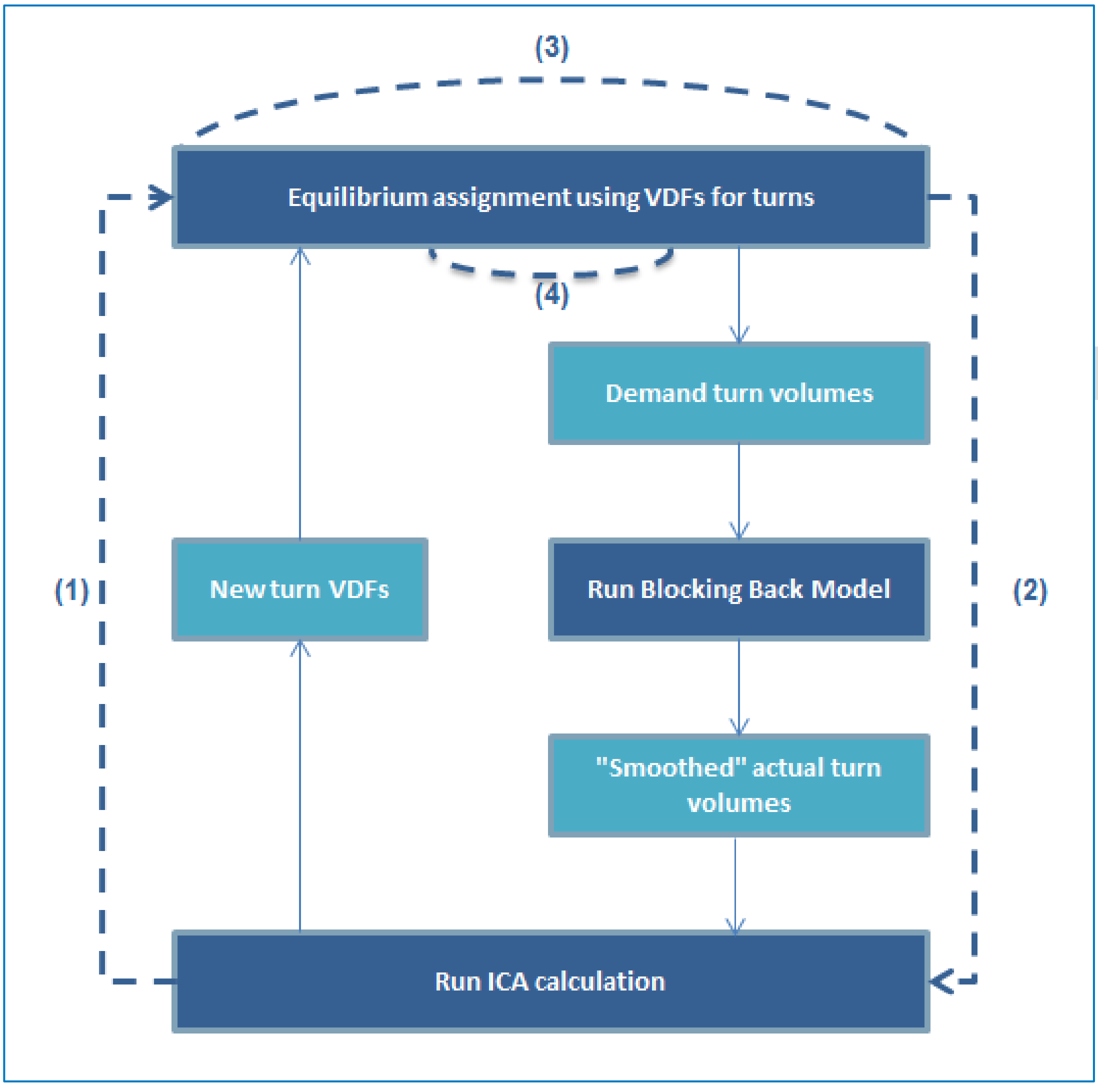
Table 2.5: Highway assignment convergence criteria

	Description	Acceptability guideline
1	The final delays of the equilibrium assignment and those obtained from running ICA are close, i.e. ICA produces delays that are consistent with the assignment result	More than 90% of turns have a relative difference in delay less than 5%
2	The turn volumes from the last equilibrium assignment are close to the smoothed volumes	More than 95% of turns have a GEH less than 1
3	The turn volumes from the last equilibrium assignment are close to those from the previous assignment	More than 95% of turns have a GEH less than 2
4	The difference between the costs along the chosen routes and those along the minimum cost routes, summed across the whole network, and expressed as the percentage of the minimum costs	Less than 0.1% or at least stable with convergence fully documented and all other criteria met

Source: WebTag Unit M3.1, Table 4.

These criteria are illustrated in Figure 2.1

Figure 2.1: Assignment convergence criteria



Source: Mott MacDonald

2.2 Key Features

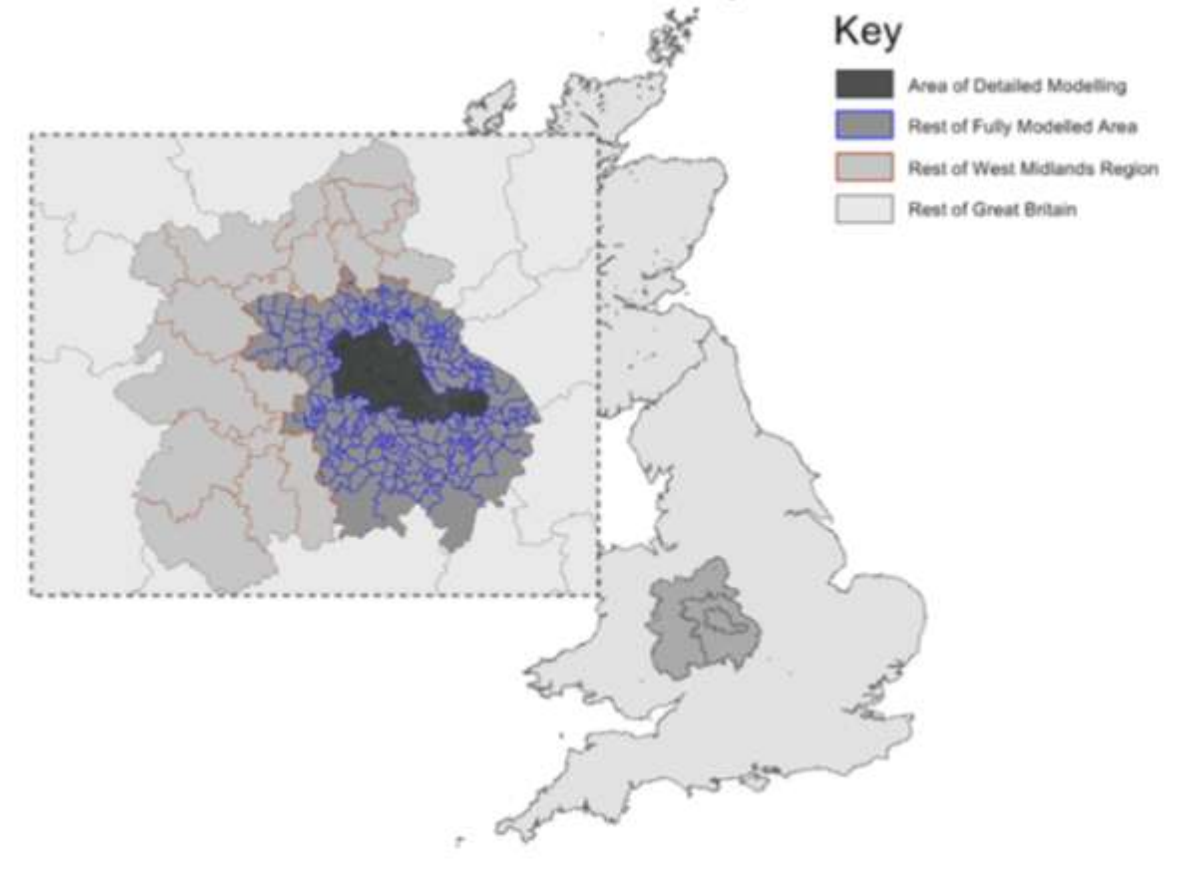
2.2.1 Fully Modelled Area and External Area

Two main areas of network coverage have been identified. These are as follows:

- **Fully modelled area (FMA)** – This is the area over which significant impacts of land use and transportation infrastructure interventions have influence. The fully modelled area is further subdivided into:
  - *Area of detailed modelling* (AoDM) - comprises the West Midlands Metropolitan Area. This is the area in which significant impacts of West Midlands (WM)-based interventions are certain. Modelling in this area is characterised by representation of all trip movements, smaller zones and, detailed network representation with junction modelling (including flow metering and blocking back). The AoDM comprises the seven metropolitan districts; and
  - *Rest of the fully modelled area (RotFMA)* - consists of an intermediate area. This is the area over which the impacts of WM-based interventions are considered to be quite likely but relatively weak in magnitude. It is characterised by: representation of all trip movements; somewhat larger zones and less network detail than for the AoDM; and speed/flow modelling (link-based).
- **External area** – This includes the remainder of the West Midlands Region and the rest of Great Britain. The impacts of WM-based interventions can be assumed to be negligible here. In terms of network, the representation of the external area is skeletal and fixed speed modelling is used. Demand is also only partially represented, characterised by large zones and external to external trips through the FMA only.

The modelled area is illustrated in Figure 2.2.

Figure 2.2: Model Area



Source: Mott MacDonald

2.2.2 Zoning System

2.2.2.1 Starting Point

The PRISM 2011 zoning system is largely based on the PRISM 2001 zoning system, which was originally developed in 2002. As part of the PRISM Refresh, the zoning system was reviewed and updated. The Centro public transport matrices and existing PRISM 2001 matrices have been used in the matrix building and estimation process. The Centro PT and PRISM 2001 zoning systems have, therefore, been used as the basis for the PRISM Refresh for reasons of consistency.

The zoning system consists of four distinct areas, with decreasing levels of detail:
- The West Midlands county
- An intermediate area
- The rest of the West Midlands region
- The rest of Great Britain

The focus of PRISM is on modelling travel within the WM County, therefore the zoning has the most detail in this area. However, it is recognised that a significant amount of travel (particularly commuting) within the county originates from the hinterland around the county. Therefore an intermediate area consisting of a band approximately 10-50 km in width around the county boundary is also modelled in some detail. Beyond the intermediate area the next level of detail is the rest of the West Midlands region, followed by the rest of Great Britain.

A number of issues were considered when developing the original zoning system in 2001:
- How it affects the assignment model in terms of routing accuracy and the number of intra-zonal trips. How it affects the accuracy of the demand model.
- Obtaining demographic and land use data for calibrating the demand model.
- Obtaining demographic and land use data for forecasting.
- Possible problems when building a base year trip matrix.

All the zone boundaries have been digitised in the MapInfo GIS package. The detailed PRISM zoning system within the WM metropolitan area (county) is based on 1998 ward boundaries. Each ward is sub-divided to form the model zones dependent on its size, land use characteristics, and population density of the district in question.

2.2.2.2 Consultation

All members of the PRISM Management Group (PMG), comprising representatives from the seven Local District Authorities, Highways Agency and Centro, were consulted on the redevelopment of the PRISM 2011 zoning system. The focus of this consultation was on the zoning system within the WM Metropolitan Area; the AoDM. Through this consultation, the following objectives were considered in the PRISM 2011 zoning system:
- A finer zoning system within local centres in the WM Metropolitan Area.
- Compatibility between PRISM and Centro zones.
- Compatibility between PRISM and BLUTS zones.
- Representation of existing and future land uses of strategic significance.

As a result of consultation, a number of minor revisions were made to the zoning system where possible, however, any suggestions that would create an inconsistency in the zoning system across the WM metropolitan districts, or that would exceed the limit on the total number of available zones were not implemented. Any adjustments to the zoning system have been balanced with the necessity to stay within a maximum number of zones (< approximately 995), due to VISUM licensing constraints at the time and the need to retain some zones for development areas that may be required in future applications. Another consideration was the need to keep the number of zones to less than 1,000 as more would have an impact on model run times.

The most significant update to the PRISM 2011 zoning system within the WM Metropolitan Area was the further disaggregation of zones in local centres. For these areas of the zoning system, the Centro public transport model zone structure was implemented to allow for disaggregation of city centres. The reason for this was to improve the representation of routes and traffic flow and to provide a more detailed basis for local modelling as well as to allow for the replacement of the PRISM 2006 PT model with an updated version based on the Centro PT model. The Centro PT zones are a direct disaggregation of the highway model zones which enabled the use of former matrices.

In addition, a number of zones were split in order to better represent either existing or potential future land-use changes within the WM Metropolitan Area. Further detail can be found in the Zoning Report.

2.2.2.3 PRISM Refresh zoning system

A summary of the number of zones in each of the modelled areas is provided in Table 2.6.

Table 2.6: Number of PRISM 2011 zones by area

Modelled area	Number of zones
WM metropolitan area	697
Intermediate area	254
Rest of the WM region	20
Rest of Great Britain	23
Total	994

Source: Mott Mac Donald

2.2.3 Network Structure

2.2.3.1 Area of Detailed Modelling

The Area of Detailed Modelling comprises the West Midlands Metropolitan Area. This area is coded with a high level of detail. All key minor and major roads are modelled. Key roads are considered to be those that carry significant levels of traffic or provide means of access and egress to important developments within the Area of Detailed Modelling. Capacity restraints are modelled through a combination of junction coding and speed/flow relationships.

The area of the network around Birmingham International Airport and the NEC has been reviewed and updated to include a greater level of network detail. This was done because the existing network coding was not considered to include sufficient network detail.

2.2.3.2 Rest of the Fully Modelled Area

The Rest of the Fully Modelled Area comprises a buffer area around the Area of Detailed Modelling. The network in the Rest of the Fully Modelled Area is represented in less detail, and for all roads capacity restraint is modelled through the use of link-based speed/flow relationships only. Motorway junctions considered to be of strategic importance that are situated within the Rest of the Fully Modelled area include detailed junction coding.

2.2.3.3 External Area

The External Area represents the rest of Great Britain in a skeletal network. Junction coding is not used but fixed “cruise” speeds are used for all roads.

2.2.4 Centroid Connectors

A zone centroid can be described as the centre of gravity, or trip attraction / generation, of a zone. During the PRISM Refresh, zone centroids were calculated based on population within each zone. For zones with a small or nil population, the zone centroids were calculated based on the centre of other activity within that zone.

A connector is a special type of link that connects a zone centroid to a node in the road network; it represents the point or points at which all traffic accesses the network. The following assumptions were used when selecting the point at which to code a connector:

- Connectors are coded realistically and, where possible, represent actual means of access to and egress from the modelled network such as a car park for example.
- Connectors do not cross barriers to movement such as rivers, railways, major roads and motorways.
- Connectors do not connect directly onto a junction, unless a junction arm exists specifically for that movement.
- Connectors for neighbouring zones will not load on to the same node.
- The number of connectors per zone can be minimised, limiting them to one where possible. [1]

2.2.5 Time Periods

The PRISM Refresh base year highway assignment model represents an average weekday in 2011. Highway assignment models have been developed to represent the average hour of the following time periods:

- AM; 0700-0930
- IP; 0930-1530
- PM; 1630-1900

2.2.6 User Classes

Within PRISM, the modelled vehicle types are:

- Car
- Light good vehicles (LGV)
- Heavy good vehicles (HGV)

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[1] WebTAG Unit 3.19, sections 2.4.12 – 2.4.17 (pp.9-10)

Vehicle types are further split by journey purpose to allow for the variation in perceived travel cost between different traveller types. A summary of PRISM user classes is shown in Table 2.7.

Table 2.7: PRISM user classes by vehicle type and journey purpose

PRISM user class	Vehicle type	Journey purpose
1	Car and LGV (personal)	Business
2	Car and LGV (personal)	Commuting and Other
3	LGV	Employers Business
4	HGV	Employers Business

Source: Mott MacDonald

Throughout all modelling work vehicles were represented in passenger car units (PCUs) based on the conversion factors shown in Table 2.8 (as agreed with the PMG). WebTAG Unit 3.19 specifies different PCU factors for HGVs by road type but it is not possible to do this within VISUM, so a single factor was assumed, this was to reflect HGVs on the strategic road network only.

Table 2.8: Passenger Car Unit conversion factors

Vehicle type	Factor
Car / LGV	1
HGV	2.5

Source: Mott MacDonald

2.2.7 Delay Mechanisms

2.2.7.1 Implementing Capacity Restraint

Table 2.9 provides a summary of how capacity restraint was implemented within the PRISM highway networks. The table shows a summary of where junction modelling, speed/flow relationships and cruise speeds were implemented prior to highway calibration.

Table 2.9: Capacity restraints within the PRISM Refresh highway network

Area	Fixed cruise speeds	Speed/flow relationships	Junction modelling
Area of Detailed Modelling	No	Yes	Yes
Rest of the Fully Modelled Area	No	Yes	Junction modelling has been implemented only on strategically important motorway junctions within the Rest of the FMA only.
External Area	Yes (effectively)	No	No

Source: Mott MacDonald

The traffic would not be fully represented in the External Area as trips from outside the Fully Modelled Area will not be modelled. The use of fixed cruise speeds (which are time period specific) is recommended by WebTAG.

2.2.7.2 Merge modelling on high speed roads

As defined in TAG Unit 3.19, a flow/delay relationship was applied to all high speed merges within the AoDM and all strategically important motorway or A-road merges within the RotFMA. Such merges were coded without priority rule. Instead, a special merge node was coded downstream. These merge nodes within the model represent the point up to which the traffic from a slip road merges with the traffic on the main carriageway on Motorways or A-roads.

The node applies the delay formula as follows: *Delay (seconds per vehicle) = 227 x (Capacity Ratio - 0.75)* where the capacity ratio is defined as the total upstream demand divided by the capacity of the downstream link[2].

This function is applied on a node located 100m downstream of the merge, effectively at the point at which the merge lane terminates. The number of lanes between the merge and the merge node is the combined number of lanes on the slip road and the main carriageway prior to actual merge.

2.2.7.3 Flow metering and blocking back

The PRISM 2011 highway assignment model contains a procedure for estimating queues and the associated effect of flow metering on the downstream network. This procedure is run following the highway assignment so that actual flows are then used during the ICA calculation.

While the blocking back procedure allows for the differentiation between demand and actual flows along links and through junctions, it should be noted that all traffic flow comparisons within this document report actual flows (in vehicles).

2.2.8 Toll

M6 Toll charge used in the demand model was based on March 2011 prices, provided by Midland Expressway Ltd. These prices for individual vehicles class and terminal type are summarised in Table 2.10 below.

Table 2.10: Actual cost of the toll in 2011

	Car	LGV	HGV
Main Plaza	£5.30	£10.60	£10.60
Local Plaza	£4.00	£10.00	£10.00

Source: Midland Expressway Ltd

The value recommended by WebTAG. To improve the calibration of the model, it was decided to use 25% of the full price as an input value.

2.2.9 Generalised cost formulation

Generalised cost refers to both the monetary (i.e. fuel cost, vehicle operating cost) and non-monetary (i.e. travelling time) costs of a journey. Generalised cost parameters are input as a series of values individual to

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[2] Design Manual for Roads and Bridges (Volume 13, Section 1, Chapter 7)

each user-class. Monetary values are input to VISUM as pence per metre and non-monetary are input as pence per second. These costs interact to affect route choice. If time is highly valued and distance is not valued at all, the quickest journey will be chosen, no matter how long the distance. Similarly, if distance is highly valued and time not at all, the shortest distance will be chosen.

Generalised cost values were calculated based on the latest vehicle operating costs, values of time and user class splits as outlined within WebTAG Unit 3.5.6 (October 2012). The resulting parameter values can be found in Table 2.11 and Table 2.12. The Car Non-Work value is the averaged value of time for Car Commute and Car Other, weighted by the matrix totals.

Table 2.11: Value of time (pence per second)

Time period	Car Work	Car Non-Work	LGV	HGV
AM	0.9100	0.2210	0.3638	0.6063
IP	0.8895	0.2610	0.3638	0.6063
PM	0.8765	0.2261	0.3638	0.6063

Source: WebTAG

Table 2.12: Vehicle operating cost (pence per metre)

Time period	Car Work	Car Non-Work	LGV	HGV
AM	0.0181	0.0094	0.0193	0.0740
IP	0.0184	0.0096	0.0196	0.0754
PM	0.0183	0.0096	0.0195	0.0753

Source: WebTAG

2.2.9.1 Vehicle operating costs – assumptions used

In line with TAG Unit 3.5.6, paragraph 1.3.36; it was assumed that non-work users do not perceive non-fuel costs.

In order to calculate fuel consumption it is necessary to state a network speed for each time period and for each vehicle type. The average network speeds were calculated based on the network speeds in the Highway model for individual vehicle types on all links within the boundary of the West Midlands Metropolitan Area. The resulting speeds are shown in Table 2.13. Further information on Traffic Master data is provided in Section 2.3.3

Table 2.13: Assumed network speeds used in vehicle operating cost calculations

Time period	Speed (km/h)
AM	27
IP	26
PM	26

Source: Mott MacDonald

2.2.9.2 Value of time – assumptions used

Tag Unit 3.19 states that the value of time for HGVs in TAG Unit 3.5.6 relates to the driver's time and does not take into account the influence of owners on the routeing of these vehicles. For this reason, the value of time for HGV can be, and has been, doubled.

2.2.10 Assignment Method

The assignment procedure used for the PRISM Refresh highway model is an interaction between an equilibrium assignment and a junction delay calculation, called Intersection Capacity Analysis (ICA). This interaction is described below.

2.2.10.1 Equilibrium assignment

The PRISM highway models use an equilibrium assignment, distributing demand according to Wardrop's first principle of traffic equilibrium:

> "Under equilibrium conditions traffic arranges itself in congested networks in such a way that no individual trip makers can reduce his path costs by switching routes"

The state of equilibrium is reached by iterating between inner and outer assignment loops. Within the inner assignment loop, two alternative routes for an origin-destination pair are brought into a state of equilibrium by shifting traffic from one route to the other until the travel time is the same. The outer loop then checks whether other routes with shorter travel times can be found as a result of the current assignment. This is repeated until no routes with an equal or shorter travel time can be found.

2.2.10.2 Intersection Capacity Analysis (ICA)

As described above, the highway model uses an equilibrium assignment procedure. Within VISUM, the equilibrium assignment method uses link and turn volume-delay functions (VDFs) to model how delay increases with increased traffic volumes.

Link VDFs can be described as "separable", as link VDFs depend only on the volume and capacity of an individual link. However, turn VDFs are non-separable as the capacity of a turn does not only depend on the volume of the turn itself, but also the volumes through all conflicting turns through the same node. For example, the capacity of a right turn from the minor arm of a priority junction would depend on the volumes on the opposing turns from the major arms.

In order to account for this, the assignment procedure uses a node impedance calculation, called Intersection Capacity Analysis (ICA) as well as the equilibrium assignment.

The ICA calculation (based on Highway Capacity Manual 2010) requires that none of the flows are above capacity. The flows resulting from the equilibrium assignment (hereafter referred to as demand flows) can go above the link capacity due to the theoretical nature of assignment. To remedy this, a blocking back model is run within Visum to create what we call actual flows – where no flow is above the capacity of links or turns.

This procedure reduces demand until nothing is above capacity and then feeds it back into the model forming queues. As well as providing queues upstream from overcapacity junctions this also produces an effect of reducing the flow after junctions as those vehicles are now represented in a queue, this effect is known as flow metering.

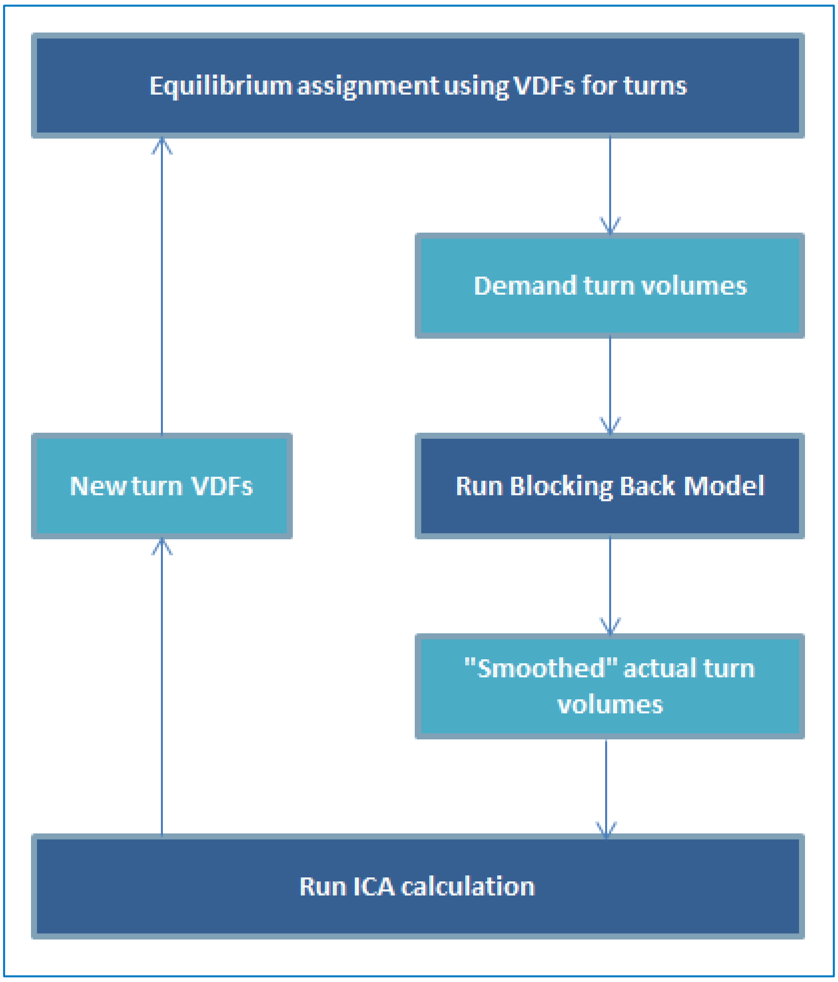
While the blocking back procedure allows for the differentiation between demand and actual flows along links and through junctions, it should be noted that all traffic flow comparisons within this document report actual flows (in vehicles).

The procedure is as follows:

- An equilibrium assignment is run to convergence. This assignment produces traffic flows on links and turns. Blocking back has not yet been run, so these flows represent the **demand** flow.
- The ICA calculation requires traffic flows to represent the actual flow, rather than demand, therefore, the Blocking Back model is then launched. This procedure estimates queue lengths and wait time for congested areas of the network. This procedure results in adjusted traffic flows which represent **actual** flow.
- Traffic flows are then "smoothed" by taking 30% of the flow from the current assignment iteration and 70% of the previous (this ratio was advised as standard by PTV). This step is undertaken to aid convergence.
- These smoothed flows are then used in the ICA calculation, which produces new VDF parameters that are fed into the next equilibrium assignment.

This process is illustrated below in Figure 2.3.

Figure 2.3: Equilibrium assignment with ICA and blocking back



Source: Mott MacDonald

The convergence criteria used within the overall ICA-and assignment loop is provided in Section 2.1.2.

2.2.11 Integration

Public transport (PT) assignment models have also been developed during the PRISM Refresh. The modelled time periods are as follows:

- AM 07:00-09:00
- IP 10:00-12:00
- PM 16:00-18:00

The PT networks have been developed by Centro and Mott MacDonald and are linked to the highway networks by a demand model developed by RAND Europe. The demand model has been built using an extensive household travel survey, undertaken in 2011 and calculates forecasts to 2021 and 2031.

Direct linkages in the development of the highway and PT networks are:

- A consistent zoning system within the AoDM.
- A bus pre-load - the number of services coded within the public transport networks have been used to create a bus pre-load for the highway models. This pre-load is considered during the highway assignment, whereby the bus pre-load multiplied by a PCU factor (2.5) is subtracted from the link and turn capacity. Due to the scale of the network, only links/turns that have more than 10 services per hour were given a bus pre-load (as agreed with PMG). This pre-load was also subtracted from the observed traffic flow on relevant links during matrix estimation.

2.3 Calibration / Validation Data

2.3.1 Non-motorway

The volume of traffic count data required for calibration and validation during the PRISM Refresh prior matrices was considerable. Guidance suggests that two-week ATC data should be used for model development. However, collecting two-week ATC data and accompanying manual classified counts for the number of sites for which data was required would have been a costly exercise, and not feasible within given funding constraints. As a result, the following existing data sets have been interrogated to source non-motorway and motorway traffic data.

2.3.1.1 Spectrum

Spectrum is a database of traffic count data collected within the West Midlands and maintained by Mott MacDonald. Traffic count data for roads within the AoDM were extracted from Spectrum using the following conditions:

- Data is from an ATC.
- The survey was undertaken between 2010 and 2012.
- The survey lasted one week or more.

Spectrum data was plotted on the highway network and used to derive screenlines and cordons. More information regarding screenlines and cordons is given in section Assignment Calibration2.6.4.

2.3.1.2 New count data

Screenlines and cordons have been checked for any data gaps on roads considered to be of strategic importance. As a result, 23 new one-week ATCs were undertaken within the AoDM in October and November 2012.

2.3.1.3 Ad hoc data

Additional traffic count data was provided by Sandwell MBC.

2.3.1.4 Roadside interviews

ATC data collected at the time of the PRISM Refresh RSIs were used in matrix estimation.

There are two sources of RSI traffic count data:

- Coventry RSIs conducted in 2009
- PRISM Refresh RSIs conducted between 2010 and 2011

A list and map of the sites used is provided in Appendix A.

2.3.1.5 Factoring

The non-motorway traffic count data used within the PRISM Refresh was collected between 2010 and 2012. In order to account for variability in traffic flow over and between different years, a series of factors have been applied to all non-motorway traffic count data in order to account for known variability in traffic volume over time.

A series of factors have been derived for this purpose:
- Factors to account for the known seasonal variation in traffic throughout a year.
- Factors to account for average change in traffic between years.

The factors were calculated from the ATC data 2008-2012 from Spectrum.

2.3.2 Motorway

The Traffic Flow Data System (TRADS) is a database maintained by the Highway Agency that contains information on traffic flows at sites on the road network. Traffic count data was extracted from TRADS for motorway sites and processed as follows:
1. 2011 yearly tabular data for each site was downloaded, providing a traffic count for each hour of the year.
2. Annual average Monday-Friday traffic volume for each of the modelled time periods, for each site, was calculated
3. The monthly classified counts for the same sites for October 2011 were downloaded.
4. Using the monthly classified data, the percentage HGVs (>6.6m in length) for each modelled time period, for each site was calculated.
5. The percentage HGVs was applied to the average traffic volume to derive light and heavy traffic counts.

The traffic volume was calculated on annual data from 2011, as such no further factoring was required.

2.3.3 Journey Times

Trafficmaster Historical Journey Time Data (TM) was used to extract observed journey time data for routes within the AoDM.

TM is congestion data produced by Trafficmaster Plc and provided to local authorities by the Department for Transport. The data is collected by placing GPS trackers in fleet vehicles and recording journeys. This data is then mapped onto the OS ITN. With the data matched to road links, it is possible to calculate average observed speeds on links.

Due to the road network changing, the OS ITN is updated annually. For this reason TM use a new version of ITN each year. As the GPS data is also date and time stamped it is possible to filter the data by specific day types, e.g. term time etc. and by time period.

For the PRISM Refresh, data from the academic year 2011/12 was used and was filtered by term time only and for the four time periods as defined below:
- AM – 0700 – 0930
- IP – 0930 – 1530

- PM – 1530 – 1900
- OP – 1900 – 0700

Data for academic year was selected to eliminate any variations in the traffic pattern due to the school holidays.

2.4 Network

The 2006 PRISM base year highway network was used as the starting point for the 2011 PRISM highway network. The following approach was adopted so that some of the information from 2006 PRISM model could be retained without the need of costly map matching. Additionally, starting from scratch would require filtering out minor roads, which would not normally be represented in a strategic model.

2.4.1 Data Sources

The existing PRISM 2006 base year network was used as the basis for the PRISM 2011 highway network. GIS data sources were also used to update highway network elements. The Ordinance Survey (OS) Master Map® Integrated Transport Network (ITN) dated August 2011 was used to inform the coding of updated junction layouts. The ITN was layered underneath the PRISM highway network within VISUM. This allowed for junctions and links to be coded accurately. Data from NAVTEQ Maps data (Q4, 2011) was used to code speed limits and to check the number of lanes on links within the Fully Modelled Area. These two sources of GIS data were supplemented by aerial photography.

2.4.2 Junctions

The effect of junctions is a key determinant in route choice within the AoDM and strategically important motorway junctions within the RotFMA. The highway network contains approximately 11,000 nodes, 7,000 of which are within the AoDM. Of these, approximately 3,500 are priority nodes, 850 signalised and 600 roundabouts. The remaining nodes are uncontrolled. All junctions within the AoDM are modelled using ICA.

Junctions within the AoDM are coded in detail to include the following:

- Control type (method for controlling vehicle movements at a junction, if any)
- Number of junction approaches
- Junction operation in terms of lane allocation
- Conflicts between vehicle movements
- Signal timings

The Intersection Capacity Analysis (ICA) module within VISUM has been used in conjunction with an equilibrium assignment to model junction delay within the AoDM. In order to correctly model a junction using ICA, it is necessary to specify junction geometry, including the number of lanes per approach, the permissible turns per lane, and the number of flared lanes.

For the majority of junctions, aerial photography from Google Maps has been used to obtain information on junction layout and operation. Where aerial imagery may have been out of date (the date stamp of the image was earlier than 2010/2011), junction details were obtained by using site layout drawings, undertaking site visits or, in a few cases, liaising with Local Authorities.

2.4.2.1 Priority Junctions

In order to model priority junctions using the ICA function within VISUM, the following data is required:

- The number of lanes for all junction approaches.
- The priority arrangement, including major flows.
- The lane arrangement, including permissible turns per lane.

Within VISUM, the most important attribute for priority nodes is the major flow, i.e. the allocation of priority at the node. The major flow orders all turning movements through a node into a hierarchy, whereby delay is assigned to the minor movements.

2.4.2.2 Roundabout Junctions

The approach used to code a roundabout within the PRISM Refresh networks is dependent upon the type and operation of the roundabout:

- **Signalised roundabouts** are coded as a series of one-way links and signal controlled nodes. There are 51 signalised roundabouts. This is because it is not possible to code a signalised roundabout as a single node within VISUM. The coordination of signals is not represented in the model.
- **Grade separated roundabouts** are also coded as a series of one-way links and priority controlled or signalised nodes. There are 57 grade separated roundabouts. This is because the layout of these junctions lends itself to becoming signalised in the future, and this method of coding allows link lengths of the gyratory to be included within route choice.
- **Other roundabouts** are coded as a single node using the roundabout control type. There are around 600 roundabouts of this type.

For roundabouts coded as a single node, delay is calculated using the Kimber / TRL method, which requires that, for each roundabout approach, detailed geometry measurements are input, such as entry width, flare length and approach half width. These are the same measurements that would be required for other roundabout junction modelling software, such as ARCADY. Due to the size of the PRISM 2011 highway network and the high cost associated with collecting this data for each roundabout, a template approach was developed for all roundabout junction approaches, whereby each approach was given default values, some of which were adjusted during network calibration. From the total of 2184 roundabout junction approaches, entry width was modified for 1042 of them, approach half width for 380 and flare length for 521 of roundabout junction approaches.

2.4.2.3 Signalised Junctions

There are approximately 850 signalised junctions modelled in PRISM 2011 within the AoDM. In order to model signalised junctions using the ICA function within VISUM, the following data is required:

- Number of lanes for all junction approaches
- Lane arrangement
- Signal staging and timing data

Signal specifications have been provided by the seven metropolitan authorities for the majority of signalised junctions within the AoDM. Each signalised node has been coded with basic staging arrangements as provided in the signal specification.

Whilst signal specifications do contain minimum and maximum green times, it is not possible to obtain actual timing data from the signal specifications. Instead, this data must be collected either on site or through control centres. The seven WM Local Authorities were not able to provide average observed green time information, and due to programme and budget constraints, it was not possible to collect detailed timing data for each signalised junction, for each of the modelled time periods. Therefore an alternative method for obtaining signal timing data has been used, as outlined below.

Green and cycle time optimisation

The signal optimiser within VISUM calculates an optimal cycle time for the signal control at the node and at the same time optimises the green time split for this cycle time. The signal optimiser calculates the critical lane group volume / saturation flow rate for each signal stage. Green times are then allocated to each stage based on these ratios.

Before it can be run, the optimiser requires the following inputs to be coded:
- Staging plans
- Minimum green and inter-green times
- A minimum and maximum cycle time
- An initial assignment

Staging arrangements were coded as per the signal specifications, and minimum green times and inter-green times were assumed to be 6 seconds for all junctions; in line with DFT guidance and best practice. The initial cycle time is set to be the sum of all green and inter-green times.

The green and cycle time optimiser includes the following steps:
1. First, the optimiser determines a set of permitted cycle times for the node.
2. Then for each of the permitted cycle times, the optimiser also calculates:
   a. optimal green times for each signal stage (green time split); and
   b. total wait time for each signal stage.
3. Finally, the cycle time and green time split with the minimum total wait time is selected.

The signal optimiser process was run during the calibration stage of network development with the objective of improving validation of the model against the traffic counts and journey time data.

The method used to optimise signal timings was as follows:
1. The highway network was assigned with the prior matrix that includes factored through trip movements[3]. This was a full equilibrium assignment with ICA and blocking back but with signalised junctions coded as uncontrolled, i.e. no delay at signalised nodes.
2. A matrix estimation process was undertaken using 2011 observed traffic count data, these matrices were then re-assigned with signal control turned off (as in step 1). Approximately 1000 count locations were included within this process, which were focussed around signalised junctions.
3. Cycle time and green time proportions were then optimised using VISUM in-built signal optimisation programme for all signalised nodes based on the assignment in step 2.
4. The prior matrices were then assigned. This was the starting point for calibration.

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[3] Trips between zones in External Area via Core Area (Area of Detailed Modelling)

2.4.3 Links

Table 2.14 summarises the link data requirements for the highways networks.

Table 2.14: Link data requirements

Data	Source / description
Link type	Link types have been derived and applied in line with TAG Unit 3.19. Further detail is provided in Section 2.4.3.1.
Capacity	Link capacities have been calculated in line with TAG Unit 3.19. Further detail is provided in Section 2.4.3.1.
Speed/flow relationship	Speed/flow relationships have been calculated based on TAG Unit 3.19.
Length	ITN has been layered onto the highway network within VISUM, allowing nodes to be placed accurately and links to be shaped accordingly. Link lengths have been set to the link polygon length.
Number of effective lanes	The number of lanes on a link has been coded as the number of lanes that are available to highway traffic under normal operation. For example, if a road has two lanes but the inside lane is used for on-street parking; the link would be coded with one lane within VISUM as this best reflects the operation of this link in reality. Similarly, if a road is two lanes wide but one is a bus-only lane, the link would be coded with one lane in VISUM. The bus only lane will not be coded as a separate link, because public transport trips will not be assigned onto the highway network. Bus flows have been taken into account in the assignment as a pre-load, except where bus flows are on a bus-only link or lane.
Direction (one-way or two-way)	One-way links have been coded based on ITN and aerial photography.
Vehicular restrictions	Vehicular restrictions relating to weight restrictions have been coded based on ITN data. Bus only links have been banned to private transport.
Speed limit	Speed limit data has been sourced from NAVTEQ. This data has been used as it is the best source available. The inclusion of speed limit data allows for sense checks against cruise speed data to be made.
Cruise speed	The calculation of this value is dependent on a number of conditions as discussed in Section 2.4.3.3

Source: Mott MacDonald

2.4.3.1 Link Types

Table 2.15 summarises link types within the highway networks.

Table 2.15: Link types

Road class	Description	Speed limit	Capacity (PCU/lane)
1	Rural single carriageway	50mph - 60mph	1330
2	Rural all-purpose dual 2-lane carriageway	50mph - 70mph	2100
3	Rural all-purpose dual 3 or more lane carriageway	50mph - 70mph	2100
4	Motorway, dual 2-lanes	50mph - 70mph	2330
5	Motorway, dual 3-lanes	50mph - 70mph	2330
6	Motorway, dual 4 or more lanes	50mph - 70mph	2330
7	Managed (Smart) Motorway, dual 4 lanes	60mph during controlled periods	2330
8	Small town	30 to 40mph	1340
9	Suburban single carriageway	30 to 50mph	1680
10	Suburban dual carriageway	30 to 50mph	3540

Road class	Description	Speed limit	Capacity (PCU/lane)
11	Urban	20 to 30mph	800
12	External motorway	70mph	6990
13	External non-motorway	30 to 50mph	4200

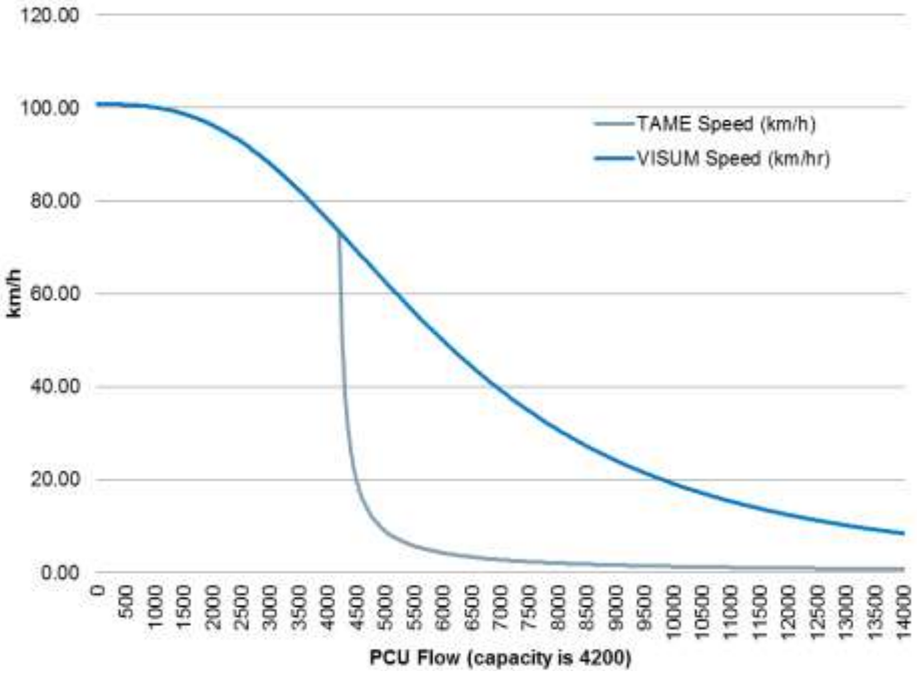
Source: Mott MacDonald

2.4.3.2 Speed/flow relationships

Speed/flow relationships have been defined for all link types in Table 2.15. In the External area, where Table 2.9 stated that fixed speeds have been used, very flat curves have been implemented to proxy a fixed speed. Flat curves have been used (rather than a fixed speed) to aid assignment convergence. This was also the case for roundabout links in the urban area.

The parameters used in the speed/flow curves are based on those provided by HA TAME which in turn are based on those in COBA. The curves provided by HA TAME include over-capacity 'tails' which have not been replicated in PRISM due to the use of the VISUM blocking back model. Figure 2.4 provides an example for a two-lane dual carriageway link type where the PRISM (VISUM) curve has been fitted to the HA TAME curve for flows below capacity. For over-capacity conditions in PRISM the blocking back model will kick in.

Figure 2.4: Speed-flow curve development for two-lane dual carriageways



Source: Mott MacDonald

Link capacities are coded in PCUs in PRISM, using the following PCU factors:

- Cars: 1
- LGVs: 1
- HGVs: 2.5

As described in Section 2.2.11, bus flows have been modelled as a pre-load, a separate PCU factor of 2.5 has been applied for these.

It is suggested in TAG Unit 3.19 (Table E.2) that the use of separate speed/flow relationships for light and heavy vehicles is preferred for rural and suburban speed/flow curves because this could provide more accurate estimates of changes in vehicle operating costs and travel times. It is impossible to adopt this approach in PRISM as VISUM does not have the necessary functionality. However, a maximum speed for HGVs has been applied in VISUM and this was implemented as follows (based on the Highway Code, 2007):

- 30mph in built-up areas (all 30 mph roads)
- 40mph on single carriageways
- 50mph on dual carriageways
- 56mph on motorways

Maximum speed has also been applied to LGVs as follows (based on the Highway Code, 2007):

- 50mph on single carriageways
- 60mph on dual carriageways

In all other instances (mainly where the maximum speeds defined for LGVs or HGVs are higher than the speed limits defined for a particular link type, Table 2.15) same speed limits are applied to all vehicle types.

2.4.3.3 Cruise speeds

Cruise speed can be defined as “the mid-link speed, separate from any junction delay, during the time period modelled” (TAG Unit 3.19, p.34).

Guidance states that one way of deriving mean cruise speeds is to establish a relationship between attributes of a link, such as road type, speed limit, activity levels and cruise speeds to estimate a mean cruise speed for each link in the network (TAG Unit 3.19, p.34).

Cruise speeds have been implemented as the ‘free-flow’ speed for use in conjunction with the link speed-flow curves and junction modelling.

2.4.3.4 Cruise Speeds – Area of Detailed Modelling

Speed data captured by automatic traffic counters (ATC) in mid-block sections of road, where speeds would be less influenced by the presence of junctions was interrogated. The process adopted was as follows:

- Match ATC speeds with the 30 mph 1 and 2-lane roads in the PRISM central and non-central area
- Derive average speeds for each of those links from the speed data by time period; and
- Calculate overall average speed for 30 mph 1 and 2-lane link types in central and non-central area by time period.

Based on the above, a single cruise speed of 18mph was assumed for all urban roads in the AM/IP/PM time periods.

2.4.3.5 Cruise speeds – External Area

The Highways Agency provided observed speeds for a selection of motorway and non-motorway links for weekdays in 2011 in the External Area. This data has been used to calculate separate average speeds for motorway and non-motorway links. Table 2.16 lists the calculated average speeds.

Table 2.16: Cruise speeds – external links

Time period	Motorway	Non-Motorway
AM	67	48
IP	67	50
PM	67	49

Source: Calculated from observed speed data provided by the Highways Agency

In agreement with the PMG, the final cruise speeds for external links were assumed to be:

- Motorway – 67mph for all time periods; and
- Non-motorway – 50mph for all time periods

2.5 Trip Matrix

2.5.1 Travel Demand Data

A substantial amount of data for the highway matrix build was collected during the period 2009-2011. This dataset consists of:

- Roadside interview survey (RSI) data collected at 90 sites
- Manual classified counts (MCCs) at the 90 RSI sites
- Automatic traffic counts for the RSI sites and for other additional sites across the West Midlands Metropolitan Area.
- Car park surveys for 53 urban sites
- GPS data (TrafficMaster and INRIX)

In addition, synthetic trip matrices were used in the matrix building process.

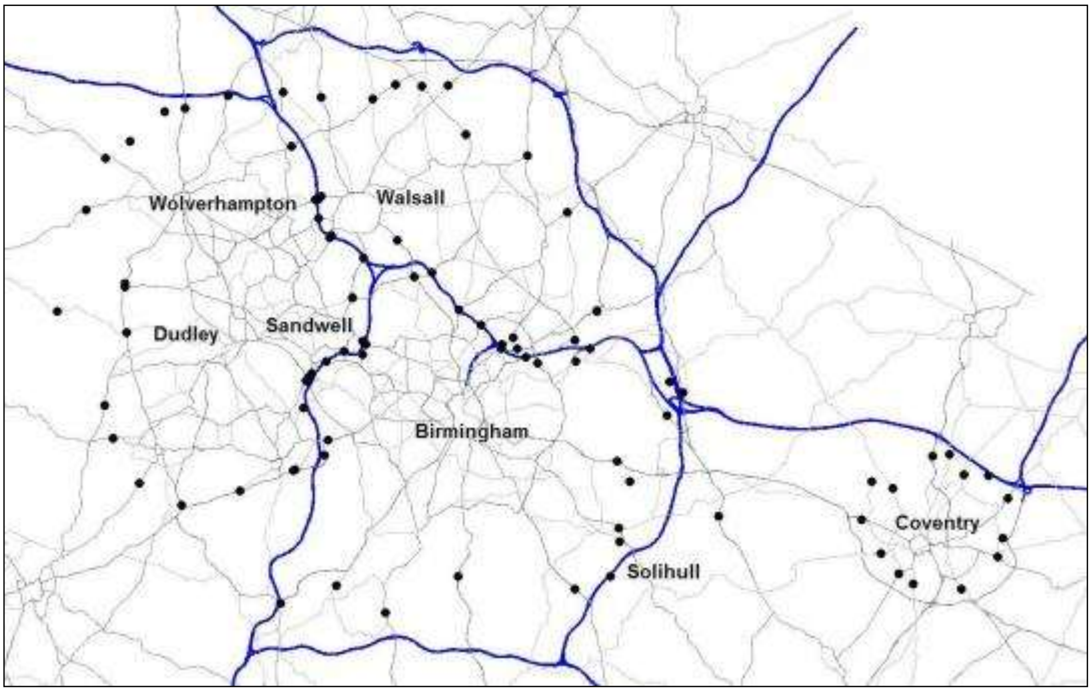
2.5.1.1 RSI data

RSI records form the major source of data for the PRISM Refresh matrix build. The survey data was a mix of face-to-face interviews and self-completion postcards covering travel information over the period 0700-1900. The roadside interviews were carried out only in one direction and did not cover the off-peak period. An off-peak model was not build for PRISM. The 90 RSI sites consisted of:

- 76 sites that captured movements into/from Birmingham, Wolverhampton, Walsall and Solihull collected by Mott MacDonald.
- 14 sites within and around Coventry provided to Mott MacDonald by Coventry City Council, which were collected for the purpose of developing a local model in Coventry.

The location of the sites can be seen in Figure 2.5.

Figure 2.5: Location of RSI interviews



Source: Mott MacDonald

Further detail can be found in PRISM Surveys 2011: Roadside Interviews.

2.5.1.2 MCC data

MCC data was collected over the 12 hour survey period for each of the 90 RSI sites for both interviewed and non-interviewed directions.

2.5.1.3 ATC data

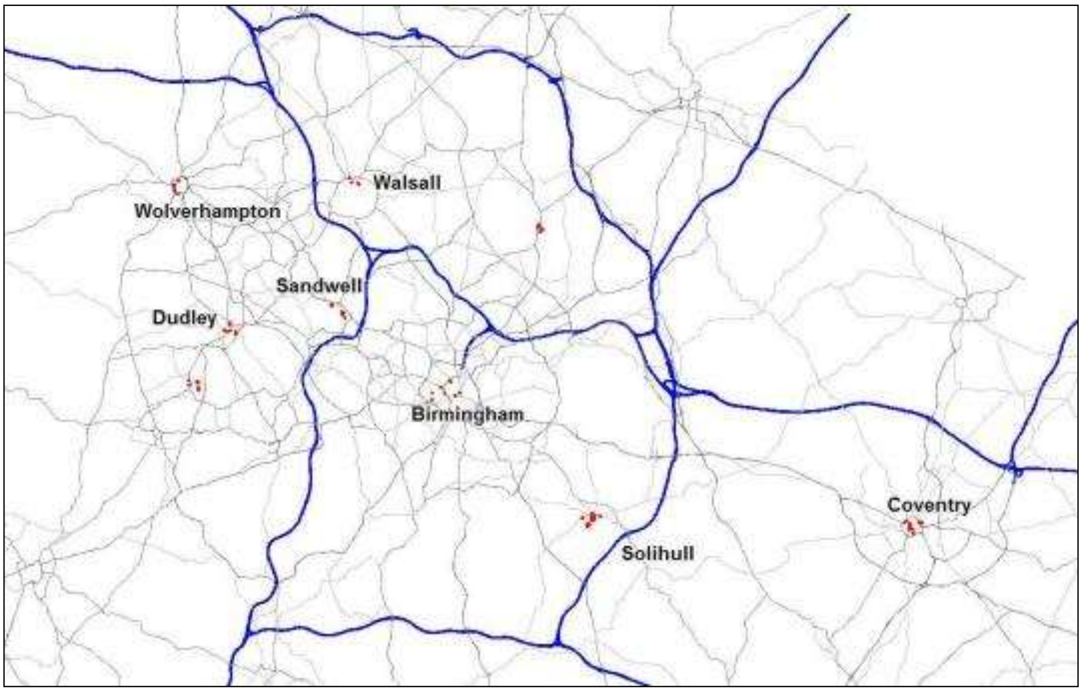
ATC data was collected for each of the 90 RSI sites for both interviewed and non-interviewed directions. ATC data was collected over a two week period.

2.5.1.4 Car park surveys

Car park data was collected in the form of self-completion postcards for off-street car parks only.

Location of the surveyed car parks is shown in Figure 2.6.

Figure 2.6: Location of car park interviews (53 sites)



Source: Mott MacDonald

Further information is provided in PRISM Surveys 2011: Urban Centres report.

2.5.1.5 Synthetic matrix data

The synthetic matrix was taken from the interim version of the 2011 demand model that had been updated to reflect travel behaviour observed in the 2009-11 household travel survey. This interim version used a proxy of 2011 travel costs rather than those produced by the calibrated and validated network models.

2.5.1.6 GPS data

Two sources of GPS data have been incorporated into the PRISM Refresh matrix build:

- **TrafficMaster** - provided by the Department for Transport (DfT) for use in the PRISM Refresh. The data covered a 12 month period (August 2010 - August 2011) and originates from vehicles belonging to TrafficMaster customers who are primarily high mileage vehicle drivers and company car drivers and HGVs.

- **INRIX** – due to the low OD coverage in the TrafficMaster HGV matrices, INRIX data served as a primary source of heavy goods vehicle data. Due to costing implications the data used in this project is restricted to movements that went through (or had an origin or destination) within a 30 mile box with its centre in Birmingham over the 7 month period April 2011 to October 2011. Vehicle journeys that had an origin outside of this box were recorded as having an origin zone on the box boundary (at the point of which the vehicles journey crosses the bounding box), likewise for destination zones. Because of this trip-length information is not directly comparable with other data sources, as the longer journeys are cut short at this boundary, however it does mean that trip-routeing through the modelled area is potentially more accurate than if the longest trips had been assigned to the coarser external zones.

2.5.2 Partial trip matrices from surveys

The observed matrices are comprised of RSI, car park and GPS data. All data used in the matrix build has been converted to the common PRISM origin-destination format prior to being developed into the trip matrices.

2.5.2.1 RSI matrices

The RSI matrices were produced from the expanded RSI records. Prior to the expansion, RSI records were processed into a common format and inconsistent and illogical records have been eliminated from the data (including missing or incomplete data, illogical origins and/or destinations and outbound and/or return travel times). These represent around 6% of all records.

The following steps were undertaken to convert the RSI data to a single format:

- Trip purpose mapping from trip purpose at origin or destination and conversion to the trip purposes used in 2011 PRISM model, including: commuting, business, education and other.
- Vehicle type identification and allocation to the vehicle type categories used in PRISM.
- Establishing time of inbound and outbound travel. As the roadside interviews were conducted only in one direction, the interview time was used as the time of travel for the outbound trip. The reverse trip was either stated on the interview form or estimated from trip purpose analyses.
- Allocation of time periods and time slots to interview records. Trips were assigned to AM, IP, PM or OP. Within these time periods, records were also assigned to a 30 minute time slot that was used during the expansion of the interview records.
- Allocation of zone numbers to the interview records. Postcodes were captured on the interview forms. This stage mapped postcodes to Ordnance Survey Grid Reference (OSGR) and then model zones for each record.
- Expansion of interview records to manual classified counts. This is the basic record expansion stage. Additional adjustments then follow:
  - Adjustments of the base expansion factors to site ATC counts
  - Adjustment of expansion factors to average weekday ATCs
  - Adjustment to common year/common month
  - Adjustments for postcard interview records to address response bias
- Expansion of interview records to manual classified counts followed by additional adjustments, including:
  - Adjustments of the base expansion factors to site ATC counts
  - Adjustment of expansion factors to average weekday ATCs totals
  - Adjustment to common year/common month
  - Adjustments for postcard interview records to address response bias

Application of expansion factors to interview records gave, by vehicle type and time of day, flows factored up to MCC count totals at each count site.

The MCC expansion factor was derived as follows:

$Expansion\ Factor\ (s,v,t) = \frac{MCC(s,v,t)}{R\ (s,v,t)}$; where:

MCC(s, v, t) – relevant manual classified count in 30 minute interval; and R(s, v, t) – sum of all interview records for a particular site (s), 30 minute time slot and vehicle type (v).

The expansion factor was then aligned to the corresponding ATCs. Since ATC is a more accurate count but lack detailed vehicle classification, the adjustment factor was calculated as:

$ATC\ Factor\ (s,v,t) = \frac{ATC\ (s,v,t)}{MCC\ (S,v,t)}$; where:

t – hourly time slot

The factors were adjusted to average weekday ATC totals. In the data used for this work, ATCs were generally available for a period of two weeks for each survey sites. The initial expansion factors were therefore adjusted by the average weekday factor calculated as:

$$Weekday\ Factor(t) = \frac{ATC(average\ weekday, t)}{ATC(interview\ day, t)}$$

Additional adjustment was to convert the data to a common year of 2011. Coventry data was collected in 2008 and 2009. This was adjusted to 2011 using the relative average annual weekday ATCs from permanent sites:

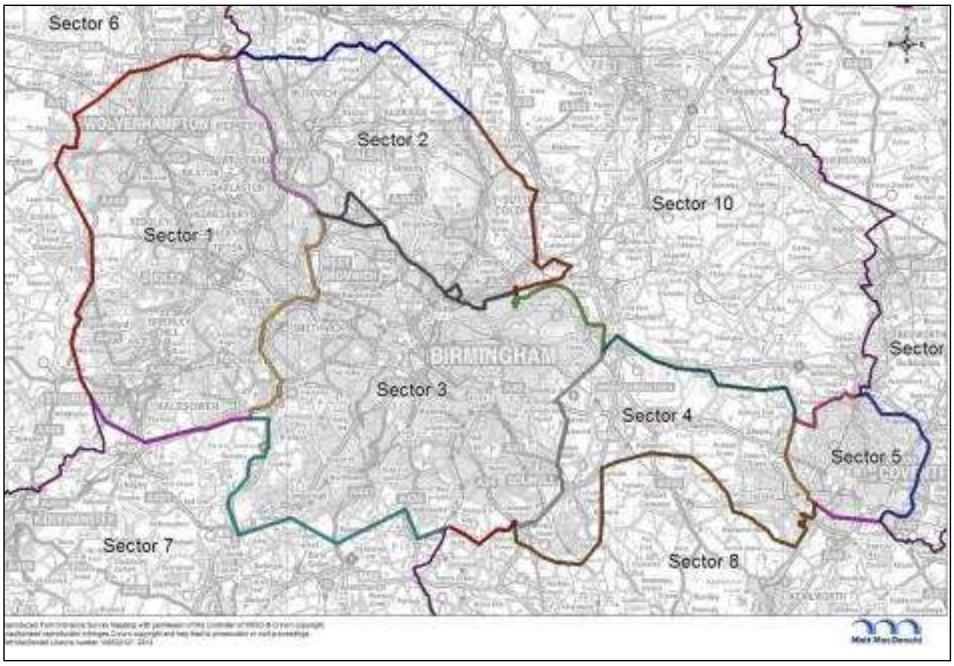
$$Year\ Factor = \frac{Average\ weekday\ ATC(Year)}{Average\ weekday\ ATC(2011)}$$

Final step was to adjust postcard interview records to address response bias. Postcard data is usually skewed towards some travel purposes. The purpose of this adjustment was to bring postcard responses in line with RSI face-to-face interviews. Data available did not allow this to be done by site. So for all sites, taken together and for purpose p, the postcard factor was determined by:

$$Postacard\ Factor = \frac{Postacard\ total\ (p)}{RSI\ total\ (p)}$$

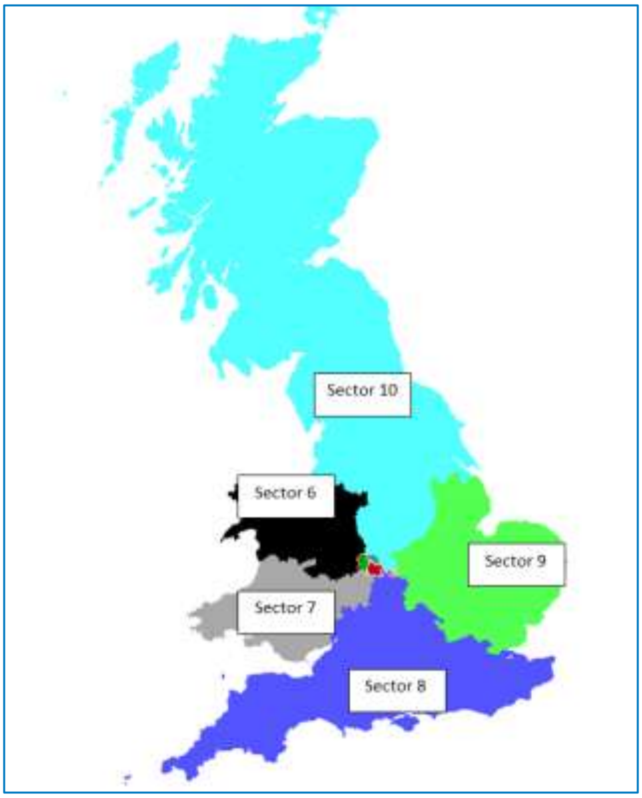
The PRISM model area was partitioned into 10 sectors in order to aid matrix building and analysis of traffic movements throughout the AoDM. Sectors 1-5 represent the AoDM (Figure 2.7) while sectors 6-10 represent the RotFMA and external area where modelling detail is not crucial (Figure 2.8).

Figure 2.7: Sectors within West Midlands



Source: Mott MacDonald

Figure 2.8: Intermediate and External Sector Coverage



Source: Mott MacDonald

The ERICA software was used to develop RSI matrices. The sreenline segments were defined in line with the requirements of the software. ERICA matrix build screenlines connect RSI sites and were defined to capture *fully observed movements*.

RSI data was assigned to cordons and screenline segments before the matrices were produced. Since RSI data did not capture all of the movements through the cordons, additional data for omitted roads that looked significant was collected from the following sources:

- 1500 survey, a set of ATCs that are collected periodically across West Midlands
- Spectrum, s set of ATCs that has the 1500 survey as a subset
- New traffic counts. These were counts specifically requested where the 1500 survey and Spectrum counts did not cover a particular road.

The counts on these additional roads were used to adjust count totals at adjacent RSI sites before they were used in the matrix build. The assumption was that trips passing through that screenline would follow the same pattern as those at the RSI site. This way, more accurate levels of traffic were recorded across cordons and screenlines.

This then formed the input to ERICA which held the full set-up files for combining the site data into time periods and purposes as well as removing any double counting in the matrix build process and also deal with movements that may cross a cordon more than once. Double counting occurs where observed movements for the same OD pair are observed and expanded at different cordons or RSI sites. A route could potentially cross a screenline more than once with the same observed movement counted and expanded in two different directions of the destination.

2.5.2.2 Car park matrices

The car park records used in the development of car park matrices were modified and expanded in the following way:

- The time periods that were derived for the RSI records were then applied in a similar way to the car park records. The length of stay and return time provided an estimate of the time of travel for inbound and outbound trips.
- Car park postcodes were considered to be the final destinations for inbound trips (and the origins for outbound trips).
- Expansion factors were applied to account for unobserved arrival flow at off-street car parks.
- Expansion factors were applied to account for unobserved on-street and PNR car parks.

Comparison of an assignment of the synthetic matrix with the un-expanded car park matrix was used to create expansion factors that take into account off-street car parks.

2.5.2.3 GPS matrix build

The DfT provided Trafficmaster (TM) data in the form of individual trip records in the TM zoning system. The TM data was aggregated into total annual weekday trips by TM vehicle types and TM time periods. The TM data for car is not split by trip purpose, as opposed to PRISM. It should also be note, that there was a 30 minute mismatch between TM and PRISM time period boundaries for Inter Peak and PM Peak.

In order to develop GPS origin-destination matrices, the following adjustments were made to the TM data:

- Conversion to the PRISM zoning system
- Creation of car trip purpose splits
- Use of INRIX data to supplement the scarce HGV data in the TM matrices

The TM zoning system was provided with MapInfo files that allowed a mapping to be made to PRISM zoning system. This was done by overlapping the two zoning systems and applying the following simple rules:

- If a TM zone was more than 90% in a PRISM zone, then all trips were assigned to that PRISM zone. Otherwise, the TM zone was split between corresponding PRISM zones according to area of overlap.
- If a TM zone is larger than PRISM zone, then the TM zone was split to PRISM zones according to area proportions in the overlaps.

This process yielded matrices in the 994 zone system that the PRISM model uses.

The data did not have trip purpose information as TM does not hold information on journey purposes for its customers. There were assumed to be no ‘other’ or ‘education’ trips in the TM data source, therefore the TM car matrices created from TM records were broken down into commute and business trip purposes.

The TM data has been treated as a random sample of car trips, so to remove any sampling bias the trip length distribution derived from the National Travel Survey (NTS) data has been used. NTS data has also served as a basis for the split of TrafficMaster car matrices into trip purposes. The TM purpose split was calculated based on the ratio of business to commute trips within each distance band of the NTS trip length distribution.

It was agreed with the PRISM Management Group that due to the differences between INRIX and TrafficMaster data for HGVs and owing to their different sources, adding the two data sets together and then factoring the totals was more appropriate than merging.

The following matrices were generated from the TM data for the four modelled time periods:

- Car Business
- Car Commuting
- LGV
- HGV

2.5.3 Trip Synthesis

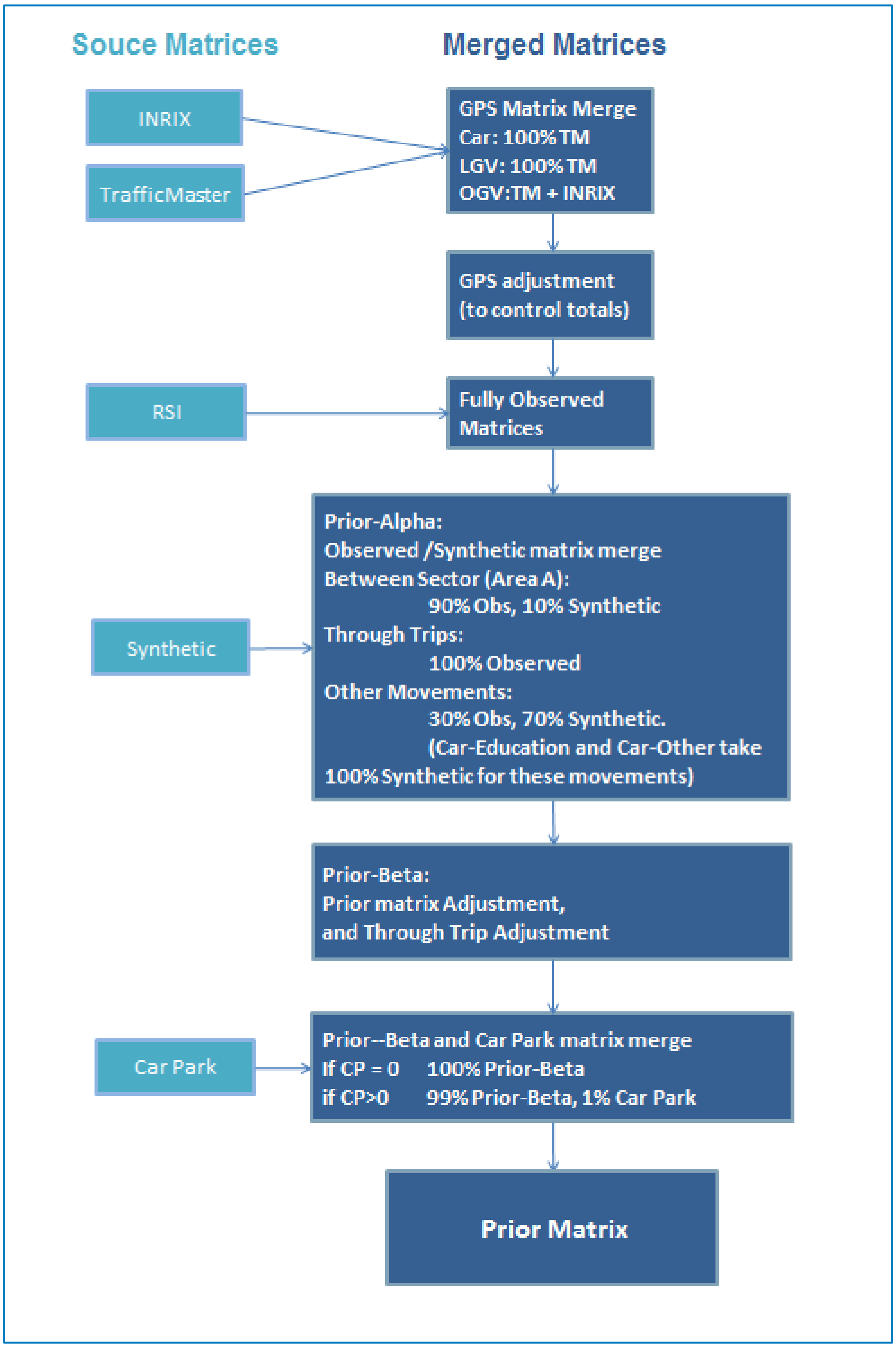
The synthetic matrix was taken from an interim version of the 2011 demand model that was updated to reflect travel behaviour observed in the 2009-11 household travel survey. Land use assumptions that fed the interim demand model were updated with early release data available from the 2011 Census including recession impacts and recently updated datasets such as educational enrolment data and employment data aggregated from the Inter-Departmental Business Register (IDBR). The resulting matrices were used as synthetic matrices for the full build.

Since the 2011 costs were not available at the time of the matrix build, travel costs used in the estimation of demand were based on the 2006 model and adjusted from the 898 zoning system in that model to the 994 zoning system in the 2011 model.

2.5.4 Merging Data

The matrix merging process was carried out with a series of C++ programs specifically developed for this purpose. The full process of the matrix merge and record of individual components used at each stage is illustrated in Figure 2.9.

Figure 2.9: Matrix Merge



Source: Mott MacDonald

2.5.4.1 Trip Components

The following components were used to derive the full set of trips for the prior matrices:

- Inter-sector trips:
  - RSI matrix (car all purposes, LGV and HGV)
  - Synthetic matrix (car all purposes)
  - TrafficMaster matrix (car business/commute, LGV and HGV)
  - INRIX matrix (HGV)

The observed matrix (RSI+GPS) provided essentially all of the inter-sector movements. The synthetic matrix was used to reduce the proportion of zero cells in these longer-distance matrices to aid matrix estimation.

- Intra-sector trips (not represented in the RSI matrix):
  - Synthetic matrix (car all purposes)
  - Parking matrix (car all purposes)
  - TrafficMaster (car business/commute, LGV and HGV)
  - INRIX matrix (HGV)

2.5.4.2 Matrix Scaling

The RSI matrix represented the major directly observed dataset in the development of the prior matrices and was used as a benchmark for the rest of the matrices used in the merging process. Since the size and/or the shape of the matrices did not correspond, additional adjustments had to be applied to the GPS and synthetic matrices before they could be used further in the merging process.

The synthetic matrices were scaled using uniform factors, calculated on the basis of the comparison with RSI totals. Care was taken to only compare those movements which would be observed in the RSI matrix.

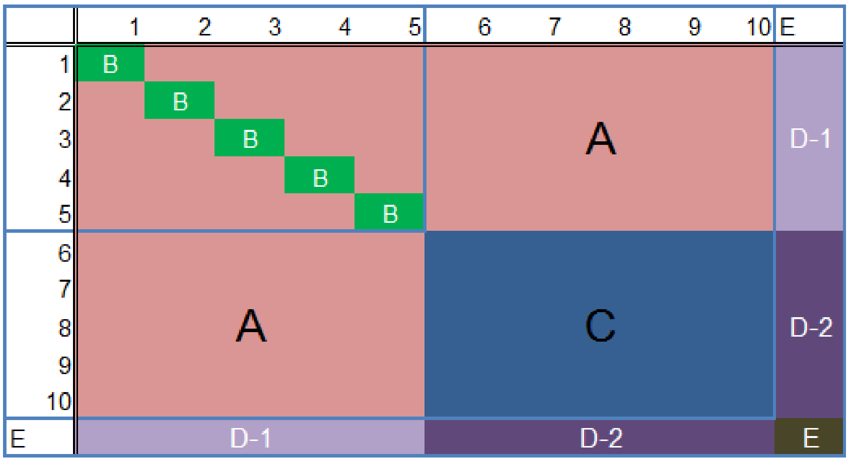
The size of the GPS matrices was adjusted using sector-specific adjustment factors. The scaled synthetic matrices were used as a proxy for the intra-sector movements, which were not captured in the RSI matrix. When expanding the matrix, different areas of the matrix were treated separately. The calculations of the factors have been based on the following elements (adjustment areas shown in Figure 2.10):

- *Inter-sector Core*: (Area A).The volume of traffic in this area was expanded to the levels in the RSI matrix. To avoid altering the trip distribution this was expanded with a single factor for the whole area.
- *Core to External/External to Core (Area D*-1). The volume of traffic in the area was expanded to the levels in the RSI matrix. This was treated separately from Area A, as the long-distance trips are different in nature to the shorter distance trips in the rest of A.
- *Intra-sector Core*: (Area B). For each sector a volume comparison with Synthetic car all purposes was used for expansion. LGV and HGV volumes were estimated using car to LGV/HGV ratios observed in the RSI matrices. This was done per-sector as it was known each core-sector could have very different volumes of trips (as observed in the household travel survey).
- *Inter and Intra-sector Intermediate*: (Area C). Volume comparison with Synthetic car all purposes was used for expansion. As the intermediate area requires less detail and only covers 7% of all OD pairs a single factor was applied to this area rather than disaggregating further. LGV and HGV volumes were estimated using car to LGV/HGV ratios observed in the RSI matrices. Area D-2 used the factor

calculated, but was not included in the calculation due to the tidal nature of the Synthetic matrix seen in Figure 2.10.

- *External*: (Area E). Expansion factor calculated from Area C comparison above was used here, this was only to give a starting point, as through-trips are reviewed further in the calibration report.

Figure 2.10: Matrix adjustment areas



Source: Mott MacDonald

2.5.4.3 Transition to two car trip purposes

The four car trip purposes (commute, business, education and other) used in the Prior-Alpha matrices (illustrated in Figure 2.9) generated from the merge process were reduced to two car trip purposes (work and non-work) during the transition to the Prior-Beta matrix.

2.5.5 Post-calibration adjustments

2.5.5.1 RSI cordons

After the completion of the merge process the demand across the RSI cordons had to be re-calibrated. This was deliberately not done at an earlier point, as it was believed that the flow across some of the cordons (in particular Coventry – sector 5) would be greatly influenced by intermediate-to-intermediate movements (e.g. Bedworth to Warwick) which were not included in the RSI matrix.

For this purpose a set of factors has been calculated for each sector-to-sector movement applied using a Furness method. Additionally flows were compared across internal screenlines within the core-sectors and used to calculate a set of factors to adjust the size of the prior matrices to meet the screenline count totals.

2.5.5.2 Through-trips

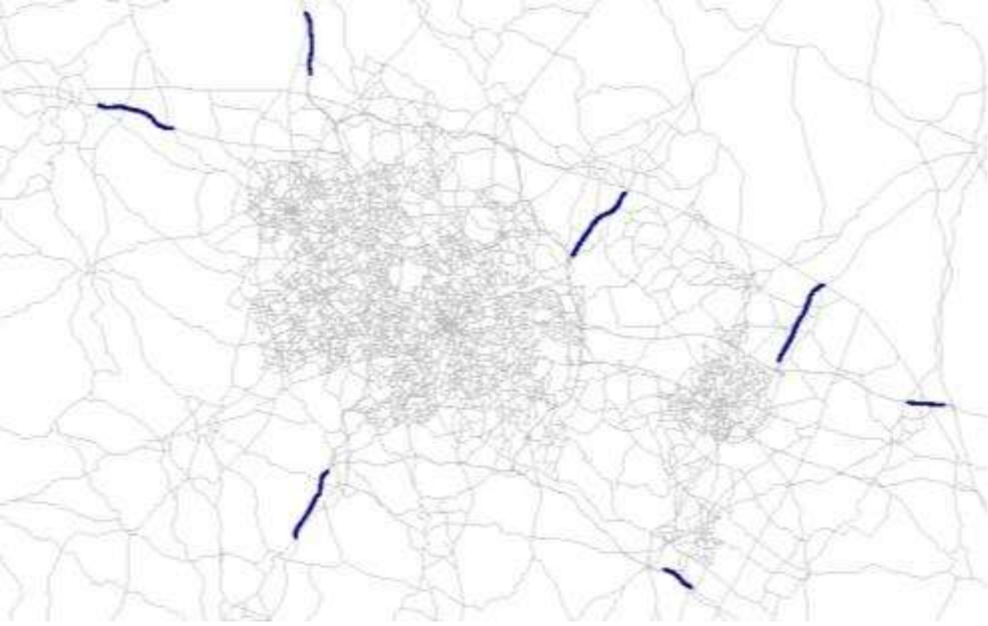
Through-traffic was required in order to obtain sensible route choices within the AoDM. Through-traffic was estimated based on the following approach:

- The prior matrices to the highway networks were assigned;
- Motorway count locations that cross the boundary of the AoDM were identified.
- A comparison of modelled to observed traffic flow for these sites was done.

- Target and range values for each site, classified into light (car and LGV) and HGV were then created.
- Matrix estimation using the small set of motorway counts was performed with the aim of producing through trips.

Figure 2.11 illustrates the sites that were used to create motorway through-trips.

Figure 2.11: Motorway sites used to create through-trips



Source: Mott MacDonald

2.5.5.3 Trip lengths

Following the assignments, trip length distributions have been examined to establish whether these are sensible and consistent with other observations. Comparison of prior matrices for each time period and each purpose against NTS data showed that the final matrices have a very close correlation with NTS. In particular:

- Car-Work has twin peaks at 5-10 miles and 15-25 miles.
- Car-Non Work peaks at 5-10 miles with 3-5 miles only slightly less.
- LGV traffic follows a similar pattern to Car-Work, with peaks in the same distance bands. This is to be expected. LGV also has a greater number of shorter distance trips than Car-Work matrices.
- HGV trips are mostly long distance trips (30% are longer than 50 miles).

The above observations confirm that the PRISM matrix reflects sensible and realistic trip lengths for each of the travel purposes

2.6 Calibration / Validation

2.6.1 Network

The pre-calibration checks of the network are summarised in Table 2.17.

Table 2.17: Network Checks

Section	Description
Link length check	All links were listed and the crow-fly distance compared to the link length. In any cases where the link length was not between 1.1 and 1.3 times the crow-fly distance, the reason has been justified. All links have a link length greater than the crow-fly distance. Link lengths match the polygon length.
Cruise speed check	Cruise speeds were plotted as thematic maps and checked for outliers. Speeds do not vary unjustifiably along a series of links.
Link attributes by direction	All links were listed and a number of attributes by direction were compared. These attributes are cruise speed (or "free-flow" speed for non-urban links within the Area of Detailed Modelling), link type, capacity, number of lanes and vehicle restrictions. Where these differ by direction they have been justified.
Link speeds	The highest speed a link can have is the free flow speed assigned to that particular link type. The free flow speed assigned to a link was checked against the speed limit sourced from NAVTEQ to check that the former does not exceed the latter.
Signalised nodes	All signalised nodes have a signal control attributed to them. All use ICA as the method of calculating impedance at the node. All coding was checked by an independent checker. Signalised nodes were labelled with several tags to be used during network calibration. These tags relate to whether the junction has yellow box markings, is coordinated with other signalised junctions and whether any other additional signal information is available in the signal specification (for example, optional stages) so that these junctions can be reviewed first during network calibration.
Priority nodes	These nodes are all set to use ICA as the method of calculating impedance at node. The logic of the turns open to traffic through priority nodes was independently checked. A normal three arm junction with all links open to traffic should have 6 turns open. Nodes where the number of open turns does not equal 6 have been justified.
Roundabouts	Small roundabouts are all set to use ICA as the method of calculating impedance at node. All roundabouts allow U-turns. All instances where the number of turns open through the node is not standard when compared to the number of junction approaches have been justified, for example a standard 4-arm junction will have 16 turns open to traffic. Links into roundabout nodes all have sensible input values for inscribed circle diameter, entry width, approach half width and flare length.
Uncontrolled	A check was done to locate uncontrolled nodes that should actually be coded with junction control.
Merge nodes	Merge coding was implemented for all high speed merges within the Area of Detailed Modelling and for all motorway junctions of strategic importance in the Rest of the Fully Modelled Area. The only turn available through the merge node is of type 9 as this node has been assigned with the merge coding function.
Network check	A set of network checks are provided by the VISUM software. These checks were run prior to network calibration: Isolated nodes Turns that are open to traffic but their from-link or to-link are closed to traffic Multiple straight turns through an ICA node (these would cause errors during assignment with ICA) Zones not connected O and D pairs that have no paths available Dead-end roads Links without succeeding links Links with a capacity or speed set to 0 Viability for ICA – to look for errors that would prevent the ICA calculation for any node Node geometries

Section	Description
Unitary matrix	A small unitary matrix was assigned. As a result, the following checks were carried out: check for links and turns that are open to traffic but have no volume assigned; check of journey times by direction (symmetry and sensibility); low or zero speeds; and large turn delays.

Source: Mott MacDonald

2.6.2 Trip Matrix Estimation

Matrix estimation is a process of refinement whereby non-zero cell values in a matrix are increased or decreased. Matrix estimation was undertaken on the prior Car Work, Car Non-Work and LGV matrices. HGV matrices have not undergone matrix estimation.

There are relatively few classified counts from which the %HGV could be determined. In addition, the HGV flows would generally be quite low which would mean they are generally without the modified acceptability criteria. In general, it is best to avoid matrix estimation if you can to retain the structure of the observed data.

Matrix estimation within VISUM requires the following inputs as a minimum:

- A network
- A matrix
- An assignment of the matrix to be estimated
- Target and range values for link traffic flows

2.6.3 Trip Matrix Validation

2.6.3.1 Matrix zonal cell values

Table 2.18 summarises the change brought about by matrix estimation for each time period at the matrix OD cell level. TAG Unit 3.19 states the following targets for zonal cell values:

- Slope within 0.98 and 1.02
- Intercept near 0
- R^2 in excess of 0.95

Table 2.18: Monitoring zonal cell values

Time period	Gradient	Intercept	R^2
AM	0.99	-0.02	0.96
IP	0.99	0.02	0.98
PM	1.00	0.03	0.97

Source: Mott MacDonald

2.6.3.2 Matrix zonal trip ends

Table 2.19 summarises the change brought about by matrix estimation for each matrix for trip origins. TAG Unit 3.19 states the following criteria for matrix zonal trip ends:

- Gradient between 0.99 and 1.01
- Intercept near 0
- R^2 in excess of 0.98

Table 2.19: Monitoring zonal trip ends – origins

Time period	Gradient	Intercept	R^2
AM	0.95	5.22	0.95
IP	0.97	27.27	0.97
PM	0.99	37.35	0.97

Source: Mott MacDonald

Table 2.20 summarises the change brought about by matrix estimation for all matrices for trip destinations.

Table 2.20: Monitoring zonal trip ends – destinations

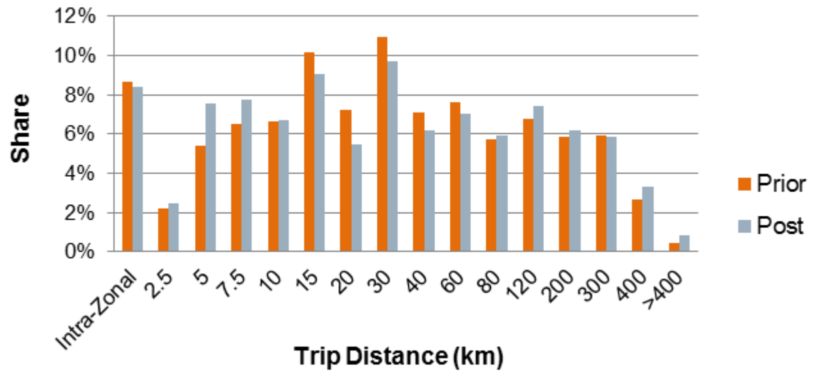
Time period	Gradient	Intercept	R^2
AM	0.97	-5.03	0.96
IP	0.98	24.30	0.98
PM	1.00	34.35	0.96

Source: Mott MacDonald

2.6.3.3 Trip length distribution

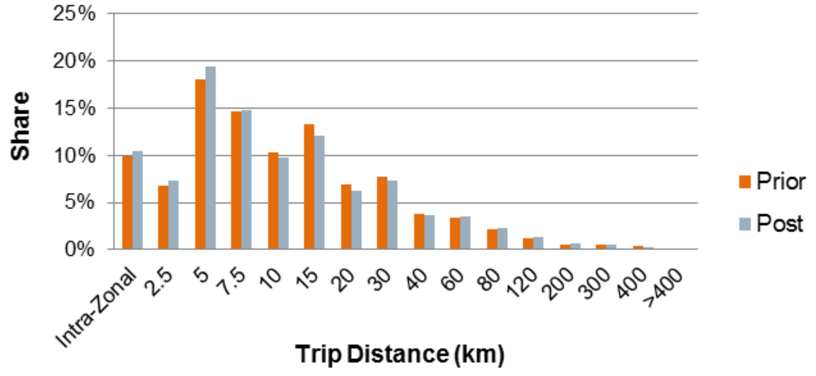
The following figures illustrate the trip length distribution before and after matrix estimation.

Figure 2.12: AM – Car Work



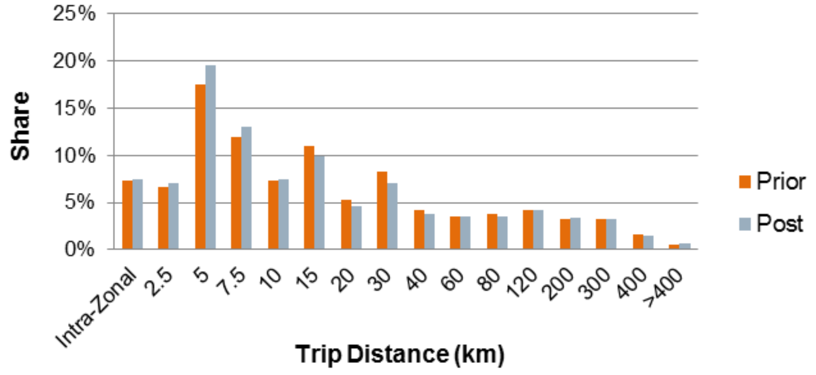
Source: Mott MacDonald

Figure 2.13: AM – Car Non – Work



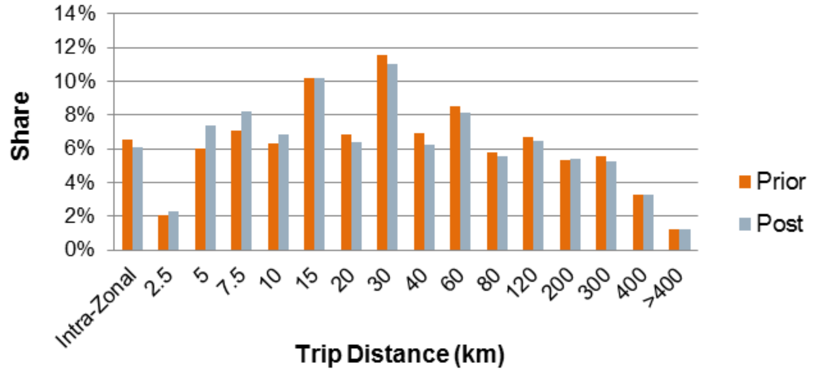
Source: Mott MacDonald

Figure 2.14: AM – LGV



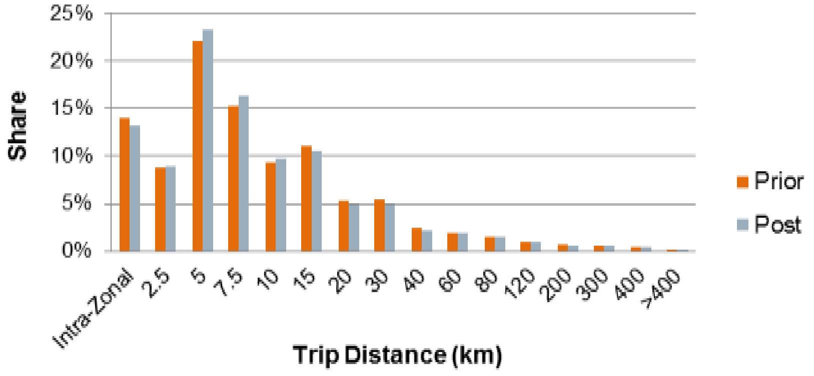
Source: Mott MacDonald

Figure 2.15: IP – Car Work



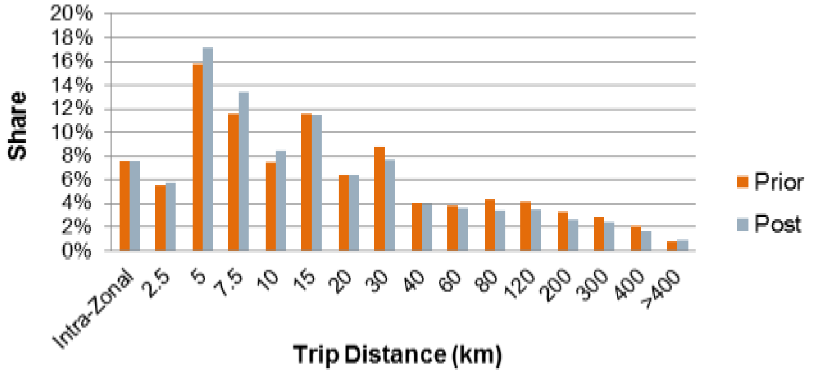
Source: Mott MacDonald

Figure 2.16: IP – Car Non – Work



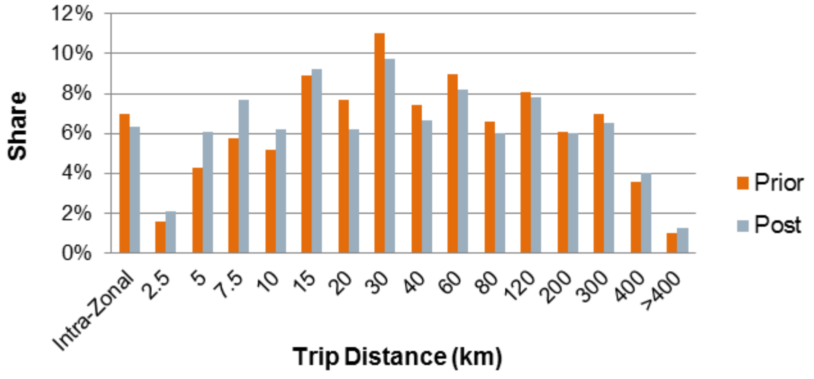
Source: Mott MacDonald

Figure 2.17: IP – LGV



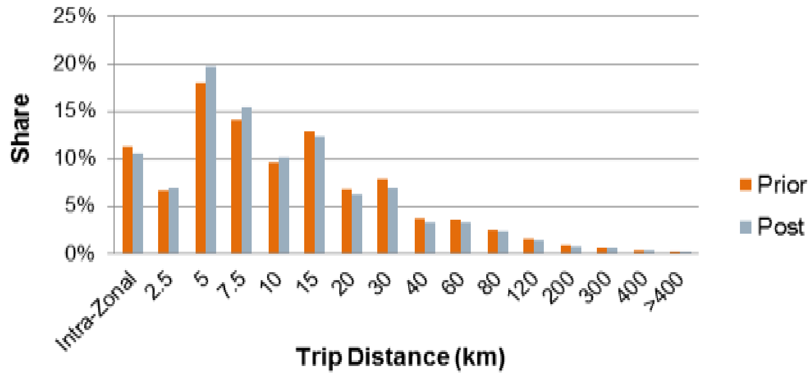
Source: Mott MacDonald

Figure 2.18: PM – Car Work



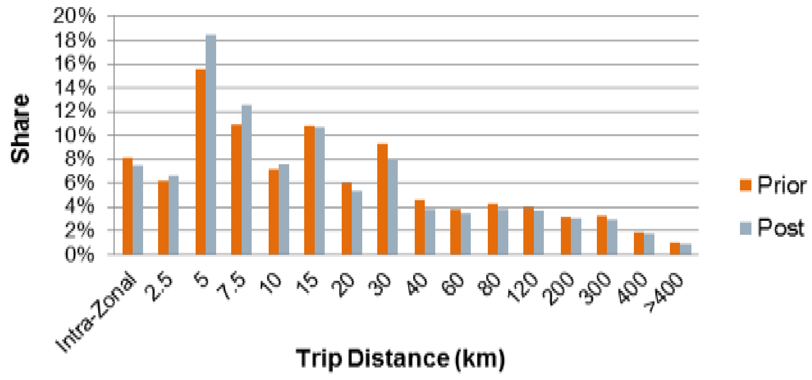
Source: Mott MacDonald

Figure 2.19: PM – Car Non – Work



Source: Mott MacDonald

Figure 2.20: PM – LGV



Source: Mott MacDonald

Table 2.21 shows the mean trip length for each matrix before and after matrix estimation.

Table 2.21: Mean trip lengths (km)

	Car Work			Car Non-Work			LGV		
	Prior	Post	% Difference	Prior	Post	% Difference	Prior	Post	% Difference
AM	58	62	7%	17	16	0%	38	37	-1%
IP	63	61	-3%	14	14	-3%	40	36	-10%
PM	69	69	0%	17	16	-5%	41	38	-7%

Source: Mott MacDonald

The table shows that matrix estimation has had little effect on mean trip length for all matrices. TAG Unit 3.19 requires that mean trip lengths before and after matrix estimation is within 5%. This is the case for most matrices, the exception being the Car Work for AM (7%) and LGV for the IP (10%) and PM (7%).

2.6.4 Assignment Calibration

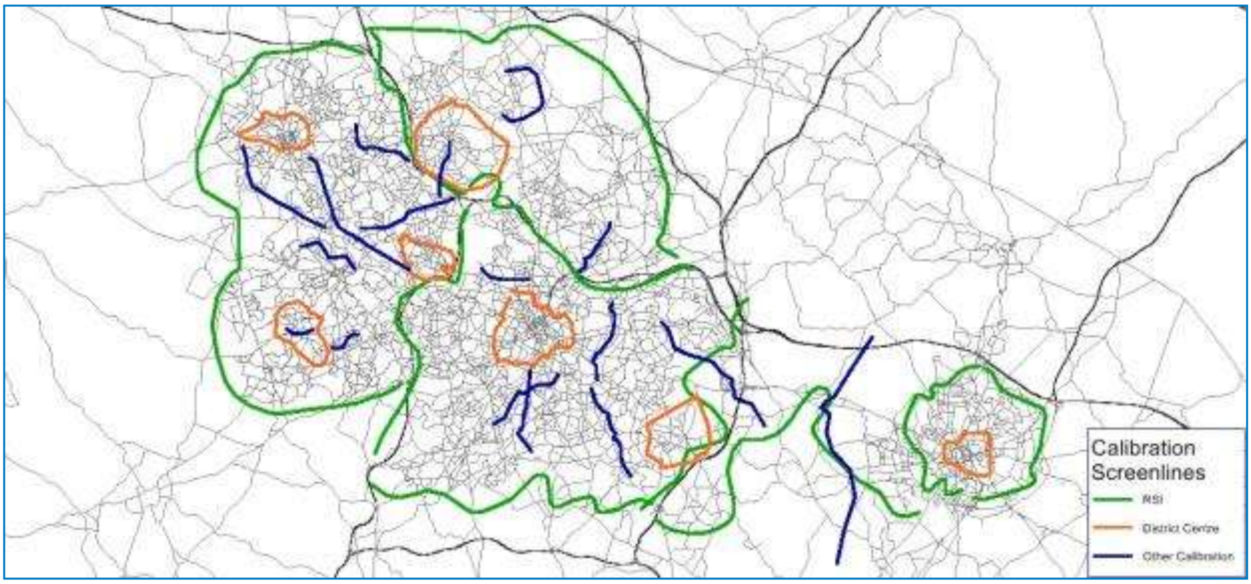
2.6.4.1 Traffic Flows: Screenlines

The following screenlines have been used within the calibration of the highway matrices:

- RSI screenlines
- District screenlines
- Other calibration screenlines

The location of these screenlines is given in Figure 2.21.

Figure 2.21: Location of calibration screenlines



Source: Mott MacDonald

Modelled and observed traffic flows have been compared for all calibration screenlines. The relative difference between modelled and observed flows is summarised in Table 2.22 and the GEH is summarised in Table 2.23.

Table 2.22: Calibration screenline results – relative difference

			Percentage of screenlines within relative difference of:									
Time period	Type	Count	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
AM	RSI	20	25%	45%	55%	60%	75%	75%	90%	90%	90%	100%
	District	14	29%	29%	43%	50%	64%	64%	71%	79%	79%	86%
	Other	34	9%	26%	41%	50%	62%	71%	76%	76%	79%	82%
	All	68	18%	32%	46%	53%	66%	71%	79%	81%	82%	88%
IP	RSI	20	25%	40%	50%	60%	80%	80%	95%	100%	100%	100%
	District	14	7%	36%	64%	64%	64%	71%	71%	71%	86%	86%
	Other	34	18%	35%	47%	50%	68%	74%	76%	85%	91%	94%
	All	68	18%	37%	51%	56%	71%	75%	81%	87%	93%	94%
PM	RSI	20	25%	35%	45%	55%	65%	70%	85%	95%	95%	100%
	District	14	50%	50%	64%	71%	71%	79%	79%	79%	93%	93%
	Other	34	15%	38%	50%	56%	74%	82%	88%	94%	94%	94%
	All	68	25%	40%	51%	59%	71%	78%	85%	91%	94%	96%

Source: Mott MacDonald

Table 2.23: Calibration screenline results – GEH

			Percentage of screenlines within GEH of:									
Time period	Type	Count	1	2	3	4	5	6	7	8	9	10
AM	RSI	20	20%	50%	55%	65%	65%	80%	90%	95%	100%	100%
	District	14	29%	29%	36%	43%	50%	57%	64%	79%	86%	93%
	Other	34	15%	41%	59%	68%	79%	88%	94%	97%	97%	100%
	All	68	19%	41%	53%	62%	69%	79%	87%	93%	96%	99%
IP	RSI	20	30%	40%	55%	65%	85%	90%	100%	100%	100%	100%
	District	14	7%	21%	43%	57%	71%	71%	71%	79%	86%	86%
	Other	34	29%	44%	65%	76%	82%	85%	91%	97%	97%	100%
	All	68	25%	38%	57%	69%	81%	84%	90%	94%	96%	97%
PM	RSI	20	20%	40%	50%	55%	65%	75%	75%	90%	100%	100%
	District	14	36%	50%	50%	64%	71%	79%	79%	93%	93%	93%
	Other	34	18%	47%	65%	79%	91%	97%	97%	97%	100%	100%
	All	68	22%	46%	57%	69%	79%	87%	87%	94%	99%	99%

Source: Mott MacDonald

The above tables illustrate that, whilst calibration screenline flows were not within 5% of the observed in all cases, the level of fit is good, given the scale of the model.

The reason for the calibration screenline flows not falling within 5% of the observed was due to the way that matrix estimation was undertaken. Individual observed link flows were input to matrix estimation, rather than screenline flows (as screenlines could not be formed from the data). This means that while the individual link calibration was good (within GEH of 5), the overall modelled screenline flow was not necessarily within 5% of the observed total.

Further detail, including pass/fail plots of calibration screenlines, is provided in Appendix B.

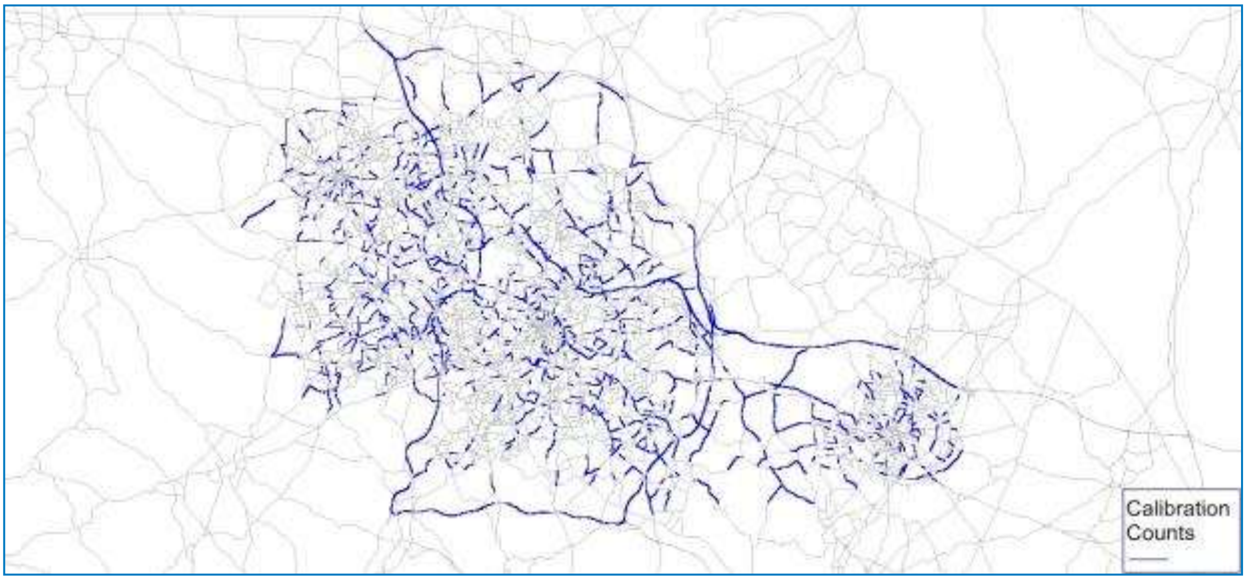
2.6.4.2 Traffic Flows: Individual Links

A comparison of modelled and observed flow on individual calibration links was also undertaken. These links are those that:

- Fall on RSI, district or other calibration screenlines
- Are on journey time routes
- Are stand-alone counts on roads of strategic importance

The location of these counts is illustrated in Figure 2.1.

Figure 2.22: Location of calibration counts



Source: Mott MacDonald

Table 2.24 summarises the level of fit between modelled and observed traffic counts against the modified WebTAG 3.19 criteria.

Table 2.24: Calibration link results – modified WebTAG criteria

Time period	Counts	Pass	Pass (%)
AM	1808	1500	83%
IP	1852	1543	83%
PM	1802	1491	83%

Source: Mott MacDonald

Table 2.25: Calibration link results – unmodified WebTAG criteria

Time period	Counts	Pass	Pass (%)
AM	1808	1403	78%
IP	1852	1462	79%
PM	1802	1433	80%

Source: Mott MacDonald

The above tables show that the modelled flows compare well to the observations in all three time periods for the assessment based on both modified and original WebTAG criteria.

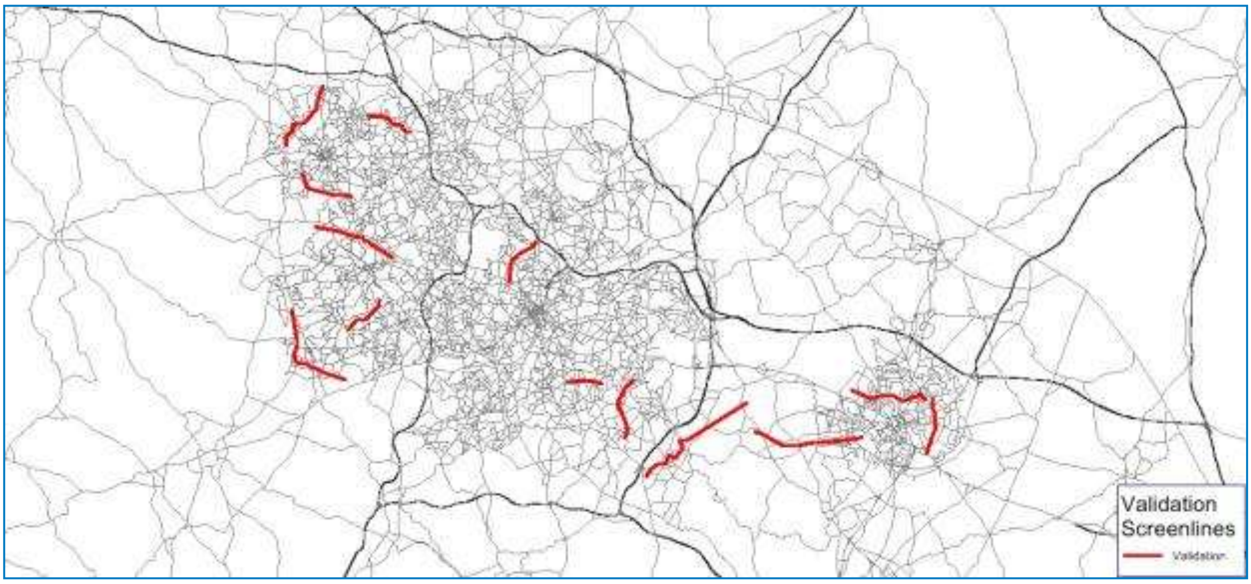
Pass / fail plots of individual calibration links and comparison against count data can be found Appendix B.

2.6.5 Assignment Validation

2.6.5.1 Traffic Flows: Screenlines

In all, thirteen screenlines were retained for independent validation as illustrated in Figure 2.23.

Figure 2.23: Location of screenlines retained for independent validation



Source: Mott MacDonald

Modelled and observed traffic flow have been compared for all 13 validation screenlines. The relative difference between modelled and observed is summarised in Table 2.26 and Table 2.27.

Table 2.26: Validation screenline results – relative difference

		Percentage of screenlines within relative difference of:									
Time period	Count	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
AM	26	19%	31%	35%	42%	50%	54%	62%	69%	81%	88%
IP	26	27%	31%	38%	46%	58%	65%	65%	69%	77%	81%
PM	26	15%	27%	42%	50%	54%	58%	62%	69%	73%	77%

Source: Mott MacDonald

Table 2.27: Validation screenline results - GEH

		Percentage of screenlines within GEH of less than:									
Time period	Count	1	2	3	4	5	6	7	8	9	10
AM	26	27%	38%	54%	73%	85%	88%	88%	96%	96%	96%
IP	26	27%	38%	58%	62%	85%	85%	92%	92%	96%	100%
PM	26	23%	38%	50%	65%	69%	81%	85%	88%	96%	96%

Source: Mott MacDonald

The above tables illustrate that, whilst validation screenline flows are not within 5% of the observed in all cases, the level of fit is good, with the majority of modelled flows on screenlines falling within 10% of observed or within a GEH of 5.

For the Pass / fail plots of validation screenlines refer to Appendix C.

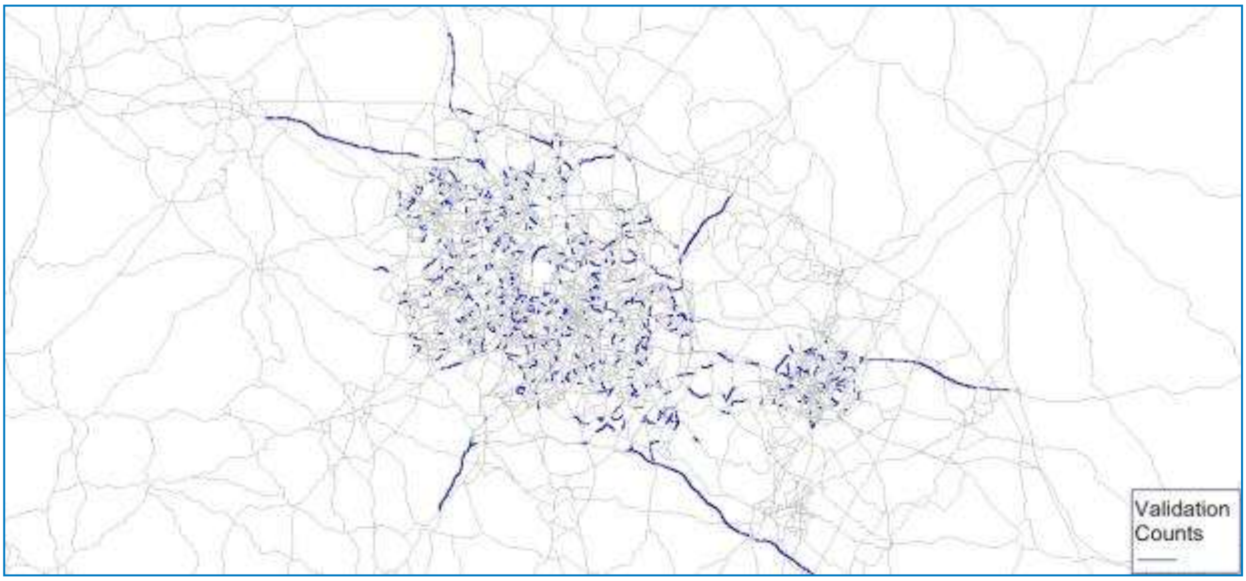
2.6.5.2 Traffic Flows: Individual Links

A comparison of modelled and observed flow on individual validation links has also been undertaken. Links selected are those that:

- Are on validation screenlines
- Are on roads of strategic importance

Figure 2.24 shows the location of count locations retained for independent validation.

Figure 2.24: Location of validation counts retained for independent validation



Source: Mott MacDonald

Table 2.28 summarises the level of fit between modelled and observed traffic counts against the modified WebTAG 3.19 criteria for all link counts retained for independent validation.

Pass/Fail plots of individual validation links and comparison against the count data is provided in Appendix C.

Table 2.28: Validation link results – modified WebTAG criteria

Time period	Counts	Pass	Pass (%)
AM	898	720	80%
IP	898	775	86%
PM	898	706	79%

Source: Mott MacDonald

Table 2.29: Validation link results – unmodified WebTAG criteria

Time period	Counts	Pass	Pass (%)
AM	898	657	73%
IP	898	733	82%
PM	898	649	72%

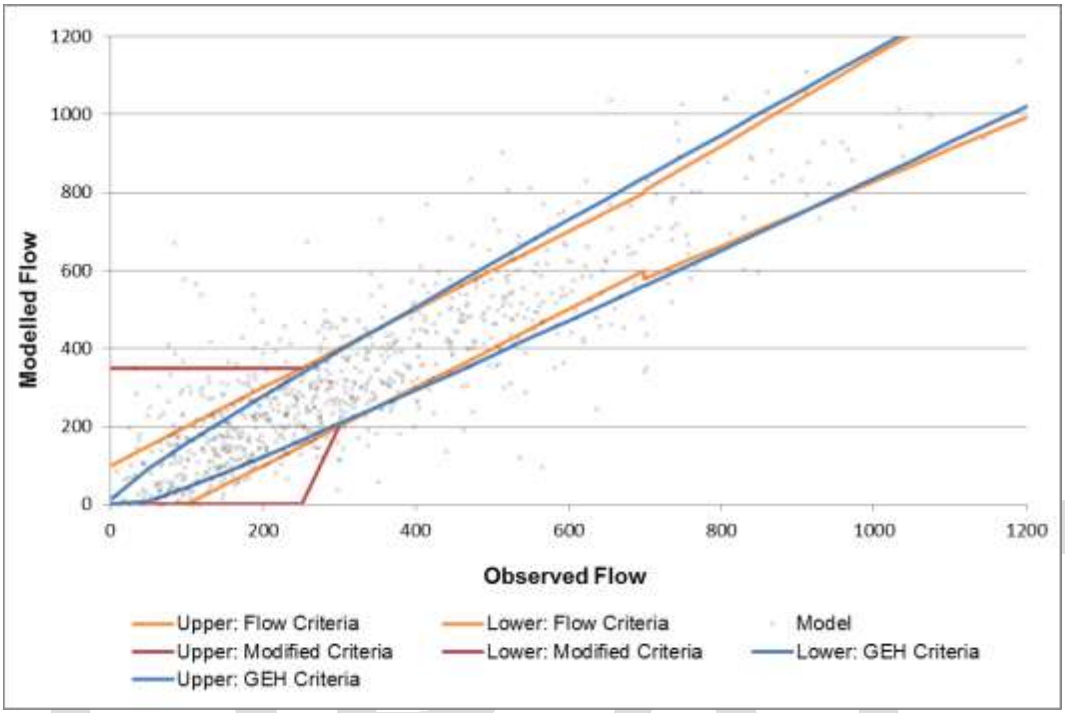
Source: Mott MacDonald

The decrease in level of validation evident from the assessment using original WebTAG criteria shows that poorer fit of modelled flows to counts mainly relates to the roads with lower observed flows (under 250 vehicle/hour), as could be seen from Figure 2.25, Figure 2.26 and Figure 2.27.

PRISM should not be expected to produce modelled traffic flows that are as close to observed traffic counts for roads with low traffic flows as for roads with higher traffic flows, as it is strategic in its nature and does not model important local effects such as pedestrian crossings, cyclists, effects of stopping bus services, increased frontage development and small / numerous side-roads. Also, the zoning system is coarse in some areas, so the loading of trips onto the network is approximate.

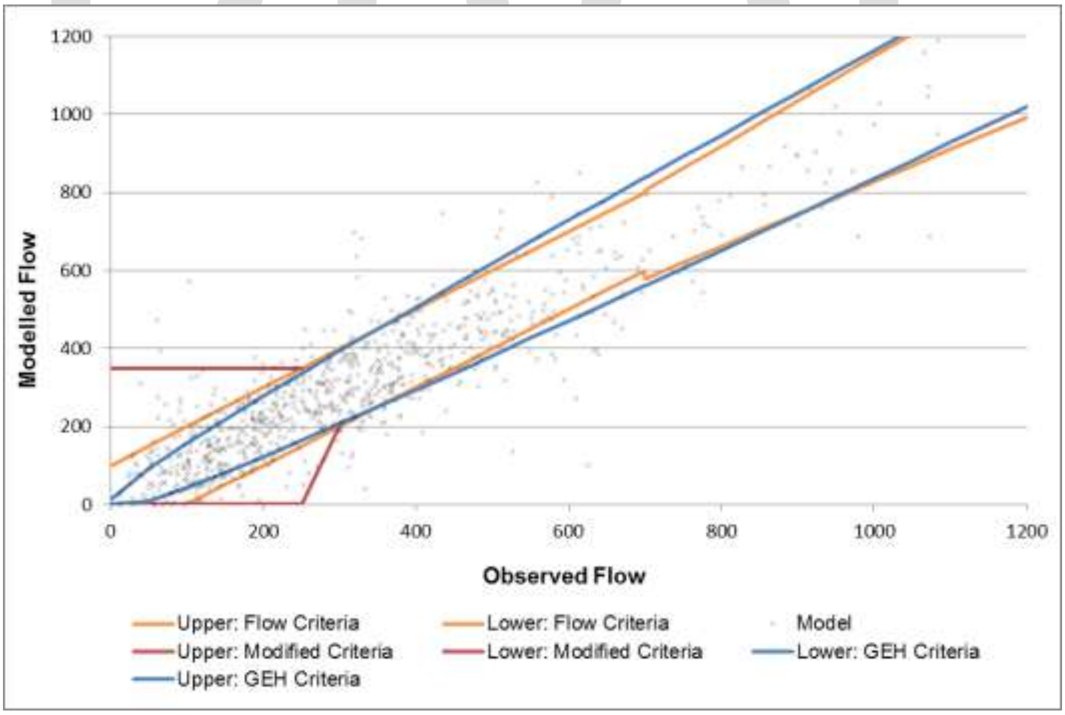
Figure's 2.24, 2.25 and 2.26 illustrate how the modified WebTAG criteria differ from the unmodified WebTAG criteria in assessing the links with low observed flows. The trend lines on the graphs represent the upper and lower bounds for link flows to pass the modified and unmodified flow criteria and the GEH statistic.

Figure 2.25: AM Validation Link Flows



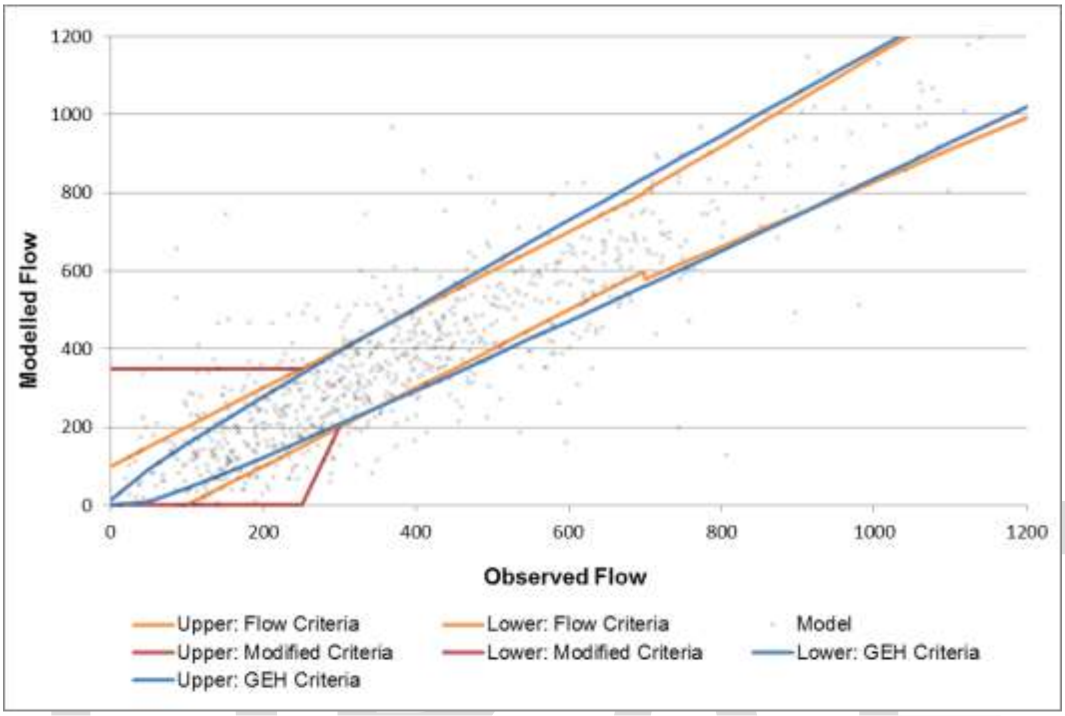
Source: Mott MacDonald

Figure 2.26: IP Validation Link Flows



Source: Mott MacDonald

Figure 2.27: PM Validation Link Flows



Source: Mott MacDonald

2.6.6 Journey Times

Modelled journey times have been compared against TM observed journey times for 54 routes (27 routes in two directions). These routes are illustrated in Figure 2.28.

Table 2.30 summarises how the modelled and observed journey times compare. Individual route comparisons are provided in Appendix D.

Table 2.30: Journey time validation

Time period	% within 1 minute or 15%
AM	78%
IP	91%
PM	81%

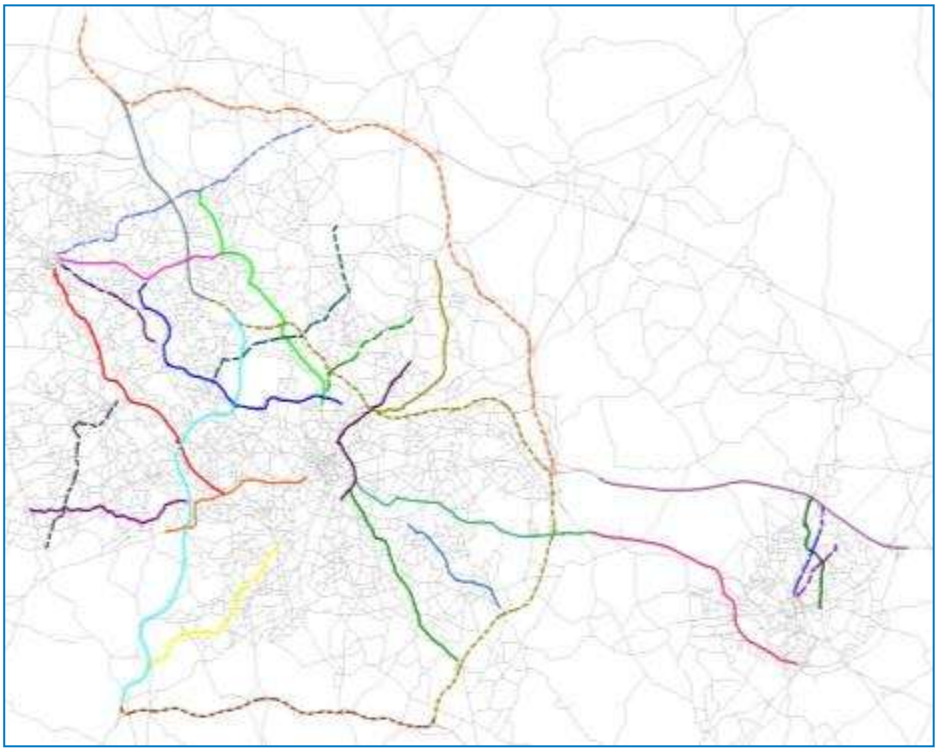
Source: Mott MacDonald

The table shows that the journey time validation is good for all three time periods, with 91% of routes passing the TAG 3.19 criteria in IP, 81% for PM and 78% for AM. In the majority of cases where AM and PM journey times do not validate the modelled journey time is less than the observed, meaning that the model journey times are lower than observed. This is because:

- During the calibration process junction coding was calibrated to reduce overall network delay and queuing on links, which in turn brought about more accurate traffic flows and assignment convergence. This reduction in junction delay may have led to lower journey times.

- Journey time routes are concentrated on strategic routes, which are characterised by signal controlled junctions. Due to the absence of observed signal data, timings for all signal controlled junctions were synthesised, as summarised in Section 2.4.2.3. While traffic flows into or close to these signal controlled junctions were input to the signal optimiser process, not all movements are covered by traffic counts, and as such the signal optimiser process may not have calculated accurate signal timings in all cases, leading to too much or too little green time for certain traffic signal stages on journey time routes.

Figure 2.28: Journey time routes



Source: Mott MacDonald

2.6.7 Assignment Convergence

The convergence criteria are described in Section 2.1.2, and summarised below for four consecutive iterations:

- The final delays of the equilibrium assignment and those obtained from running ICA are close, i.e. ICA produces delays that are consistent with the assignment result.
- The turn volumes from the last equilibrium assignment are close to the smoothed volumes.
- The turn volumes from the last equilibrium assignment are close to those from the previous assignment.

Table 2.31: Level of convergence

		Criteria					
		1		2		3	
Time period	Number of iterations	Target	Achieved	Target	Achieved	Target	Achieved
AM	27	90%	100%	95%	100%	95%	100%
AM	28	90%	99%	95%	100%	95%	100%
AM	29	90%	99%	95%	100%	95%	100%
AM	30	90%	100%	95%	100%	95%	100%
IP	27	90%	100%	95%	100%	95%	100%
IP	28	90%	100%	95%	100%	95%	100%
IP	29	90%	100%	95%	100%	95%	100%
IP	30	90%	100%	95%	100%	95%	100%
PM	27	90%	99%	95%	100%	95%	100%
PM	28	90%	99%	95%	100%	95%	100%
PM	29	90%	99%	95%	100%	95%	100%
PM	30	90%	99%	95%	100%	95%	100%

Source: Mott MacDonald

Table 2.32 summarises %GAP for the last four iterations of the assignment and three time periods.

Table 2.32: %GAP

Time Period	Number of Iterations	Target	Achieved (Car Work)	Achieved (Car Non-Work)	Achieved (HGV)	Achieved (LGV)
AM	27	<0.1%	0.0014%	0.0070%	0.0005%	0.0010%
AM	28	<0.1%	0.0013%	0.0070%	0.0009%	0.0010%
AM	29	<0.1%	0.0005%	0.0059%	0.0005%	0.0007%
AM	30	<0.1%	0.0010%	0.0068%	0.0013%	0.0025%
IP	27	<0.1%	0.0008%	0.0056%	0.0002%	0.0006%
IP	28	<0.1%	0.0005%	0.0044%	0.0001%	0.0004%
IP	29	<0.1%	0.0003%	0.0030%	0.0001%	0.0002%
IP	30	<0.1%	0.0002%	0.0031%	0.0000%	0.0001%
PM	27	<0.1%	0.0010%	0.0094%	0.0002%	0.0010%
PM	28	<0.1%	0.0011%	0.0076%	0.0003%	0.0007%
PM	29	<0.1%	0.0007%	0.0095%	0.0003%	0.0012%
PM	30	<0.1%	0.0013%	0.0071%	0.0001%	0.0013%

Source: Mott MacDonald

The above tables show that the level of convergence achieved for all three highway models successfully meet the standards outlined in WebTAG for the highway assignment.

2.7 Summary

2.7.1 Model Development

The PRISM 2011 highway models have been developed using VISUM version 12.52 as a basis for travel demand forecasting. The models have been built with a tiered level of detail, with detailed junction coding in the Area of Detailed Modelling, speed/flow curves within the Rest of the Fully Modelled Area and fixed speeds within the external. The highway models described in this report incorporate blocking back and the associated flow metering effects within the AoDM, allowing for the more accurate modelling of route choice.

The model includes two car user-classes, LGV and HGV. The models have been built in line with TAG Unit 3.19 guidance for the AM, IP and PM time periods for an average weekday.

Data collected for the development of the base year highway models included RSI surveys to cover trip patterns for all user classes, Trafficmaster data for high mileage drivers, INRIX data for goods vehicle trip patterns, 2011 household travel survey data for travel behaviour, automatic and manual traffic counts for link volume flows and journey time route data.

2.7.2 Standards Achieved

TAG Unit 3.19 criteria were used to assess the performance of the highway models in terms of link volumes, journey times, screenlines, and changes brought about by matrix estimation and convergence.

Whilst the model does not meet or exceed all validation criteria in all cases, the final models validate well against TAG criteria, given the size of the model and the quality of the trip matrix has not been compromised to meet the guideline validation criteria.

3 Public Transport

3.1 Model Standards

3.1.1 Validation Criteria and Acceptability Guidelines

Guidance for the calibration and validation of the PRISM Public Transport Assignment Model (PTAM) was taken from WebTAG unit 3.11.2. This provides criteria for three types of validation:

- Validation of the trip matrix
- Network and service validation
- Assignment validation

Validation of the trip matrix involves comparing modelled flow and observed count values across complete screenlines. The criterion states that in 95% of cases modelled flows should be within 15% of observed counts.

Network and service validation refers to checks completed on the link geometry and comparisons of modelled and observed values on individual services.

Assignment validation refers to comparison of flows on links on screenlines with observed data and also comparison of boardings and alightings in urban centres. In this case flows across modelled screenlines should be within 15% of observed counts and on individual links within the network flows should be within 25% of counts except where the observed flows are below 150. WebTAG does not define the criteria in the case where observed flows are below 150. Therefore a comparison between flows and counts is not made.

Data used for calibration and validation is detailed in section 3.3. The standards achieved and processes undertaken during calibration and validation are given in section 3.6.

3.2 Key Features

3.2.1 Fully Modelled Area and External Area

The PRISM PTAM has similar network coverage to the PRISM HAM, with the same boundary definitions for the FMA (AoDM and RotFMA) and External areas as described in section 2.2.1. Key features of those areas in relation to the PTAM are as follows:

- **Fully modelled area (FMA).** The fully modelled area is subdivided into:
  - *Area of detailed modelling* (AoDM) **-** Modelling in this area is characterised by smaller zones, a detailed link and node network, extra detail within urban centres and all PT services.
  - *Rest of the fully modelled area (RotFMA)* **–** Modelling in this is area is characterised by somewhat larger zones, straight line links between bus stops and all PT services.
- **External area.** Modelling in this area is characterised by a skeletal network, large zones and only external demand through or with one trip end in the FMA represented. The rail network has been simplified in this area to account for the partially represented demand and only PT services which pass into the FMA are included.

3.2.2 Zoning System

The PRISM PTAM zoning system has essentially been constructed by combining the AoDM zones from the Centro 2005/2008 model and the RotFMA and external area zones from the HAM zoning system (see section 2.2.2). Within the AoDM there is a correspondence between the PTAM and HAM zoning systems and typically three to five PTAM zones fit into a HAM zone.

To account for cases where PRISM HAM zones overlapped Centro zones and where more accurate land use modelling was required, five adjustments were made to the PTAM zoning system in the AoDM:

- A zone in Walsall city centre has been split into two parts.
- The zone containing the proposed Curzon Street HS2 station has been split into two parts.
- Three zones in Sandwell have each been split into two parts.

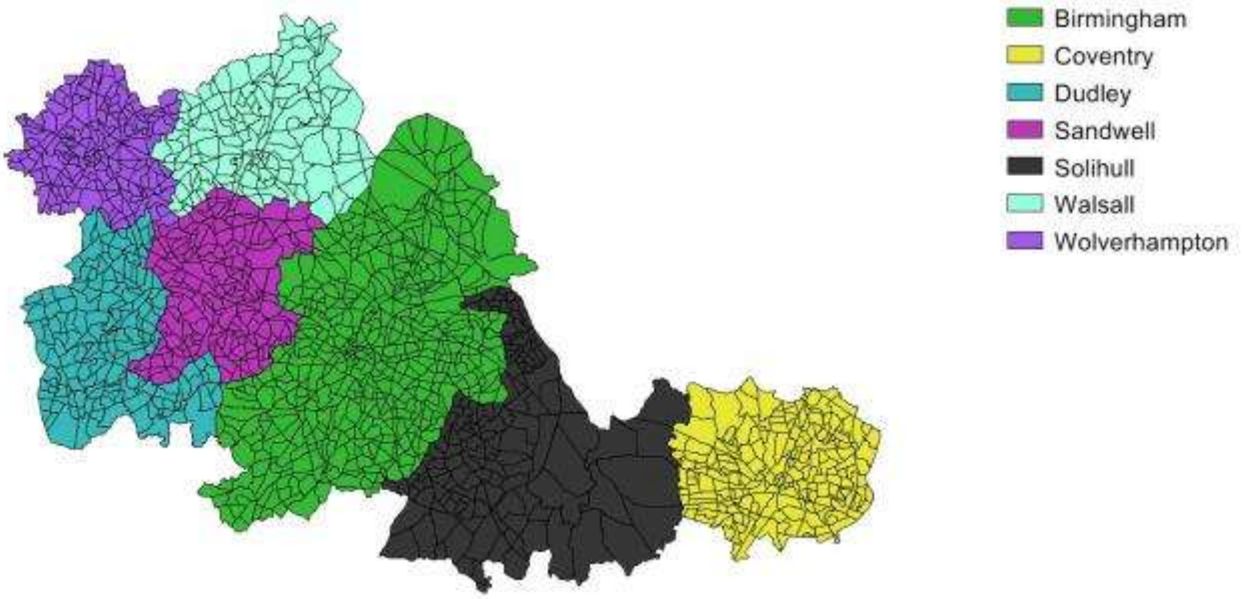
Table 3.1 gives an overview of the zoning system. For detail on centroids and connectors see section 3.2.4.

Table 3.1: Overview of Zoning System

System	Area	Frequency	Comment
PRISM PTAM	All	1900	
	Polygon	1855	Non Park and Ride Zones
	Point	45	Park and Ride Zones
From Centro 2005/2008 Model (including the five adjustments above and Park and Ride zones)	Birmingham	512	Sum = 1603
	Coventry	204	
	Dudley	170	
	Sandwell	179	
	Solihull	154	
	Walsall	150	
	Wolverhampton	189	
	Park and Ride	45	
PRISM HAM	Intermediate	254	Sum = 297
	Rest of WM	20	
	External	23	

Figure 3.1 below shows the zoning system within the AoDM area to give an example of the level of detail that it contains.

Figure 3.1: PTAM zones in the Area of Detailed Modelling



Source: Mott MacDonald

3.2.3 Network Structure

This section gives a brief description of the network structure. For further information see section 3.4.

Historically the PRISM HAM and the PRISM/Centro PTAMs contained different link and node topology. As a result of this there is no direct correspondence between links or nodes between the PRISM HAM and PTAM. See section 3.2.11 for more detail on the relationship between the two models.

The network structure of the PRISM PTAM is based on the Centro 2005/2008 PT model. It contains the following:

- A detailed link network within the AoDM, taken from Centro's 2005/2008 model which was originally built on the 2001 OS OSCAR road network dataset.
- A less detailed link network outside of the AoDM where only straight links exist between PT stops.
- A large number of links included within the urban areas of the AoDM which are used to model passengers walking to and between services.
- A rail and Midland Metro network coded separately to the bus network with a realistic representation of the actual rail and Metro services. Only the rail lines which are relevant to the model are included.

There are no changes to the link and node network since 2005. This is because any major highway changes have not significantly affected bus routes and only small revisions have been made during the checking stages. The implications of any highway changes are reflected in modelled journey times, as the 2011 bus timetable data will include the stop to stop scheduled service times.

3.2.4 Centroid Connectors

Zone centroids have been coded based on the location of population within each zone in a similar way to the PRISM HAM (see 2.2.4)

In the PRISM PTAM a connector will generally represent the path a person takes to walk on to the network. The following assumptions have been used to add connectors into the network:

- Where possible, connectors have been coded such that they do not cross barriers to movement, i.e. rivers, railways and major roads such as motorways.
- Where possible, several connectors are coded from each zone to model the choice of services available.
- At least one PT service should be accessible from any zone in at least one of the modelled time periods.
- The length of connectors has been multiplied by 1.2 to represent the bendiness of roads.
- The travel time along any connector is limited to 15 minutes and all connector distances are limited to 1km. This is generally applied in the RotFMA and external areas since catchment areas have been defined for the AoDM.
- Where possible consecutive stops of a service are not joined to the same zone via a connector.

A catchment area has been set for each mode of travel within the AoDM:

Bus	400m
Midland Metro	600m
Heavy Rail	800m

This helps to improve access and to model realistic mode choices.

3.2.5 Time Periods

The services within the PRISM PTAM represent an average weekday in October 2011. The demand assigned to the networks represents an average weekday (during school term) in 2011. The following 2-hour time periods are represented in the PRISM PTAMs:

- AM: 0700-0900
- IP: 1000-1200
- PM: 1600-1800

3.2.6 User Classes

There are three demand segments included in the model, and each demand segment is allowed to use any bus, metro or train service:

- The Fare and No Fare demand segments include all trips between any zones in the FMA
- The PLD (Planet Long Distance) demand segment contains demand to or from external area zones

The Fare demand segment is for passengers who pay full cash fares for each service boarded. The No Fare demand segment assumes that no fares are paid at the point of use and represents season ticket and concessionary fares. Therefore a passenger who pays for a season ticket or a concessionary fare pays no fare in the assignment. For more information on the relevance of fares within the model see section 3.2.8.

The PLD demand segment is based on data available from the PLD model. For more information see section 3.5.4.

The fare and no-fare demand segments have been used by Centro in public transport modelling in previous models, meaning much of the demand data available is already assigned to these classes. In scoping the model development the user class definition was revisited, considering the potential for a new approach. On the basis that the current classes work well in assignment, produce plausible results, and can interface with the PRISM Demand Model, the decision was taken to retain this approach.

3.2.7 Crowding

The issue of whether to include a representation of the impacts of crowded conditions on public transport vehicles was considered in detail. The topic was reviewed and advice was sought from various parties including the Department for Transport at the beginning of 2013. While recognising that crowding does occur on the West Midlands rail network, and on Midland Metro Line One, the decision was taken not to model crowding in the PTAM. This view was informed by a number of factors:

- There is a lack of observed data available – particularly for the bus network
- Other models held by Centro are capable of modelling crowding (e.g. Radform model based on PDFH crowding costs and elasticities)
- Model outputs can be checked against capacity, with crowding changes for future scenarios calculated through post assignment processing

In order to future-proof the model a method has been identified which will allow crowding costs to be included but would require re-estimation of the PRISM Demand Model.

3.2.8 Fares

Fares are only taken into account by passengers who belong to the Fare demand segment. Concessionary fares such as all-day fares or return fares were not taken into account. Therefore, only data related to single cash fares was collected.

Fare is coded in the PTAM in two parts which are added together to calculate the total fare:

- A boarding fare, which is paid by passengers when they board a service in the model.
- A distance based fare, which is incurred by a passenger based on the distance they travel.

Passengers boarding a bus service pay a fee of £1.80 and they do not pay a distance based fare. This price has been chosen as it was the National Express West Midlands price for a single ticket in 2011. Train and Metro services include a boarding fare as well as a distance based fare.

The fare points for Metro have been calculated using a fare matrix which uses Microsoft Excel solver to best fit a linear distance based fare with the actual fare matrix. Table 3.2 and Table 3.3 show the actual fare matrix used and the fare points calculated by Microsoft Excel solver.

Table 3.2: Midlands Metro Fares

From Stop To Stop	Snow Hill	St Paul's	Jewellery Quarter	Soho Benson Road	Winson Green	Handsworth Booth Street	The Hawthorns	Kenrick Park	Trinity Way	West Bromwich Central	Lodge Road	Dartmouth Street	Dudley Street	Black Lake	W'bury Great Western Street	Wednesbury Parkway	Bradley Lane	Loxdale	Bilston Central	The Crescent	Priestfield	The Royal	St George's
Snow Hill		1.90	1.90	1.90	2.60	2.60	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
St Paul's	1.90		1.90	1.90	2.60	2.60	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
Jewellery Quarter	1.90	1.90		1.90	1.90	2.60	2.60	2.60	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
Soho Benson Road	1.90	1.90	1.90		1.90	1.90	1.90	2.60	2.60	2.60	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
Winson Green	2.60	2.60	1.90	1.90		1.90	1.90	2.60	2.60	2.60	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
Handsworth Booth St.	2.60	2.60	2.60	1.90	1.90		1.90	1.90	1.90	2.60	2.60	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
The Hawthorns	2.60	2.60	2.60	1.90	1.90	1.90		1.90	1.90	1.90	2.60	2.60	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30	3.30	3.30
Kenrick Park	2.60	2.60	2.60	2.60	2.60	1.90	1.90		1.90	1.90	1.90	1.90	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30	3.30	3.30
Trinity Way	2.60	2.60	2.60	2.60	2.60	1.90	1.90	1.90		1.90	1.90	1.90	1.90	1.90	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30	3.30
West Bromwich Central	2.60	2.60	2.60	2.60	2.60	2.60	1.90	1.90	1.90		1.90	1.90	1.90	1.90	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30
Lodge Road	3.30	3.30	2.60	2.60	2.60	2.60	2.60	1.90	1.90	1.90		1.90	1.90	1.90	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30
Dartmouth Street	3.30	3.30	2.60	2.60	2.60	2.60	2.60	1.90	1.90	1.90	1.90		1.90	1.90	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30	3.30
Dudley Street	3.30	3.30	3.30	2.60	2.60	2.60	2.60	2.60	1.90	1.90	1.90	1.90		1.90	1.90	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30
Black Lake	3.30	3.30	3.30	2.60	2.60	2.60	2.60	2.60	1.90	1.90	1.90	1.90	1.90		1.90	2.60	2.60	2.60	2.60	3.30	3.30	3.30	3.30
W'bury Great Western	3.30	3.30	3.30	3.30	3.30	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	1.90		1.90	1.90	2.60	2.60	2.60	2.60	2.60	3.30
Wednesbury Parkway	3.30	3.30	3.30	3.30	3.30	3.30	3.30	2.60	2.60	2.60	2.60	2.60	2.60	2.60	1.90		1.90	2.60	2.60	2.60	2.60	2.60	3.30
Bradley Lane	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	2.60	2.60	2.60	2.60	2.60	2.60	1.90	1.90		1.90	1.90	1.90	2.60	2.60	2.60
Loxdale	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	2.60	2.60	2.60	2.60	2.60	2.60	2.60	1.90		1.90	1.90	1.90	2.60	2.60
Bilston Central	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	2.60	2.60	2.60	2.60	1.90	1.90		1.90	1.90	1.90	2.60
The Crescent	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	2.60	2.60	1.90	1.90	1.90		1.90	1.90	2.60
Priestfield	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	2.60	2.60	2.60	1.90	1.90	1.90		1.90	1.90
The Royal	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	2.60	2.60	2.60	2.60	1.90	1.90	1.90		1.90
St George's	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	2.60	2.60	2.60	2.60	1.90	1.90	

Source: Centro

Table 3.3: Midland Metro Fare Implementation as Calculated using Microsoft Excel Solver

From Stop / To Stop	Fare Points	Snow Hill	St Paul's	Jewellery Quarter	Soho Benson Road	Winson Green	Handsworth Booth Street	The Hawthorns	Kenrick Park	Trinity Way	West Bromwich Central	Lodge Road	Dartmouth Street	Dudley Street	Black Lake	W'bury Great Western Street	Wednesbury Parkway	Bradley Lane	Loxdale	Bilston Central	The Crescent	Priestfield	The Royal	St George's
Snow Hill	0.0		1.90	1.92	1.92	2.27	2.28	2.30	2.31	2.32	2.62	2.62	2.62	2.96	2.97	2.97	2.97	3.47	3.47	3.47	3.54	3.56	3.58	3.58
St Paul's	0.0	1.90		1.92	1.92	2.27	2.28	2.30	2.31	2.32	2.62	2.62	2.62	2.96	2.97	2.97	2.97	3.47	3.47	3.47	3.54	3.56	3.58	3.58
Jewellery Quarter	0.0	1.92	1.92		1.90	2.26	2.27	2.28	2.30	2.31	2.60	2.60	2.60	2.95	2.95	2.95	2.95	3.45	3.45	3.45	3.53	3.55	3.57	3.57
Soho Benson Road	0.0	1.92	1.92	1.90		2.25	2.25	2.27	2.28	2.29	2.59	2.59	2.59	2.93	2.94	2.94	2.94	3.44	3.44	3.44	3.51	3.54	3.55	3.55
Winson Green	0.4	2.27	2.27	2.26	2.25		2.25	2.27	2.28	2.29	2.58	2.59	2.59	2.93	2.94	2.94	2.94	3.44	3.44	3.44	3.51	3.53	3.55	3.55
Handsworth Booth St.	0.0	2.28	2.28	2.27	2.25	2.25		1.91	1.93	1.94	2.23	2.23	2.23	2.58	2.58	2.58	2.58	3.08	3.08	3.08	3.16	3.18	3.20	3.20
The Hawthorns	0.0	2.30	2.30	2.28	2.27	2.27	1.91		1.92	1.93	2.22	2.23	2.23	2.57	2.57	2.57	2.57	3.07	3.07	3.07	3.15	3.17	3.19	3.19
Kenrick Park	0.0	2.31	2.31	2.30	2.28	2.28	1.93	1.92		1.91	2.21	2.21	2.21	2.55	2.56	2.56	2.56	3.06	3.06	3.06	3.13	3.16	3.17	3.17
Trinity Way	0.0	2.32	2.32	2.31	2.29	2.29	1.94	1.93	1.91		2.19	2.20	2.20	2.54	2.54	2.54	2.54	3.04	3.04	3.04	3.12	3.14	3.16	3.16
West Bromwich Central	0.3	2.62	2.62	2.60	2.59	2.58	2.23	2.22	2.21	2.19		2.19	2.19	2.53	2.53	2.53	2.53	3.03	3.03	3.03	3.11	3.13	3.15	3.15
Lodge Road	0.0	2.62	2.62	2.60	2.59	2.59	2.23	2.23	2.21	2.20	2.19		1.89	2.23	2.24	2.24	2.24	2.74	2.74	2.74	2.82	2.84	2.85	2.85
Dartmouth Street	0.0	2.62	2.62	2.60	2.59	2.59	2.23	2.23	2.21	2.20	2.19	1.89		2.23	2.24	2.24	2.24	2.74	2.74	2.74	2.81	2.83	2.85	2.85
Dudley Street	0.3	2.96	2.96	2.95	2.93	2.93	2.58	2.57	2.55	2.54	2.53	2.23	2.23		2.24	2.24	2.24	2.74	2.74	2.74	2.81	2.83	2.85	2.85
Black Lake	0.0	2.97	2.97	2.95	2.94	2.94	2.58	2.57	2.56	2.54	2.53	2.24	2.24	2.24		1.90	1.90	2.40	2.40	2.40	2.47	2.49	2.51	2.51
W'bury Great Western	0.0	2.97	2.97	2.95	2.94	2.94	2.58	2.57	2.56	2.54	2.53	2.24	2.24	2.24	1.90		1.89	2.39	2.39	2.39	2.46	2.48	2.50	2.50
Wednesbury Parkway	0.0	2.97	2.97	2.95	2.94	2.94	2.58	2.57	2.56	2.54	2.53	2.24	2.24	2.24	1.90	1.89		2.39	2.39	2.39	2.46	2.48	2.50	2.50
Bradley Lane	0.5	3.47	3.47	3.45	3.44	3.44	3.08	3.07	3.06	3.04	3.03	2.74	2.74	2.74	2.40	2.39	2.39		2.39	2.39	2.46	2.48	2.50	2.50
Loxdale	0.0	3.47	3.47	3.45	3.44	3.44	3.08	3.07	3.06	3.04	3.03	2.74	2.74	2.74	2.40	2.39	2.39	2.39		1.89	1.96	1.98	2.00	2.00
Bilston Central	0.0	3.47	3.47	3.45	3.44	3.44	3.08	3.07	3.06	3.04	3.03	2.74	2.74	2.74	2.40	2.39	2.39	2.39	1.89		1.96	1.98	2.00	2.00
The Crescent	0.1	3.54	3.54	3.53	3.51	3.51	3.16	3.15	3.13	3.12	3.11	2.82	2.81	2.81	2.47	2.46	2.46	2.46	1.96	1.96		1.98	2.00	2.00
Priestfield	0.0	3.56	3.56	3.55	3.54	3.53	3.18	3.17	3.16	3.14	3.13	2.84	2.83	2.83	2.49	2.48	2.48	2.48	1.98	1.98	1.98		1.93	1.93
The Royal	0.0	3.58	3.58	3.57	3.55	3.55	3.20	3.19	3.17	3.16	3.15	2.85	2.85	2.85	2.51	2.50	2.50	2.50	2.00	2.00	2.00	1.93		1.90
St George's	0.0	3.58	3.58	3.57	3.55	3.55	3.20	3.19	3.17	3.16	3.15	2.85	2.85	2.85	2.51	2.50	2.50	2.50	2.00	2.00	2.00	1.93	1.90	
Boarding Penalty	**1.9**																							

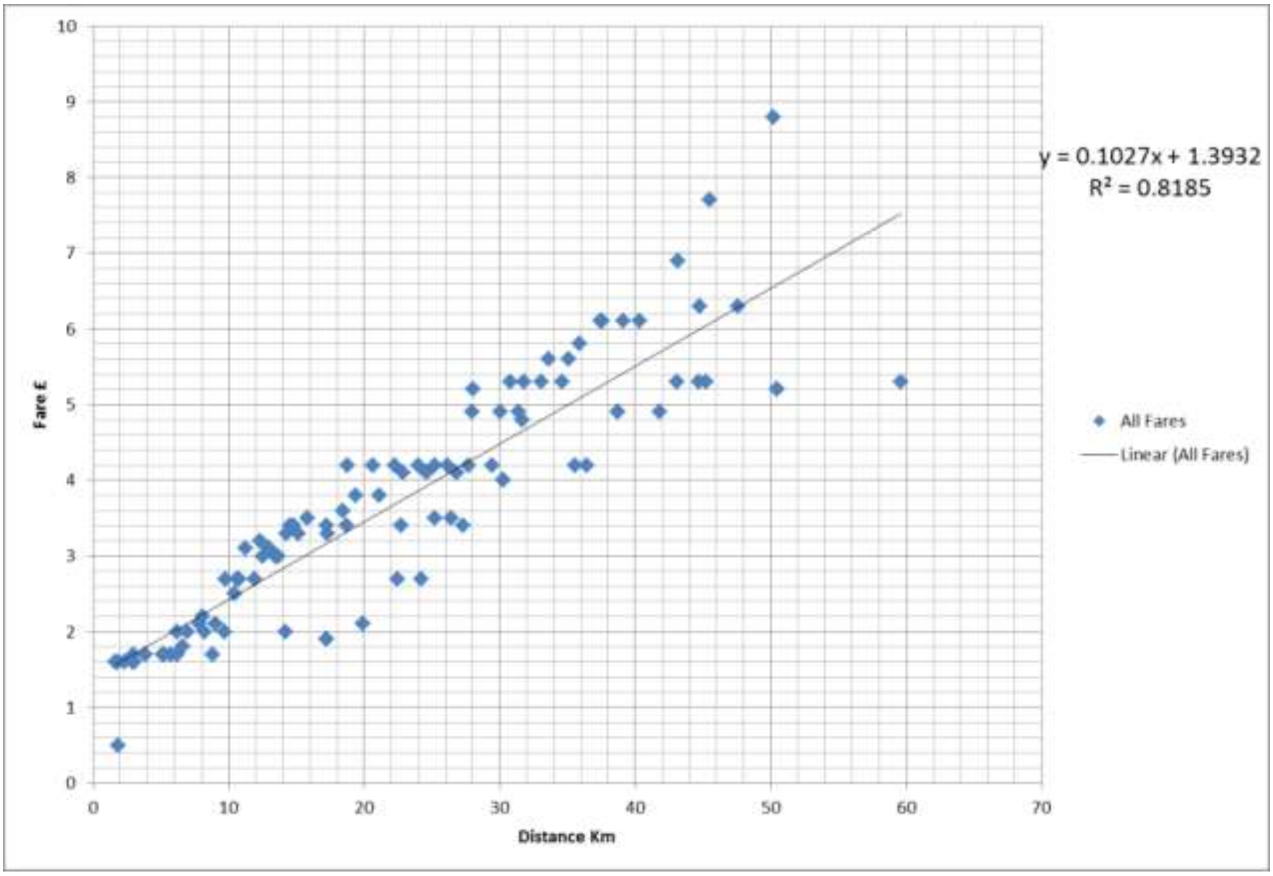
Source: Centro

In order to include rail fares within the model data has been sourced from Centro's London Midlands fare matrices and www.nationalrail.co.uk. This data has been used to plot a scatter graph of the distances of each leg against the prices of the tickets for each leg.

A linear regression was calculated to create a linear fare based on distance. One regression line was created for services outside of the AoDM and one was created for services outside of the AoDM. The regression for fares outside of the AoDM was specified to have the same intercept as the within-AoDM regression for practical reasons.

The outcome was a rail boarding penalty of £1.39 and a fare per kilometre in the AoDM and non-AoDM of £0.10 and £0.28 respectively. Figure 3.2 shows the regression line created based on the data available in the AoDM.

Figure 3.2: Linear Regression for Fares in the AoDM



3.2.9 Generalised Cost Formulation

The generalised cost calculation takes into account the various legs of a passenger journey including walk access, waiting for a service, on board time, fares, and interchanges. The various weightings of each trip leg element have been calibrated as part of the overall network calibration. As an example Table 3.4 below presents the tests conducted for the AM/PM PTAM assignment models.

Table 3.4: AM / PM PTAM generalised cost calibration

Scenario	VOT	Access Time	Egress Time	Walk Time	Origin Wait Time	Transfer Wait Time	Transfer Penalty	Walk Speed	IVT Metro	Coordination	Boarding Penalty Factor
Base	£2.32	1.75	1.75	1.75	2.00	2.00	10mins	4.8kph	0.95	Groups	1
Test 1	£6.45	1.75	1.75	1.75	2.00	2.00	10mins	4.8kph	0.95	Groups	1
Test 2	£2.32	1.75	1.75	1.75	2.00	2.00	8mins	4.8kph	0.95	Groups	1
Test 3	£2.32	2.00	2.00	2.00	2.00	2.00	10mins	4.8kph	0.95	Groups	1
Test 4	£2.32	1.75	1.75	1.75	2.00	2.00	10mins	4.8kph	0.95	Groups	1
Test 5	£2.32	1.75	1.75	1.75	2.00	2.00	10mins	4.8kph	1	Groups	1
Test 6	£2.32	1.75	1.75	1.75	2.00	2.00	10mins	4.8kph	0.95	Groups	1
Test 7	£2.32	1.75	1.75	1.75	2.00	2.00	10mins	4.8kph	0.95	Groups	1
Test 8	£2.32	1.75	1.75	1.75	2.00	2.00	10mins	4.8kph	0.95	Off	1
Test 9	£2.32	1.75	1.75	1.75	2.00	2.00	10mins	4.8kph	0.95	On	1
Test 10	£2.32	1.75	1.75	1.75	2.00	2.00	10mins	6kph	0.95	Groups	1
Test 11	£2.32	1.75	1.75	1.75	2.00	2.00	10mins	4.8kph	0.95	Groups	1.5
Test 12	£2.32	1.75	1.75	1.75	2.00	2.00	10mins	4.8kph	0.95	Groups	1

Source: Centro

The above tests used the PT prior matrix and compared flows to observed counts to identify the optimum settings. The final values used are shown in Table 3.5.

Table 3.5: Final PTAM generalised cost weightings by time period

Attribute	AM / PM	IP
VOT	£2.32	£1.60
Access Time	1.75	2.5
Egress Time	1.75	2.5
Walk Time	1.75	2.5
Origin Wait Time	2	2
Transfer Wait Time	2	3
Transfer Penalty	10mins	8mins

Attribute	AM / PM	IP
Walk Speed	4.8kph	4.8kph
IVT Metro	0.95	0.95
IVT Rail	0.9	0.9
Fare Split	AM 27%, PM 15%	18%
Coordination	Off	Groups
Boarding Penalty Factor	1	1

Source: Centro

3.2.10 Assignment Method

The assignment methodology makes use of the headway based assignment and parameters provided in the VISUM software. The decision to use this, rather than the timetable based method was informed by the large scale of the model, the high proportion of high frequency services, the need to have sensible model run times and was also related to the type of schemes that the model will be used to test.

Specific attributes incorporated into the assignment procedure include:
- Fare modelling through the use of a boarding penalty and fare points.
- Origin wait time factor to reduce wait time for infrequent services.
- Local value of time (adjusted through network calibration).
- Assumption that passengers know the service frequency, but route sections are not assumed to be coordinated

3.2.11 Integration

The PRISM PTAM and PRISM HAM are separate assignment models but are integrated in a number of ways. The PTAM does not react to any type of congestion on the road network however the demand model accounts for the change in speed of buses in the future. For more information see the PRISM Forecasting Report. The Highway network takes a bus pre-load from the PT network.

3.3 Calibration Data

Please see Appendix E for plots of the various calibration data described below.

3.3.1 Bus Count Data

3.3.1.1 LTP Bus Cordon Counts

Cordon counts were conducted at nine centres across the Metropolitan area:
- Birmingham City Centre
- Wolverhampton City Centre
- Coventry City Centre

- Walsall Town Centre
- Dudley Town Centre
- Sutton Coldfield Town Centre
- Solihull Town Centre
- West Bromwich Town Centre
- Brierley Hill Centre

Conducted bi-annually at each centre, these counts capture passengers boarding, alighting and on-board all buses between 0700 and1230 on an average weekday. A selection of sites within each cordon is surveyed in both directions, which provides factors by which outbound passenger flows at all sites are calculated. To provide the PM passenger counts, the surveys conducted in 2010 and 2011 were extended to finish at 1800.

3.3.1.2 Local Centre Cordon Counts

In building the previous Centro public transport model it was recognised that there is a lack of calibration data for bus trips taking place away from LTP centres. In order to improve subsequent model builds Centro commissioned a programme of bus cordon counts at local and district centres across the WMMA. This provides passenger boarding, alighting and on-board counts for all buses crossing the cordon. In total there are 22 local centre cordons including areas such as Harborne, Perry Barr and Kings Heath.

3.3.1.3 Origin-Destination Survey Passenger Counts

Passenger counts were conducted alongside origin-destination surveys conducted since 2005. Passenger boarding and alighting counts were processed into stop boarding and alighting flows by time period for use in calibration. These typically form cordons of local centres or interchange sites, where all relevant stops have been surveyed.

3.3.1.4 Bus Showcase Counts

These have been conducted in a number of corridors across the Metropolitan area over the period from 2008 to 2011 for the purposes of monitoring passenger use. They are in the same format as the bus cordon counts and they provide boarding, alighting and on-board counts. They typically comprise a stop at the outer end of the route, mid route, and at the corresponding LTP cordon site (as the majority of services run into main centres).

3.3.1.5 Bus Station Counts

Passenger boarding and alighting counts conducted at a number of Centro operated bus stations have been made available, processed into boarding and alighting flows.

3.3.2 Rail Count Data

3.3.2.1 LTP Centre Rail Cordon Counts

When conducting the bus LTP cordon counts, if a rail station lies within the cordon passenger boarding and alighting counts are conducted. Passenger counts for 2010 and 2011 were available for calibrating the 2011 base year public transport model, as for the bus counts they are conducted on a bi annual programme in the locations referred to in section 3.3.1.1.

3.3.2.2 Control Station Counts

For general rail monitoring purposes passenger boarding and alighting counts are conducted on one weekday per month for one station on each passenger rail line. The 2011 counts have been averaged and used in model calibration.

3.3.2.3 Local Station Passenger Counts

Subject to funding availability Centro aims to conduct a one day weekday passenger count at all local rail stations in the WMMA once every five years. The most recent data available is from 2008/09 and this has been used in calibration.

3.3.2.4 Park and Ride Counts

Centro conducts a monthly occupancy count at all car parks in their control. This involves a vehicle count at around 11am on the third Thursday of each month. This is processed into passengers by means of an average occupancy rate. They are further processed into time periods based on arrival / departure counts conducted in 2008. As mentioned previously there are 45 park and ride sites.

3.3.2.5 PLANET Rail Counts

To fix the demand flows from the through-trip matrices; matrix estimation was carried out to fit the flows to the link counts taken from the PLD model. For more information of the PLD model and PLD matrices used see section 3.5.4.2. Links were chosen so that a cordon was formed around the core modelled area, so that key links in central Birmingham where the flows are high in volume were included and so that any links which are important in terms of model accuracy were included.

3.3.3 Midland Metro Count Data

An annual passenger count is conducted each October by Midland Metro, and this data is shared with Centro. This provides a full one day count of passengers boarding and alighting at every Midland Metro Line One stop. This data is considered suitable for calibration and has been converted into the appropriate format for each time period.

3.4 Network

3.4.1 Data Sources

This section refers to the data sources of the network, and not the data relating to the transport matrices or the calibration process. The public transport networks were developed jointly by Centro and Mott MacDonald making best use of existing data held by both parties. The complete network comprises:

- A link and node network based on Centro's 2005/2008 model (originally built on the 2001 OS OSCAR road network dataset) in the AoDM but only straight lines between stops outside of the AoDM.
- Bus stops, rail stations and Midland Metro stops sourced from the NPTDR (National Public Transport Data Repository), processed, snapped and adjusted to the appropriate location on the link and node network.
- A network of routes representing each bus route, rail line and Midland Metro service operating in the West Midlands on an average weekday in October 2011 from the NPTDR.

3.4.2 Timetable

Timetable data has been sourced from the NPTDR which contains the timetable data for a selected week in October 2011 for every PT service in the UK. Data has been filtered from this data-set so that the PT model represents trips in an average weekday. Centro liaised with PTV, providers of the VISUM software, to develop a tool for automating the process of building public transport networks from the ATCO-CIF data.

The ATCO-CIF data contains the timetable information and the process developed by PTV takes this information to create the route information. The final product is a public transport network file, incorporating all services including bus, rail and Midland Metro. This network of services was then read into the base network after any additional stops were added. Once imported a series of checks were conducted:

- All routes successfully imported
- Origin and destination of services are correct
- Routes follow the correct path through the network
- Stops served by each route are correct
- Routes do not traverse the same point multiple times
- Journey times are correct

The route information has been checked against paper timetables and journey times using www.networkwestmidlands.com journey planner.

3.5 Trip Matrix

3.5.1 Travel Demand Data

Centro and Mott MacDonald developed a programme of passenger origin-destination surveys over the period 2009 to 2011. These surveys (comprising of passenger interviews and counts) were conducted at main, local and district centres across the West Midlands. The surveys were conducted at stops to include bus, rail and Midland Metro passengers.

3.5.2 Partial Trip Matrices from Surveys

The public transport demand matrices were updated by means of origin-destination surveys. Centro has a rolling programme of annual surveys for this purpose. With the PRISM refresh it was possible to extend the coverage of this programme, pooling resources. The programme of surveys was informed by a multi criteria approach which took into account:

- The age of the data held for a particular area (the last survey year).
- The status of the location (LTP, district, local, no status).
- Location of any known large development which will have impacted on travel behaviour.
- Location of any known project for which the model will be used to quantify its impact.

On the basis of the prioritisation, and making full use of resources available, 18 centres across Birmingham and the Black Country were selected as survey locations (as shown in Appendix F). No surveys were conducted in Coventry as a significant data collection exercise had been conducted to develop base year matrices for the 2008 Coventry/Warwickshire public transport model. These matrices formed an input to the prior matrix.

The data was collected in a face to face interview at stops with bus passengers, and a post back survey form with Midland Metro and rail passengers. The two different approaches were adopted as rail and Metro passengers typically arrive close to the departure time of their train/tram and therefore face to face sample rates are low. The survey matrices were derived from the passenger interview returns and expanded using the counts conducted parallel to interviews. A well-established approach is documented in further detail in the Survey and Matrix Building Report.

Centro have historic survey data from OD matrix surveys carried out prior to the PRISM refresh programme. These were conducted between 2005 and 2009, also being informed by the prioritisation approach outlined above. They were converted to the 1900 zoning system from the 1418 former Centro zoning using correspondence files agreed between Centro and Mott MacDonald.

The combination of historic and PRISM refresh surveys produced 78 site survey matrices for each time period which fed into the matrix combination process.

3.5.3 Trip Synthesis

The synthetic matrix was taken from an interim version of the 2011 PRISM demand model that was updated to reflect travel behaviour observed in the 2009-11 household travel survey. For more information on the demand model see section 4. The synthetic matrix was from an interim version of the demand model because the HAM and PTAMs were not yet complete to be able to provide more recent travel costs. In particular:

- Travel costs such as time, distance and toll were derived from the 2006 PRISM HAM and PTAMs.
- PT fares were derived and applied using a distance-based regression using PT fare information extracted from the Centro 2005 PT model.

3.5.4 Existing Matrices

3.5.4.1 Centro Matrices

The approach adopted by Centro in building public transport matrices made use of existing demand matrices from earlier models, applying lower confidence to the data to act as infill data where survey matrices or synthetic data was weak.

Data for these matrices comes from two models Centro 2005 Birmingham / Black Country base year model and the 2008 Coventry / Warwickshire model. The latter owned jointly by Centro and Coventry. The spatial coverage of these two models overlaps in the Solihull area, where there is a correspondence between the two zoning systems as the Coventry model uses the Centro zoning. A process was established which joined the two matrices together, taking the demand from the model for which each OD pair movement will have the highest confidence (i.e. Birmingham city centre to Solihull from the Birmingham to Black Country model) and removing double counting.

3.5.4.2 Through-trip Matrices

The synthetic and observed data does not represent through trips by public transport for those trips with either a single, or both trip ends outside the core model area. In order to represent these passenger flows PLANET (Planet Long Distance, or PLD) matrices were used. Demand matrices for a 16 hour period along with link flows were provided from the 2011 base year. A number of adjustments were made in order to derive time periods and to convert the demand to the new zoning system.

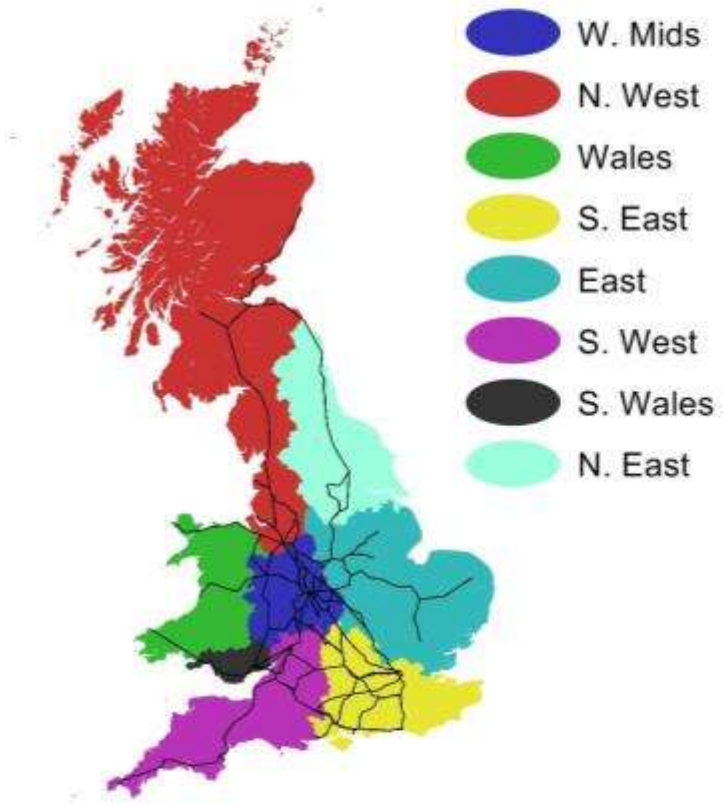
The factors used to convert from all day matrices have been derived from local Birmingham city centre cordon count data collected at city centre stations. A mask has been applied to filter out trips for which we feel would not travel through the modelled area. Table 3.6 shows the movements between segments which are kept. A map of the segments can be seen in Figure 3.3.

Table 3.6: PLD Mask Matrix

From/To	W. Mids	N. West	Wales	S. East	East	S. West	S. Wales	N. East
W. Mids	0	1	1	1	1	1	1	1
N. West	1	0	0	1	0	1	0	0
Wales	1	0	0	0	1	0	0	0
S. East	1	1	0	0	0	0	0	0
East	1	0	1	0	0	0	0	0
S. West	1	1	0	0	0	0	0	1
S. Wales	1	0	0	0	0	0	0	0
N. East	1	0	0	0	0	1	0	0

Source: Mott MacDonald

Figure 3.3: Area Segments Used to Mask PLD Matrices



Source: Mott MacDonald

3.5.5 Confidence Settings

Matrices of confidence values were established for each demand matrix by time period. These were used in matrix building to ensure each OD value was weighted in terms of the confidence for that movement from each of the input matrices.

3.5.5.1 Survey matrix confidence

For each survey matrix a confidence matrix by OD was calculated. The criteria by which the confidence is calculated were as follows:

- Age of the data
- Sample size
- Sample rate
- Centre status (LTP, district, local)

The starting point for setting the matrix confidence was 100, with the main confidence change being attributed to the survey year. The confidence is set to decrease by 10% for each year counting back from 2011. The range of confidence values across all time periods is between 70 and 100 for the most recent survey matrices, summarised in Table 3.7.

Table 3.7: Confidence of OD Values in Survey Matrix

Year	Location	Starting Confidence	AM Peak Final Confidence	IP Peak Final Confidence	PM Peak Final Confidence
2011	Various	100.0	98.54	98.29	98.26
2010	Various	90.0	88.53	88.42	88.44
2010	Various	90.0	88.74	88.44	88.42
2009	South Birmingham	81.0	80.08	79.87	79.74
2008	Bus	72.9	71.11	71.08	70.44
2008	Rail Stations	72.9	71.03	70.88	70.94
2011	Various	100.0	98.54	98.29	98.26

3.5.5.2 Existing matrix confidence

The existing matrices as described in section 3.5.4 were built up from many updates over years of model development going back to the mid 1980’s. The survey location information, trips surveyed and sample size (for most) was retained to feed into the process of allocating an overall confidence to the entire matrix. It is possible to calculate OD specific values, however due to a structural change in the model zoning in 2005 this would introduce bias in allocating stop matrices to zones.

The process utilised involved calculating the proportion of trips observed in each survey using a weighting by age of the data to calculate the contribution to the overall matrix. As confidences calculated for each survey matrix are available back to the mid 1980’s the trip proportions were applied to each survey matrix confidence, and when aggregated together an overall matrix confidence was produced. As with the survey matrix confidence this is expressed as a proportion of 100.

3.5.5.3 PRISM synthetic confidence

The synthetic trip matrix was treated as a variable within the matrix merging process, as it is produced by the PRISM variable demand model, and is regarded as having consistently high quality across all zones. The starting point for the confidence value applied across all OD's by time period was 75 as this is the mid-range of the confidences of the other matrix confidences.

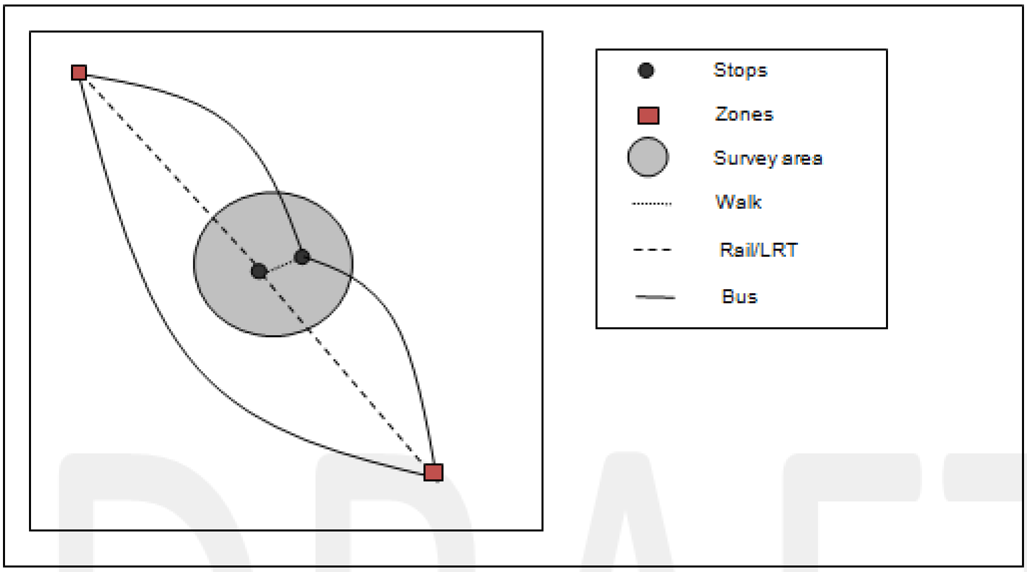
3.5.6 Merging Data

3.5.6.1 Combining site survey matrices

The individual time period site survey matrices were combined into a single time period survey matrix, which forms one of the inputs to the observed / synthetic matrix merging. To combine the survey matrices they were expanded and any trips included within more than one site survey were removed.

Expansion factors were calculated by assigning each site matrix to the 2011 public transport network, creating a matrix of trips which pass through the survey stop and dividing the site matrix by the survey stop matrix. The factors were calculated for each OD pair and were limited to 15 to prevent the matrix growing to an unrealistic size. Figure 3.4 presents the reason why these expansion factors are applied.

Figure 3.4: Trips Produced from a Site Survey Matrix (Single OD Pair)



Confidence matrices were created for each expanded matrix and also a single confidence matrix was created for the final combined matrix.

Each step in the process is analysed so that matrix totals do not drastically change as a result.

3.5.7 Merging Matrices

This stage of the matrix building takes the combined survey matrix, PRISM synthetic and existing demand matrix to merge into the prior matrix. The technical detail behind this approach is explained in the Modelling Methodology Report[4]. The merging was controlled by an Excel VBA macro, which allows monitoring of matrix changes as they occur. As there was no previous PM period matrix, the prior 2011 AM matrix was transposed and used as a proxy.

The merging procedure was an iterative process, which involved adjusting factors to produce the best fit to count data. The variables adjusted were predominantly the factor matrices which controlled the weighting of the existing and PRISM synthetic matrices. The aim was to achieve a minimum of 50% of calibration sites to be within a GEH of 5 if the count exceeds 100 trips, and otherwise within 25%. This was achieved in the AM, IP and PM periods with a pass rate of 67%, 67% and 52% respectively.

The PM period results were expected to be lower as it has been created from the AM matrix yet the result was considered to be sufficient. These matrices are known as the prior matrices as their position in the matrix build process is prior to the calibration stage. The calibration stage is explained in the next section. The performance of the prior matrices is presented in the following tables.

The first set of results in the top three rows shows fit to GEH between count and flow, the middle results within the table show within specific percentage ranges, with the final results comparing calibration against overall target as outlined above.

The overall process is presented in Figure 3.5.

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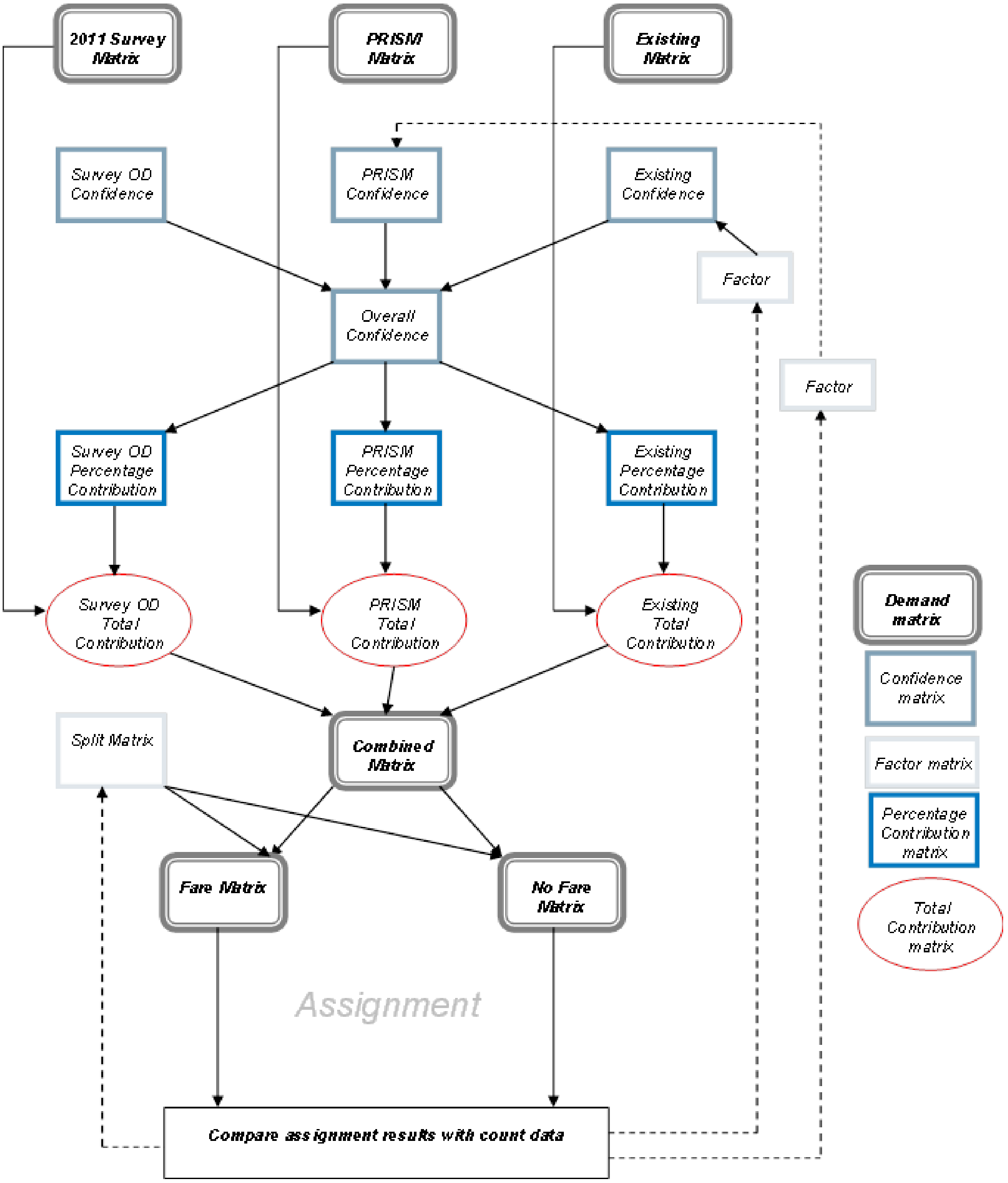
[4] Centro (2008) Modelling Methodology Report

Figure 3.5: Matrix Merging Process



Source: Centro

3.6 Calibration / Validation

Calibration and Validation of the PRISM PTAM has been completed to a high level. Calibration and validation guidelines used are given in section 3.1.1.

3.6.1 Passenger Flows on Links

Given the size of the model and the various sources of the calibration data given in section 3.3 it was decided that the WebTAG calibration criteria should be considered as an aim rather than a direct target. The validation criteria previously defined corresponds to subsets of count data and it was therefore decided that a measure of the accuracy of all the count data should be collected.

The GEH measure was used to define a new set of criteria, which also applies to the validation of boarding and alighting counts. The new criteria were defined as follows:

- For links with a count greater than 150 the difference between the modelled flow and the count should be within a GEH of 5.
- For links with a count less than or equal to 150 the difference between the modelled flow and the count should be within 100.

During calibration the aim was to reach both targets in 90% of cases. The lower boundary criteria defined above is a broad target as it was found that this was more suitable for boarding and alighting counts as they are generally much lower than link counts. All count data described in section 3.3 has been used during the calibration process. This accounts for roughly 750 cases of observed data.

The calibration process was split into two parts. Firstly the PLD matrices were calibrated using the PLD link flows as described in section 3.5.4. The resulting post-ME matrix was then assigned to the network to obtain link flows and boardings and alightings.

In order to calibrate the Fare and No Fare matrices these modelled values were subtracted from the relevant counts to create proxy count values. In order to calibrate the Fare and No Fare matrices the available counts had to be split into Fare and No Fare portions. The counts were split based on the modelled flows produced from an assignment of the Prior Fare and No Fare matrices. The counts were split on an individual basis using the ratio between the Fare and No Fare proportion of the relevant modelled value.

Table 3.8 shows the pass rates achieved during calibration of passenger flows on links using the criteria given above.

Table 3.8: Calibration Pass Rates (All Links)

Time Period	Number Of Passes	% Pass Rate	Total Number of Counts
AM	499	85	587
IP	700	92	761
PM	373	87	429

Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

3.6.2 Passenger Usage at Stops

Passenger usage at stops refers to the boarding and alighting outputs produced by the model. The PLD matrices have not been calibrated using boarding and alighting counts.

Table 3.9 illustrates the calibration pass rates achieved with regard to passenger boardings for all modes of transport using the newly defined criteria given in section 3.6.1.

Table 3.9: Calibration Pass Rates (Boarding at Stops)

Time Period	Number Of Passes	% Pass Rate	Total Number of Counts
AM	159	95	167
IP	189	84	225
PM	145	89	163

Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

Table 3.10 illustrates the calibration pass rates achieved with regard to passenger alighting for all modes of transport using the newly defined criteria given in section 3.6.1.

Table 3.10: Calibration Pass Rates (Alighting at Stops)

Time Period	Number Of Passes	% Pass Rate	Total Number of Counts
AM	159	95	167
IP	203	90	225
PM	134	82	163

Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

3.6.3 Route Choice

A rigorous set of checks have been undertaken in order to test the network and route choice within the model. Route choice is dependent on many different elements.

Route choice has been validated by comparing a selection of journey times produced by the model with those produced using a journey planning tool on the website networkwestmidlands.com. The results of Mott MacDonald’s checking for the IP model can be seen in Table 3.12. The results of Centro’s checking for the AM model can be seen in Table 3.11.

Table 3.11: AM Modelled Journey Times vs Traveline West Midlands Journey Times (including origin wait time)

		PRISM AM PT Model		Traveline		Difference	
Origin	Destination	Ride Time	Total	Ride Time	Total	Ride Time	Total
New Street	Coventry	19	29	20	26	5%	12%
New Street	London	65	81	73	83	12%	-2%
Wol'hampton	Stratford	66	92	73	94	11%	-2%
New Street	Edgbaston Reservoir	12	23	16	24	33%	-4%
Russell's Hall	Kingstanding	68	84	52	91	-24%	-8%
Redditch	Leamington	68	102	124	134	82%	-24%
Tamworth	Sutton Coldfield	40	62	25	49	-38%	27%
Dudley	Wol'hampton	33	37	24	33	-27%	12%
Walsall	Solihull	32	45	35	41	9%	10%
Solihull	Smethwick	28	46	29	40	4%	15%
Kings Norton	Halesowen	45	63	39	62	-13%	2%
E. Coventry	N. Wol'hampton	89	140	87	140	-2%	0%
Cardiff	New Street	146	162	120	146	-18%	11%
Crewe	New Street	54	70	58	82	7%	-15%
Coventry	Stafford	63	87	62	68	-2%	28%
Birmingham	Birmingham Airport	10	20	9	27	-10%	-26%
Coventry	Leamington	45	54	12	42	-73%	29%
Brierley Hill	Birmingham	70	80	67	84	-4%	-5%
Walsall	Birmingham	27	36	21	33	-22%	9%

Source: Centro

Table 3.12: IP Modelled Journey Times vs Traveline West Midlands Journey Times (excluding origin wait time)

		PRISM IP PT Model		Traveline		Difference	
Origin	Destination	Ride Time	Total	Ride Time	Total	Ride Time	Total
New Street	Coventry	18	28	20	23	11%	-18%
New Street	London	72	88	84	84	17%	-5%
Wol'hampton	Stratford	65	91	80	96	23%	5%
Redditch	Leamington	62	98	62	112	0%	14%
Tamworth	Sutton Coldfield	40	62	19	49	-53%	-21%
Dudley	Wol'hamtpon	33	37	25	34	-24%	-8%
Walsall	Solihull	32	39	38	41	19%	5%
Kings Norton	Halesowen	45	58	37	59	-18%	2%
East Coventry	N. Wol'hampton	85	135	91	141	7%	4%
New Street	Coventry	18	28	20	23	11%	-18%

Source: Mott MacDonald

3.6.4 Cordons and All-Mode Counts

The overall calibration shows an excellent fit between model and counts for both link flows and passenger boarding and alighting's, all being above the target of 85% passing the WebTAG criteria. Further analysis of the trip matrix has been conducted at more spatially detailed level. The table below presents the link calibration results at LTP cordon and district cordon (bus), and separately for rail and Metro.

Table 3.13: Link Calibration Results at LTP Cordon, District Cordon (Bus only), All-Rail and All-Metro Levels

	AM		IP		PM	
Cordon/Mode	Total Sites	% Sites Pass	Total Sites	% Sites Pass	Total Sites	Sites Pass
LTP Cordons	205	74%	210	91%	176	74%
District Cordons	171	81%	192	95%	94	80%
All-Rail counts	134	77%	134	97%	86	81%
All-Metro counts	34	100%	46	83%	31	100%
P&R counts	42	92%	84	99%	95	73%

Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

As seen in Appendix E, when the overall model statistics are broken down there are areas which perform above the pass criteria, and those which fall below. The lowest % achieved is 73%, which is still a good fit when considering the scale of the model, and the number of counts available for use in calibration. Overall the model is considered to be of a high quality in terms of calibration.

3.6.5 Trip Matrix

The change in matrix size as a result of matrix estimation is presented in Table 3.14 below. A further test of the model is to measure the impact of matrix estimation by assessing matrices before and after against WebTAG criteria. Although the criteria for measuring the change in the matrix have been designed for highway matrices, it is felt that this is a good test for the PT matrices and is good practice to carry out.

Table 3.14: Matrix totals before and after matrix estimation

Period	Before ME	Post ME	Change
AM	111,042	110,909	-0.12%
IP	120,667	115,661	-4.1%
PM	161,758	133,223	-17%

Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

WebTAG Unit 3.19 states the following criteria for matrix zonal trip ends:

- Slope within 0.99 and 1.01
- Intercept near 0
- R^2 in excess of 0.98

The changes to matrix trip ends as a result of matrix estimation are presented in Table 3.15 and Table 3.16 below:

Table 3.15: Changes to origin trip ends as a result of matrix estimation

Period	Slope	Intercept	R^2
AM	0.872	7.426	0.793
IP	0.826	8.393	0.881
PM	0.768	3.807	0.889

Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

Table 3.16: Changes to destination trip ends as a result of matrix estimation

Period	Slope	Intercept	R^2
AM	0.895	6.112	0.957
IP	0.905	3.373	0.926
PM	0.733	6.833	0.703

Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

TAG Unit 3.19 states the following values for zonal cell values:
- Slope within 0.98 and 1.02
- Intercept near 0
- R^2 in excess of 0.95

The results of the zonal test are presented in Table 3.17.

Table 3.17: Changes to origin—destination pairs as a result of matrix estimation

Period	Slope	Intercept	R^2
AM	0.845	0.04	0.769
IP	0.857	0.003	0.817
PM	0.741	0.003	0.501

Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

The changes to the matrices are very close to the WebTAG guidelines in most cases. As expected there are bigger changes applied to the PM matrices. Given that this is a new modelled time period, the matrix change statistics suggest that this can be improved in subsequent model enhancements. This test is not a guideline for PT matrices in WebTAG; however it was felt it was good practice to carry out the analysis, to demonstrate that the impact of matrix estimation is not significantly impacting on the structure of the matrices.

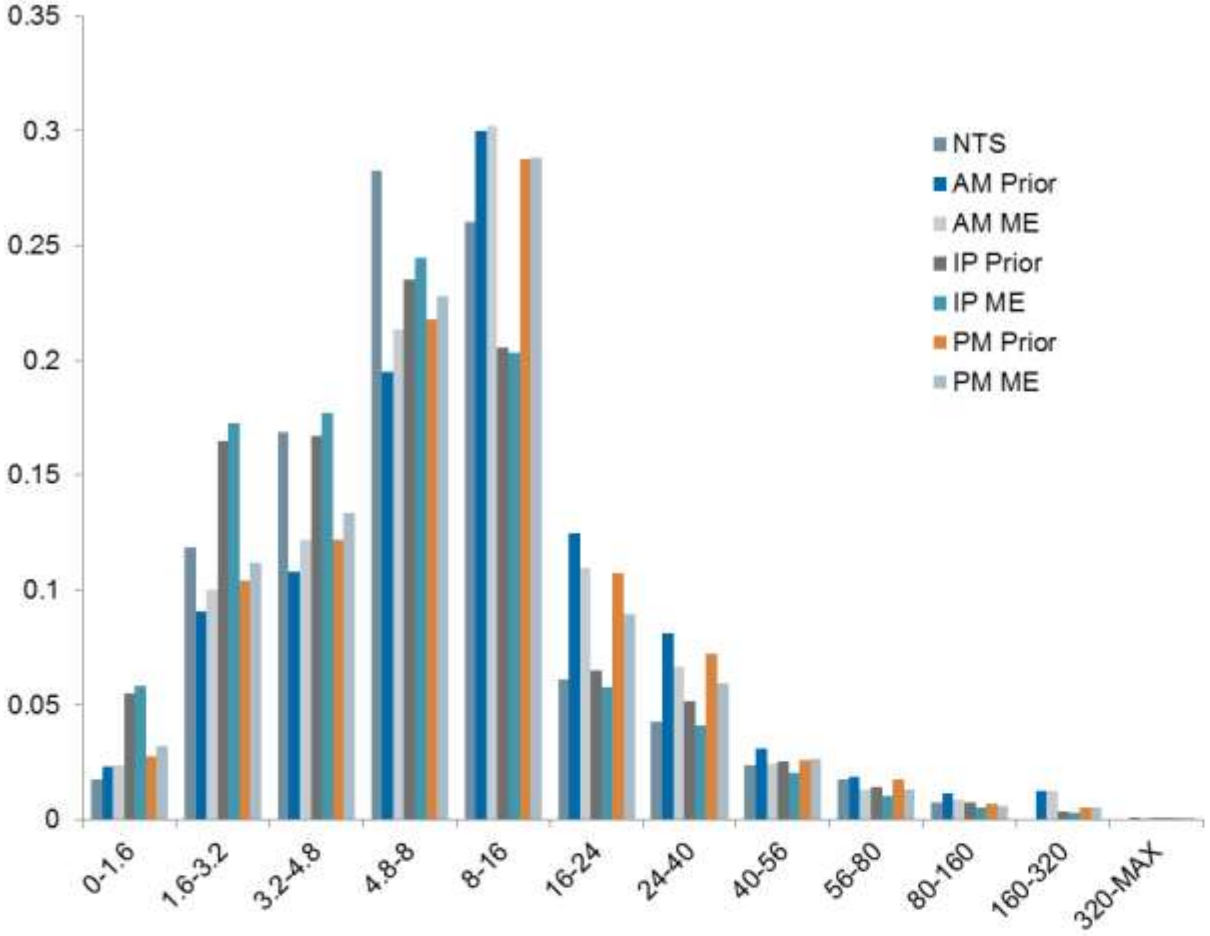
It is good practice to compare trip length distributions both in terms of before and after matrix estimation, and where possible against independent data. For the PT model both comparisons have been done for all time periods, using National Transport Survey (NTS) data (as provided by the HA) as the independent trip length data.

The NTS data is already packaged in to trip length bands, with model outputs calculated to match so that direct comparisons can be made. Due to sample size limitations the NTS data has been aggregated to all day, for trips which have a trip end in the West Midlands. There are particularly small samples of rail data, which is exaggerated in the IP period, meaning that splitting the data by time period would introduce bias.

As can be seen in Figure 3.6:

- Overall there is a good fit across all time periods to NTS distribution, with a general pattern of an underestimate of short trips, and an over estimate of long trips
- The impact of matrix estimation is relatively small for all time periods, which demonstrate in part that the shape and structure of matrices are only subject to small changes

Figure 3.6: Public transport trip length distributions before and after matrix estimation and NTS



Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

3.6.6 Independent Validation

Validation of the model uses counts and statistics independent of calibration to confirm that the model is producing sensible outputs. The original specification included using the district cordon data for validation; however in developing the matrices it was felt that this data would be better used in calibration.

The above trip length analysis is regarded as validation in terms of comparing modelled versus NTS distribution, and in addition to this the model is validated in terms of:

- Total annual bus, rail and Metro patronage, comparing modelled values to Centro's annual statistics report
- Average bus wait time, access/egress time, journey time and number of interchanges compared to Centro's bus user profile
- Select links on Midland Metro which were not included in matrix estimation

Table 3.18 compares assigned bus, rail and Metro annual patronage against those reported in Centro's Annual Statistics.

Table 3.18: Comparison of annual patronage against Centro's annual statistics

Mode	Centro Annual Statistics	AM Assigned	IP Assigned	PM Assigned	Annualised Assigned	Difference
Bus	286,100,000	101,302	113,084	132,937	238,870,099	-47,229,901
Rail	41,800,000	39,169	19,720	58,379	58,835,375	17,035,375
Metro	5,000,000	2,913	2,368	3,369	5,419,254	419,254

Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

As can be seen there is a very good fit to Midland Metro, a reasonable fit to rail and an underestimate against bus. The good fit to Metro is due to having proportionately a good coverage of counts, compared to bus. The modelled rail figures are high as this includes all trips – including through trips. Excluding them brings the modelled rail total down to 31 million (the long distance matrix includes some local trip ends so the figures do balance, with local versus long distance calibrated separately).

On bus in the main LTP and local centres there is a good fit between modelled and observed which suggests trips being made wholly outside of these areas is being underestimated. Due to a lack of observed data for such movements, and no data on trip making outside the core it is difficult to adjust the matrices to better fit the overall observed trips numbers without skewing the trip data.

Table 3.19 presents assigned bus trip leg assignment outputs compared to Centro's Bus User Profile (BUP). The BUP data is presented for all bus passengers interviewed; it is not possible to split this by time period so it represents an overall average for comparison.

Table 3.19: Comparison of bus average journey times against Centro’s Bus User Profile

Trip element	Bus User Profile	AM	IP	PM
Walk access / egress time	07:07	05:12	04:45	05:56
Wait time	07:10	09:17	06:10	08:05
Journey time	23:10	27:30	23:08	29:06
Average number interchanges	1.2	1.5	1.4	1.7

Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

The modelled results have been taken from the assigned bus trips, so a direct comparison is possible with the bus survey. All of the bus user profile data is based on perceived rather than actual. The perceived walk access time is higher than those extracted from the model. This can be explained partly by the catchment approach used in the model, where only bus stops within 400m of a zone centroid are connected in the network, whereas in reality there are likely to be passengers walking further and therefore longer. It is not considered appropriate to widen catchments in the model as this will impact upon route choice and exaggerate issues already know with matrix building from survey data. Although the above results show that in all time periods there are on average more interchanges modelled than observed, this can be explained by a number of factors:

- Definition of interchange in the survey (within stop being perceived differently)
- Assignment parameters – already a 10 min interchange penalty being used, which is towards the upper limit of guidance and good practice
- High levels of interchange observed at survey sites
- Over 60% of trips are “no fare” so do not have the penalty of paying a fare when changing between services

By the nature of the dense PT network, and stops modelled at clusters (i.e. a bus station is a single stop) will also mean that interchange is more attractive.

A full set of passenger counts were available, in the form of boarding and alighting counts for all Midland Metro stops. Selected counts were not used in calibration and retained for validation. The performance of these links, comparing modelled versus counts, are presented in Table 3.20 overleaf.

Table 3.20 shows a high level of fit between counts and modelled flows on Midland Metro in all time periods. All individual counts are within the 25% WebTAG criteria, and only one link is above 15%. Along with the calibration data presented above this confirms that the assignment fit on Midland Metro is at a high level for both calibration and validation.

Table 3.20: Comparison of Metro link flows against comprehensive count data

	AM			IP			PM		
Link	Count	Assigned	Difference	Count	Assigned	Difference	Count	Assigned	Difference
The Crescent to Bilston Central	686	700	1.97%	569	522	-8.34%	541	541	-0.05%
Bilston Central to The Crescent	445	468	5.19%	505	540	6.85%	726	717	-1.24%
Wednesbury Parkway to Wednesbury Great Western Street	1079	1,201	11.32%	533	530	-0.52%	562	567	0.86%
Wednesbury Great Western Street to Wednesbury Parkway	395	390	-1.17%	499	442	-11.49%	1,047	931	-11.05%
Dartmouth Street to Lodge Road-West Bromwich Town Hall	1438	1,454	1.11%	614	580	-5.50%	1,157	1,067	-7.76%
Lodge Road-West Bromwich Town Hall to Dartmouth Street	404	389	-3.66%	496	448	-9.59%	558	525	-5.89%
The Hawthorns to Handsworth Booth Street	1524	1,527	0.21%	578	537	-7.09%	1,259	1,179	-6.37%
Handsworth Booth Street to The Hawthorns	366	425	15.99%	373	376	0.69%	563	532	-5.51%

Source: Public Transport Calibration Results, September 2013, Note to PMG from Centro and Mott MacDonald

3.7 Summary

3.7.1 Model Development

The PRISM PTAM was built based roughly on two older models and was designed so that one network could be used by both Mott Macdonald and Centro. The model is most detailed within the core area where there are smaller zones and the link network is built from the OS OSCAR road network dataset. Outside of the core area there is less detail and links exist as straight lines only between stops. The rail network is more detailed outside of the core area than the bus network and rail links match the actual path of rail lines.

All data belonging to PT services including the service route and timetable information has been downloaded from the NPTDR for 2011. Data from the NPTDR is in ATCO-CIF file format. This data has been converted to VISUM format by PTV during the beginning stages of the model development.

The model has been updated in various other ways. Firstly the fares included in the model have been updated to a 2011 rate. A single boarding penalty is applied to all bus services whereas metro and train services include a fixed boarding penalty plus a distance based fare. The PT matrices have been updated using various sources from survey data to synthetic data produced by the PRISM demand model to matrices from older PT models to PLD matrices. New count data has been collected from various sources in order to calibrate the model.

3.7.2 Standards Achieved

The WebTAG guidance available for Public Transport modelling is not plentiful but it has been incorporated where possible. The criteria defined in the WebTAG units as been used as a guide rather than a strict set of targets. This is because the observed data available warranted a different approach. The criteria defined by Centro and Mott Macdonald are similar to the WebTAG criteria but account for lower observed counts.

The model meets these targets well and the results are consistent across time periods and different modes of transport. The quality of the trip matrix has not been compromised to meet the guideline validation criteria.

4 Variable Demand Model

4.1 Key Features

4.1.1 Variable Demand Process

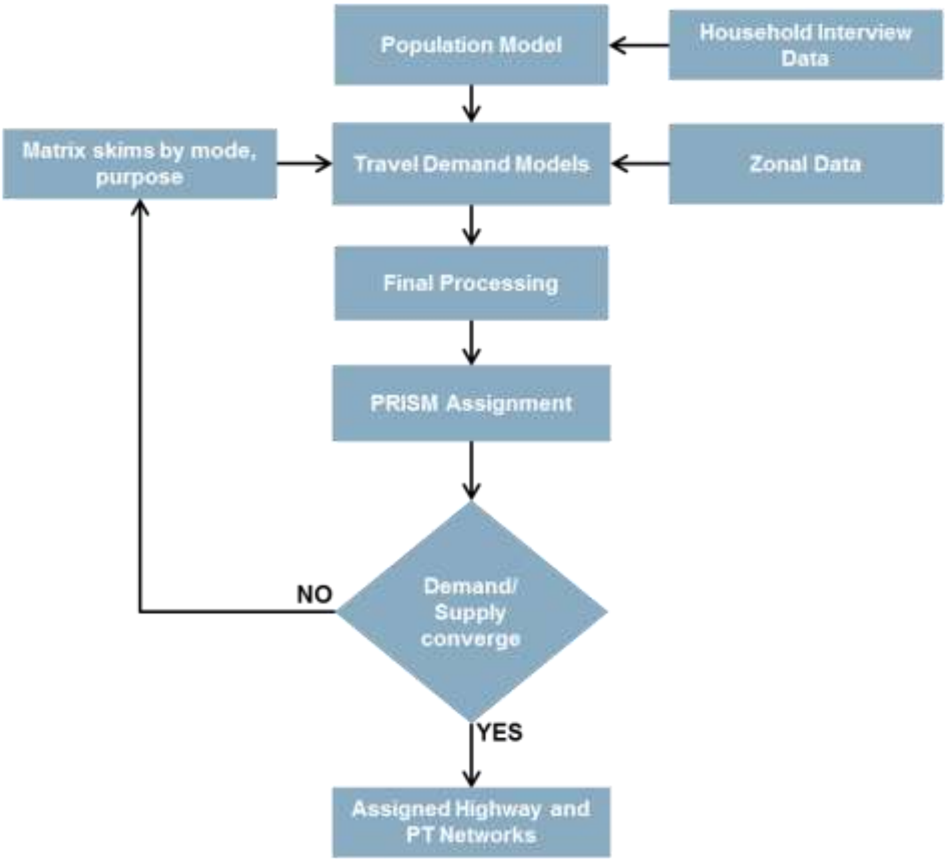
The PRISM Variable Demand Model (VDM) is a system comprised of three main components:

- Demand Model
- Highway Assignment Model (HAM)
- Public Transport Assignment Model (PTAM)

The demand model was developed by RAND Europe using household interview data collected between 2009 and 2012. It interacts with the PRISM assignment models as shown in Figure 4.1 below (demand model processes are the first three central boxes in red). The 2011 highway and public transport demand matrices are supplied to the demand model together with corresponding assignment costs.

The HAM and PTAM are as described in the preceding chapters.

Figure 4.1: Overall PRISM Variable Demand Processes



Source: Mott MacDonald

The VDM process iteratively adjusts the travel demand matrices according to the demand model responses until a demand supply gap[5] of less than 0.2% has been achieved.

4.2 Demand Model

4.2.1 Overview

The demand model consists of the following three main components:

1. The Population Model. This contains a prototypical sampling procedure and a car ownership model that produce projections of the future West Midlands population that are not influenced by accessibility. The population segmentation adopted is as described further below.

2. The Travel Demand Model. This calculates travel accessibility and applies frequency, mode choice, destination choice, PT access mode and station choice, and time period choice – the variable demand responses. Essentially this component predicts the future travel choices of the West Midlands population projected by the Population Model.

3. The Final Processing Model takes the predicted trip matrices for each mode, purpose and time period, sums these matrices over travel purposes to reflect the more aggregate segmentations represented in the assignments, and then applies a pivoting procedure to predict changes in demand relative to the base matrices.

The outcome of these three processes is a set of revised demand matrices for assignment in the HAM and PTAM. These new matrices include responses to cost changes in the assignment model. An important consideration is that the PTAM is not demand-constrained meaning that, unlike the HAM, the assignment costs do not change when the demand matrices change. It is for this reason that the PTAM is a fixed input to the VDM process rather than being part of the so-called VDM-loop.

4.2.1.1 Purpose Segmentation

The demand model uses population segments that define the key social-economic effects that are represented in the frequency and mode destination models including car availability and income. The demand to travel for each of these population segments is applied separately for the various purpose segments in the PRISM Demand Model, as shown in Table 4.1.

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[5] WebTAG Unit 3.10.4: Variable Demand Modelling – Convergence Realism and Sensitivity

Table 4.1: Demand model purpose segmentation

Home Based	Non-home based
HB Work (commuting)	NHB work-work tours
HB Business	NHB work-other tours
HB Primary education	NHB other-other tours
HB Secondary education	NHB work-work detours
HB Tertiary education	NHB work-other detours
HB Shopping	NHB other-other detours
HB Escort	
HB Other	

Source: Mott MacDonald

4.2.1.2 The Population Model

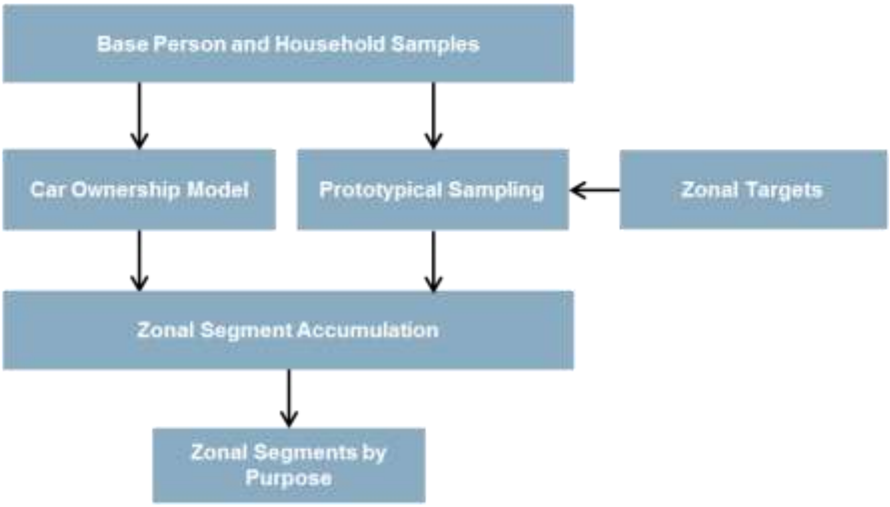
The Population Model uses the 2009-2012 West Midlands household interview samples *and* zonal targets to generate zonal population segments by purpose which are then supplied to the Travel Demand Model. Essentially the Population Model has three sub-processes:

a) **Prototype sampling.** This expands the base household interview (HI) sample to meet zonal population targets that are defined for each PRISM zone in the FMA. The base HI data has been drawn from 5,030 interviews collected in 2009-2012 and contains enough person and household information to define all the required socio-economic segmentation.

b) **Car ownership modelling**. This calculates the car ownership probabilities for each household in the prototypical sample. The complete car ownership model predicts the probability that a household owns zero, one, two and three-plus cars using household income, household licence holding, number of workers, number of infants and children and head of household gender, age and ethnicity. The car ownership model then expands these predictions to the predicted number of households in each zone.

c) **Zone segment accumulation.** The outputs from the prototypical sampling procedure and the car ownership model are combined and the forecast population is accumulated over the social-economic segmentations represented in the travel demand models. This gives zonal segments by purpose.

Figure 4.2: Population Model



Source: Mott MacDonald

Validation of the prototype sampling, car ownership modelling and zone segmentation accumulation are summarised in Section 4.3.3 and 4.3.4 and demonstrates that the variable demand model has been constructed to fit well with the datasets used and is consistent with NTEM forecasts. The demand model response parameters for frequency, distribution and mode choice have been calibrated to DfT recommended ranges.

4.2.1.3 The Travel Demand Model

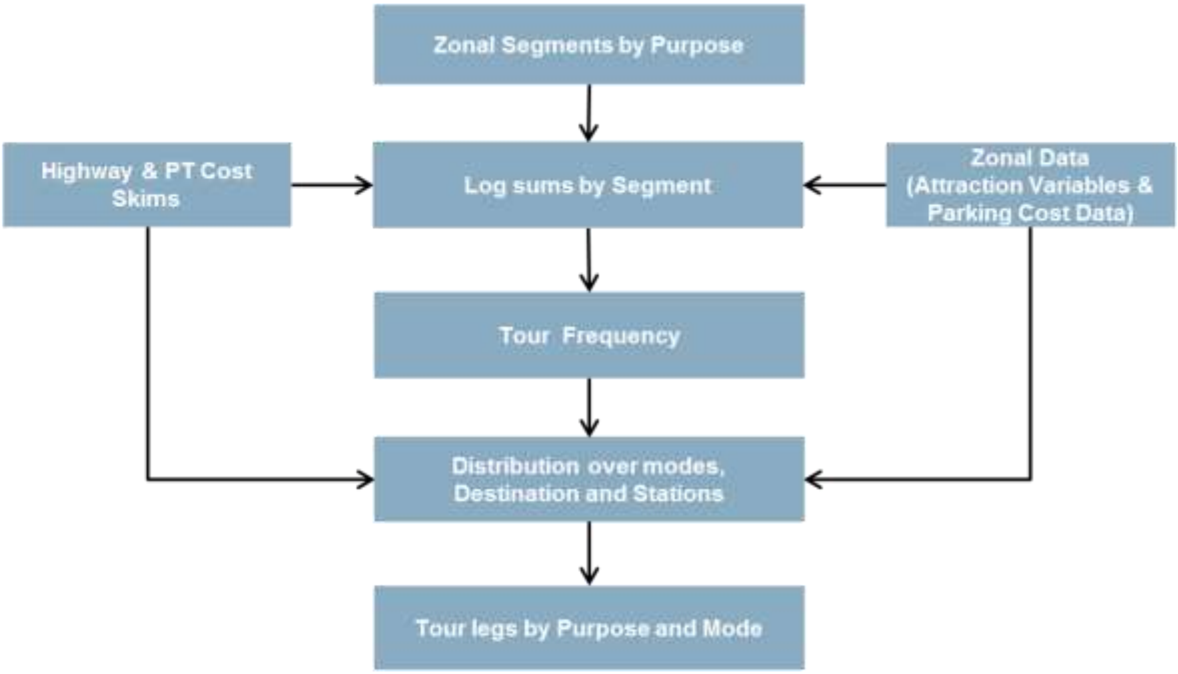
The Travel Demand Models calculate total travel demand by applying tour frequencies to zonal populations by segment and purpose that are produced by the Population Model. These are then distributed over the available modes, destinations and any other alternatives represented. The full process is shown in Figure 4.3 below.

The Travel Demand Model uses the following intervals for *time period choice*:

- AM-peak: 0700-0930hrs
- Inter-Peak: 0930-1530hrs
- PM-Peak: 1530-1900hrs
- Off-Peak: 1900-0700hrs

For *destination choice* the process includes all PRISM model zones that cover core, intermediate and external areas. Travel Demand Model only considers destination alternatives where a non-zero *attraction variable* is defined for the destination.

Figure 4.3: Travel Demand Models



Source: Mott MacDonald

For *mode choice* the following seven main modes are modelled:

- Car driver
- Car passenger
- Train
- Metro
- Bus
- Cycle
- Walk

In Figure 4.3, **Zone Segments by Purpose** are generated by the Population Model and are provided as separate files for each HB travel purpose. Each file gives the number of persons in each model zone for each of the travel segments relevant for that travel purpose. **Zone Data** consists of attraction variables and parking cost data (for each zone) and describes the attractiveness of destinations. **Highway & PT Skims** include travel time costs, toll costs and distance costs from the HAM as well as level-of-service skims from the PTAM. The output from the Travel Demand Models consists **of tour legs by purpose, mode and time period** that are in Production-Attraction format.

Detailed descriptions of the calculation of log sums, tour frequency and distribution over modes, destination and stations can be found in the Demand Model Implementation report[6]. It suffices here to indicate that the calculated log sums are used to compute the choice probabilities across levels of the nesting structure for the demand model. Tour frequencies give the probability of trip making. The demand predicted by the frequency model is then distributed over available main modes, time periods and destinations. This produces the PA tour matrices that are used in the Final Processing Model.

4.2.1.4 The Final Processing Model

As a last main stage of the VDM processes, the Final Processing Model transposes the calculated PA-based tour legs to create an OD matrix by transposing and adding relevant home-based purposes. This is then followed by a simple pivoting process.

Essentially, for the eight HB purposes, matrices of outward and return tour legs are output split by the four model time periods. Outward tour leg matrices, which represent travel from the home to primary destinations, are equivalent to trip matrices and so are used directly. However return tour leg matrices, need to be transposed before they can be treated as trip matrices. ALOGIT code is used to transpose the matrices. The next step is to add up the matrices across purposes to reflect the segmentations used in the VISUM assignments.

This VDM stage uses a pivoting procedure that makes best-estimate forecasts by predicting changes relative to the known base matrices at matrix cell level. For a specific origin, destination, mode, time of day and – for car driver only – purpose, adjustments are made relative to the corresponding cell in a base matrix. Where the cell values are non-zero and the forecast change is not extreme, the *pivot* is simply the ratio of model outputs for base and forecast situations applied as a growth factor to the base matrix:

$$P = B \cdot \frac{Sf}{Sb}$$

where:

B is the base matrix
Sb is the base year synthetic trips
Sf is the future year synthetic trips.

A series of *pivoting rules* are used to deal with zero values and extreme change and there is a final *row normalisation* step. Details of the full process may be found in the main demand model implementation report[6].

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[6] PRISM 2011 Base Demand Model Implementation, J Fox, B Patruni, A Daly (http://www.rand.org/pubs/research_reports/RR314.html)

4.3 Planning Data

4.3.1 VDM Inputs

Planning data is a key input to the Population Model and a key driver to the travel patterns forecast by the Travel Demand Models. The following data is supplied to the models:

- **Zonal Targets**: The Population Model requires targets for each zone in the FMA, broken down in to various population strata for use in the calculation of the future West Midlands population:
  - Gender; age group; worker status; students; household type; and total income
- **Population**: Some of the Travel Demand Models use total population as an *attraction variable*s
- **Employment**: Some of the Travel Demand Models use total employment , retail employment and service employment as *attraction variables*
- **Enrolments**: The education-purpose Travel Demand Models use primary, secondary or tertiary enrolments as *attraction variables*

The planning data variables used by the Travel Demand Models are called *attraction variables*. The attraction variables used by each Travel Demand Model are given in Table 4.2 below.

Table 4.2: Attraction Variables Used by each Travel Demand Model

Purpose	Attraction Variable
Home-Commute	Total Employment
Home-Business	Total Employment
Home-Shopping	Retail Employment
Home-Escort	Total Employment Population Primary Enrolments Secondary Enrolments
Home-Primary Education	Primary Enrolments
Home-Secondary Education	Secondary Enrolments
Home-Tertiary Education	Tertiary Enrolments (including further education) Total Employment
Home-Other	Population Service Employment Retail Employment

Source: PRISM 2011 Base: Demand Model Implementation, Table 54, RAND Europe, http://www.rand.org/content/dam/rand/pubs/research_reports/RR300/RR314/RAND_RR314.pdf

4.3.2 Data Sources and Key Assumptions

4.3.2.1 Population

2011 population figures for PRISM zones in the AoDM were calculated from Census data for Output Areas (OAs) by apportioning based on residential Address Points (APs). Outside of the AoDM, the OA populations were attributed to the zone containing the OA centroids. All figures were then constrained to 2011 NTEM district totals to be consistent with WebTAG guidance.

The 2011 population figures can be found in Appendix G.

4.3.2.2 Employment

Data from the Inter-Departmental Business Register (IDBR) was used to calculate the number of jobs within each PRISM zone in the PRISM AoDM. This was taken from an IDBR file sourced via Solihull for use with the PRISM model only. Following checks on the IDBR source data, a number of changes were made to the file to amend records identified as being inaccurate. These figures were then constrained to 2011 NTEM district totals to be consistent with WebTAG guidance.

Outside of the AoDM, Lower-Super Output Area (LSOA) Business Register and Employment Survey (BRES) figures were used to calculate an initial jobs before being constrained to 2011 NTEM district totals to be consistent with WebTAG guidance.

There were some areas where LSOAs overlapped multiple PRISM zones. A number of alternatives were explored including using proportional overlap to apportion these zones. However this was found to introduce a number of significant errors and it was decided to that using LSOA centroids was the best method. Detailed checks outlined one significant issue where the zone containing Coventry airport had all the jobs assigned to its neighbouring zone due to the location of the LSOA centroid. Manual adjustments were made using the modellers judgement, assigning 10% of jobs in zone 8576 and 90% to 8598 where the airport is located.

The 2011 employment figures can be found in Appendix H.

4.3.2.3 Enrolments

2011 enrolments were derived from four key sources:

- **Department for Education Source 1**: “DfE: Schools, Pupils and their Characteristics, January 2011” – The statistical first release (SFR) based on the 2011 School Census.
- **Edubase**: Data from the Department for Education downloaded in June 2012.
- **Higher Education Statistics Agency Source 1**: “Table 1 - All students by HE institution, level of study, mode of study and domicile 2010/11”
- **Department for Education Source 2**: “Performance tables 2010: Key Stage 5”

Data from the first Department for Education source (above) was combined with the Edubase source. The majority of schools appear in both lists but duplicates were removed. Any schools which opened from 1st September 2011 were not included and schools which have closed since this date were retained.

Nursery school pupils are excluded from the PRISM enrolments data but most nursery establishments were removed based on the 'type' of the establishment. Where the 'type' of establishment was unavailable the following assumptions were made:

- If >80% of pupils were aged 0-3, ALL pupils were considered to be of nursery school age
- If >80% of pupils were aged 4-10, ALL pupils were considered to be of primary school age
- If >80% of pupils were aged 11+, ALL pupils were considered to be of secondary school or further education age.

If less than 80% of pupils were any particular age category, the total number of pupils was split proportionally by the number of pupils in each age category.

Other assumptions:

- Further education students were separated from secondary school pupils based on age.
- In the small proportion of cases were pupil or student numbers were unknown, capacities were assumed to equal pupil numbers.
- Websites for establishments with the word 'college' or university in their names were checked to see if they have more than one campus. A comparison to Ordnance Survey 1:25,000 maps identified some other campuses but the majority of schools shown on Ordnance Survey maps but missing from the list had closed in recent years.

The 2011 enrolments figures can be found in Appendix I.

4.3.2.4 Zonal Targets

The Population Model requires population targets for each zone in the AoDM. These targets are broken down in to various population strata for use in the calculation of the future West Midlands population. At the time the model was developed, the only information available at the required level of detail came from the 2001 Census and this was the starting point for developing the 2011 Zonal Targets.

To be precise, the zonal targets from the original PRISM model were used as the starting point. The data required re-zoning (to the new PRISM zoning system) before being adjusted to match the population totals for each zone that *was* available from the 2011 Census. The following information for each zone was therefore retained from the 2001 Census:

- Gender proportions
- Age group proportions
- Household-type proportions
- Worker status proportions
- Worker-to-population ratio
- Student-to-population ratio
- Household-to-population ratio

An important zonal target that was not used in the original PRISM model is total household income. The following approach was used for estimating the total household income for each zone in the AoDM:

1. Take CACI household income data from 2004/5 (available from PRISM v2)
2. Apply real increase in household income from 2004/5 to 2011 of 1.2%[7]

The 2011 zonal target figures can be found in Appendix J.

4.3.3 Demand Model Validation

Various validation tests are made with the Demand Model which essentially consist of running the model for 2011 and comparing the outputs against observations in the 2009-2012 household interview

4.3.3.1 Population Model Validation

Three validation tests of the Population Model are presented here:

- Overall fit to zonal targets
- Car ownership validation
- Population distribution validation

Overall fit to zonal targets

The prototype sampling step of the Population Model expands the 2011 HI sample to meet zonal population targets. This validation test looks at how well the prototypical sampling step has performed to reach the overall zonal targets, as shown in Table 4.3 below.

Table 4.3: Prototypical sample expansion compared to zonal targets

Population Segment	Target Total	Predicted Total	% diff.
males	2,116,559	2,133,750	0.8%
females	2,180,139	2,154,473	-1.2%
aged 0–20	1,091,867	1,135,038	4%
aged 21–44	1,452,310	1,484,962	2.2%
aged 45–64	1,054,830	1,024,633	-2.9%
aged 65+	697,706	643,471	-7.8%
full-time worker	1,502,704	1,508,458	0.4%
part-time worker	372,352	378,134	1.6%
students	213,433	231,154	8.3%
single person	516,179	521,205	1%
lone parent	185,611	176,340	-5%
couples, no children	298,420	337,944	13.2%
couples, with children	502,197	509,148	1.4%

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[7] Office National Statistics, UKEA and Blue Book; World Database of Happiness

Population Segment	Target Total	Predicted Total	% diff.
other households	265,625	205,595	-22.6%
total income (£)	4,970,842	4,004,770	-19.4%
population	4,296,698	4,288,223	-0.2%
workers	1,875,056	1,886,592	0.6%
households	1,768,032	1,750,232	-1%
mean household inc. (£)	28,115	22,881	-18.6%

Source: Base Model Implementation Report[6]

This comparison shows that the prototypical sampling procedure expands well to total population, workers and households but there are some significant differences for the household type and also for total income. The procedure struggles to reach the household type targets due to a fundamental difference between the distributions of the base sample and the target variables (i.e. bias in the HHI).

The main issue with prototypical sampling procedure is that mean household incomes are under-predicted by 19%. As income is a key variable in explaining car ownership, in the car ownership implementation an adjustment factor is applied so that the average income reflects the target income value, and therefore this under-prediction does not introduce a bias. However, the under-prediction of income will have an impact on the distribution of the population over the income segments represented in the commute and home–other travel mode-destination models, which are the two purposes where cost sensitivity is segmented by income.

Car ownership model validation

A key stage in the development of the demand model is forecasting car ownership based on household licence holding, household income, number of workers, number of infants and children and the head of household age, ethnicity and gender. As discussed in Section 4.2.1 above, car ownership predictions are calibrated to 2009-2012 HI data. The validation of these predictions however, has been done against TEMPRO data and is presented in Table 4.4.

Table 4.4: Validation of car ownership forecasts again TEMPRO

Household cars forecasts	2009–2012 HI data	HI data %	TEMPRO	TEMPRO %	Car ownership model	Car ownership model %
0	752	23.30%	293,004	26.90%	333,180	30.90%
1	1,390	43.10%	515,640	47.40%	450,494	41.80%
2	811	25.10%	228,244	21%	219,973	20.40%
3+	273	8.50%	52,105	4.80%	73,092	6.80%
Total households	3,226	100%	1,088,993	100%	1,076,740	100%

Source: Base Model Implementation Report[6]

This shows that the car ownership model predictions are reasonably close to TEMPRO forecast data (which acts as an independent data source here). However, there are a noticeably greater proportion of zero car households in the forecasts which, as discussed further below, does not appear to result in any significant under-prediction of car travel in the full model. The car ownership model therefore performs close to independent validation data.

Population distribution validation

To validate the population distributions predicted by the Population Model, comparisons have been made between the segment distributions in the un-weighted 2009–2012 HI data and the segment distributions predicted by the Population Model for 2011. Table 4.5 shows a summary of these comparisons for each of the eight HB purposes.

Table 4.5: Population Model validation against Household Interviews

Validation results against 2009-2012 HI data	Maximum Difference (all categories)	Minimum difference (all categories)
Commute car availability validation	2.60%	1.40%
Commute worker type validation	1.20%	0.50%
Commute income segmentation validation	4.50%	0.00%
Home–business car availability validation	1.30%	0.40%
Home–business car availability validation	1.70%	1.70%
Home–primary education car availability validation	2.50%	1.20%
Home–secondary education car availability validation	2.10%	0.00%
Home–tertiary education car availability validation	4.00%	1.70%
Home–tertiary education status validation	0.80%	0.80%
Home–shopping car availability validation	3.60%	0.20%
Home–shopping status validation	3.00%	0.50%
Home–shopping income validation	4.00%	4.00%
Home–escort car availability validation	4.00%	1.40%
Home–escort presence of children validation	7.60%	7.60%
Home–other travel status validation	3.10%	0.60%
Home–other travel income validation	1.70%	4.10%

Source: Base Model Implementation Report[6]

Each of the comparisons above summarise the maximum and minimum differences between the distributions forecast by the Population Model and that observed in the HHI. Table 4.6 below gives an example of the Commute car availability validation in detail. These comparisons tell us that the Population Model distributions match the un-weighted HHI data rather well. Some differences are expected due to the targets being provided for the FMA whereas the HHI was undertaken only in the AoDM. More information on this validation test can be found in the Base Model Implementation Report[6].

Table 4.6: Population Model Commute Car Availability Validation

Description	2009-12 HI	2011 Forecast	% diff.
no cars in HH	12.5%	15.1%	2.6%
no licence, 1+ cars	13.8%	12.4%	-1.4%
licence, one car, free car use	13.9%	15.8%	1.9%
licence, one car, car competition	15.8%	13.3%	-2.6%
licence, 2+ cars, free car use	36.4%	34.1%	-2.3%
licence, 2+ cars, car competition	7.6%	9.3%	1.7%

Source: Base Model Implementation Report[6]

4.3.3.2 Travel Demand Model Validation

Three validation tests are presented here for the Travel Demand Models:

- Tour and detour rates
- Mode shares
- Mean tour lengths

Tour and detour rates

The tour and detour rates have been validated by comparing the predicted tour rates to the tour rates observed in the 2009–2012 HI data used to estimate the models. The results are shown in Table 4.7 and confirm that, for most of the purposes, the predicted tour rates are very close to those in the estimation samples. These are generally within 5% for both HB and NHB purposes.

There are a number of significant differences that are accounted for as follows:

- As can be seen in Table 4.7, for tour and detour rates, there is a generally a good match to the HI data for most HB purposes. However, for home–tertiary education, the application tour rate is significantly lower than the rate observed in the 2009–2012 HI data. This difference is caused by the lower fraction of full-time students in the predicted 2011 population compared with the HI data.
- For home–escort, the application tour rate is also significantly lower than the rate observed in the HI; this difference is caused by a higher fraction of individuals in no child households in the predicted 2011 population compared with the HI data.
- Four of the six NHB models validated well, the two significant differences between the predicted and observed rates are due to the use of mean proportions to implement some of the frequency model terms.

Table 4.7: Tour frequency rates validation

Purpose	%Diff	Purpose	%Diff
HB		NHB	
commute, S=0	0.20%	work–work tours	-14.70%
commute, S=3	-1.50%	work–other tours	-1.60%
commute, S=3,destination sampling	-1.50%	other–other tours	1.50%
home–business	-4.60%	work–work detours	-2.40%
home–primary	-1.90%	work–other detours	-15.40%
home–secondary	-0.20%	other–other detours	-2.90%
home–tertiary	-15.40%		
home–shopping, S=0	4.60%		
home–shopping, S=3	4.70%		
home–shopping, S=3,dest.sampling	4.70%		
home–escort	-23.90%		
home–other travel, S=0	3.30%		
home–other travel, S=3	1.70%		
home–other travel, S=0 dest.samp.	1.70%		
home–other travel, S=0 dest.samp.	1.70%		

Source: Base Model Implementation Report[6]

Mode shares

To calculate a summary measure of the replication of mode share to observed HI data, a root-mean-square (RMS) measure has been used, defined as follows:

$$RMS(M) = \sqrt{\sum \frac{(HI_m - TD_m)^2}{M}}$$

where:
m represents the modes, with *M* modes in total;
HI_m are the mode shares from the 2009–2012 HI data;
TD_m are the mode shares predicted by the demand model.

Table 4.8 gives a tabulation of the RMS and confirms that the mode shares are predicted well, with RMS errors of no more than 4% for most purposes – home-based and non-home-based alike.

Table 4.8: Mode share validation against Root Mean Squares

Purpose	RMS(M)	Purpose	RMS(M)
Home-based		Non-home based	
commute, S=0	1.6%	work–work tours	3.7%
commute, S=3	1.6%	work–other tours	5.3%
commute, S=3,destinationsampling	1.6%	other–other tours	4.1%
home–business	1.3%	work–work detours	3.3%
home–primary	8.2%	work–other detours	0.8%
home–secondary	2.7%	other–other detours	2.4%
home–tertiary	2.7%		
home–shopping, S=0	3.3%		
home–shopping, S=3	3.2%		
home–shopping, S=3,dest.sampling	3.3%		
home–escort	2.1%		
home–other travel, S=0	3.6%		
home–other travel, S=3	3.6%		
home–other travel, S=0 dest.	3.6%		

Source: Base Model Implementation Report[6]

4.3.3.3 Mean tour lengths

A comparison of HI and demand model trip lengths was undertaken for all home-based and non-home-based purposes which showed that there was a general pattern of over-prediction of tour lengths relative to the 2009–2012 HI data as shown in Table 4.9 below. However, this can be accounted by the fact that HI data covered the AoDM only whereas the demand model predictions are for the FMA and longer tour lengths would be expected in the FMA.

Table 4.9: Comparison of mean tour and detour lengths between HI and demand model

Purpose	HI Data (km)	Demand Model (km)	Difference
Home based			
commute, S=0	22.6	25.7	13.7%
commute, S=3	22.5	25.8	14.3%
commute, S=3,destination sampling	22.5	25.8	14.3%
home–business	68.3	93.7	37.3%
home–primary	5.2	5.7	11%
home–secondary	8.1	9.9	21.7%
home–tertiary	19.8	22.1	11.6%
home–shopping, S=0	10.3	10.4	0.9%
home–shopping, S=3	10.3	10.5	1.3%
home–shopping, S=3,dest.sampling	10.3	10.4	1.1%
home–escort	7.3	7.1	-3.4%

Purpose	HI Data (km)	Demand Model (km)	Difference
home–other travel, S=0	18.3	18.2	-0.5%
home–other travel, S=3	18.4	18.1	-1.8%
home–other travel, S=0dest.samp.	18.4	18.1	-1.5%
Non-home based			
work–work tours	59.6	53	-11.1%
work–other tours	7.4	7.3	-1.9%
other–other tours	8.5	10.9	29.1%
work–work detours	18.9	17.6	-6.9%
work–other detours	9.5	9.4	-2.0%
other–other detours	6.2	6	-3.3%

Source: Base Model Implementation Report[6]

4.4 Realism Testing

4.4.1 Acceptability Guidelines

WebTAG Unit 3.10.4 sets out guidelines for checking that a variable demand model behaves realistically. These checks are made by running tests where various components of travel costs and times are changed and the overall impact on demand response investigated. The tests are called *realism tests* and the measure of demand response is called the *demand elasticity* which is calculated as follows, where T is demand, C is cost, and the subscripts 0 and 1 represent before and after the change in cost respectively.

$$e = \frac{(\log(T^1) - \log(T^0))}{(\log(C^1) - \log(C^0))}$$

The three so-called *primary* realism tests described in WebTAG Unit 3.10.4 and the recommended demand elasticities for each are as follows:

- **Car fuel cost:** matrix-based and network-based car kilometrage elasticity in the range [-0.25,-0.35] with employers' business closer to -0.1 and discretionary trips closer to -0.4; commuting and education somewhere in the middle. Network-based elasticities lower than matrix-based.
- **Public transport fares:** public transport demand (trip) elasticity in the range [-0.2,-0.9] with discretionary purposes less elastic than non-discretionary purposes.
- **Car journey time:** car demand (trip) elasticity no stronger than -2.0

4.4.2 Elasticities

4.4.2.1 Car Fuel Cost

This realism test was implemented by applying a 10% increase to the cost of fuel within the demand model and HAM. The PRISM VDM was then run for five iterations achieving a demand/supply GAP of 0.138%.

Two elasticity measures were then calculated; one where the kilometrage is calculated based on distance and demand matrices; and another where the kilometrage is based on summing over links in the HAM.

The car fuel cost elasticities presented in Table 4.10 shows slightly more responsiveness to car fuel costs than the WebTAG guideline range. The relative elasticities between car work (business) and car non-work are in line with WebTAG guidelines and the network based calculation is indeed less elastic than the matrix-based calculation.

Table 4.10: PRISM VDM Car Fuel Cost Elasticities

	Matrix-Based			**Network-Based**		
	Car Work	**Car Non-Work**	**Car All**	**Car Work**	**Car Non-Work**	**Car All**
AM	-0.16	-0.49	-0.42	-0.13	-0.46	-0.39
IP	-0.15	-0.45	-0.35	-0.12	-0.43	-0.31
PM	-0.20	-0.50	-0.43	-0.15	-0.47	-0.38
12-hour	-0.17	-0.48	-0.40	-0.13	-0.45	-0.35

Source: Mott MacDonald

4.4.2.2 Public Transport Fare

This realism test was implemented by applying 10% and 20% increases to the PT fares that are input to the demand model. The PRISM VDM was then run for four and three iterations respectively achieving a demand/supply GAP of 0.116% and 0.153% respectively.

The public transport fare elasticities presented in Table 4.11 show that PRISM is slightly less responsive overall to public transport fares than the WebTAG range. The relative elasticities between discretionary and non-discretionary are in line with WebTAG guidelines with the Fare demand segment being more responsive to an increase in fares than the No-Fare demand segment.

Table 4.11: PRISM VDM Public Transport Fare Elasticities

	10% increase			**20% increase**		
	Fare	No Fare	PT All	Fare	No Fare	PT All
AM	-0.57	-0.04	-0.17	-0.57	-0.03	-0.16
IP	-0.45	-0.04	-0.11	-0.44	-0.03	-0.10
PM	-0.52	-0.04	-0.22	-0.51	-0.03	-0.21
12-hour	-0.50	-0.04	-0.16	-0.50	-0.03	-0.15

Source: Mott MacDonald

4.4.2.3 Car Journey Time

This realism test was implemented by applying a 10% increases to the car journey time skims before they are fed to the demand model. This test requires only a first-order response; i.e. no iteration between the demand model and network models.

The car journey time elasticities presented in Table 4.12 show that PRISM is within the WebTAG range, having a demand elasticity of less than -2.0.

Table 4.12: PRISM VDM Car Journey Time Elasticities

	Car Work	Car Non-Work	Car All
AM	-0.14	-0.22	-0.21
IP	-0.16	-0.35	-0.33
PM	-0.14	-0.20	-0.20
12-hour	-0.15	-0.27	-0.26

Source: Mott MacDonald

4.4.3 Summary

The response of the PRISM variable demand model to changes in car fuel cost, public transport fares and car journey time is realistic, albeit slightly outside the recommended WebTAG ranges in some cases. The relative elasticities within each test between demand segments is also realistic, suggesting PRISM is a robust model for forecasting the travel demand patterns of the West Midlands population.

4.5 Summary

4.5.1 Model Development

The PRISM Variable Demand Model (VDM) is a system comprised of three main components:
- Demand Model
- Highway Assignment Model (HAM)
- Public Transport Assignment Model (PTAM)

The demand model was developed by RAND Europe using household interview data collected between 2009 and 2012. The 2011 highway and public transport demand matrices are supplied to the demand model together with corresponding assignment costs. The validation of these models is described above.

The demand model was calibrated based on these data.

4.5.2 Standards Achieved

Validation of the demand model indicates a good level of fit between the demand model and the household interview data.

TAG Unit 3.19 criteria were used to assess the performance of the demand model in terms results of realism testing. The elasticities presented show that PRISM is very close to or within the WebTAG ranges.

5 Summary

5.1 Model Development

The PRISM 2011 highway models have been developed using VISUM version 12.52 as a basis for travel demand forecasting.

The models have been built with data collected specifically for the purpose of model development, calibration and validation over the period 2009-2011. Data collected for the development of the base year models included RSI and public transport surveys to cover trip patterns for all user classes, Trafficmaster data for high mileage drivers, INRIX data for goods vehicle trip patterns, 2011 household travel survey data for travel behaviour, automatic and manual traffic counts for link volume flows and bus passengers and journey time route data.

The highway model includes two car user-classes, LGV and HGV, the public transport model includes two user classes, fare and no-fare. The models have been built in line with TAG Unit 3.19 guidance for the AM, IP and PM time periods for an average weekday in 2011.

The highway models incorporate detailed junction coding, blocking back and associated flow metering effects. The public transport models include all public transport modes. Levels of convergence meet WebTAG guidelines and the models validate well considering the size of the models.

The variable demand model has been constructed to fit well with the datasets used and is consistent with NTEM forecasts. The demand model response parameters for frequency, distribution and mode choice have been calibrated to DfT recommended ranges.

5.2 Standards Achieved

TAG Unit 3.19 criteria were used to assess the performance of the highway models in terms of link volumes, journey times, screenlines, and changes brought about by matrix estimation and convergence. Whilst the model does not meet or exceed all validation criteria in all cases, the final models validate well against TAG criteria, given the size of the model and the quality of the trip matrix has not been compromised to meet the guideline validation criteria.

For the public transport model, the validation criteria were defined by Centro and Mott Macdonald and are similar to the WebTAG criteria but account for lower observed counts. The model meets these targets well and the results are consistent across time periods and different modes of transport.

TAG Unit 3.19 criteria were used to assess the performance of the demand model in terms of realism testing. The elasticities presented show that PRISM is very close to or within the WebTAG ranges.

Appendices

Appendix A. Roadside Interview Sites

Appendix B. Highway model count calibration

Appendix C. Highway model count validation

Appendix D. Highway model journey time validation

Appendix E. Public transport model calibration data

Appendix F. Public transport model survey locations

Appendix G. 2011 population data

Appendix H. 2011 employment data

Appendix I. 2011 enrolment data

Appendix J. 2011 zonal targets