Oxfordshire Strategic Model

Highway Assignment Model Report

Oxfordshire County Council

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Plan Design Enable

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1. Introduction

1.1. Background

Oxfordshire County Council has commissioned Atkins to develop a suite of multi-modal strategic models to provide evidence to support robust future assessments for funding bids and scheme prioritisation, particularly in regard to transport scheme assessments that meet the DfT Web Transport Appraisal Guidance (WebTAG). The strategic model will also help develop business cases for future major schemes, route strategies and carry out scenario testing of the transport impacts of new development and mitigation measures.

In specifying the model, there was to be particular emphasis on developing a model to identify the impact of transport and development in Oxfordshire as well developing a model that could be used to support business cases and planning applications. The Oxfordshire Strategic Model (OSM) is a new, strategic transport model that has been developed specifically to assess land use and transport interventions in Oxfordshire. The model is multi-model and WebTAG compliant to underpin specific requirements of the Department for Transport.

The model development involves the delivery of the following Work Packages:

- WP 1 Data and Survey requirements
- WP 2 Main Demand Model Specifications
- WP 3 Road Traffic Model (RTM) and Public Transport Model (PTM) Specifications
- WP 4 Study Objectives
- WP 5 Calibration and Validation of: RTM
- WP 6 Calibration and Validation of: PTM
- WP 7 MDM Development
- WP 8 Model Forecasting
- WP 9 Appraisal Tools

This report covers the fifth element of the deliverables, WP5 which is calibration and validation of the Highway Assignment model.

1.2. Scope and Contents of this Report

Following this Introduction, the remainder of the report is structured as follows:

- Chapter two describes Key Model Design Considerations;
- Chapter three presents Model Standards;
- Chapter four provides Key Features of the Model;
- Chapter five describes Calibration and Validation Data;
- Chapter six presents Trip Matrix Development;
- Chapter seven provides Model Calibration and Validation; and
- A summary of the model development is presented in Section eight.
- The appendices provided at the end portray the model results mentioned in this report.

2. Proposed Uses of the Model and Key Model Design Considerations

2.1. Background

The existing suite of strategic models available to Oxfordshire County Council (OCC) include highway assignment model in SATURN, public transport model in EMME3 and a variable demand model also in Excel. These form the Central Oxford Transport Model (COTM).

The Local Model Validation Report (LMVR) for the highway and public transport elements of the strategic model were submitted in August and September 2009. The models were calibrated and validated on 2005-06 data for a base year of 2007.

2.2. Key Model Design Considerations

The key considerations for developing a new WebTAG compliant Oxfordshire Strategic Model (OSM) are to provide an evidence base for the planning and development mitigation as well as the appraisal of major highway and public transport schemes. The major interventions are principally around Bicester, Oxford, and the Science Vale. The model also pays special attention to the A40 corridor between Whitney and J8 of the M40, as well as public transport and Park and Ride (P&R).

Other considerations required by OCC for the model are that the run time should not exceed an overnight 16 hour period.

The principal objective of the OSM is to appropriately represent travel conditions on the highway and public transport networks for the appraisal of various schemes. The OSM will provide:

- changes in the travel cost between the base year and forecast years for input to the Demand Model;
- changes in traffic flows for input to the environmental appraisal of a scheme; and
- changes in travel costs for input to the economic appraisal.

The potential interventions for appraisal will relate to major highway improvements, large traffic management schemes, or large scale complex public transport schemes. The OSM should have the following capabilities:

- reflecting the impact of changes in land use policies, economic conditions and interventions on travel demand;
- testing for scenario development using less detailed modelling; and
- testing of schemes using more detailed modelling to be put forward for inclusion in funding programmes.

A fundamental feature of the model is that it is strategic in nature. For local traffic assessments outputs from OSM should be used with the appropriate junction modelling software or micro-simulation packages. It may be that in such situations local calibration and validation is needed for the model to accurately reflect flows on the network.

3. Model Standards

This section describes the standards that the highway assignment model needs to achieve in line with WebTAG.

3.1. Validation Criteria and Acceptability Guidelines

Validation and convergence standards for highway assignment models are specified in TAG Unit M3.1. In general, the advice in TAG Unit M3.1 applies to models created for both general and specific purposes; however, in the case of models created for the assessment of specific interventions, '*it will be natural to pay greater attention to validation quality in the vicinity of the interventions'*.

The unit states that it is important that the fidelity of the underlying trip matrices is not compromised in order to meet the validation standards.

3.1.1. Trip Matrix Validation

For trip matrix validation, the measure which should be used is the percentage difference between modelled flows and counts. Comparisons at screenline level provide information on the quality of the trip matrices. TAG Unit M3.1 describes the validation criterion and acceptability guideline as shown in Table 3-1.

Table 3-1 – Screenline Flow Validation Criterion and Acceptability Guideline

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

Source: TAG Unit M3.1 Table 1

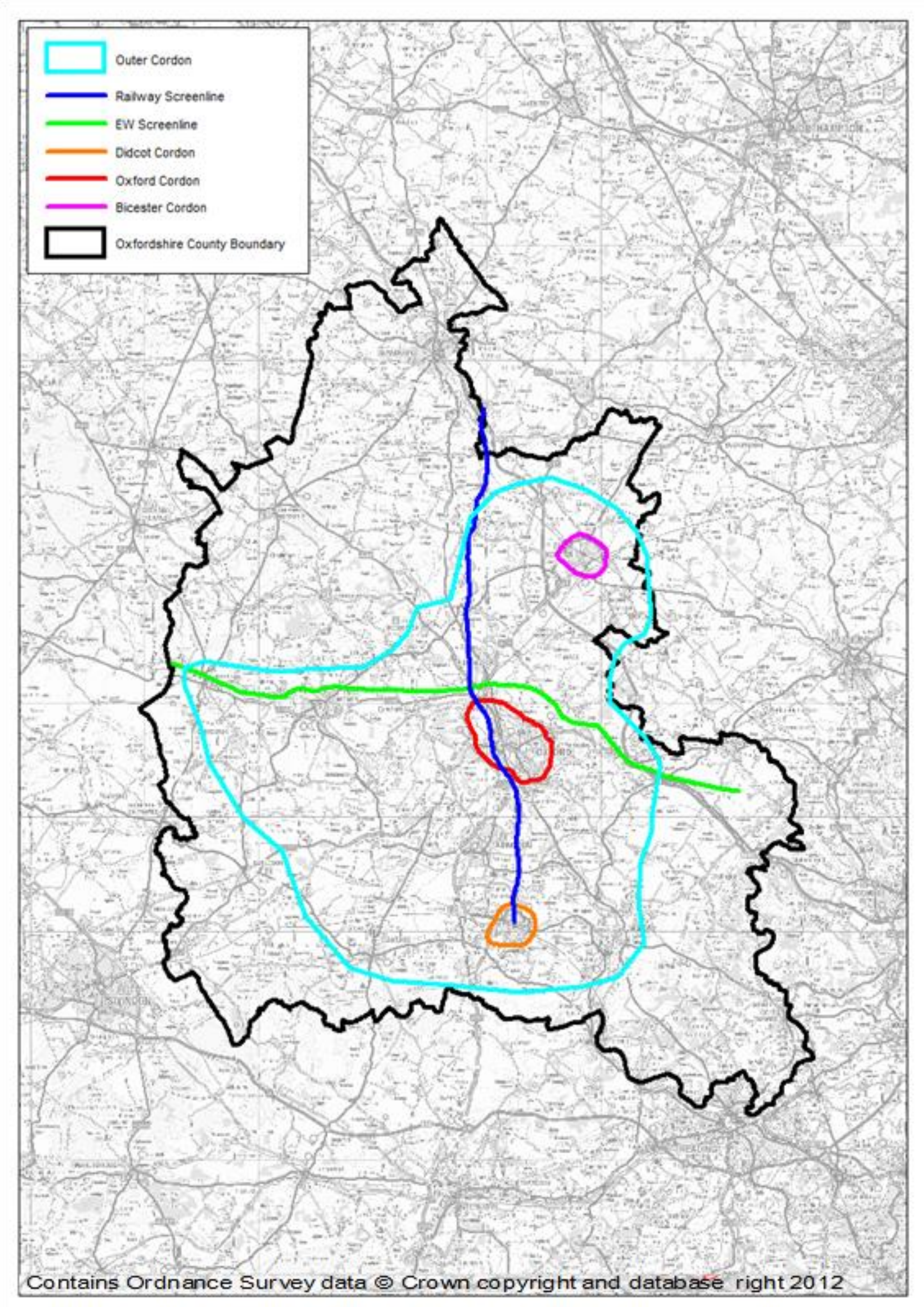
With regard to screenline validation, the following should be noted:

- screenlines should normally be made up of 5 links or more;
- the comparisons for screenlines containing high flow routes such as motorways should be presented both including and excluding such routes;
- the comparison should be presented separately for roadside interview screenlines where they exist;
- the other screenlines (made up of ATC[1] for example) used as constraints in matrix estimation (ME) excluding the roadside interview screenlines even though they have been used as constraints in ME); and screenlines used for independent validation.
- the comparisons should be presented by vehicle type (cars, light goods vehicles and other goods vehicles)
- the comparisons should be presented separately for each modelled period.

For this highway assignment model, there are four calibration cordons, one each around Oxford, Bicester and Didcot, one outer cordon and one screenline namely and East-West screenline. The Railway screenline is used for validation and all are shown in Figure 3.1.

[1] Automatic traffic count

Figure 3-1 Proposed Screenlines and Cordons for OSM



3.1.2. Link Flow and Turning Movement Validation

There are two measures which are used for the individual link validation are flow and GEH. The flow measure is based on the relative flow difference between modelled flows and observed counts, with three different criteria set depending on the observed flows. The GEH measure uses the GEH statistic as defined below:

$$\text{GEH} = \sqrt{\frac{(M-C)^2}{(M+C)/2}}$$

Where GEH is the GEH statistic

M is the modelled flow, and

C is the observed flow

TAG Unit M3.1 describes the Link Flow and Turning Movements Validation Criteria and Acceptability Guidelines as shown in Table 3-2.

Table 3-2 – Link Flow and Turning Movements Validation Criteria and Acceptability Guidelines

Criteria and Measures	Acceptability Guideline
Individual flows within 15% for flows from 700 to 2,700 veh/h	> 85% of cases
Individual flows within 100 veh/h for flows less than 700 veh/h	> 85% of cases
Individual flows within 400 veh/h for flows more than 2,700 veh/h	> 85% of cases
GEH <5 for individual flows	> 85% of cases

Source: TAG Unit M 3.1 Table 2

With regard to flow validation, the following should be noted:

- the above criteria should be applied to both link flows and turning movements;
- the acceptability guideline should be applied to link flows but may be difficult to achieve for turning movements especially given the strategic nature of OSM covering the whole County;
- the comparisons should be presented for cars and all vehicles but not for light and other goods vehicles unless sufficiently accurate link counts have been obtained;
- the comparisons should be presented separately for each modelled period; and
- it is recommended that comparisons using both measures are reported in the model validation report.

Consistent with a strategic model, no turning movements were collected for the highway assignment model. The accuracy of the counts (ATC without accompanying MCC) is not sufficient to enable flow and GEH criteria to be examined separately for light and other goods vehicles.

3.1.3. Journey Time Validation Criterion and Acceptability Guidelines

For journey time validation, the measure which should be used is the percentage difference between modelled and observed journey times, subject to an absolute maximum difference. TAG Unit M3.1 describes the Journey Time Validation Criterion and Acceptability Guideline as shown in Table 3-3.

Table 3-3 Journey Time Validation Criterion and Acceptability Guideline

Criterion and Measure	Acceptability Guideline
Modelled times along routes should be within 15% (or 1 minute, if higher)	> 85% of routes

Source: TAG Unit M 3.1 Table 3

With regard to the journey time validation, the comparisons should be presented separately for each modelled period.

There is no disaggregation of journey time data to enable validation by vehicle type and a single speed/flow relationship is applied to all vehicle types and hence the validation is performed for total vehicles only.

Observed journey time data is obtained from Tom-Tom data that uses Satnav technology.

3.1.4. Convergence Criteria and Standards

The advice on model convergence is set out in TAG Unit M3.1 (Table 4) and is reproduced below in Table 3-4. A more stringent set of standards may be achieved for the highway assignment model with a target of 99% of links satisfying the convergence measure rather than suggested 98% of links.

Table 3-4 Summary of Convergence Criteria

Convergence Measures	Type	Base Model Acceptable Values
Delta & %GAP	Proximity	Less than 0.1% or at least stable with convergence fully documented and all other criteria met
Percentage of links with flow change (P1) < 1%	Stability	Four consecutive iterations greater than 98%
Percentage of links with cost change (P2) < 1%		Four consecutive iterations greater than 98%
Percentage change in total user costs (V)		Four consecutive iterations less than 0.1% (SUE only)

Source: TAG Unit M3.1 Table 4

3.1.5. Impact of Matrix Estimation (ME)

Tag Unit M3.1 states that the changes brought about by ME should be carefully monitored by the following means:

- scatter plots of matrix zonal cell values, prior to and post ME, with regression statistics (slopes, intercepts and R2 values);
- scatter plots of zonal trip ends, prior to and post ME, with regression statistics (slopes, intercepts and R2 values);
- trip length distributions, prior to and post ME, with means and standard deviations; and
- sector to sector level matrices, prior to and post ME, with absolute and percentage changes.

The changes introduced by the application of ME should be understood and may be assessed using TAG Unit M3.1 (Table 5), as shown in Table 3-5 below.

Table 3-5 Significance of Matrix Estimation Changes

Measure	Significance Criteria
Matrix zonal cell levels	Slope within 0.98<Slope<1.02 Intercept near zero R^2 in excess of 0.95
Matrix zonal trip ends	Slope within 0.99<Slope<1.01 Intercept near zero R^2 in excess of 0.98
Trip length distributions	Means within 5% Standard deviations within 5%
Sector to sector level matrices	Differences within 5%

Source: TAG Unit M3-1 Table 5

The unit states that it is important that the fidelity of the underlying trip matrices is not compromised in order to meet the validation standards. All exceptions to these criteria should be examined and assessed for their importance for the accuracy of the matrices in the Fully Modelled Area.

The comparisons should be presented by vehicle type (preferably cars, light goods vehicles and other goods vehicles). The comparisons should also be presented separately for each modelled period or hour.

3.2. Interpretation of the Guidelines

TAG Unit M3.1 states that the achievement of the validation acceptability guidelines specified in Table 1, Table 2 and Table 3 (of TAG Unit M3.1) does not guarantee that a model is ‘fit for purpose’ and likewise a failure to meet the specified validation standards does not mean that a model is not ‘fit for purpose’.

Furthermore, in some models, particularly models of large congested areas, it may be difficult to achieve the link flow and journey time validation acceptability guidelines set out in Table 2 and Table 3 (of TAG Unit M3.1) without ME bringing about changes greater than the limits shown in Table 5 (of TAG Unit M3.1). In these cases, the limits set out in Table 5 (of TAG Unit M3.1) should be respected, the impacts of ME should be reduced so that they do not become significant, and a lower standard of validation reported. In other words, ME should not be allowed to make significant changes to the prior matrices in order that the validation standards are met.

4. Key Features of the Model

4.1. Base Year

October 2013 is considered as base year. The Highway Model is developed using the latest SATURN version 11.2.05, to take advantages of up-to-date software improvements.

4.2. Modelled Area

TAG Unit M3.1 states that the geographic coverage of highway assignment models generally needs to: allow for the strategic re-routeing impacts of interventions; ensure that areas outside the main area of interest, which are potential alternative destinations, are properly represented; and ensure that the full lengths of trips are represented for the purpose of deriving costs. The modelled area therefore needs to be large enough to include these elements, but within the modelled area the level of detail should vary as follows:

- **Fully Modelled Area**: the area over which proposed interventions have influence, and in which junctions are in SATURN simulation, is further subdivided as:
  - **Area of Detailed Modelling** – the area over which significant impacts of interventions are certain and the modelling detail in this area would be characterised by: representation of all trip movements; small zones; very detailed networks; and junction modelling (including flow metering and blocking back).
  - **Rest of the Fully Modelled Area** – the area over which the impacts of interventions are considered to be quite likely but relatively weak in magnitude and would be characterised by: representation of all trip movements; somewhat larger zones and less network detail than for the Area of Detailed Modelling; and speed/flow modelling (primarily link-based but possibly also including a representation of strategically important junctions).
- **External Area:** the area where impacts of interventions would be so small as to be reasonably assumed to be negligible and would be characterised by: a SATURN buffer network representing a large proportion of the rest of Great Britain, a partial representation of demand (trips to, from and across the Fully Modelled Area); large zones; skeletal networks and simple speed/flow relationships or fixed speed modelling.

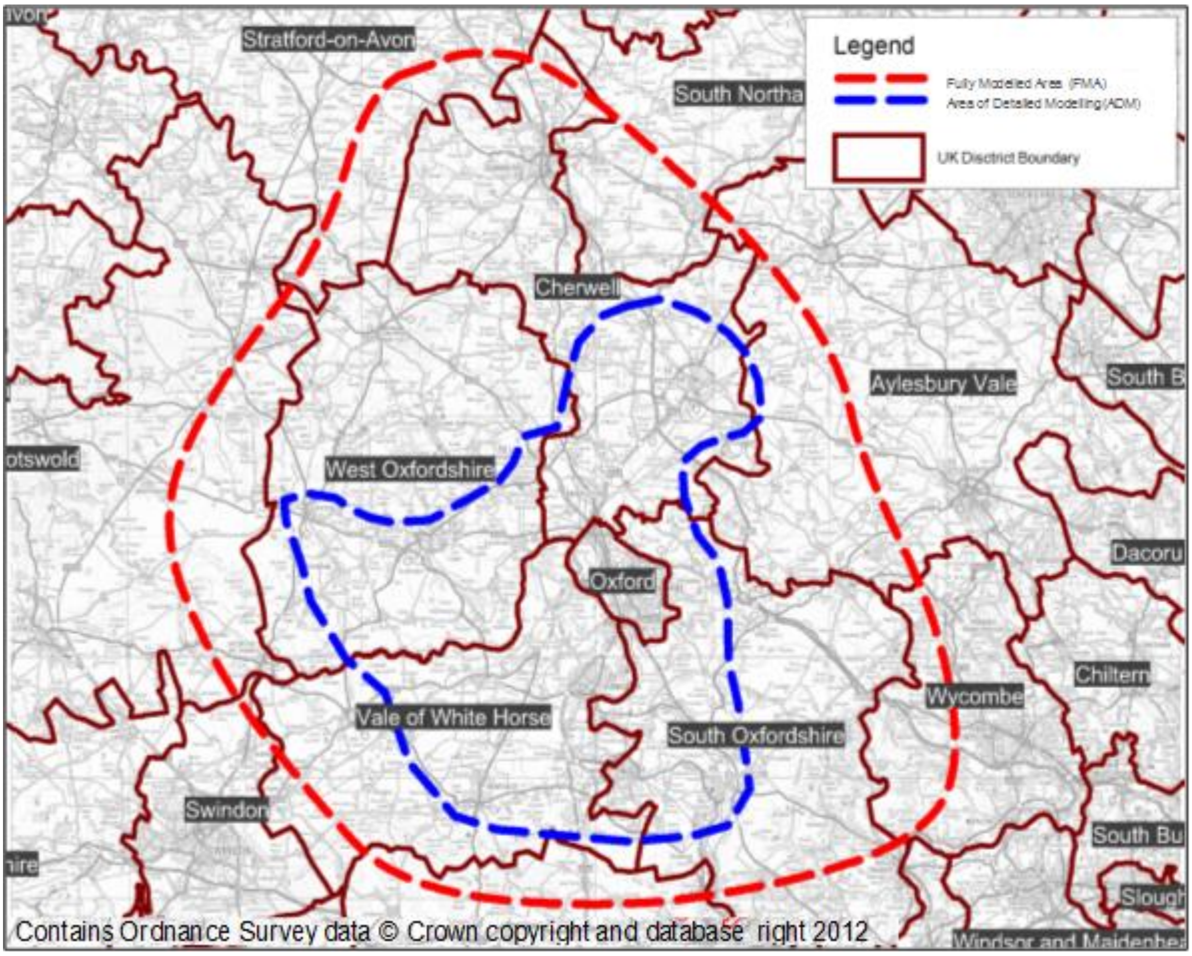
In the OSM the Area of Detailed Modelling (ADM) covers the area bounded by:

- Bicester to the north;
- Wallingford to the east;
- Burford and Witney to the west; and
- Wantage and Didcot to the south.

The Fully Modelled Area (FMA) covers the rest of Oxfordshire plus some hinterland area including Banbury, Swindon, Reading, High Wycombe and Stratford-upon-Avon etc. Figure 4-1 shows the extent of ADM and FMA for OSM.

The External Area covers the rest of Great Britain in a skeletal form and the relationship between the ADM and FMA.

Figure 4-1 Area of Detailed Modelling and Fully Modelled Area for OSM



4.3. Zoning System

The highway model is part of an integrated modelling suite, which links the MDM[2] to both the highway assignment and public transport assignment models. A new zoning system is built for OSM with COTM zones as basis and the zone structure is made compatible with TEMPRO and UK Census Output Areas, which contains demographic information such as number of households etc. In particular, zones in Oxfordshire are aggregated from UK census Output Area zones, attempting to have less than 500 households per zone. This ensures that zones are fine enough in the core study area, with no zone generating a demand of more than 300 pcu[3] per hour, following current best practice.

The resulting number of zones by area is shown in Table 4-1. In total, there are 704 zones covering the whole of Great Britain, with 553 zones falling in Oxfordshire. In particular, all the five P&R sites and major car parks in Oxford are given specific zones, together with two separate airport zones for Heathrow and Gatwick. It is also assumed that an additional 100 dummy zones will be added later to allow for future development proposals.

Figure 4-2 to Figure 4-5 show zones in the major towns of Oxford, Bicester, Abingdon/Didcot and Banbury respectively. Figure 4-6 presents the whole zone system in Oxfordshire. The rest of the zones in the hinterland and external area is shown in Figure 4-7.

[2] Main demand model
[3] Passenger car unit

Table 4-1 OSM Zoning System

Area	No. of Zones
Oxford	130
Didcot / Wallingford / Wantage	42
Bicester	26
Abingdon	30
Witney	25
Banbury	7
Rest of Oxfordshire	293
Hinterland	115
Rest of UK	36
Total	704

Figure 4-2 OSM Zones in Oxford

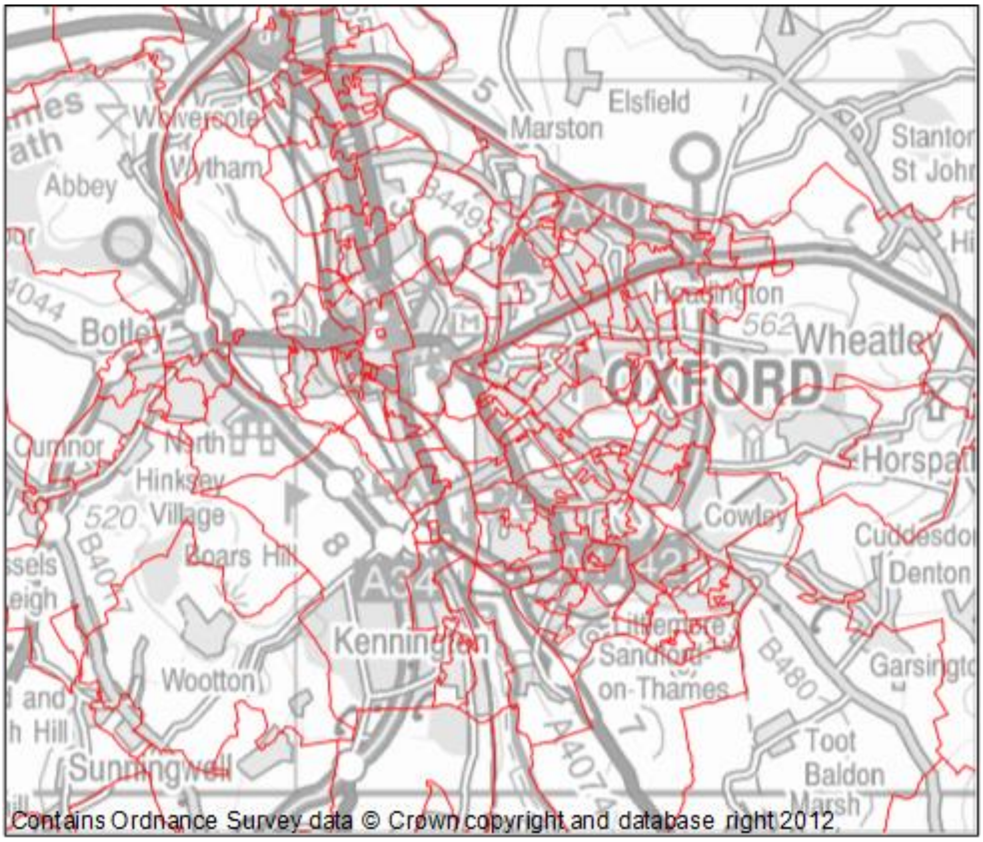


Figure 4-3 OSM Zones in Bicester

Figure 4-4 OSM Zones in Abingdon and Didcot

Figure 4-5 OSM Zones in Banbury

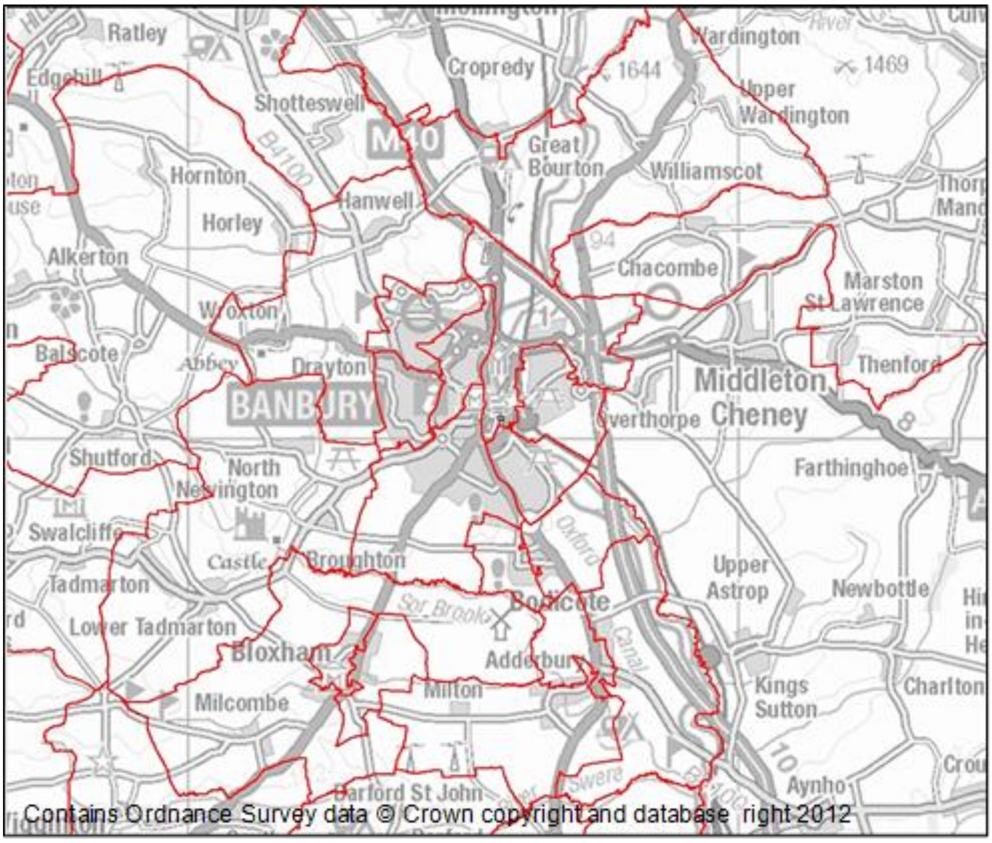


Figure 4-6 OSM Zones in the whole of Oxfordshire

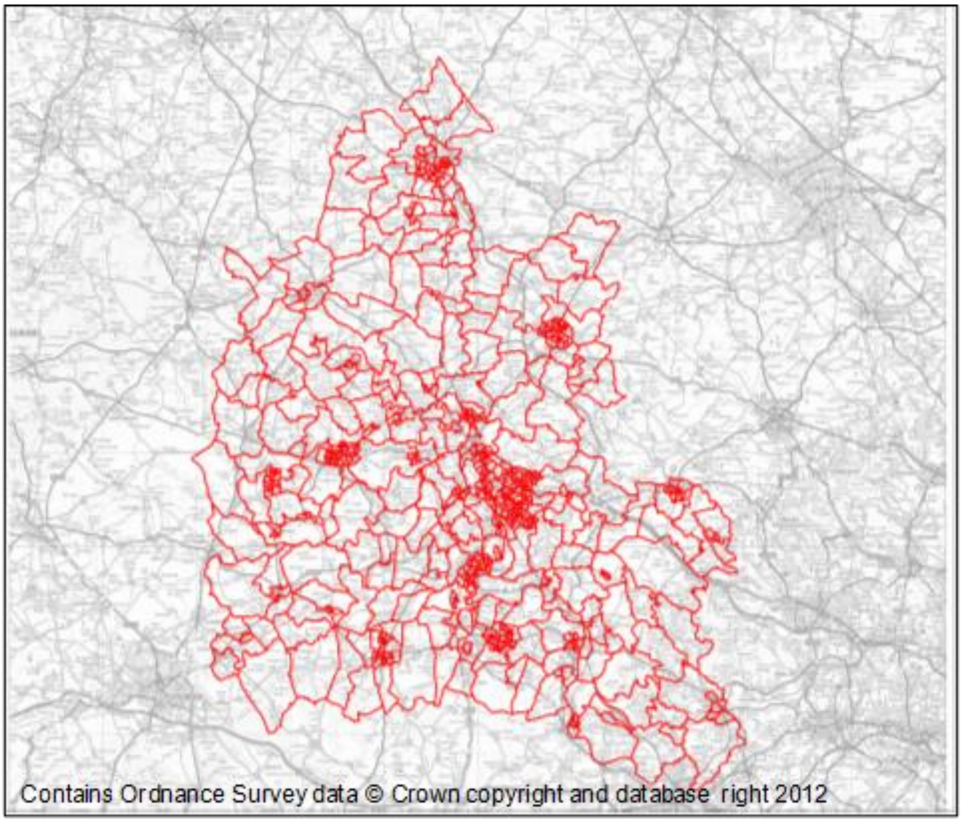
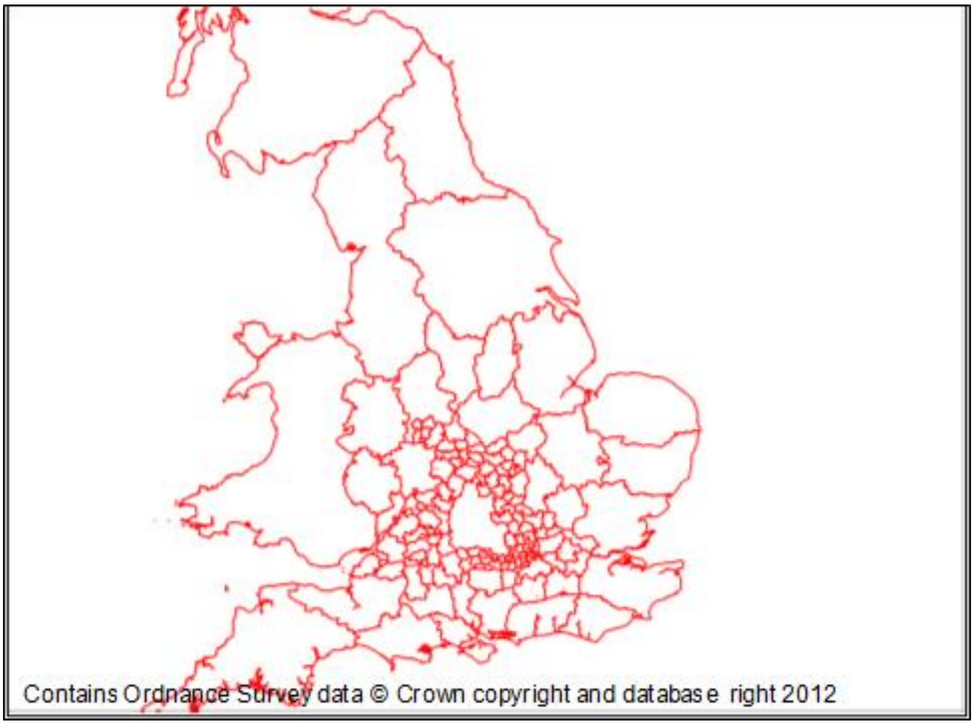


Figure 4-7 OSM Zones in the Hinterland and External Area



4.4. Sectoring System

During the development of OSM highway assignment model, a 13-sector system was developed to assist with matrix manipulation analysis and comparison at a more aggregated level. The sectors are generally compatible with NTEM and district boundaries. The size of the sectors decreases in size from the external sectors, to hinterland sectors, to the sectors in the core study area in Oxfordshire. The 13-sector system is also further aggregated into a four-sector and two-sector system, as shown in Table 4-2 and Figure 4-8 and Figure 4-8 presents the 4sector and the four sector system is shown in Figure 4-9.

Table 4-2 Sector Systems

Sector Description	2 sectors	4 sectors	13 Sector
Oxford	1	1	1
Bicester	1	2	2
Abingdon	1	3	3
Wantage/Grove and rest of Vale of White Horse	1	3	4
Didcot & rest of South Oxfordshire	1	3	5
Witney& rest of West Oxfordshire	1	3	6
Kidlington, Banbury & rest of Cherwell	1	3	7
West Midlands & Wales	2	4	8
Gloucestershire & Wiltshire & rest of SW region	2	4	9
Rest of SE Region	2	4	10
Greater London	2	4	11
Milton Keynes, Buckinghamshire & East of England	2	4	12
East Midlands, Northern Regions and Scotland	2	4	13

Figure 4-8 13 sectoring system

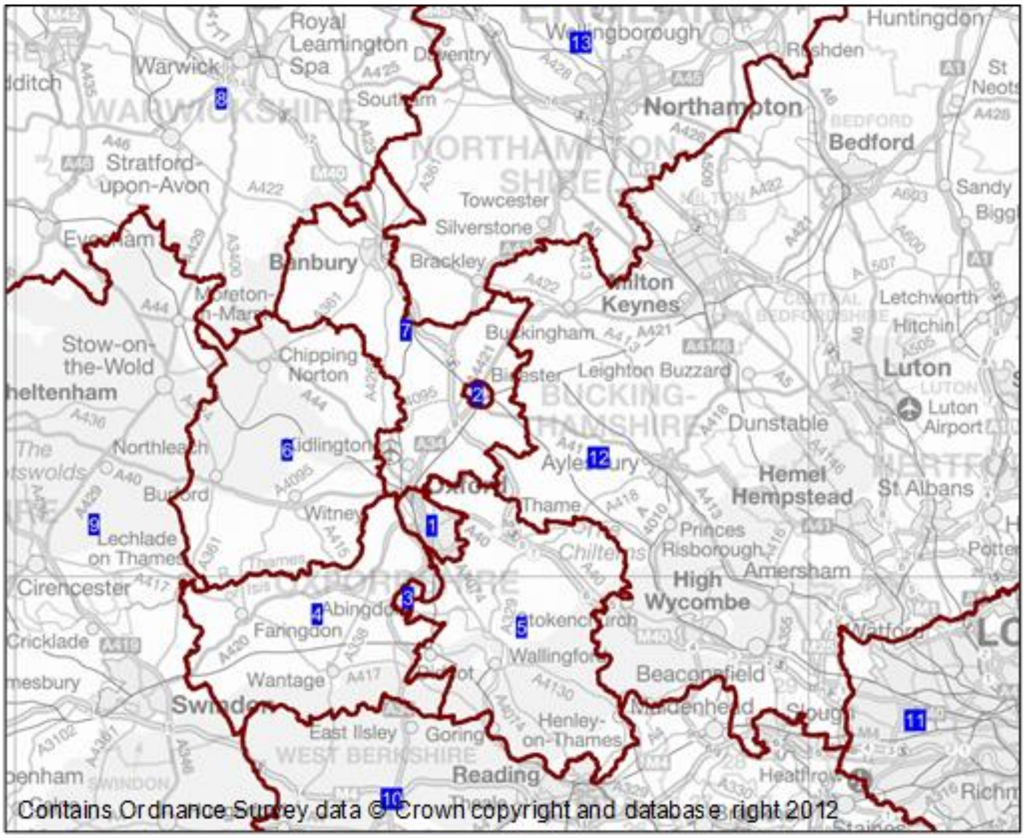
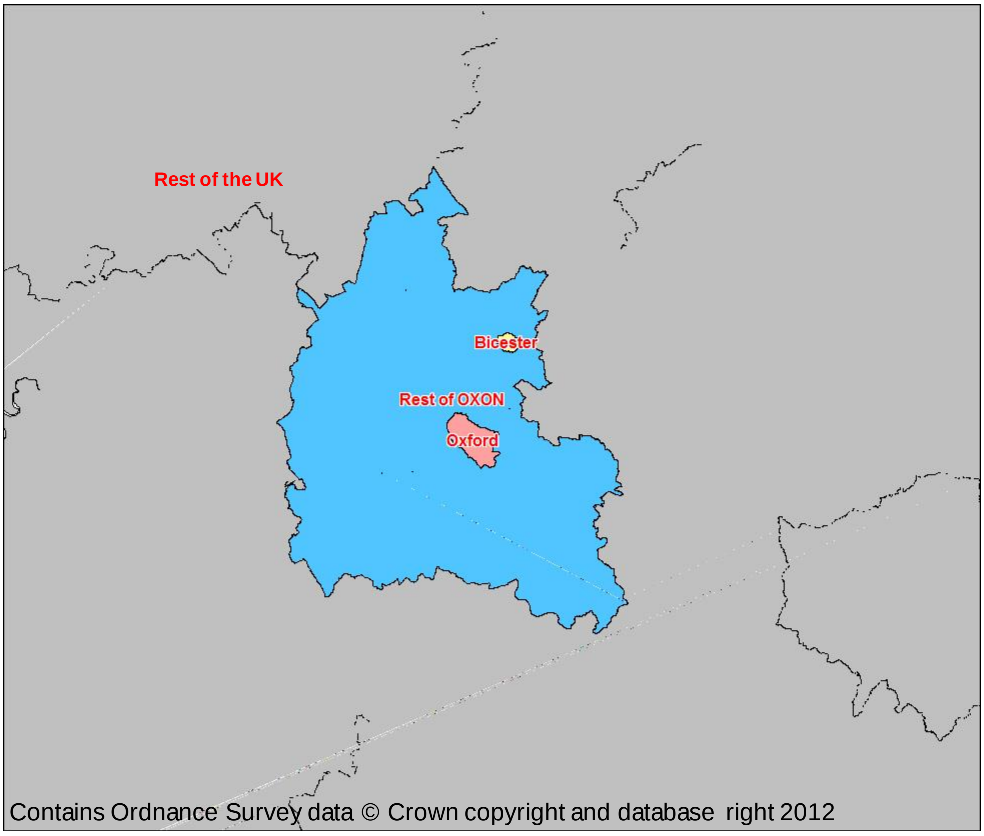


Figure 4-9 4 sectoring system



4.5. Network Structure

The highway network structure was developed with COTM as the starting point. The density of the network structure differed between the FMA and External Area as follows:

- within the FMA, all major A-roads, B-roads and motorway links are represented along with the main residential roads and access roads to major developments and car parks; whereas
- the External Area only included the major A-roads, B-roads and motorway networks with reducing detail further away from the FMA.

The FMA is coded in the SATURN simulation network (with explicit junction modelling) whilst the External Area is coded in SATURN buffer network. The level of detail and accuracy of the network decreases as progression is made from the ADM to the External Area.

4.5.1. Centroid Connectors

The centroid connectors enable the zones to be attached on to the link network. The centroid connectors are coded with:

- specific entry / exit junctions from local access roads onto the main road network from self-contained residential areas, business parks, retail areas and car parks for example; or
- selected junctions representing multiple access points (i.e. removing the need to explicitly code every junction on each link).

Judgement is used to determine the number of centroid connectors required from each zone to represent locations where the traffic from the zones was likely to load in reality, using as many or as few zone connectors as was considered appropriate.

4.5.2. Link Coding

The link coding includes link length and road standard. The link lengths of roads are based on the measurements taken from MapInfo by reshaping the network and Google Earth. Distances coded are checked against the crow-fly distance to ensure that the distance is greater than or equal to the crow-fly distance.

Within the FMA the links were classified by road type and the speeds adopted are discussed in section 4.5.4 below. For the buffer network the standard Cost Benefit Analysis (COBA) definitions are applied.

4.5.3. Saturation flow

The saturation flows used for HAM are arrived at based on the previous experience of highway model development by Atkins and Appendix H from SATURN user-manual which suggests the saturation flows for various junction types. The principle update in the saturation flow calculations is the inclusion of flare length to calculate the saturation flow.

Saturation flow of signalised junction, priority junction and roundabout are presented in Table 4-3 to Table 4-5 below.

Table 4-3 Saturation flow for Signalised Junctions (pcu/hr)

Turn Link Type	Approach Lane Type	Left	Ahead	Right
Major Arm	Nearside	1,686	1,711	1,597
	Offside or Middle	1,815	1,836	1,714
Short/Flare/Setback Bus lane / parking	Flare only	843	n/a	857
	Main lane plus Flare	1,686	1,836	1,714

Turn Link Type	Approach Lane Type	Left	Ahead	Right
Downstream Capacity Restriction	Nearside	1,584	1,607	1,501
	Offside or Middle	1,705	1,725	1,610
Bicycle Advanced Stop -major arm	Nearside	1,645	1,739	1,593
	Offside or Middle	1,771	1,866	1,709
Bicycle Advanced Stop - Downstream Rest	Nearside	1,610	1,701	1,558
	Offside or Middle	1,733	1,825	1,672
Bicycle Advanced Stop -short lane, flare	Flare only	823	n/a	854
	Main lane plus Flare	1,645	1,866	1,709

Table 4-4 Saturation flow for Priority Junctions (pcu/hr)

Turn Link Type	Approach Lane Type	Left	Ahead	Right
Major Arm -No Marker	Full lane (No Flare)	1,650	2,000	1,650
Major Arm X Major arm	Full lane (No Flare)	n/a	1,250	1,200
Minor Arm -Gives way	Full lane (No Flare)	1,200	950	875
Major Arm -No Marker	Main plus Flare	1,681	2,038	1,681
Major Arm X Major arm	Main plus Flare	n/a	1,274	1,223
Minor Arm -Gives way	Main plus Flare	1,223	968	892
Minor Arm -Merge	Full lane (No Flare)	1,200	n/a	n/a

Table 4-5 Saturation flow for Roundabouts (pcu/hr)

Roundabout Type	Approach Lane Type	Number of Lanes at Stop line			
		1	**2**	**3**	**4**
Mini Roundabout	Any	950	n/a	n/a	n/a
Standard Roundabout	1 Lane	1,106	1,655	2,046	2,421
	2 Lane	n/a	2,212	2,682	2,942
	3 Lane	n/a	n/a	3,318	3,756

4.5.4. Link Speeds

The free flow speed for links in the detailed modelling area is coded using Strat-e-GIS data disaggregated by road type for the hours 7pm to 7am to reflect the cruise speed as defined in TAG Unit M3.1:

"Cruise Speed - the speed of traffic on links between queues at modelled junctions. The cruise speed is dependent on the attributes of the link and activity levels alongside and crossing the link. It is not related to flow to any significant degree and is not necessarily equal to the speed limit".

The cruise speed is applied to all links within the ADM based on link classification. The cruise speeds are maintained at the same level in all time periods as presented below in Table 4-6.

Table 4-6 Model Cruise Speeds

Description	Road Type	Speed Limit	Free Flow Speed (kmph)	Speed at Capacity (kmph)	Number of Lanes
A Road 60mph	A Road	60mph 97kph	97	76	2
			87	45	1
A Road 50 mph	A Road	50mph 80kph	80	61	1
			80	61	2
A Road 40 mph	A Road	40mph 64kph	64	25	1
			64	35	2
A Road 30mph	A Road	30mph 48kph	45	25	1
B Road 60mph	B Road	60mph 97kph	87	45	1
B Road 50 mph	B Road	50mph 80kph	78	45	1
B Road 40 mph	B Road	40mph 64kph	61	25	1
B Road 30mph	B Road	30mph 48kph	47	30	1
D2M	Motorway	70mph 113kph	104	77	2
D3M	Motorway	70mph 113kph	109	83	3
D4M	Motorway	70mph 113kph	109	83	4

4.5.5. Signal Timings

Signal timings are collected from OCC for the existing and newly designated junctions. Priority was given to ensure that all signals which were along the journey time routes were updated. These are entered into the SATURN junction coding.

4.6. Time Periods

The highway assignment model represents three time periods, namely the morning and evening peak period hours and an average inter-peak hour. The three periods explicitly modelled were determined on the basis of ATC peak period count data around Oxford, and are:

- Morning Peak hour 08:00 – 09:00;
- Average Inter-Peak hour 10:00 – 16:00; and
- Evening Peak hour 17:00 - 18:00.

For the morning peak and evening peak hour, a previous shoulder peak period is also modelled (although this is not separately validated), and queues which build up during this period are carried over to the start of the peak hour using the SATURN PASSQ option.

4.7. User Classes

The highway assignment model represents highway demand with three user classes as detailed below:

- cars;
- light goods vehicles; and
- heavy goods vehicles.

Scheduled local bus services which are represented in the public transport model are coded into the HAM as fixed flow.

4.7.1. PCU Factors

Passenger car units (pcus) are used as standard unit for demand and capacities rather than vehicles. This allows the effect of longer/slower vehicles that occupy more road space and take longer to clear junctions to be represented. The conversion factors used for the various vehicle types are summarised below in Table 4-7.

Table 4-7 Vehicle to PCU Conversion Factors

Vehicle Type	Equivalent PCUs	Comment
Car	1.0	Private cars
LGV	1.0	Goods vehicles using car-based chassis
HGV	2.3[4]	For both OGV1 & OGV2 vehicle types
PSV / Bus	3.0	Scheduled coach and local bus services

4.8. Assignment Methodology

SATURN version 11.2.05 is used for highway assignment. SATURN uses the SATALL module to iterate between successive loops of SATASS module (which assigns the user class matrices to the network in accordance with Wardrop's First Principle of Traffic Equilibrium using the Frank-Wolfe algorithm) and SATSIM module (which takes the flows derived by SATASS and calculates the revised flow/delay relationships at each junction within the simulated area) until the resulting travel times and flows do not change significantly (that is, convergence criteria is met).

The process starts with SATASS using the free-flow times (without any delays arising from vehicle interactions at the simulated junctions) from the network building program, SATNET. After the first set of path-builds in SATASS, the resulting flows are passed to SATSIM for the turn-based flow/delay curves representing the detailed interactions at each junction to be updated. These revised flow/delay relationships are passed back to SATASS for the travel time and flows to be recalculated.

In order to cut down on the assignment run time, the SPIDER network function which is a new feature in the latest SATURN release is adopted.

4.9. Generalised Cost Formulations and Parameter Values

The route choice within highway assignment model is modelled using the generalised cost of travel time, vehicle operating cost and tolling / congestion charging in accordance with the TAG Unit A1.3. This is to make it compatible with the demand model which also uses generalised costs. The coefficients for the individual components of generalised costs were calculated using TAG Unit A1.3.

The model base year is 2013 with all monetary values calculated at 2010 prices.

4.9.1. Values of Time

Perceived values are used throughout. Note that, in the case of HGVs, cars and LGVs in work time, the perceived and resource values are the same. The process is summarised below:

- equivalent 2013 values are calculated by applying the specified growth in working and non-working values of time (Annual Parameters in TAG Unit A1.3);
- the relative proportions of Car Non-work for 'Other' and 'Commuting' are calculated from the RSI surveys;

[4] TAG Unit M3-1 provides two pcu values for HGVs: either 2.3 pcus for motorways and all-purpose dual carriageways or 2.0 pcus for all other road types.

- the equivalent values for vehicles were calculated by applying the occupancies obtained from the RSI surveys;
- HGV travel is assumed to be in work time with the split between OGV1 and OGV2 recorded from the RSI surveys; and
- the values are converted from £ per hour to p/min.

4.9.2. Vehicle Operating Costs

Vehicle Operating Costs are calculated using TAG A1.3 (January 2014) and defined separately for fuel and non-fuel elements before being combined for the use in the SATURN assignment. Non-fuel costs are only taken into consideration by travellers in work-time.

4.9.2.1. Fuel Costs

The consumption of fuel (in litres per km), adjusted by the fuel efficiency factors, is multiplied by the cost per litre to provide the cost per km in the model base year (2013). Fuel duty is included in the calculations as a perceived cost as businesses are not able to reclaim it. However, VAT is excluded because businesses are able to recover it. For non-work purposes, the perceived cost of the fuel Vehicle Operating Cost was the market price. LGV fuel costs were derived using the same work/non-work proportions used to calculate their average Value of Time.

4.9.2.2. Non-Fuel Costs

The non-fuel cost element is derived using the formulae set out in TAG A1.3 Table A1.3.14 and is a function of average network speed. No further adjustments are required as the non-fuel costs are assumed to remain constant, in real terms, over time. As noted above, the non-fuel cost element is only included for work trips.

4.9.3. Assignment Parameters

The resulting cost coefficients of PPK and PPM calculated later are presented in Table 4-8 below.

Table 4-8 Generalised cost coefficients

Category	VoT (pence/min) by vehicle	VOC (pence/km), Fuel+Non-fuel
Morning Peak(7:00-10:00)		
Cars	19.17	7.96
LGV	19.80	15.96
HGV	20.05	39.16
Inter Peak(10:00-16:00)		
Cars	20.96	7.94
LGV	19.80	16.28
HGV	20.05	39.07
Evening Peak(16:00-19:00)		
Cars	19.34	8.02
LGV	19.80	15.91
HGV	20.05	39.22

4.10. Capacity Restraint

Capacity restraint is modelled in the FMA (i.e. simulation area) predominantly through junction modelling. All modelled junctions in this area are allocated a junction type, capacities for each turn, lane allocations and traffic signal timings for roundabouts and signalised junctions respectively. The capacity of a link is therefore determined by the junction arm capacities.

5. Trip Matrix Development

5.1. Introduction

This section describes the methodology adopted for the development of the highway demand matrix. The matrix development process depends largely on the use of INRIX mobile phone data and the methodology is explained in detail in Technical Note 10 'INRIX data processing' issued 10th February 2014. In summary it involves in the following steps:

Travel demand data

- collection, editing and expansion of intercept (RSI) survey data at the three sites in Oxford and Abingdon;
- collection, editing and expansion of INRIX mobile phone survey data;
- collection, editing and reconciliation of count data;

Partial car matrices

- creation of partial car trip matrices consisting of observed data;
- analysis of the accuracy of the partial car trip matrices at sector level by examining daily symmetry of origins and destination, and comparing trip ends and trip length distribution to independent sources. This is followed by expanding the demand against screenline or cordon counts;

External trips

- assembly of matrices of external to external movements.

Merging sources

- assembly of prior car demand matrices of trips with light goods vehicles (LGVs) and heavy goods vehicles (HGVs);
- pre-adjustments to the prior trip matrices in the light of the comparisons between modelled flows and counts across screenlines and cordons;

Matrix estimation

- ME to ensure greater consistency of the trip matrices with the count data;
- adjustments to the prior trip matrices if the magnitudes of the changes brought about by ME are regarded as significant; and
- Adjustments to the prior trip matrices as a result of traffic rerouting in the light of the journey time validations.

5.2. Travel demand data

5.2.1. Mobile Phone Data

In contrast to the traditional method in developing prior trip matrices by collecting origin-destination movements by Roadside Interview (RSI) surveys, the O2 mobile phone data, supplied by INRIX has been used instead as the primarily source for this task.

The mobile phone data captured includes one week's worth of daily mobile phone movements in November 2013 for any traffic moving within or across Oxfordshire. The data records are aggregated to retain **complete anonymity** and consists of on-call but mostly off-call signals. More detailed discussion about the procedures adopted in INRIX mobile data processing can be found in Atkins Technical Note[5]. Some key points relating to the mobile phone data are summarised as follows:

- The sample is around 28% on average, from evidence provided by INRIX through previous studies[6]. The data therefore has a significantly higher sample rate than what is normally achieved by RSI and in covering all movements within the FMA is considerably more extensive than RSI;
- The INRIX data capture area was initially focused on Oxfordshire only, but later extended to approximately 40 miles from the centre of Oxford to capture more longer-distance movements. This helped recover 14-16% of the mobile phone OD records with an ultimate O or D outside of Oxfordshire.
- The mobile phone data includes any personal movement and thus covers not only cars, but also LGV, HGV, public transport users as well as active modes (pedestrians and cyclists). The data for active modes was removed by INRIX through a speed cut-off process before being issued to Atkins whilst the treatment of LGV, HGV and public transport users will be described in more detail below;
- The INRIX mobile phone data is produced in a more aggregated zoning system, e.g. 253 zones compared to 704 OSM zones. The correspondence between INRIX and OSM has been established based on population density;
- Dwell time is the time over which the phone is not 'active', and when that period exceeds a certain number of minutes, the trip is deemed to have ended. This dwell time threshold has been defined as 30 minutes. Therefore if a probe is inactive for 30 minutes or more, the trip is deemed to have ended.

5.2.2. LGV and HGV matrices

As mentioned above, the INRIX data contained LGV and HGV trips (as well as public transport trips). The LGV and HGV matrices for OSM highway models were separately derived from the TrafficMaster data provided by DfT

5.3. Development of Partial trip matrices

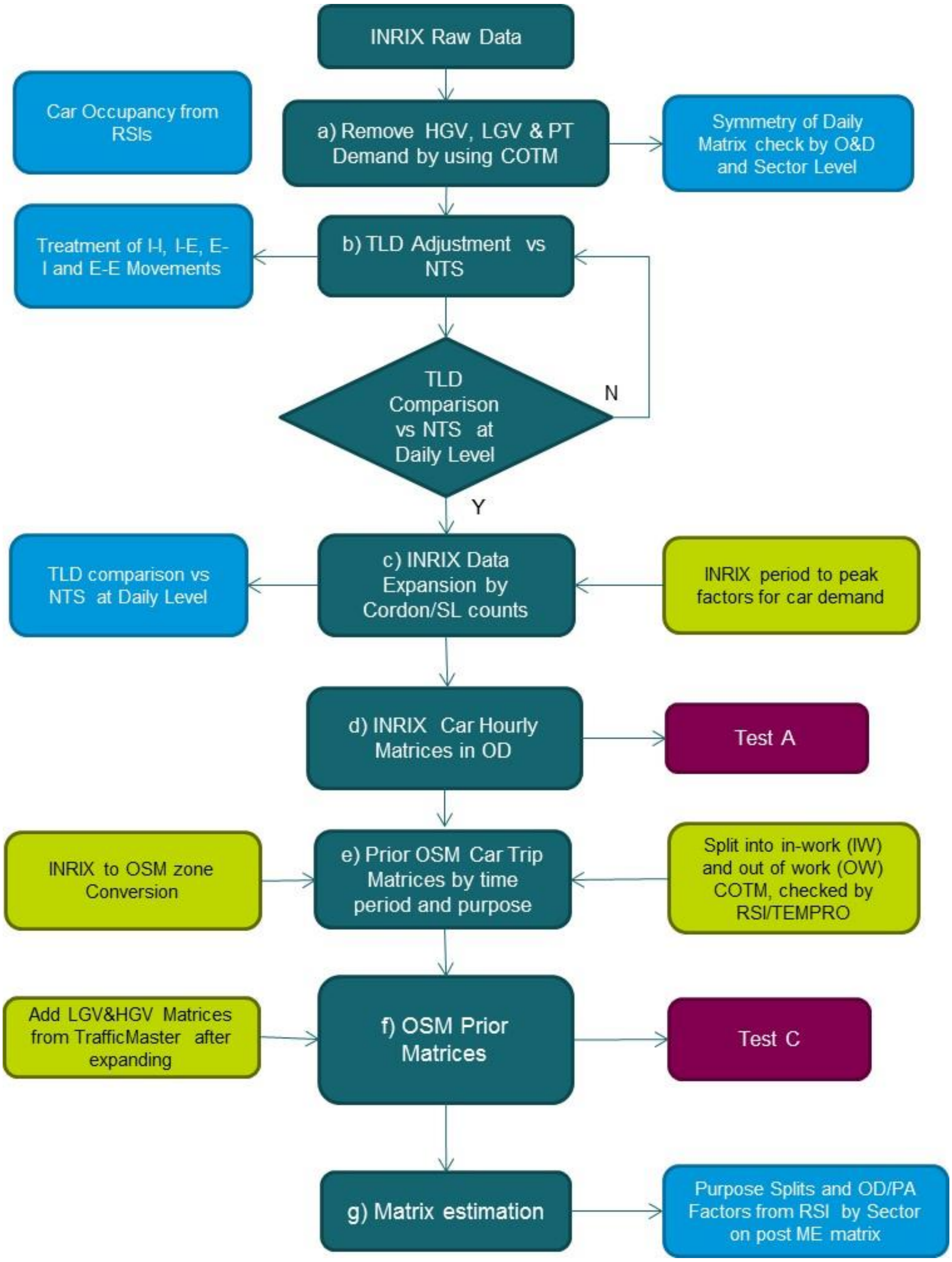
The highway matrix development process is summarised in the flow chart shown in Figure 5-1 below. The key steps (as marked in the flow chart) are described as follows:

a) Clean, rezone INRIX raw data and create a car trip matrix by 'removing' LGV, HGV and public transport demand from the raw INRX mobile phone dataset;
b) Plot the trip length distribution (TLD) for INRIX car trips and compare it to TLD from the National Travel Survey (NTS) provided by DfT specifically for Oxfordshire. Carry out TLD adjustments if necessary, and check post-adjustment TLD at daily level against NTS;
c) Expand the INRIX car matrices to cordon traffic counts, and in so doing compare trip ends and sector totals to TEMPRO and COTM[7];
d) Create INRIX hourly car demand matrices and carry out matrix Test A;
e) Convert INRIX car trip matrices into OSM zoning system and apply purpose splits for Work and Non-Work derived from RSI at sector level.
f) Assemble the OSM car matrices with LGV and HGV matrices expanded from TrafficMaster data and create OSM prior matrices for matrix Test C;
g) Add external trips and carry out ME in SATURN for model calibration as required.

A detailed description of each of these tasks is given in the following sections.

[5] See TN10a INRIX data processing v1.docx
[6] Such as Atkins Data Fusion project for HA
[7] Central Oxfordshire Transport Model

Figure 5-1 Highway Matrix Building Process



5.3.1. Task A

The raw INRIX data supplied to Atkins contained person trips for all motorised modes including car, LGV, HGV, and public transport. As confirmed from INRIX, it was technically more difficult to classify different motorised trips by applying a speed cut-off. To overcome this issue, the trip matrices from the existing COTM models were used, which were sectored for car, LGV, HGV and bus and rail demand matrices by time period. This provided an indication of the different proportions of trips by each vehicle type and mode at a sector to sector level.

Having undertaken a small sample of RSI to confirm whether the old COTM RSI were still valid, Atkins used the combined 2007 and new RSI data to estimate the car occupancy factors (1.26 for AM, 1.39 for IP, and 1.34 for PM), and convert car matrices from person into vehicular unit. Overall the mode share for cars is around 77%-82% in modelled time periods depending on which sector to sector movements were considered.

Having generated an INRIX car demand matrix, a data symmetry check was carried out for the 12 hour period by trip ends and by sector pairs, as shown in **Figure 5-2** and **Figure 5-3**. It would be expected that during 12 hours most outbound trips will have returned. In general, it can be seen the outbound and return journeys on INRIX zoning system are quite symmetrical, with high R square values reported in both cases. There are a few outliers that could be due to short distance trips that are not captured and that are between the ends of a trip in one zone the origin in a neighbouring one.

Figure 5-2 Origin & Destination symmetry of INRIX 12 hour car trips for INRIX trip ends

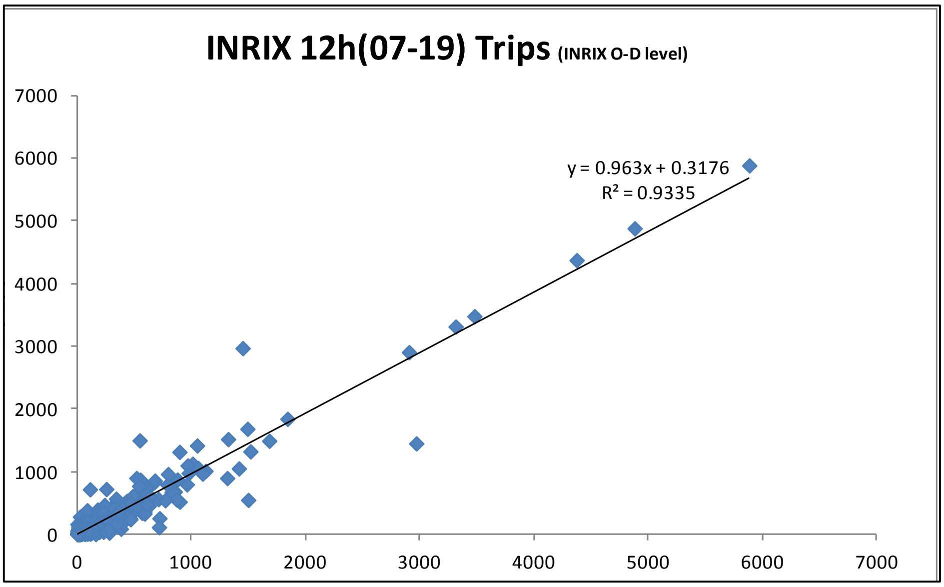
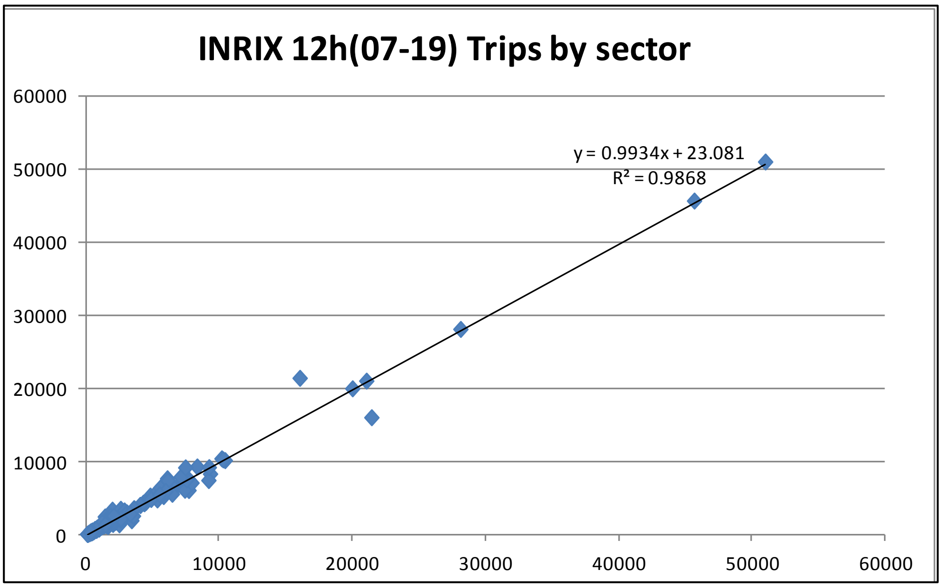


Figure 5-3 Origin & Destination symmetry of INRIX 12 hour car trips by sector



5.3.2. Task B

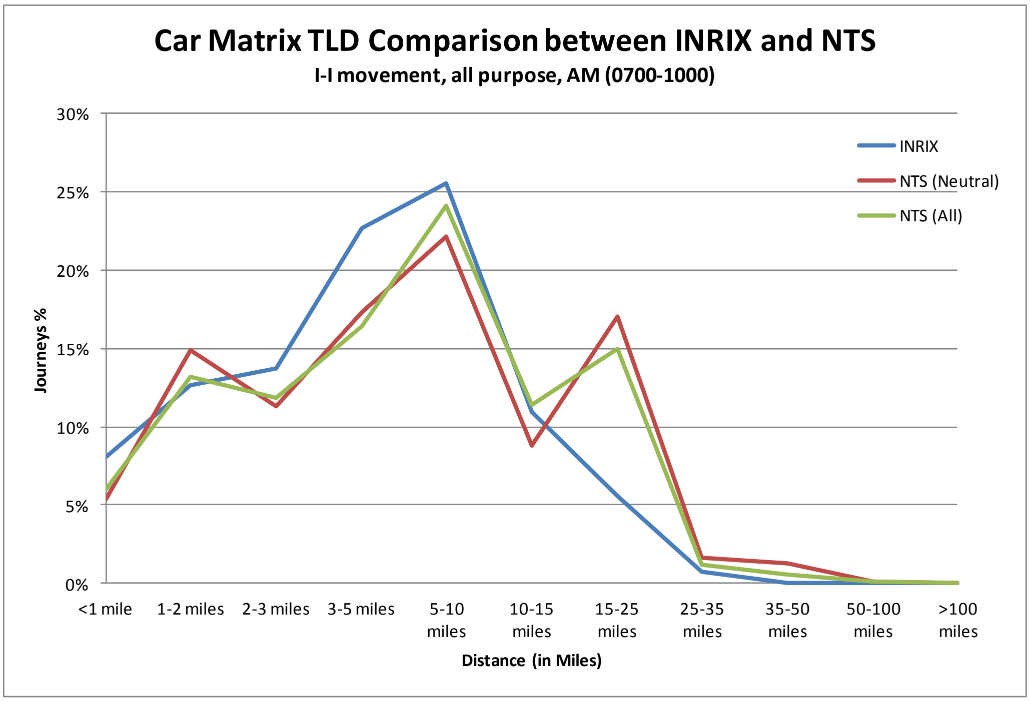
The trip length distributions (TLD) for INRIX car matrices derived during Task A were checked against the TLD from NTS data for trips made in Oxfordshire.

The sample size of the NTS data was found to be too small to be reliable, especially for employer business trips, even at the 12 hour level. As a result the TLD analysis and adjustments were carried out at an aggregated 'all purposes' level by time of day. Figure 5-4 to Figure 5-6 below present the TLD for internal-internal movement comparisons in Oxfordshire between INRIX and NTS [8].

The figures show that whilst the INRIX and NTS data had broadly similar TLD patterns the two datasets were not so similar for certain journey lengths. In particular, it was noted that the INRIX data appear to have less demand than NTS for the 15-25 mile distance band .

To rectify this, the INRIX car demand matrices were adjusted accordingly by applying factors for each distance band so that the INRIX TLDs are consistent with NTS TLDs. Table 5-1 show that adjustment factors by distance band for each time period.

Figure 5-4 TLD comparison plot for AM peak period at all purpose level



[8] The figures also show the NTS TLD for data collected in neutral months, however only for comparison purpose.

Figure 5-5 TLD comparison plot for IP peak period at all purpose level

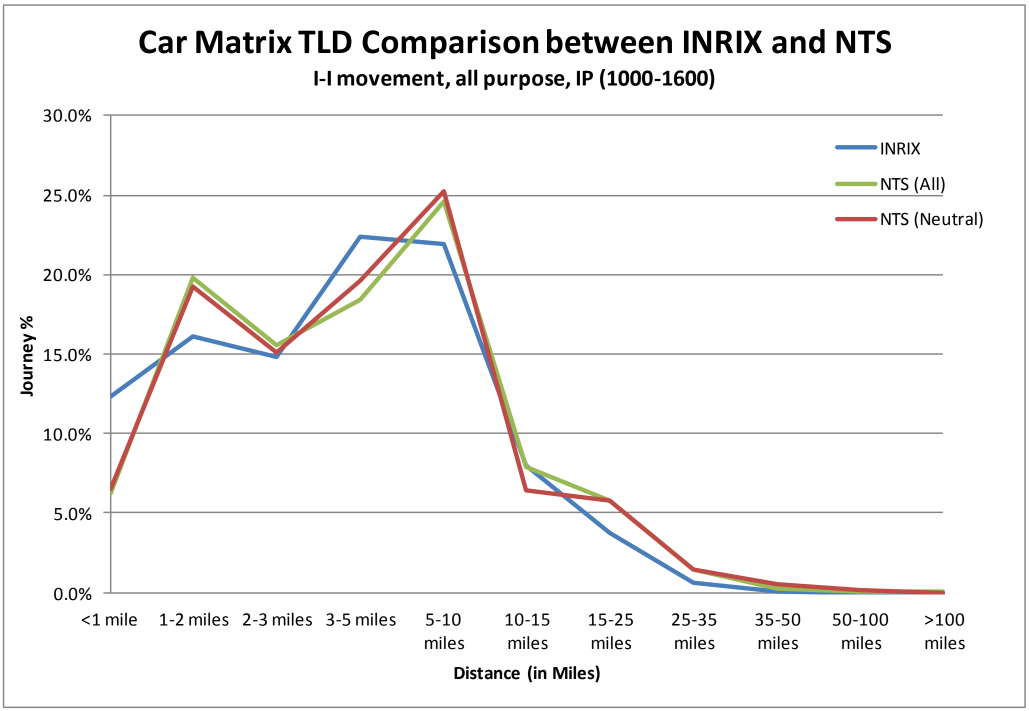


Figure 5-6 TLD comparison plot for PM peak period at all purpose level

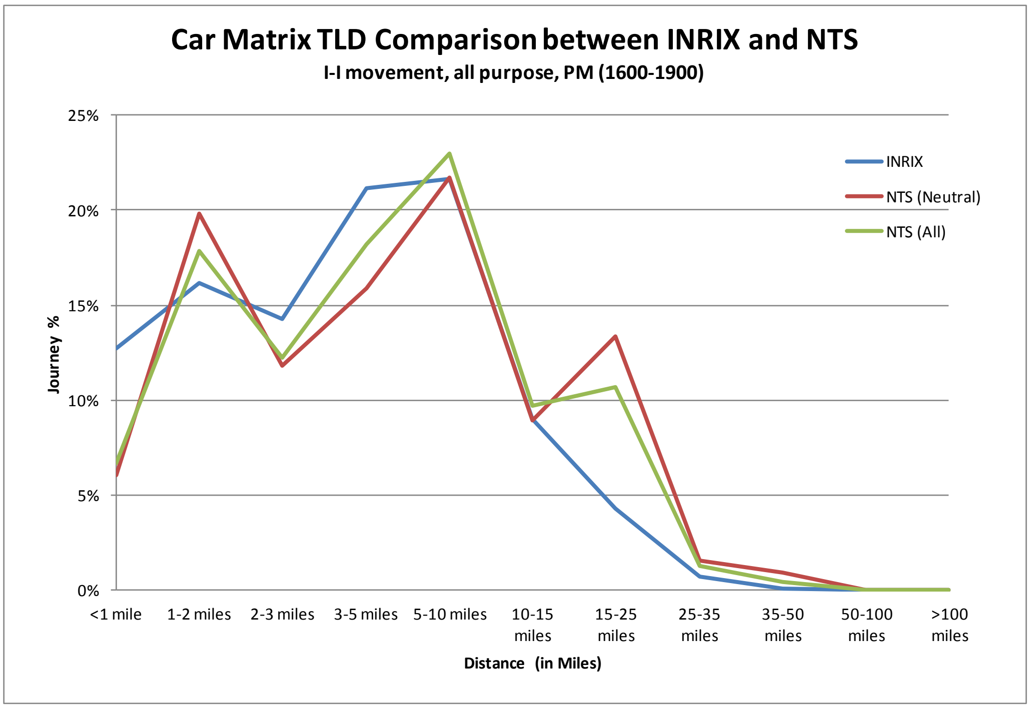


Table 5-1 Correction factors by distance by time period

Distance Band	AM(0700-1000)	IP(1000-1600)	PM(1700-1900)
<1 mile	0.75	0.51	0.53
1-2 miles	1.04	1.22	1.10
2-3 miles	0.87	1.05	0.86
3-5 miles	0.72	0.82	0.86
5-10 miles	0.94	1.12	1.06
10-15 miles	1.04	0.98	1.08
15-25 miles	2.69	1.54	2.49
25-35 miles	1.62	2.29	1.83
35-50 miles	11.53	6.11	7.18
50-100 miles	1.00	1.00	1.00
>100 miles	1.00	1.00	1.00

5.3.3. Task C

The INRIX data captures mobile phone units for O2 service provider, which accounts for around a third of UK mobile phone market. Therefore the data, as in RSI, is only of a sample of OD movements for the whole population, and needs to be expanded to match screenline or cordon counts for certain sector movements.

The INRIX data was first aggregated to reflect the AM peak period (07:00 to 10:00), inter-peak (10:00 to 16:00) and PM peak period (1600:19:00). The data expansion process first requires the creation of peak hour matrices by applying the peak period to peak hour conversion factors derived from the INRIX datasets at 2 sector level as presented in Table 5-2 and Table 5-3 below for AM and PM respectively. The inter-peak was an average of data between 10am and 4pm.

Table 5-2 AM Peak period to peak hour factors

Sector	Internal	External
Internal	0.400	0.354
External	0.375	0.322

Table 5-3 PM Peak period to peak hour factors

Sector	Internal	External
Internal	0.380	0.373
External	0.372	0.364

The INRIX mobile phone data was expanded based on the 4-sector system shown in Table 4-2. Recent traffic counts are available for most roads crossing the Oxford (sector 1) and Bicester (sector 2) cordons. For minor or unclassed roads without counts available, flows were estimated either by referring to adjacent roads with a similar road standard where a count is available, or by infilling with some nominal figures (related to the flow magnitude on similar roads in other part of network). As a result, the Oxford and Bicester cordons became water tight and the cordon flows could be used to expand the observed partial INRIX car trip matrices, as shown in Table 5-4. These are referred to as 'controlled' movements in that there is a cordon count to control matrix expansion. .

Care has been taken to identify cross-cordon count flows in association with sector movements. This is particularly the case for the Oxford cordon, which is located just inside the Oxford Ring Road. It was found, for example in the AM Peak, that there was outbound traffic crossing the cordon, travelling along the Ring

Road and arriving at a destination inside the Ring Road. The movements were for traffic from sector 1 to sector 1, and these should not influence the factors derived for movements to and from Sector 1. SATURN selected link analysis (SLA) were conducted to compare the existing 2007 COTM model to the 2007 RSI. It was found that the model outputs are quite similar to the RSI for the Bicester cordon but 10% higher for the Oxford cordon. It was thus decided to rely on the 2007 RSI data to estimate cordon crossing movements. A factor was therefore derived to discount the cordon count in order to allow for movements that are intra-sector though they use the cordon. This outbound movement discount factor, for Oxford was 0.87, 0.94, 0.96 for the AM, IP and PM respectively, and 0.54, 0.52, 0.48 for the AM, IP and PM respectively for Bicester. These factors were used to eliminate intra sector traffic from the cordon crossing counts.

The expansion factors were derived and applied to 'control' sectors in Table 5-4 for Oxford and Bicester cordons in turn. For the uncontrolled sector pairs, the trip totals from OD trip ends present in the TEMPRO 6.2 database were used as the control total. These are shown in Table 5-5. As an example: for sector 1 to sector 1, the sector total target was calculated by deducting from the TEMPRO trip ends[9] the expanded observed movements, i.e. sector 1 to 2, 3 and 4. The expansion factor for uncontrolled sector pairs were then derived. The external to external movement for sector 4 to 4 was not expanded due to the lack of an accurate data source.

Table 5-4 Sector pairs check for INRIX data expansion

Sectors		Oxford	Bicester	Rest of Oxfordshire	Rest of the UK
		1	**2**	**3**	**4**
Oxford	**1**	U	C	C	C
Bicester	**2**	C	U	C	C
Rest of Oxfordshire	**3**	C	C	U	U
Rest of UK	**4**	C	C	U	U

Note: C = Controlled and U = Uncontrolled

Table 5-5 TEMPRO OD Trip Ends for Car Driver in Oxfordshire in 2013

	AM Peak Hour (08:00-09:00)		Average Inter Peak hour (10:00-16:00)		PM Peak Hour (17:00-18:00)	
District	Origin	Destination	Origin	Destination	Origin	Destination
Cherwell	18503	17217	12232	12457	19477	20762
Oxford	16933	19842	12600	12170	20276	18879
South Oxfordshire	17017	14838	10889	11022	16914	18767
Vale of White Horse	15687	14798	10199	10136	16061	17081
West Oxfordshire	13722	12658	9442	9624	14573	15621
Oxfordshire	**81862**	**79353**	**55361**	**55408**	**87300**	**91111**

Table 5-6 shows the sector based factors used for expanding the INRIX car demand matrices. It can be seen that the expansion factors for controlled sector movements are close to 3, consistent with the mobile phone market share of O2 service. It is noted that the expansion factors for intra-town are larger than inter-town movements. The main reason for this is likely to be the lower spatial granularity of the INRIX zoning and its inability to pick up shorter distance moments.

[9] TEMPRO origin trip ends were considered as the primary source as it is household dependant and deemed more reliable than destination trip ends. We also checked the destination total after matrix expansion to ensure the trip ends are consistent with TEMPRO.

Table 5-6 Expansion factors for INRIX car demand matrices

Time	Location	Oxford	Bicester	Rest of Oxfordshire	Rest of UK
AM Peak (08:00-09:00)	Oxford	7.28	3.51	3.51	3.51
	Bicester	3.38	4.87	1.87	1.87
	Rest of Oxfordshire	3.38	2.62	3.71	3.71
	Rest of UK	3.38	2.62	3.51	1.00
Inter Peak (10:00-16:00)	Oxford	5.71	4.15	4.15	4.15
	Bicester	4.40	7.73	3.53	3.53
	Rest of Oxfordshire	4.40	2.87	4.10	4.10
	Rest of UK	4.40	2.87	5.88	1.00
PM Peak (17:00-18:00)	Oxford	5.37	2.97	2.97	2.97
	Bicester	3.14	10.08	3.12	3.12
	Rest of Oxfordshire	3.14	2.32	3.84	3.84
	Rest of UK	3.14	2.32	5.36	1.00

After matrix expansion, the INRIX hourly car matrices were produced for the modelled AM, IP and PM peaks. Table 5.6 below presents the comparison of INRIX unexpanded and expanded car trip totals. The overall expansion factor is between 3.5 and 4 depending on time period, again consistent with the mobile phone market share of O2 service.

Table 5-7 Unexpanded and Expanded INRIX Car Trips

Peak Hour	Unexpanded Trips	Expanded Trips
AM	28183	98049
IP	17074	69397
PM	30235	112373

A comparison of NTS and expanded INRIX data was made to confirm that the matrix expansion process retained the TLD adjustments. The comparisons are presented in Figure 5.7 to **Error! Reference source not found.** Figure 5.9 below and it can be seen that there is a good match between the two datasets.

Figure 5-7 TLD comparison plot for AM peak after screenline expansion

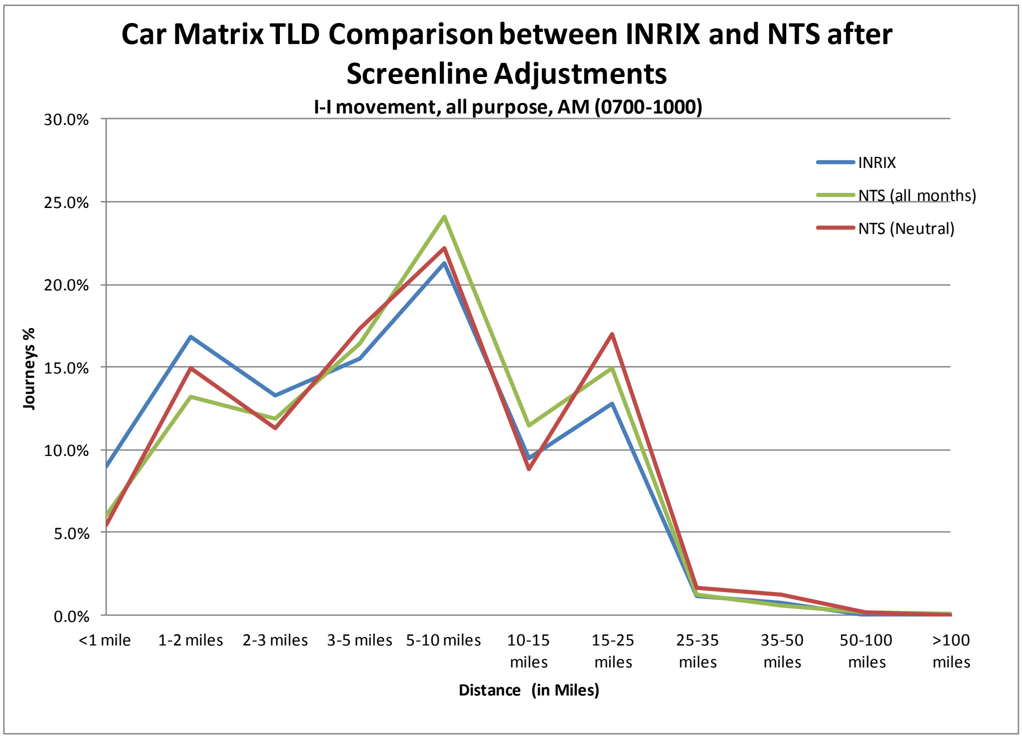


Figure 5-8 TLD comparison plot for Inter peak after screenline expansion

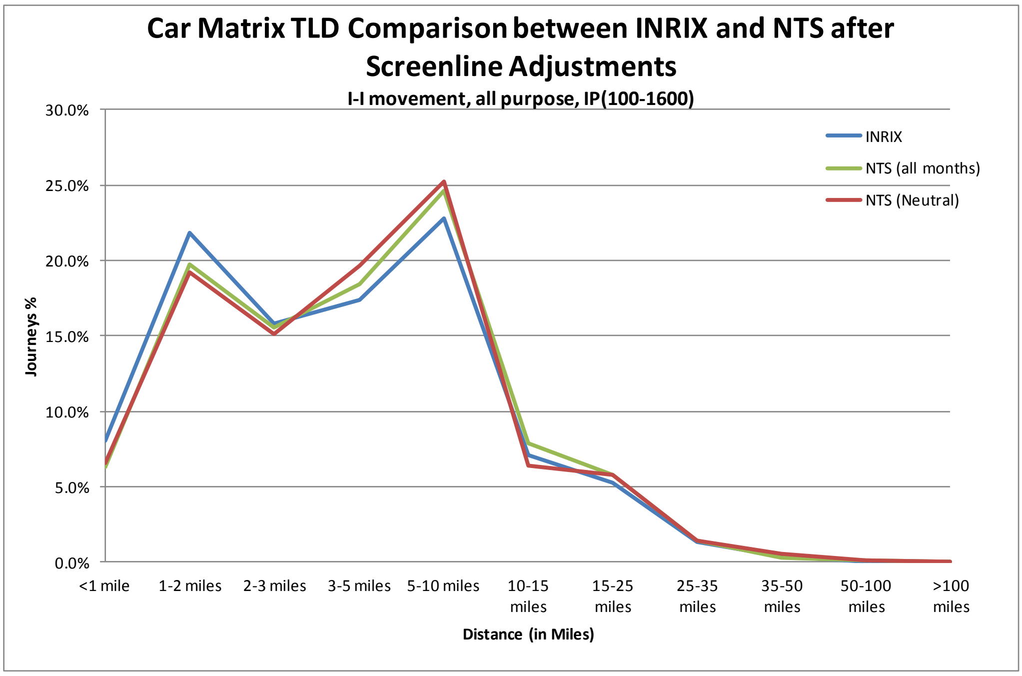
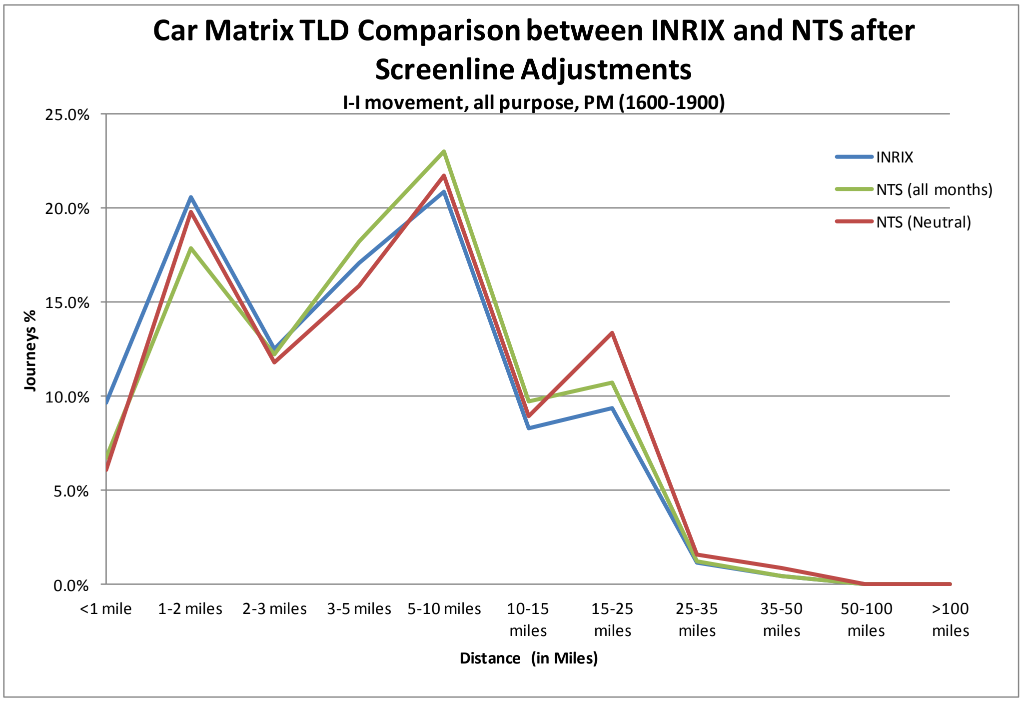


Figure 5-9 TLD comparison plot for PM peak after screenline expansion



5.3.4. Task D

With the INRIX car hourly matrices obtained from Task C, the matrix TEST A process was carried out which is described in detail in the following sections.

WebTAG does not contain advice on how matrices need to be built in a robust manner. At various key stages of constructing the prior trip matrices checks were made to ensure that the process has derived accurate trip movements. The aim of these tests and the consequent adjustments are:

- to detect errors at each stage of matrix build which otherwise might remain undetected and be compensated for, erroneously, by ME;
- to ensure that the prior trip matrices are reasonably close to the count data, so as to limit the scale of the changes that ME will bring about; and
- to maximise transparency by making explicit the factors or adjustments that need to be applied to the various inputs and outputs which are necessary to bring the matrices in line with the counts.

Two matrices tests, namely, Test A and Test C, were implemented as their acceptance guidance specified in Table 5.8 below. To undertake Test A the matrix needs to be compared against screenline or cordon counts, and for this exercise the Oxford and Bicester cordons were considered for both inbound and outbound directions where water-tight screenline or cordon counts were available[10]. Test A does not require model assignment but demonstrates that the matrix broadly contains the right number of trips.

10 Test A and C were not implemented for LGV and HGV matrices due to uncertainty of their quality as a result of lower sample rates in TrafficMaster data.

Table 5-8 Trip Matrix Development Tests – Test A

Test	Comparison	Measure	Criterion	Acceptability guideline
A	Flows and counts of trips across cordons, for the modelled hours separately.	Flow differences	< 5%	All or nearly all

Notes: A - Test A should be done without an assignment,

Test A was carried out on the INRIX (partial) trip matrices and results are presented in Table 5-9 below. The results show that the INRIX trip matrix met the Test A criteria and suggests that the trip matrix building process has created matrices that contain a very good approximation of the right number of trips crossing the two cordons. However, this is still at the INRIX zonal level, which is more aggregated than the OSM zone system.

Table 5-9 Test A results on Partial Trip Matrices for Car

Cordon Direction	AM			IP			PM		
	Count	Partial Matrix	% Diff	Count	Partial Matrix	% Diff	Count	Partial Matrix	% Diff
Oxford Inbound	8746	8742	0%	5694	5677	0%	6883	6865	0%
Oxford Outbound	5749	5770	0%	5451	5479	1%	8269	8281	0%
Bicester Inbound	4043	4239	5%	2489	2554	3%	3836	3916	2%
Bicester Outbound	3425	3611	5%	2629	2651	1%	4714	4926	5%

5.3.5. Task E

This task included the allocation of INRIX data into the OSM system, and the identification of ultimate OD's for external trips.

The expanded INRIX car matrices were converted into OSM zoning system by using a spatial correspondence between INRIX and OSM that is controlled by the 2011 Census population density. The cases evaluated are explained below:

- When the boundary of INRIX zone and multiple OSM zones exactly match, the proportion of population density was used.
- When an OSM zones falls in multiple INRIX zones, a combination of area overlap and population was used.

The trip matrices provided by INRIX were effectively cordoned at the edge of the capture area, some 40 miles from the centre of Oxford, and so the ultimate OD's are lost. Outside of INRIX data capture area, the trip OD was attributed to one of eight INRIX external zones, as illustrated the

Table 5-10 below. In order to obtain a more realistic distribution of ultimate ODs, the trip matrices from COTM were used to reallocate the INRIX external zones to COTM external-external zone distribution. This avoids the excessive assignment of external trips, for example, from/to South West of Oxfordshire, to a remote zone such as in Cornwall instead of Swindon or Bristol & Bath.

Table 5-10 INRIX External Zones

7 Stratford and North West	6 Rugby and North	5 Northampton, MK, and North East
8 Gloucester and West	Oxfordshire & extended data capture area	4 Aylesbury, London and East
1 Swindon and South West	2 Newbury and South	3 Reading and South East

After zone conversion, the trip ends of expanded OSM car demand matrices within Oxfordshire was checked to ensure that the volume of trip ends was appropriate for the number of houses and jobs in each zone, as follows:

- Trip ends calculated by applying a trip rate from TEMPRO onto the demographic data from 2011 Census for households and jobs;
- Visualisation check of land use for zones with aerial background photos.

The checks revealed a small number zones whose trip ends were inconsistent with Census data or land use observed from aerial background photos. The trip ends for these zones were adjusted accordingly and a Furness processes (which ensures that the matrix row and column trip totals match) was carried out for each modelled time period to obtain revised OSM car demand matrices.

5.3.6. Task F

For LGV and HGV demand matrices TrafficMaster data was provided by the DfT from 2012 to 2013 in the PASS3 zoning system. A correspondence between PASS3 and OSM zoning was created by using MapInfo GIS tool.

The expansion process follows the same steps as for the car matrices, with increasing focus on providing a matrix that matches traffic counts when assigned.

The first expansion was undertaken at a four sector level focusing on Oxford and Bicester cordons (where the COTM RSI data is collected), and the rest of Oxfordshire and rest of the UK.

- For Oxford and Bicester sectors, the expansion was controlled to the RSI and count data available.
- For the rest of the Oxfordshire and rest of the UK, controlling to count data was not possible and the expansion was controlled to trip ends from COTM model rebased to 2013.

5.3.7. Task G

Oxfordshire has five park and ride sites and within the modelling structure these sites were allocated a zone each. The park and ride sites in Oxford are not used exclusively by people driving to use the park and ride facility and as a result the Redbridge site charges both vehicles parking and bus passengers, as a number of drivers either walk or cycle to their destinations after parking their car. At other sites, people park and use longer distance coach services.

The car leg matrices for each park and ride site were produced in a manner that was consistent with the public transport model and is discussed in detail in the Public Transport Model Report utilising surveys at the park and ride sites. Such that in both models the number of cars at the park and ride site matches the number of bus passengers, adjusting for vehicle occupancy and park and walk/cycle.

This completed the creation of matrices that could be assigned to the highway network. These matrices were not complete, they excluded external to external trips (a small element of trips crossing the Oxford and Bicester cordons).

Matrix Test C was not undertaken as it is pertinent to assessing a synthetic trip matrix, which has not been used in this study. For matrix Test C the matrices were assigned onto the OSM highway network and the modelled flows were compared to the counts for the Oxford and Bicester cordons and the criteria specified in Table 5-11 below was applied.

Table 5-11 Trip Matrix Development Tests – Test C

Test	Comparison	Measure	Criterion	Acceptability guideline
C	Flows and counts of trips across cordons, for the modelled hours separately.	Flow differences	< 7.5%	All or nearly all

The results of Test C shows that the matrices meet the criteria for Test C for car trips. This again confirms that the matrix broadly contains the right number of trips that would cross the two cordons within the Test C tolerance.

Table 5-12 Test C results on Prior Trip Matrices for Car (pcu)

Cordon Direction	AM			IP			PM		
	Count	Model	% Diff	Count	Model	% Diff	Count	Model	% Diff
Oxford Inbound	8746	8659	-3%	5694	5490	-4%	6883	6073	-4%
Oxford Outbound	5749	6257	7%	5451	5147	-6%	8269	7746	1%
Bicester Inbound	4043	3723	-4%	2489	2619	5%	3836	3482	1%
Bicester Outbound	3425	3289	1%	2629	2658	1%	4714	4058	-5%

This concludes this stage of the development of trip matrices. Matrix sizes in pcu's are shown in Table 5-14 below.

Table 5-13 Matrix Sizes

	AM Peak Hour	Inter-Peak Hour	PM Peak Hour
Cars	95415	68878	112465
LGV	11350	7968	8485
HGV	5961	4832	3073

Whilst the matrix building process has attempted to develop matrices in a consistent way, only those trips crossing the Oxford and Bicester cordons have been controlled to counts and considered to be complete. Movements within the rest of Oxfordshire that do not cross these cordons have been controlled to TEMPRO trip ends and can also be considered as complete. However, external to external trips could not be controlled counts are such counts are not available across the County boundary. Moreover, they could not be controlled to TEMPRO as the external trips of interest, i.e. passing through the County represent only a small % of trips out of a zone (i.e. trips from Kent to Birmingham passing through the County are only a small proportion of total trips originating from Kent). The process acknowledges that the matrix which has been built will underestimate the number of external to external trips in the model, although this is expected to be a small % of the total trips that need to be modelled.

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6. Network Calibration and Validation

6.1. Introduction

During the model calibration stage, adjustments are made to the model parameters and trip matrices to improve the match between observed and modelled data. This section of the report provides details of the techniques used and the changes made during the model calibration process and the results achieved.

The calibration procedure involved a number of activities namely:

- checks to ensure that link speeds on the network were realistic, and speed/flow calculations were operating as expected;
- checks to ensure that delay calculations at junctions were realistic;
- adjustment and checking of the network to ensure plausible and realistic routeing of traffic; and
- use of ME to adjust the prior trip matrices to match observed traffic flows from link and turning counts.

6.2. Network Calibration and Validation

Highway network calibration is undertaken to achieve observed traffic characteristics in terms of speeds, traffic throughputs and delays by investigating pinch points and problem areas highlighted by the initial model assignments.

The process involved checking and adjusting the highway network principally along the major corridors. Checks are undertaken to ensure that link lengths, turn saturation flows and capacities are correct. Adjustments are also made to speed/flow curves and to centroid connector loading points where appropriate.

The allocation of centroid connectors for internal zones is examined to verify that trips are loading onto the network at locations that are both sensible and realistic.

Other checks carried out include:

- **Counts in excess of capacity** – where an observed count is noticeably higher than the coded network capacity, the capacities are checked and amended if necessary;
- **Excessive junction delays** – the largest node delays, and the largest differences between the link travel times and the observed data from TOMTOM are checked and junction coding checked;
- **Low/high flows** – where the modelled flow is substantially different from the observed count; this reveals locations where traffic was either restricted at an upstream junction or where a competing route was more attractive or the delays on ground are not well represented in the model;
- **Poor reproduction of observed travel times** - detailed comparisons of modelled travel times against the observed journey time routes reveal locations where additional modifications to signal settings may be necessary in order to replicate the observed levels of delay.

6.2.1. Route Choice Calibration and Validation

The accuracy of the assignment depends on the network structure, the trip matrix and the realism of modelled routes. The calibration and validation of the routes chosen by the model is carried out as follows:

The ability of model to robustly represent route choice within the network depends on:

- correct zone sizing and definition, network structure and the realism of the zone connections to the modelled network (centroid connectors);
- the accuracy of the network coding and the appropriateness of the simplifications adopted;

- the accuracy with which delays at junctions and link cruise speeds are modelled, which in turn is dependent not only on data and/or coding accuracy but also on the appropriateness of the approximations inherent in the junction flow/delay and link speed/flow relationships; and
- how accurately the trip matrices have been built, which, when assigned, will impact on the route choice process (via the flow/delay and speed/flow relationships).

No specific criterion exists for validating route choices within a modelled network. However, it is common practice to undertake to review the routing chosen by the model between key locations and TAG Unit M3.1 suggests that the number of routes (OD pairs) should be estimated as:

Number of OD pairs = $(\text{number of zones})^{0.25}$ x the number of user classes

This equates to approximately 16 OD pairs for route validation for each modelled time period.

Routing was checked between 20 selected OD pairs in the assignment model by comparing modelled routing against the routing observed from Google Earth. These are presented in Appendix A. When compared against the routing from Google Earth (rather than TomTom to provide some independence from the journey time data) in the study area, the figures indicate the model routing is comparable to internet based journey planners.

7. Matrix Calibration and Validation

7.1. Case for Matrix Estimation

TAG Unit M3-1 advises that the primary purpose of ME is to refine estimates of trips not intercepted in surveys which have been synthesised, usually by means of a gravity model. In this instance, although the INRIX data provides an alternative to RSI surveys and gravity models, its relatively high degree of granularity still means that a level of matrix refinement is still required.

The development of the prior matrix was described in the previous section and the modelled flows were compared to the observed counts for the calibration cordons and screenlines to determine whether further matrix calibration was required using ME.

With the matrices developed by controlling the Oxford and Bicester cordons passing Test C, the external to external movements are added to produce the prior matrix. The comparison of the observed and modelled flows across the screenlines is summarised in Table 7-1 for the prior trip matrices (including external to external movements). The total flow represents the sum of all three user classes plus bus flows and PassQ flows. They show that the addition of external to external trips has meant that the replication of the observed cordon and screenline flows was outside of the TAG targets (as defined in Table 1 for total screenline flow) for all three time periods.

Table 7-1 – Summary of Screenline and Cordon Validation (Prior Matrix) – AM Peak hour

Cordon	Direction	Percent difference -cars	Percent difference – LGV	Percent difference – HGV	Percent difference – Total
Oxford Cordon	Inbound	3%	-14%	-21%	9%
	Outbound	-1%	-7%	-7%	6%
Bicester Cordon	Inbound	-4%	14%	72%	5%
	Outbound	0%	19%	97%	10%
Didcot Cordon	Inbound	5%	-57%	80%	6%
	Outbound	12%	-53%	-29%	4%
Outer Cordon	Inbound	11%	-6%	48%	13%
	Outbound	7%	-3%	56%	12%
East - West Screenline	Northbound	-12%	-25%	39%	-7%
	Southbound	9%	1%	87%	18%

Table 7-2 – Summary of Screenline and Cordon Validation (Prior Matrix) – Inter Peak hour

Cordon	Direction	Percent difference -cars	Percent difference – LGV	Percent difference – HGV	Percent difference – Total
Oxford Cordon	Inbound	-9%	-5%	-7%	-2%
	Outbound	-9%	-5%	-5%	-2%
Bicester Cordon	Inbound	-12%	-3%	118%	-2%
	Outbound	-15%	-9%	116%	-6%
Didcot Cordon	Inbound	15%	-65%	32%	7%
	Outbound	13%	-69%	26%	4%
Outer Cordon	Inbound	16%	-8%	101%	20%
	Outbound	4%	-10%	89%	10%
East - West Screenline	Northbound	-16%	-5%	149%	-3%
	Southbound	-7%	-32%	109%	-2%

Table 7-3 – Summary of Screenline and Cordon Validation (Prior Matrix) – PM Peak hour

Cordon	Direction	Percent difference -cars	Percent difference – LGV	Percent difference – HGV	Percent difference – Total
Oxford Cordon	Inbound	-5%	6%	-40%	7%
	Outbound	-11%	-8%	-47%	-2%
Bicester Cordon	Inbound	-7%	27%	177%	3%
	Outbound	-13%	26%	158%	-3%
Didcot Cordon	Inbound	8%	-34%	-76%	6%
	Outbound	15%	-38%	-10%	12%
Outer Cordon	Inbound	17%	-3%	87%	20%
	Outbound	6%	-11%	56%	10%
East - West Screenline	Northbound	-12%	-4%	109%	-3%
	Southbound	-11%	-32%	34%	-9%

As such, ME was applied to the prior trip matrix to improve the matrix calibration and the following principles were adopted:

- counts used as constraints in ME were usually derived from two-week ATCs; and
- constraints were applied at the car, LGV and HGV level.

7.2. Application of Matrix Estimation

The SATURN modules SATME2 and SATPIJA are used for ME and in combination attempt to match assigned link flows in the model with observed traffic counts. The ME process forms part of the calibration process and is designed to modify the origin-destination volumes by reference to the observed traffic counts. Trips are adjusted in the prior matrix to produce the estimated matrix, which is most likely to be consistent with the traffic counts.

The equation used may be written as:

$$T_{ij} = tij \prod_a X_a^{Pija}$$

where:

T_{ij} is the output estimated matrix of OD pairs ij;

tij is the prior matrix of OD pairs ij;

$\prod_a$ is the product over all counted links a;

X_a is the balancing factor associated with counted link;

Pija is the fraction of trips from I to j using link a.

This process is dependent on other factors, and therefore must be monitored closely to ensure that:

- the trip matrix is converging to a stable solution;
- travel patterns at a sector level are reasonable; and
- changes should not be significant; and
- trip length distributions are reasonable.

Using the SATPIJA control file, checks are made to ensure that the overall trip distribution of the original prior trip matrix is maintained by limiting the change to cell values for cars and LGV.

The ME process is applied to adjust the car matrix followed by light vehicle matrix and then followed by heavy vehicle matrix. In total six ME iterations are implemented. As described previously, the link counts used in the ME process are formed as a series of calibration screenlines for car, LGV and HGV matrices. In addition, diligence is exercised to ensure that the quality and consistency of the input count data is high.

7.3. Impact of Matrix Estimation

7.3.1. Significance of Matrix Estimation Changes

WebTAG unit M3.1 states that the changes brought by ME should not be significant. The criteria by which the significance of changes brought about by ME are presented in Table 7-4 below.

Table 7-4 – Significance of Matrix Estimation Changes

Measure	Significance Criteria
Matrix zonal cell values	Slope within 0.98 and 1.02 Intercept near zero R^2 in excess of 0.95
Matrix zonal trip ends	Slope within 0.99 and 1.01 Intercept near zero R^2 in excess of 0.98
Trip length distributions	Means within 5% Standard deviations within 5%
Sector to sector level matrices	Differences within 5%

7.3.2. Matrix totals

A comparison of matrix totals before and after ME is shown in Table 7-5. In order to clearly show the impacts of ME on the matrix changes in the study area, the external trips are removed from this analysis as they were outside of the matrix building process and controls on these movements were less restrictive.

Table 7-5 – Comparison of Matrix Totals – Prior and Post ME2 (only internal movements)

Time Period	Cars			Lights			Heavies		
	Prior	Post ME2	% Change	Prior	Post ME2	% Change	Prior	Post ME2	% Change
AM	64917	62292	-4.0%	6115	6457	5.6%	1762	1902	7.9%
IP	43621	42912	-1.6%	4033	4390	8.8%	2060	2001	-2.8%
PM	70344	69129	-1.7%	4881	4928	1.0%	622	592	-4.8%

7.3.3. Matrix zonal values

Matrix zonal changes, excluding the external trips, by time period are presented in Table 7-6 below. In most cases the criteria are met. The only notable exception is the slope of the trip ends rows in the morning peak hour, which is 0.95 rather than within 0.99 and 1.01 but still has a R-squared value within the criteria.

Table 7-6 – Matrix Estimation Changes by time period (excluding external trips)

Measure	Significance Criteria	AM	IP	PM
Matrix Zonal Cell Values	Slope within 0.98 and 1.02	0.980	0.991	0.990
	Intercept near zero	0.000	0.000	0.000
	R^2 in excess of 0.95	0.940	0.980	0.970
Matrix Zonal Trip Ends (Rows)	Slope within 0.99 and 1.01	0.940	0.980	0.990
	Intercept near zero	0.940	0.220	-0.150
	R^2 in excess of 0.98	0.970	0.990	0.990
Matrix Zonal Trip Ends (Columns)	Slope within 0.99 and 1.01	0.960	0.990	0.962
	Intercept near zero	0.960	-0.110	2.440
	R^2 in excess of 0.98	0.990	0.990	0.980

7.3.4. Matrix trip length distribution

The comparison of trip length distribution between the pre and post ME matrices is shown in Figure 7.1 through to Figure 7.6 for each time period and user class. This analysis demonstrates that ME has not significantly affected the length of trips in the matrices for cars and LGV but has made some impact on the HGV matrix. However, the source of the HGV matrix was not as comprehensive as the data for cars and LGV, hence the ME process for HGV movements was given more flexibility.

Table 7-7 – Mean and Standard Deviation for Trip Length Distribution by time period

Time Period	CAR		LGV		HGV	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
AM	-2%	1%	-4%	-5%	-18%	-8%
IP	-0.1%	1%	-2%	-4%	-24%	-10%
PM	-2%	-0.1%	-1%	-2%	-17%	-5%

Figure 7.1 Trip Length Distribution for AM Peak (UC1 Cars)

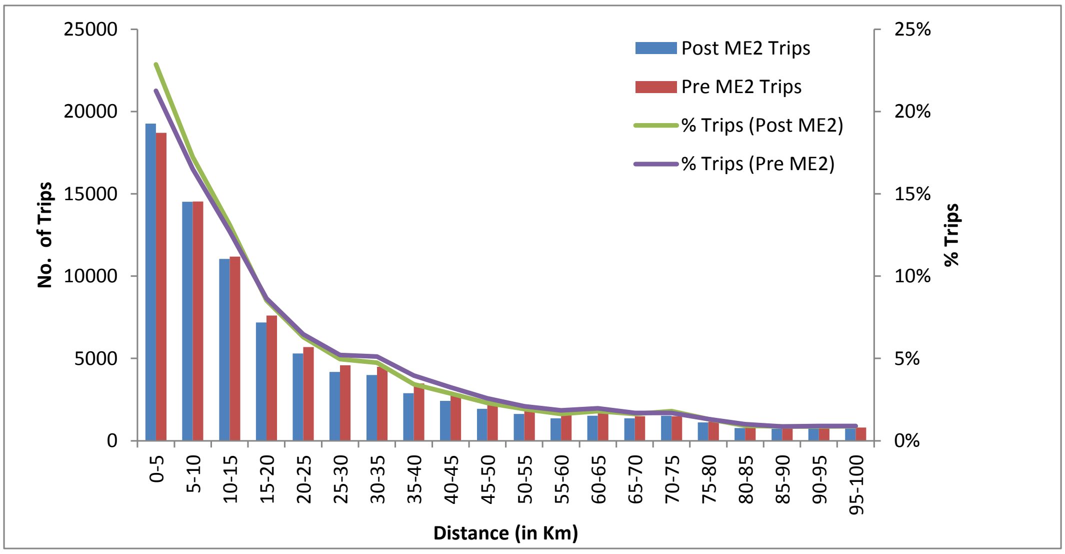


Figure 7.2 Trip Length Distribution for AM Peak (UC2 Lights)

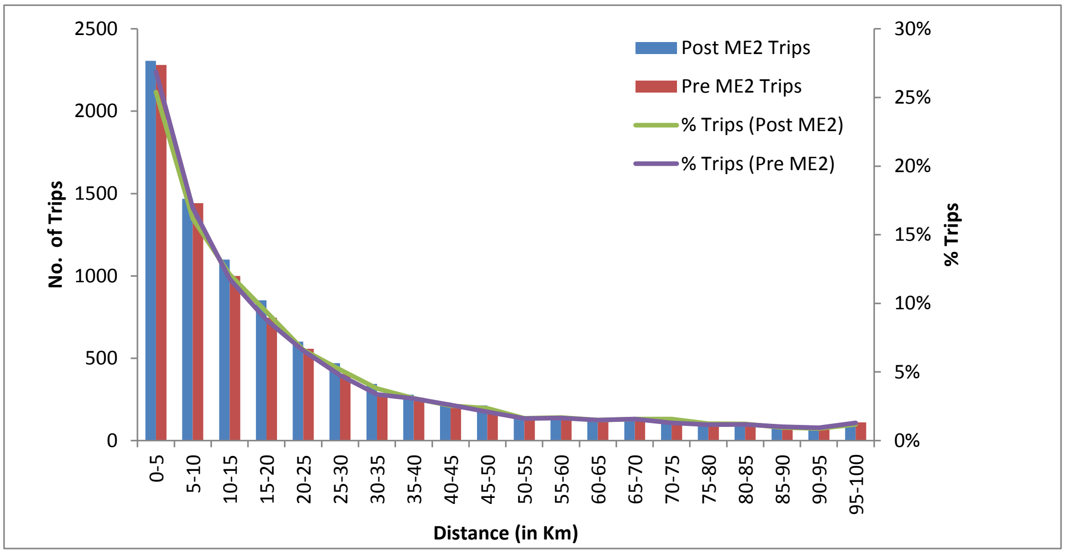


Figure 7.3 Trip Length Distribution for AM Peak (UC3 Heavies)

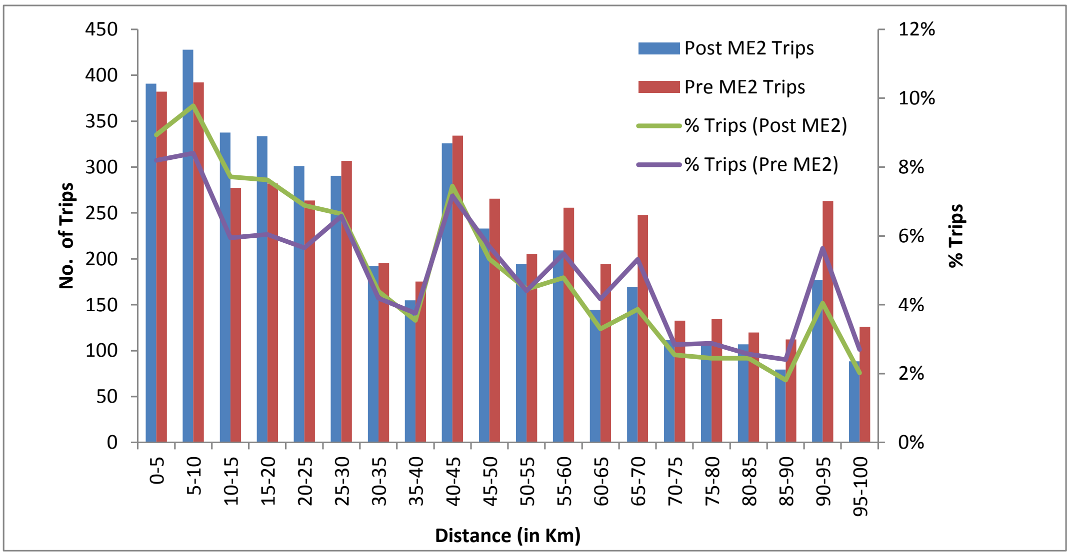


Figure 7-4 Trip Length Distribution for Inter Peak (UC1 Cars)

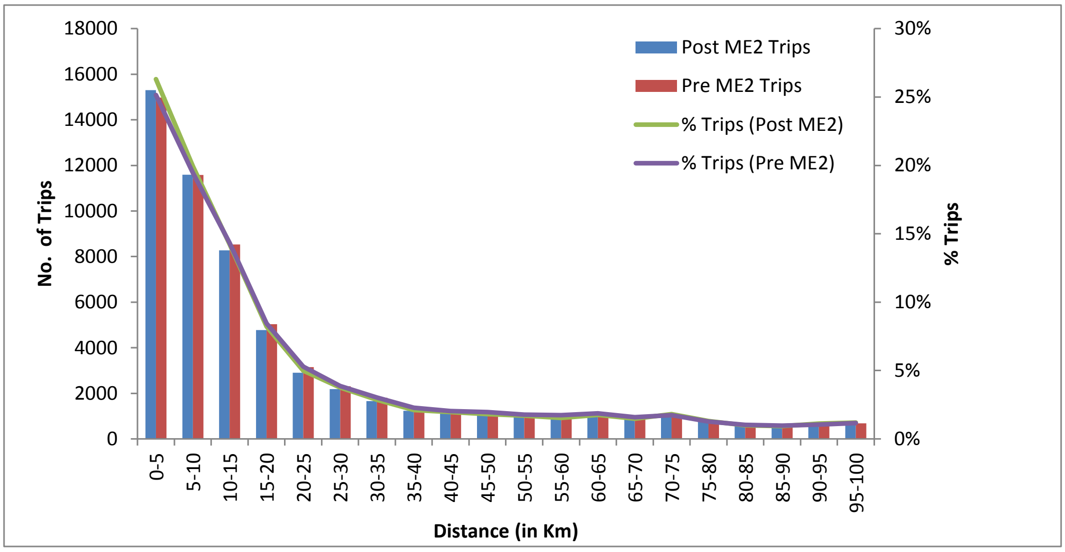


Figure 7.5 Trip Length Distribution for Inter Peak (UC2 Lights)

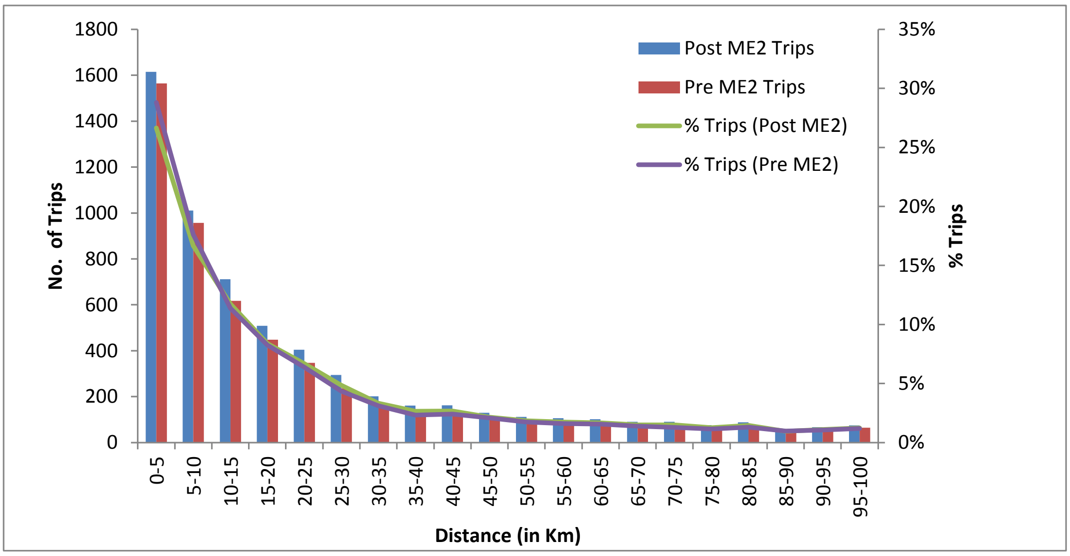


Figure 7.6 Trip Length Distribution for Inter Peak (UC3 Heavies)

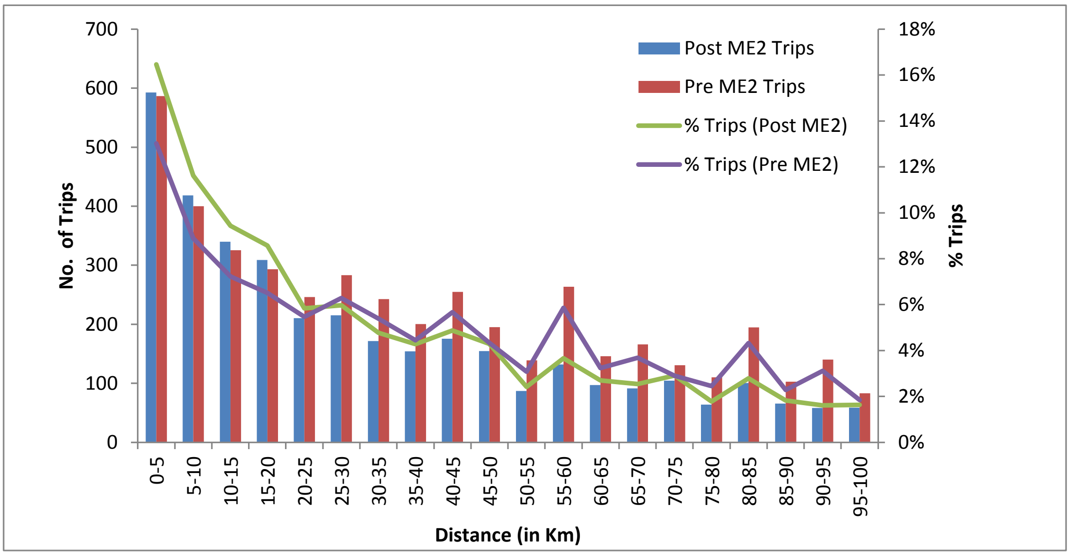


Figure 7-7 Trip Length Distribution for PM Peak (UC1 Cars)

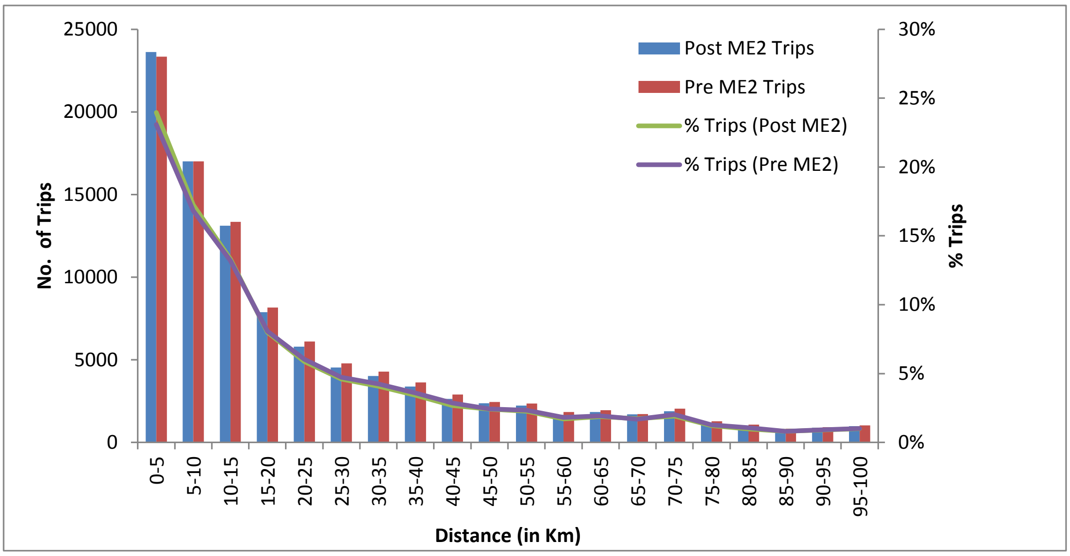


Figure 7.8 Trip Length Distribution for PM Peak (UC2 Lights)

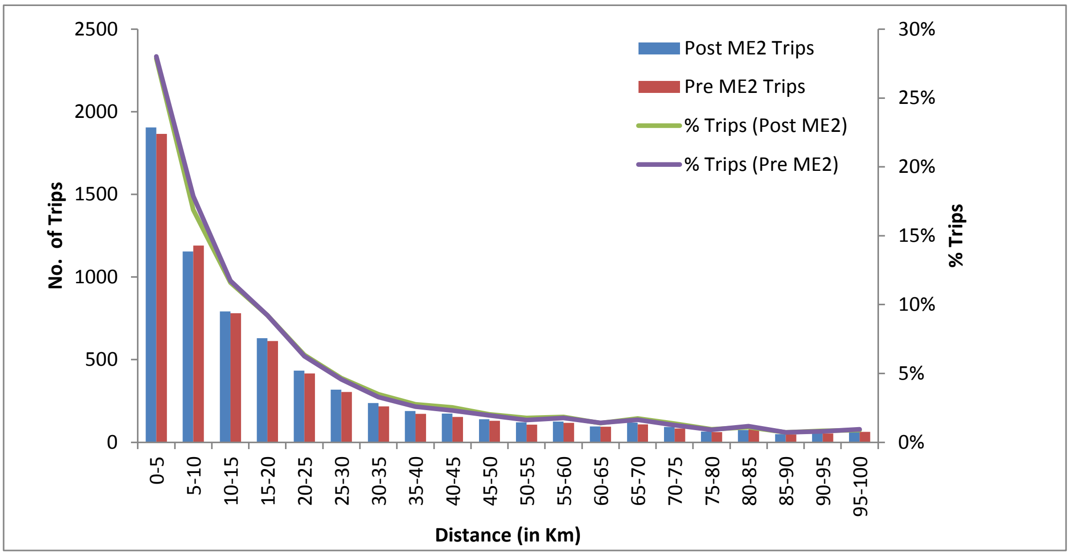
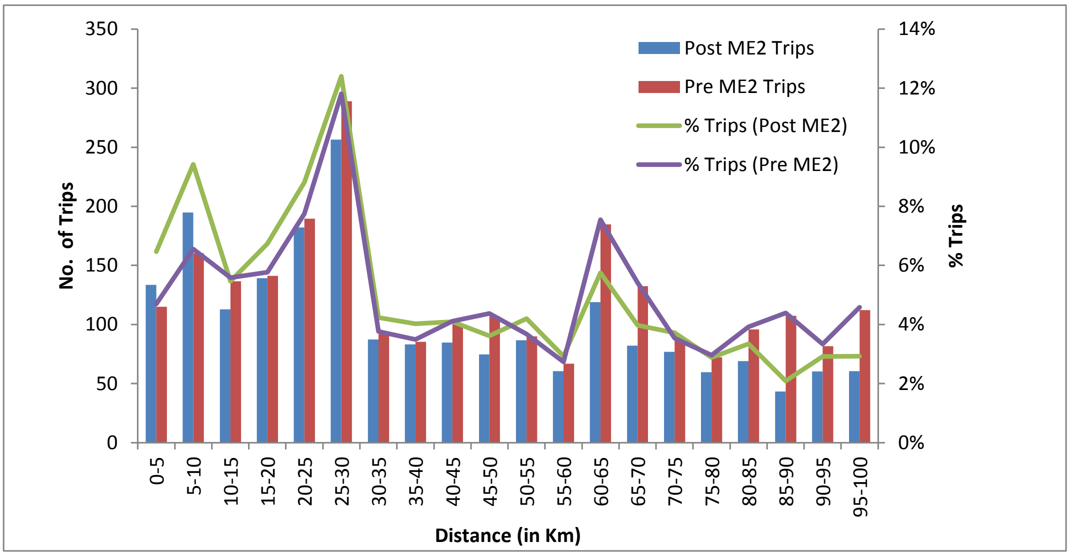


Figure 7.9 Trip Length Distribution for PM Peak (UC3 Heavies)



7.3.5. Sector changes

In this analysis, the extent of ME is tested to look at impact in terms of absolute difference of trips and percentage difference at a sector to sector level. The analysis below uses a sector system that matches the cordons used in the ME process rather than the 13 sectors used in matrix development as shown:

1. Oxford
2. Bicester
3. Didcot
4. Inside outer cordon
5. Outside of outer cordon

Although the overall impact of ME is low, some sectors to sector movements do show significant percentage changes brought about by ME (Table 7-8 to 7-10). The table highlights those sector to sector movements in bold that exceed TAG criteria and shades those cells which have a significant number of trips (as defined by at least 5% of the total matrix given the large sectors).

In the morning peak hour the following observations were made by vehicle type for those sector to sector movements exceeding the TAG criteria and containing a significant proportion of trips:

- Cars
  - Sector 4 to sector 5 shows a -14% change brought about by ME and this sector contributes 9% of the total matrix. This represents a decrease in trips crossing the outer cordon in an outbound direction which was previously uncontrolled in the matrix development process (only the Oxford and Bicester cordons were controlled).
  - Sector 5 to sector 4 shows a -13% change brought about by ME and this sector contributes 10% of the total matrix. This represents a decrease in trips crossing the outer cordon in to Oxford.
- LGV
  - Sector 4 to sector 5 shows a 10% change brought about by ME and this sector contributes 6% of the total matrix. This represents an increase in trips crossing the outer cordon in an outbound direction which was previously uncontrolled in the matrix development process
  - Sector 5 to sector 4 shows a 24% change brought about by ME and this sector contributes 7% of the total matrix. This represents an increase in trips crossing the outer cordon in to Oxford.

- HGV
  - Sector 4 to sector 5 shows an -17% change brought about by ME and this sector contributes 10% of the total matrix which we need to investigate further based on the new schemes coming up if any. As previously stated, the source of the HGV matrix was not as comprehensive as the data for cars and LGV, hence the ME process for HGV movements was given more flexibility.
  - Sector 5 to sector 4 shows an -13% change brought about by ME and this sector contributes 10% of the total matrix which we need to investigate further based on the new schemes coming up if any. As previously stated, the source of the HGV matrix was not as comprehensive as the data for cars and LGV, hence the ME process for HGV movements was given more flexibility.
  - Sector 5 to sector 5 shows a -26% change brought about by ME and this sector contributes 53% of the total matrix which we need to investigate further based on the new schemes coming up if any. As previously stated, the source of the HGV matrix was not as comprehensive as the data for cars and LGV, hence the ME process for HGV movements was given more flexibility.

Table 7-8 – Impact of Matrix Estimation at a Sector to Sector level -AM Peak

User	Sector	1	2	3	4	5
Car	1	4%	**-11%**	1%	5%	**-17%**
	2	**-7%**	0%	**44%**	**-15%**	**34%**
	3	**-38%**	**7%**	0%	-3%	**10%**
	4	-2%	**11%**	0%	-2%	**-14%**
	5	**-26%**	**11%**	-2%	**-13%**	0%
User	**Sector**	**1**	**2**	**3**	**4**	**5**
LGV	1	0%	**-7%**	**133%**	**18%**	-1%
	2	-4%	0%	**185%**	**-7%**	-2%
	3	**8%**	**127%**	0%	**126%**	**205%**
	4	1%	5%	**28%**	4%	**10%**
	5	**13%**	**-14%**	**191%**	**24%**	-3%
User	**Sector**	**1**	**2**	**3**	**4**	**5**
HGV	1	**68%**		**-6%**	**26%**	**-25%**
	2	**10%**	0%		**-7%**	**-60%**
	3	**231%**		0%	**45%**	**182%**
	4	**49%**	**47%**	**-60%**	-4%	**-17%**
	5	**-34%**	-3%	**-29%**	**-13%**	**-26%**

Note: bold text shows exceeding the TAG Criteria of 5% and Shaded text shows a sector has more than 5% of the total matrix

In the inter-peak hour the following observations were made by vehicle type for those sector to sector movements exceeding the TAG criteria and containing a significant proportion of trips

- Cars
  - Sector 5 to sector 4 shows a -13% change brought about by ME and this sector contributes 9% of the total matrix. This represents a decrease in trips crossing the outer cordon in inbound direction which was previously uncontrolled in the matrix development process.

- LGV
  - Sector 4 to sector 4 shows a 10% change brought about by ME and this sector contributes 12% of the total matrix.

- Inter peak hour – HGV
  - Sector 4 to sector 4 shows a -9% change brought about by ME and this sector contributes 11% of the total matrix. As previously stated, the source of the HGV matrix was not as comprehensive as the data for cars and LGV, hence the ME process for HGV movements was given more flexibility.
  - Sector 4 to sector 5 shows an -43% change brought about by ME and this sector contributes 12% of the total matrix which we need to investigate further based on the new schemes coming up if any. As previously stated, the source of the HGV matrix was not as comprehensive as the data for cars and LGV, hence the ME process for HGV movements was given more flexibility.
  - Sector 5 to sector 4 shows an -48% change brought about by ME and this sector contributes 13% of the total matrix which we need to investigate further based on the new schemes coming up if any. As previously stated, the source of the HGV matrix was not as comprehensive as the data for cars and LGV, hence the ME process for HGV movements was given more flexibility.
  - Sector 5 to sector 5 shows a -33% change brought about by ME and this sector contributes 46% of the total matrix which we need to investigate further based on the new schemes coming up if any. As previously stated, the source of the HGV matrix was not as comprehensive as the data for cars and LGV, hence the ME process for HGV movements was given more flexibility.

Table 7-9 – Sector to Sector level Matrices – IP Peak

User	Sector	1	2	3	4	5
Car	1	4%	**-8%**	**-7%**	4%	**-9%**
	2	-2%	0%	**14%**	**24%**	**15%**
	3	**-21%**	**22%**	0%	**-10%**	3%
	4	**7%**	**20%**	**-12%**	-1%	-2%
	5	**-14%**	**7%**	**-13%**	**-13%**	0%
User	**Sector**	**1**	**2**	**3**	**4**	**5**
LGV	1	-2%	**-9%**	**97%**	**10%**	**10%**
	2	3%	0%	**250%**	**20%**	2%
	3	**141%**	**239%**	0%	**99%**	**237%**
	4	-4%	**8%**	**100%**	**10%**	**38%**
	5	**23%**	**-8%**	**249%**	**34%**	1%
User	**Sector**	**1**	**2**	**3**	**4**	**5**
HGV	1	**13%**	**-26%**	**194%**	**46%**	**-47%**
	2	**-22%**	0%	**183%**	0%	**-51%**
	3			0%	**-49%**	**25%**
	4	**37%**	**11%**	**-43%**	**-9%**	**-43%**
	5	**-54%**	**-20%**	**-34%**	**-48%**	**-33%**

In the evening peak hour the following observations were made by vehicle type for those sector to sector movements exceeding the TAG criteria and containing a significant proportion of trips

- Cars
  - Sector 5 to sector 4 shows a -13% change brought about by ME and this sector contributes 8% of the total matrix. This represents a decrease in trips crossing the outer cordon in inbound direction which was previously uncontrolled in the matrix development process.
- PM peak hour – LGV
  - Sector 4 to sector 5 shows a 20% change brought about by ME and this sector contributes 7% of the total matrix. This represents an increase in trips crossing the outer cordon in an outbound direction which was previously uncontrolled in the matrix development process.
  - Sector 5 to sector 4 shows a 9% change brought about by ME and this sector contributes 7% of the total matrix. This represents an increase in trips crossing the outer cordon in to Oxford.

- PM peak hour – HGV
  - Sector 4 to sector 5 shows an -13% change brought about by ME and this sector contributes 10% of the total matrix which we need to investigate further based on the new schemes coming up if any. As previously stated, the source of the HGV matrix was not as comprehensive as the data for cars and LGV, hence the ME process for HGV movements was given more flexibility.
  - Sector 5 to sector 4 shows an -29% change brought about by ME and this sector contributes 14% of the total matrix which we need to investigate further based on the new schemes coming up if any. As previously stated, the source of the HGV matrix was not as comprehensive as the data for cars and LGV, hence the ME process for HGV movements was given more flexibility.
  - Sector 5 to sector 5 shows a -31% change brought about by ME and this sector contributes 58% of the total matrix which we need to investigate further based on the new schemes coming up if any. As previously stated, the source of the HGV matrix was not as comprehensive as the data for cars and LGV, hence the ME process for HGV movements was given more flexibility.

Table 7-10 – Sector to Sector level Matrices – PM Peak

User	Sector	1	2	3	4	5
Car	1	1%	**-12%**	0%	**18%**	**-8%**
	2	-5%	0%	**37%**	**33%**	-2%
	3	**-27%**	**18%**	0%	-2%	-1%
	4	0%	-4%	**-7%**	0%	-4%
	5	**-12%**	**21%**	**-17%**	**-13%**	-3%
User	**Sector**	**1**	**2**	**3**	**4**	**5**
LGV	1	4%	**-17%**	**34%**	-5%	**10%**
	2	**-20%**	0%	**280%**	**11%**	**-28%**
	3	**18%**	**214%**	0%	**12%**	**177%**
	4	**-13%**	**-9%**	**54%**	3%	**20%**
	5	**-11%**	**-12%**	**159%**	**9%**	-1%
User	**Sector**	**1**	**2**	**3**	**4**	**5**
HGV	1	**130%**			**51%**	**-25%**
	2		0%		**-14%**	**-65%**
	3			0%	**-43%**	**-36%**
	4	**-25%**	**11%**	**64%**	0%	**-13%**
	5	**-53%**	**-72%**	**62%**	**-29%**	**-31%**

The results above show that at a cell and trip end level the impact of ME has been controlled and is generally within WebTAG criteria. The incidence of exceedances of the benchmark criteria at a sector to sector level is a result of small changes at a cell to cell level combining to form larger change at a sector level.

7.4. Matrix Validation

Validation of the post ME matrices was undertaken by comparing total screenline and cordon modelled flows and counts by vehicle type and time period. The assessment criteria follows those defined in TAG Unit M3.1 Table 1, which states that differences between modelled flows and counts should be less than 5% of the counts for all or nearly all screenlines. The focus of the validation effort was on cars and all vehicles as cars represent typically 80% to 90% of flow on roads in the area of detailed modelling. The results of this assessment are shown in Table 7-11 and are summarised below.

- In the morning peak
  - All the calibration screenlines (five screenlines in two directions) meet acceptability guidelines for all vehicles and seven screenlines meet acceptability guidelines for cars.
  - The Oxford outbound and Didcot inbound screenlines fail with a slight difference of -6% for cars.
  - All of the validation screenlines meet acceptability guidelines for cars and all vehicles.
- In the inter-peak:
  - Eight out of ten calibration screenlines meet acceptability guidelines for all vehicles and four screenlines meet acceptability guidelines for cars.
  - The East-West screenline fails with a flow difference of -7% and -6% for Northbound and Southbound for all vehicles respectively.
  - Of the six screenlines that fail to meet acceptability guidelines for cars, the Bicester cordon failed slightly by -6% in both directions and Outer cordon inbound by 7%.
  - All of the validation screenlines meet acceptability guidelines for cars and all vehicles.
- In the evening peak:
  - Eight out of ten of the ME screenlines meet acceptability guidelines for all vehicles and four screenlines meet acceptability guidelines for cars. The Oxford inbound, Bicester outbound fail with a slight difference –6%.
  - All of the validation screenlines meet acceptability guidelines for all vehicles. For cars, the Eastbound Railway screenline fails with a slight flow difference of -6%.

Table 7-11 – Summary of Screenline and Cordon Validation (Post Matrix Estimation)

Cordon	Direction	AM Cars	AM Total	IP Cars	IP Total	PM Cars	PM Total
Calibration Oxford Cordon	Inbound	-3%	4%	-3%	3%	-6%	3%
	Outbound	-6%	2%	-10%	-1%	-9%	0%
Calibration Bicester Cordon	Inbound	-1%	1%	-6%	-3%	-1%	1%
	Outbound	-1%	2%	-6%	-3%	-6%	-4%
Calibration Didcot Cordon	Inbound	-6%	-3%	2%	0%	-3%	-1%
	Outbound	0%	-1%	4%	0%	8%	7%
Calibration Outer Cordon	Inbound	0%	-1%	7%	4%	5%	5%
	Outbound	0%	0%	2%	0%	-2%	0%
Calibration East - West Screenline	Northbound	-7%	-5%	-9%	-7%	-8%	-5%
	Southbound	-2%	0%	-10%	-8%	-14%	-11%
Independent validation Railway Screenline	**Eastbound**	**2%**	**4%**	**3%**	**0%**	**-6%**	**-1%**
	Westbound	**2%**	**-1%**	**4%**	**2%**	**-2%**	**1%**

Note – Total flows represent sum of three user classes, bus flows and passq flows

8. Assignment Calibration and Validation

8.1. Overview

The assignment calibration and validation was undertaken in conjunction with the ME process previously described in Section 7. An iterative process was undertaken whereby the validation of the model was assessed using comparisons of the modelled and observed data as discussed below. Adjustments were made to the model to reduce the differences between the modelled and observed data. These adjustments were undertaken as part of the model calibration and were described earlier in this report and included:

- revisions to the network coding (as described in section 6 and 8) including local revisions to the junction coding, typically focussed on the signal timings; and
- revisions to the demand matrices (as described in Section 9).

The model was validated by means of the following comparisons:

- modelled and observed traffic flows on links compared by cars and all vehicles and by time period; and
- modelled and observed journey times along routes, as a check on the quality of the network and the assignment.

Each of these validations is presented in separate sections below. The final section presents the levels of model convergence achieved.

8.2. Traffic Flows on Links

Assignment validation was undertaken by comparing modelled flows and counts on individual links by vehicle type and time period. The assessment criterion follows those defined in TAG Unit M3.1 Table 2, which states that 85% of the criteria should meet acceptability guidelines for flow criteria and GEH criteria. The results are shown in Table 8-1 to Table 8-3 below. A summary of percentage of screenlines and percentage of individual links complying with DMRB are summarised below.

- In the AM Peak model,
  - In calibration 100% of screenlines comply with the DMRB flow validation criteria, and 90% on the GEH criteria; whilst the percentage of individual links which comply with the DMRB flow criteria is 92% (85% target) and 84% comply on the GEH criteria.
  - In validation 100% of screenlines comply with the DMRB flow validation criteria, and 50% on the GEH criteria; however, the percentage of individual links which comply with the DMRB flow criteria is 58% (85% target) and only 44% comply on the GEH criteria.
- In the Inter Peak model,
  - In calibration 80% of screenlines comply with the DMRB flow validation criteria, and 70% on the GEH criteria; however, the percentage of individual links which comply with the DMRB flow criteria is 94% (85% target) and 83% comply on the GEH criteria.
  - In validation 100% of screenlines comply with the DMRB flow validation criteria and the GEH criteria. The percentage of individual links which comply with the DMRB flow criteria is 81% (85% target) and 67% comply on the GEH criteria.
- In the PM Peak model,
  - In calibration 80% of screenlines comply with the DMRB flow validation criteria, and 70% on the GEH criteria. However, the percentage of individual links which comply with the DMRB flow criteria is 84% (85% target) and 73% comply on the GEH criteria.
  - In validation 100% of screenlines comply with the DMRB flow validation criteria and the GEH criteria. However, the percentage of individual links which comply with the DMRB flow criteria is 64% (85% target) and 56% comply on the GEH criteria.

Table 8-1 – Summary of individual lines (Post Matrix Estimation) – AM Peak hour

Calibration or validation	Direction	Number of counts	Flow criteria (% pass)		GEH (% pass)	
			Car	Total	Car	Total
Calibration	Oxford Cordon - IN	19	100	100	95	95
	Oxford Cordon - OUT	19	79	79	63	58
	Bicester Cordon - IN	9	100	89	100	100
	Bicester Cordon - OUT	9	100	100	100	100
	Didcot Cordon - IN	7	86	86	86	86
	Didcot Cordon - OUT	7	100	100	100	100
	Outer Cordon - IN	69	97	94	87	86
	Outer Cordon - OUT	69	100	100	88	88
	East - West Screenline - NB	17	76	76	65	65
	East - West Screenline - SB	17	76	71	65	71
Validation	**Railway Screenline – EB**	**18**	**44**	**50**	**44**	**39**
	Railway Screenline - WB	**18**	**78**	**67**	**67**	**50**

Table 8-2 – Summary of individual lines (Post Matrix Estimation) – IP hour

Calibration or validation	Direction	Number of counts	Flow criteria (% pass)		GEH (% pass)	
			Car	Total	Car	Total
Calibration	Oxford Cordon - IN	19	89	95	84	89
	Oxford Cordon - OUT	19	89	84	68	68
	Bicester Cordon - IN	9	100	100	89	89
	Bicester Cordon - OUT	9	100	100	100	100
	Didcot Cordon - IN	7	100	100	71	86
	Didcot Cordon - OUT	7	100	100	86	86
	Outer Cordon - IN	69	97	96	80	80
	Outer Cordon - OUT	69	96	94	78	87
	East - West Screenline – NB	17	94	94	76	82
	East - West Screenline - SB	17	88	82	71	71
Validation	**Railway Screenline - EB**	**18**	**94**	**83**	**94**	**67**
	Railway Screenline - WB	**18**	**83**	**78**	**83**	**67**

Table 8-3 – Summary of individual lines (Post Matrix Estimation) – PM Peak hour

Calibration or validation	Direction	Number of counts	Flow criteria (% pass)		GEH (% pass)	
			Car	Total	Car	Total
Calibration	Oxford Cordon - IN	19	68	84	68	79
	Oxford Cordon - OUT	19	58	63	47	53
	Bicester Cordon - IN	9	100	100	100	89
	Bicester Cordon - OUT	9	100	100	89	89
	Didcot Cordon - IN	7	71	71	71	71
	Didcot Cordon - OUT	7	86	86	86	86
	Outer Cordon - IN	69	90	90	77	80
	Outer Cordon - OUT	69	83	84	70	72
	East - West Screenline - IN	17	76	82	76	71
	East - West Screenline - OUT	17	71	71	35	41
Validation	**Railway Screenline - IN**	**18**	**89**	**89**	**83**	**72**
	Railway Screenline - OUT	**18**	**50**	**39**	**39**	**39**

The detailed flow calibration results are presented in Appendix B.

8.3. Summary of Model Convergence

The convergence for each model period is summarised in Table 8-4 below. This shows that the model has achieved a high level of convergence for all three time periods, they are stable for at least four consecutive assignment-simulation loops and the delta values (as reported by the %GAP statistic in SATURN) comfortably exceed the targets specified in the DMRB of 1%. Similarly, the P achieved is higher than the 98% required by guidance.

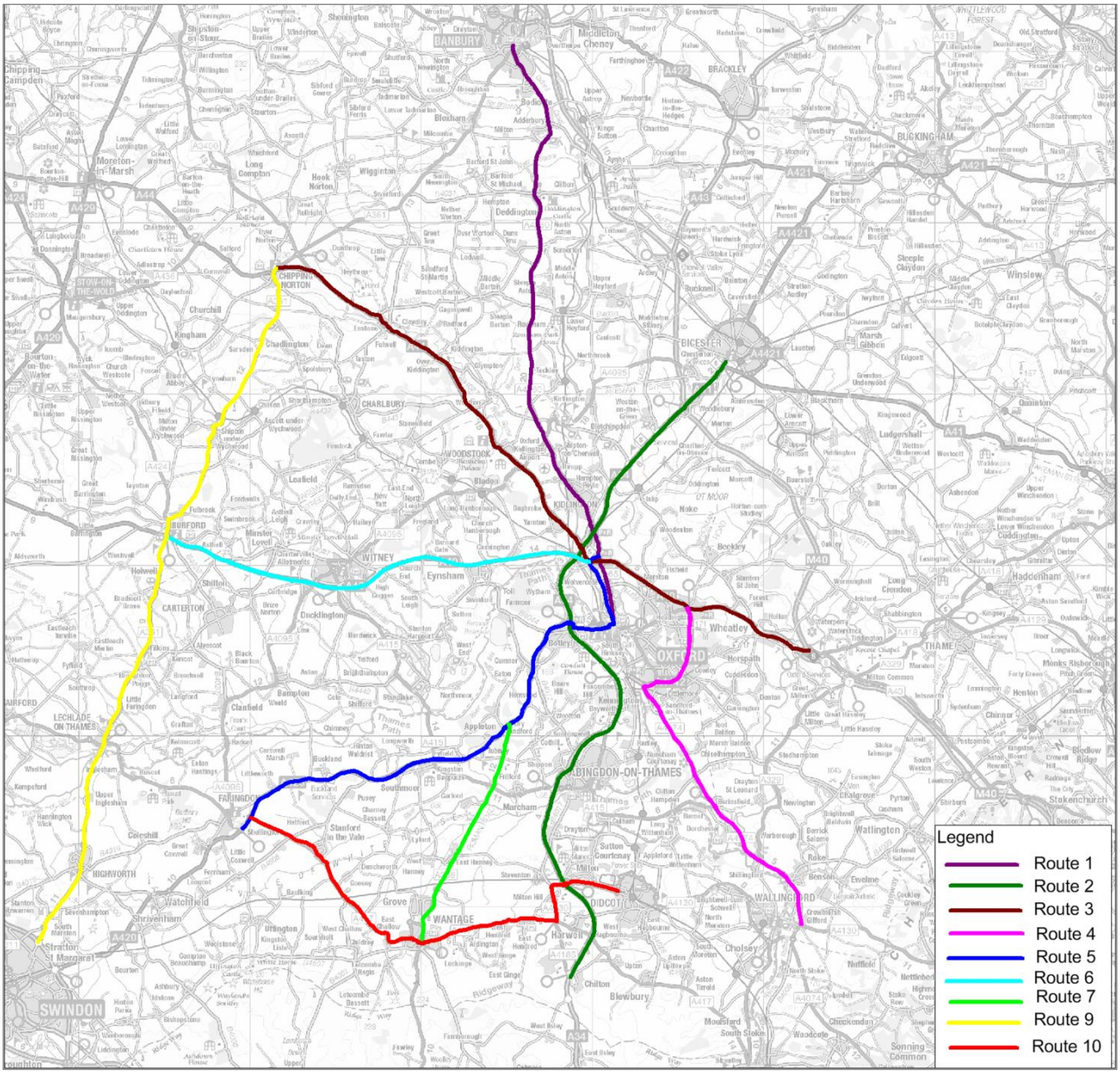
Table 8-4 – Summary of Model Convergence

Time Period	Assignment - Simulation Loop	Delta (%)* (δ)	%Gap	% Flow Change (P)
AM	23	0.0089	0.011	98.5
	24	0.0087	0.0097	98.9
	25	0.0070	0.0091	99.2
	26	0.0063	0.0091	99.2
IP	16	0.0058	0.0052	99.2
	17	0.0047	0.0062	99.2
	18	0.0067	0.0039	99.3
	19	0.0032	0.0054	99.2
PM	23	0.0145	0.014	98.7
	24	0.0129	0.020	98.7
	25	0.0139	0.015	98.8
	26	0.0130	0.012	99.0

8.3.1. Journey Time Validation

Journey time validation is undertaken using the 2013 TOMTOM data collected for the peak hours. Journey time results are presented in Figure 8.1.

Figure 8.1 Journey Time Routes



Modelled journey times are compared against observed data for all modelled periods. Summaries of the overall modelled and observed journey time comparisons for each route are provided in Table 8-5 through to Table 8-7 for the AM Peak, Inter Peak and PM Peak periods. The results are summarised as

- in the AM peak 17 out of 18 routes (94%) satisfy the DMRB journey time validation criteria;
- in the Inter Peak 18 out of 18 routes (100%) satisfy the DRMB criteria for journey time validation; and
- in the PM Peak period 15 out of 18 routes (83%) satisfy the DMRB criteria for journey time validation.

Of the three routes failing in PM, journey time for one route is within +/- 20% of the observed data rather than +/-15%. The plots for individual routes by time period are presented in Appendix C.

Table 8-5 – AM Peak Journey Time Validation

Journey Time Route	Route Name	Direction	Observed	Modelled	Obs +15%	Obs -15%	Compliance with DMRB criteria
Route 1	Banbury to Oxford	NB	3010	2786	3462	2559	✓
		SB	3621	3347	4164	3078	✓
Route 2	Bicester to Didcot	NB	1943	1974	2234	1651	✓
		SB	2404	2107	2764	2043	✓
Route 3	Chipping Norton to Oxford	NB	3014	2522	3466	2561	×
		SB	2875	2623	3307	2444	✓
Route 4	Oxford to Wallingford	NB	1709	1537	1965	1453	✓
		SB	1529	1430	1759	1300	✓
Route 5	Farringdon to Oxford	NB	3152	3281	3624	2679	✓
		SB	2808	2545	3229	2387	✓
Route 6	Burford to Oxford	EB	1875	1747	2157	1594	✓
		WB	1369	1280	1574	1164	✓
Route 7	Appleton to Wantage	NB	1186	1320	1363	1008	✓
		SB	1007	1026	1158	856	✓
Route 9	Swindon to Chipping Norton	NB	2678	2569	3080	2276	✓
		SB	2837	2462	3263	2412	✓
Route 10	Farringdon to Didcot	EB	2169	2065	2495	1844	✓
		WB	2042	1786	2348	1736	✓

Table 8-6 – Inter Peak Journey Time Validation

Journey Time Route	Route Name	Direction	Observed	Modelled	Obs +15%	Obs -15%	Compliance with DMRB criteria
Route 1	Banbury to Oxford	NB	2701	2617	3106	2296	✓
		SB	2665	2850	3064	2265	✓
Route 2	Bicester to Didcot	NB	1692	1903	1946	1439	✓
		SB	1675	1906	1926	1423	✓
Route 3	Chipping Norton to Oxford	NB	2487	2283	2860	2114	✓
		SB	2426	2288	2790	2062	✓
Route 4	Oxford to Wallingford	NB	1425	1418	1639	1211	✓
		SB	1362	1377	1566	1158	✓
Route 5	Farringdon to Oxford	NB	2435	2313	2801	2070	✓
		SB	2316	2261	2664	1969	✓
Route 6	Burford to Oxford	EB	1315	1254	1512	1118	✓
		WB	1255	1231	1444	1067	✓
Route 7	Appleton to Wantage	NB	960	976	1104	816	✓
		SB	934	984	1074	794	✓
Route 9	Swindon to Chipping Norton	NB	2758	2466	3171	2344	✓
		SB	2727	2446	3136	2318	✓
Route 10	Farringdon to Didcot	EB	1818	1721	2091	1546	✓
		WB	1832	1640	2106	1557	✓

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Table 8-7 PM Peak Journey Time Validation

Journey Time Route	Route Name	Direction	Observed	Modelled	Obs +15%	Obs -15%	Compliance with DMRB criteria
Route 1	Banbury to Oxford	NB	3426	3196	3940	2912	✓
		SB	2983	3149	3431	2536	✓
Route 2	Bicester to Didcot	NB	1889	1979	2172	1605	✓
		SB	1716	2063	1974	1459	✗
Route 3	Chipping Norton to Oxford	NB	2807	2937	3228	2386	✓
		SB	2688	2647	3091	2285	✓
Route 4	Oxford to Wallingford	NB	1983	1497	2280	1685	✗
		SB	1784	1676	2052	1516	✓
Route 5	Farringdon to Oxford	NB	2771	2585	3186	2355	✓
		SB	2879	3196	3311	2447	✓
Route 6	Burford to Oxford	EB	1462	1306	1682	1243	✓
		WB	1907	1646	2193	1621	✓
Route 7	Appleton to Wantage	NB	966	1132	1111	821	✗
		SB	1034	1113	1190	879	✓
Route 9	Swindon to Chipping Norton	NB	2761	2614	3175	2347	✓
		SB	2911	2532	3347	2474	✓
Route 10	Farringdon to Didcot	EB	1856	1950	2134	1577	✓
		WB	1838	1967	2114	1563	✓

9. Summary of Model Development

The OSM Highway Assignment Model (HAM) has been developed to simulate the movement of traffic on the strategic road network within the Oxfordshire County area. It can be used to test and assess the traffic impacts of future land-use scenarios, proposed highway schemes and mitigation measures. The model includes Oxford authority in detail along with Cherwell, West Oxfordshire, Vale of White Horse and South Oxfordshire coded as detailed modelled area. Rest of the UK is included in the fully modelled area.

The model represents a typical weekday (Monday – Thursday) in October, 2013. It covers the AM peak hour (08:00 – 09:00), an average inter-peak hour (10:00 – 16:00) and the PM peak hour (17:00 - 18:00).

The model has utilised data from a number of local and national sources, supplemented by bespoke data collected for the study, which includes INRIX, Traffic Master and TOMTOM data.

This Local Model Validation Report has described the development of the modelled networks and trip matrices, and their calibration and validation. In particular, ME procedures have been used to fit the highway prior trip matrices to a set of observed traffic count data.

The model has been tested against the TAG calibration and validation criteria for:

- Link flows across selected screenlines, individual flows;
- Model convergence;
- Journey time comparison;
- Significance of ME Changes;

The assignment model is stable for the three modelled peak hours and meets the convergence criteria.

Modelled flows across cordons and screenlines meet TAG criteria for all or nearly all screenlines. However, at a link level the model performance against TAG criteria shows high level of compliance for total flow across the screenlines but that validation screenlines did not perform so well. This is a result of the compromise to ensure that the impact of ME was kept to a minimum. Tests that increased the role of ME yielded better link flow performance but also impacted the prior matrix more significantly.

The replication of observed journey times meets TAG requirements.

On this basis, the model is considered to be fit for the purpose of forecasting the strategic effects of land-use strategies and the public transport schemes and highway improvements within the core modelled area. Whilst the matrix includes trips across a much large part of the county, care would need to be taken when assessing land use changes and network interventions outside of this area until a validation exercise was undertaken.

Appendix A.