Milton Keynes Multi-Modal Model Update

Highway Model Local Model Validation Report

Milton Keynes Council

Project Number: 60516496

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Quality information

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1. Introduction and Overview

1.1 Study Background and Objectives

1.1.1 Milton Keynes Council (MKC) wishes to update the Milton Keynes Multi-Modal Model (MKMMM) in advance of the need for its use to test alternative planning options for Plan:MK. The main purpose of the model will be to provide a robust means of assessing alternative land-use options and development phasing and for this to withstand public scrutiny. The goal is to develop a Reference Case to enable testing of plan options. This requires the model to be sufficiently well validated to 2016 compared with the existing 2009 model) using additional new data sources.

1.1.2 It is also envisaged that the model will help to inform the Local Transport Plan 4 development or similar transport strategy document. As such the model will also be required to inform bids for various kinds of transport infrastructure and other MK initiatives though there is no current requirement to use the model to assess a major transportation scheme.

1.2 Model Description

1.2.1 On the supply side, the existing SATURN model has been updated from 2009 to 2016. In addition to the updates the simulation network area was extended to better model the impacts of the proposed expansion areas. A public transport model sits alongside the highways model. The Milton Keynes Multi-Modal Model (MKMMM) public transport model was developed in INRO's Emme software, and covers both bus and rail modes. It is designed to model public transport in and around the Milton Keynes urban area. The public transport model is described in detail in the Public Transport Local Model Validation Report[1].

1.2.2 On the demand side, a variable demand model has been developed to estimate the effects of changes in transport infrastructure, other than choosing different routes which is forecast by the highway and public transport assignment models.

1.3 Report Structure

1.3.1 This Highway Model Local Model Validation Report (LMVR) describes the base model calibration and validation using the following structure:

- Section 2: Model Requirements and Design Considerations (the purpose of the modelling and factors influencing the modelling approach;
- Section 3: Modelling Standards (the appropriate guidance followed and targets to be met to ensure adequate model validation);
- Section 4: Key Features of the Model (the key assumptions that define the modelling such as network, zone and time period definition);
- Section 5: Calibration and Validation Data (description and reference to data collected including observed traffic counts and journey times);
- Section 6: Network Development (how the network was built up from existing models, checked and refined);

[1] Milton Keynes Model Update - TN09 Public Transport LMVR v2, June 2017

- Section 7: Trip Matrix Development (how the matrices were built up from mobile phone and Traffic master data);
- Section 8: Model Calibration (the process of adjustment including Matrix Estimation to achieve satisfactory calibration, and results);
- Section 9: Route Choice Calibration and Validation; (To ensure traffic is assigned along sensible routes)
- Section 10: Trip Matrix Calibration and Validation; (The Matrix Estimation process)
- Section 11: Assignment Calibration and Validation (reports the independent validation results.)
- Section 12: Variable Demand Model (the use of Realism Testing to ensure model elasticities in the expected ranges);
- Section 13: Summary and Conclusions;

2. Model Requirements and Design Considerations

2.1 Introduction

2.1.1 This section gives an overview of the purpose of the modelling work and the key factors influencing the model development.

2.2 Use of the Model, Scenarios and Interventions

2.2.1 The primary use of the model is to assess the impacts of Plan:MK on the strategic road network and test plan options, providing robust evidence to support the plan in the face of public scrutiny.

2.2.2 It is also envisaged the model will be used to inform the Local Transport Plan 4 and be used as a tool to help support future transport infrastructure bids. Depending on the scheme specific circumstances, including the scale, size and location of the scheme, the model may need to be updated further (particularly on the demand side and in the vicinity of the scheme) to support the economic case for such schemes.

2.3 Key Model Design Considerations

The Model needs to be capable of assessing 'variable' demand impacts of trip re-distribution and frequency shift in addition to route choice. As such the highway assignment model was linked to a bespoke variable demand model.

This report also includes details of the demand model and its calibration to ensure the base year elasticities of response to overall changes in costs were in the ranges defined in WebTAG.

To better represent highway re-assignment around the expansion areas the model simulation network area was extended.

2.4 Model Description and Specification

2.4.1 The traffic assignment model was built in SATURN version 11.3.12U and linked to the variable demand model built using Emme software. The SATURN network originated from the existing 2009 model and was updated as detailed in section 4. Details of the Variable Demand Model are in section 12.

3. Modelling Standards

3.1 Link Flow Calibration and Validation Criteria

3.1.1 The UK Department for Transport (DfT) guidelines have been used as a measure of the model calibration and validation in terms of link flows, screenline and journey time comparisons (Modelled against observed) and model convergence criteria. The WebTAG guidelines for modelled and observed link flow comparisons are listed in Table 1.

Table 1: Link Flow and Turning Movement Validation Criteria and Acceptability Guidelines

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

Source: WebTAG Unit M3.1 Table 2

3.2 Journey Time Validation Criteria

3.2.1 Similarly to the flow criteria, the DfT WebTAG guidelines as shown in Table 2, have been used as guidance for the journey time validation

Table 2: Journey Time Validation Criterion and Acceptability Guideline

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

Source: WebTAG Unit M3.1 Table 3

4. Key Features of the Model

4.1 Introduction

4.1.1 This section details the model extent, updates and additions to the simulation and buffer networks and to the zone system. The time periods, user classes, generalised cost formulations and the overall model set-up are also outlined.

4.2 Study Area

4.2.1 The model study area covers Milton Keynes and the proposed expansion areas.

4.3 Modelling Detail

4.3.1 As shown in Figure 1, the network coding is split into three levels of detail:

- The simulation area covering Milton Keynes and this has been extended to the north, east, south and west;
- The buffer network with speed flow curves which extends across the districts surrounding Milton Keynes and;
- The buffer network with fixed speeds which covers the network further beyond the hinterland around Milton Keynes.

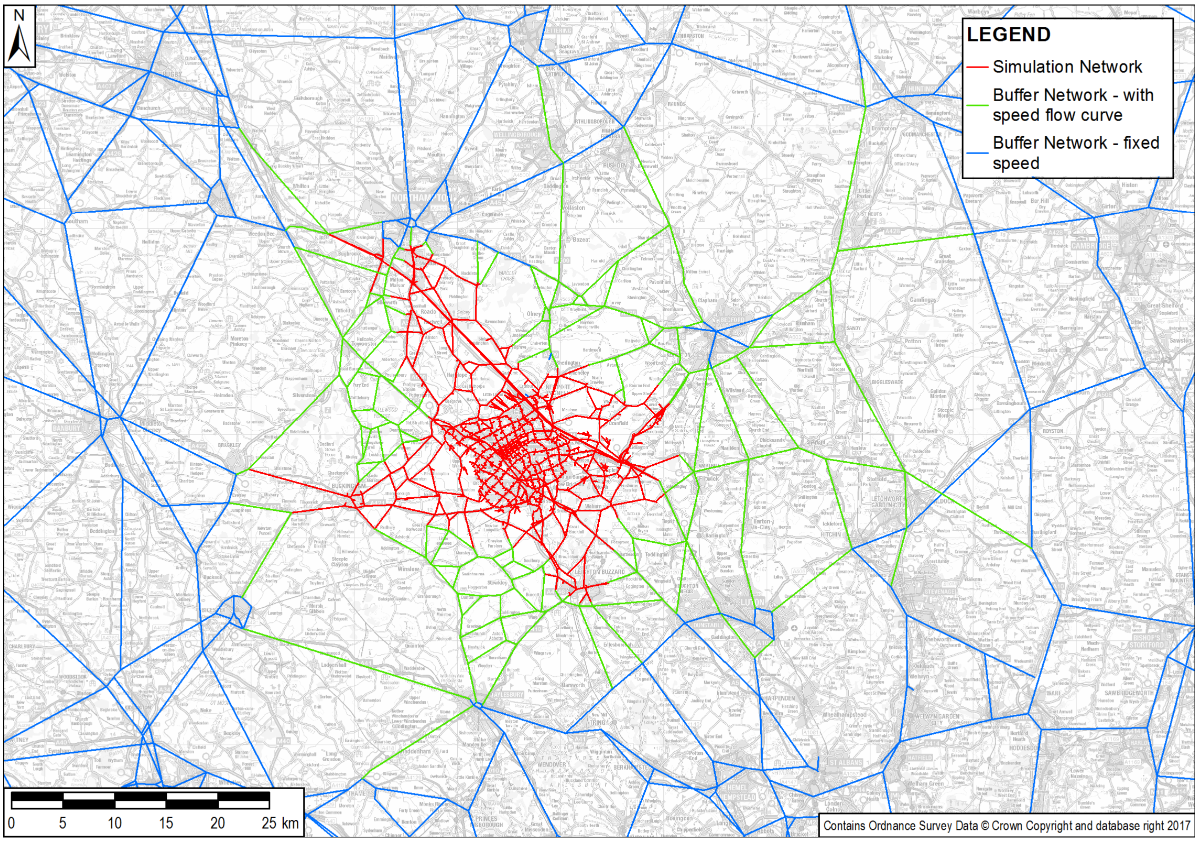

Figure 1. Network Coding Levels of Detail

4.4 Zone and Sector System

4.4.1 The existing 2009 model zone system was revised, mostly in areas external to Milton Keynes, to be consistent with NTEM version 7, 2011 census and the SERTM (South-East Regional Traffic Model) zoning system. In addition larger zones in proposed development areas were disaggregated to provide a higher level of detail. There are 513 zones in the updated model.

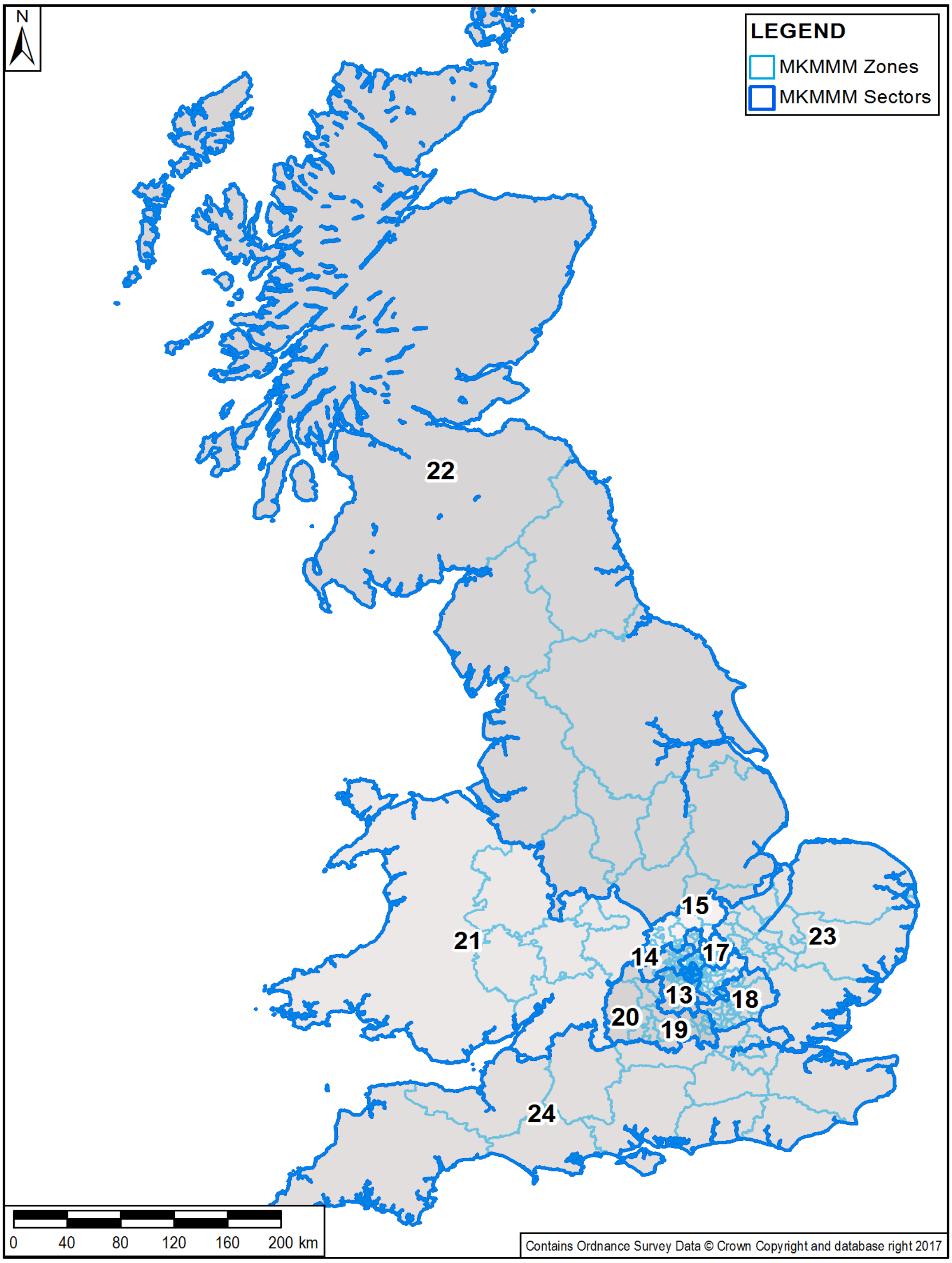

Figure 2. MKMMM Zone Plan Version 1.4 and Sectors – UK

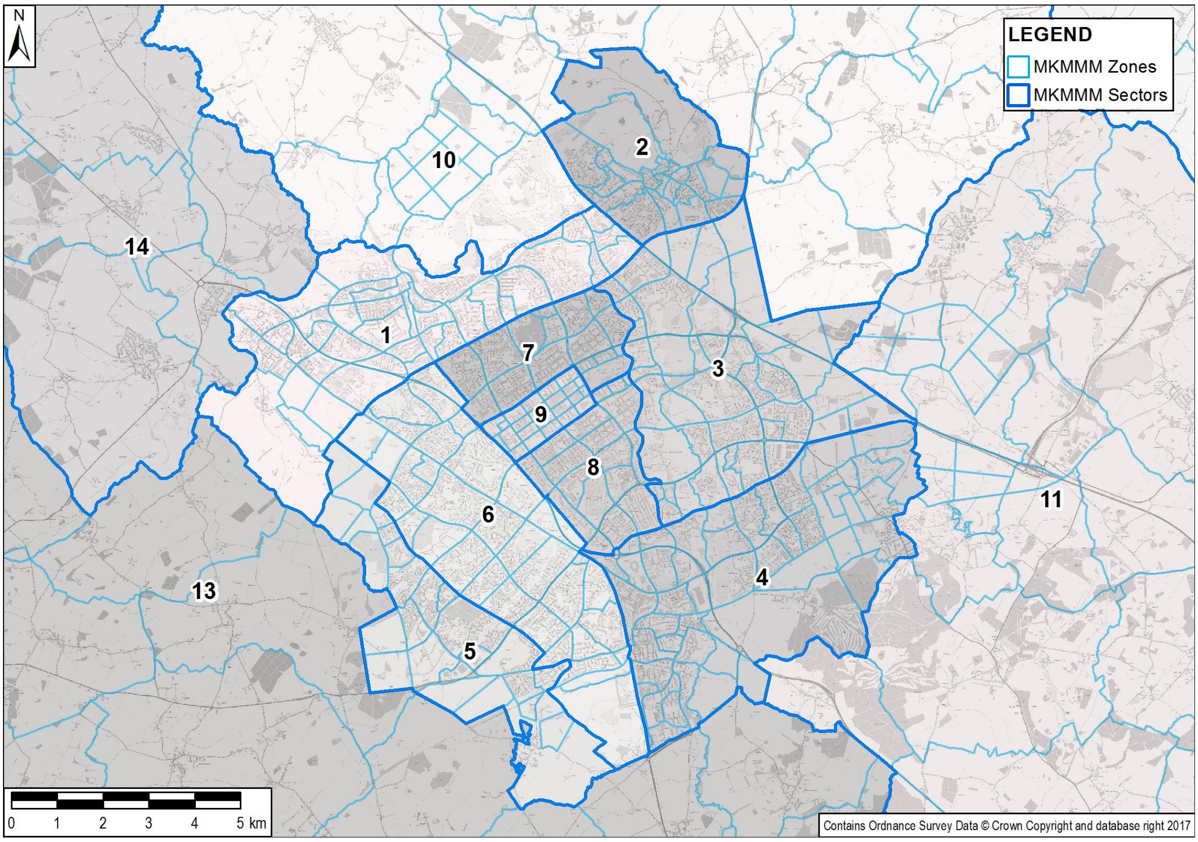

Figure 3. MKMMM Zone Plan Version 1.4 and Sectors – Milton Keynes Local Area

4.4.2 The highway network has been updated to incorporate the revised zone system. The 2009 inter-peak matrices were converted to the revised zone system and assigned to generate initial ‘travel skim’ matrices for input to the matrix building process.

4.5 Time Periods

4.5.1 The base year represents an average Monday to Thursday in June 2016 even though additional new traffic data were collected in autumn 2016. This was governed by the availability of Trafficmaster journey time data (data for autumn 2016 would not be available in time to complete the model update) and disruption to the network caused by roadworks on the A421 between Kingston Roundabout and M1 J13 in the Spring 2016 which meant that a later neutral period was desirable.

4.5.2 The modelled time periods remain unchanged as most historic MKC data has been collected for 60 minute periods commencing at the start of each hour. These periods being:

- AM peak – 0800-0900;
- PM Peak – 1700-1800; and
- Inter-peak – average of 1000-1600.

4.5.3 Existing 2015 and 2016 ATC data collected at 15 minute intervals was analysed for a representative sample of 13 locations as shown in Figure 4. As presented in Figure 5 and Figure 6 this indicated that the peak hours were indeed 0800-0900 and 1700-1800 and matched the modelled time periods. The next busiest hours were 0745-0845 and 1645-1745.

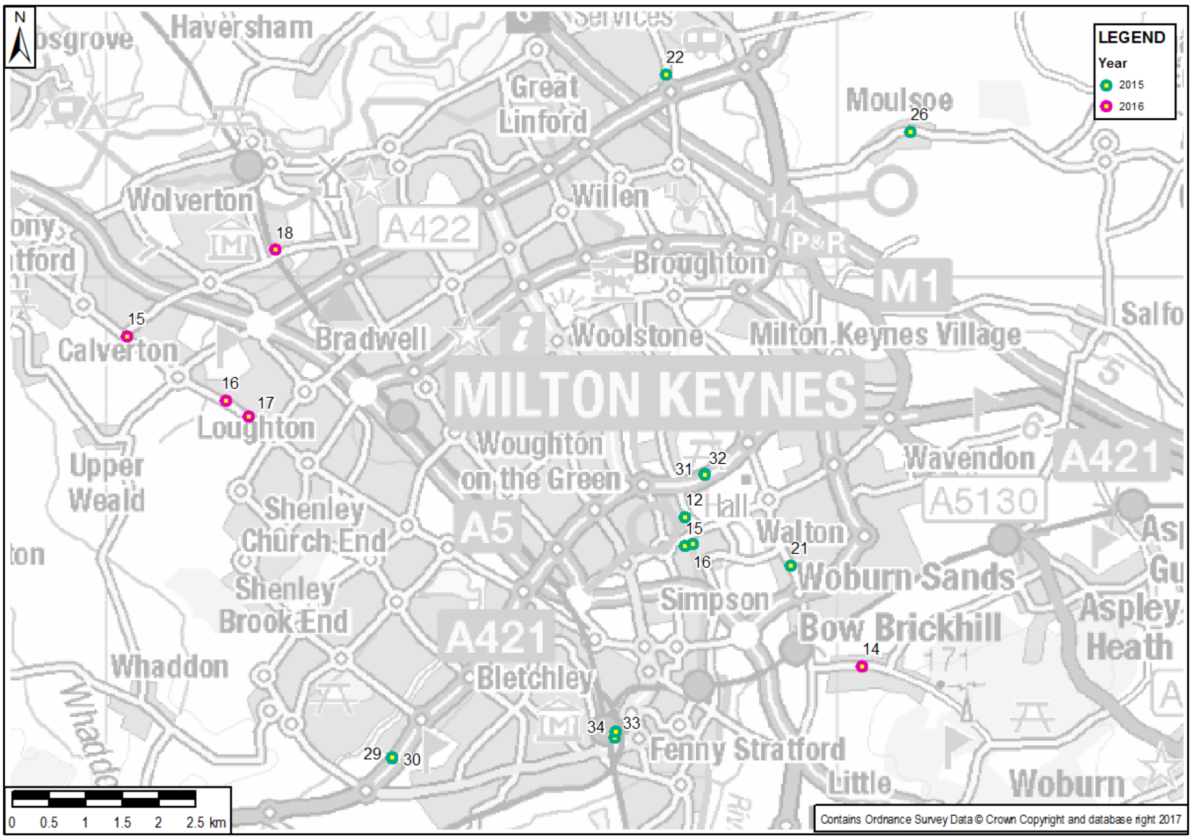

Figure 4. MKC Ad-hoc ATC sites

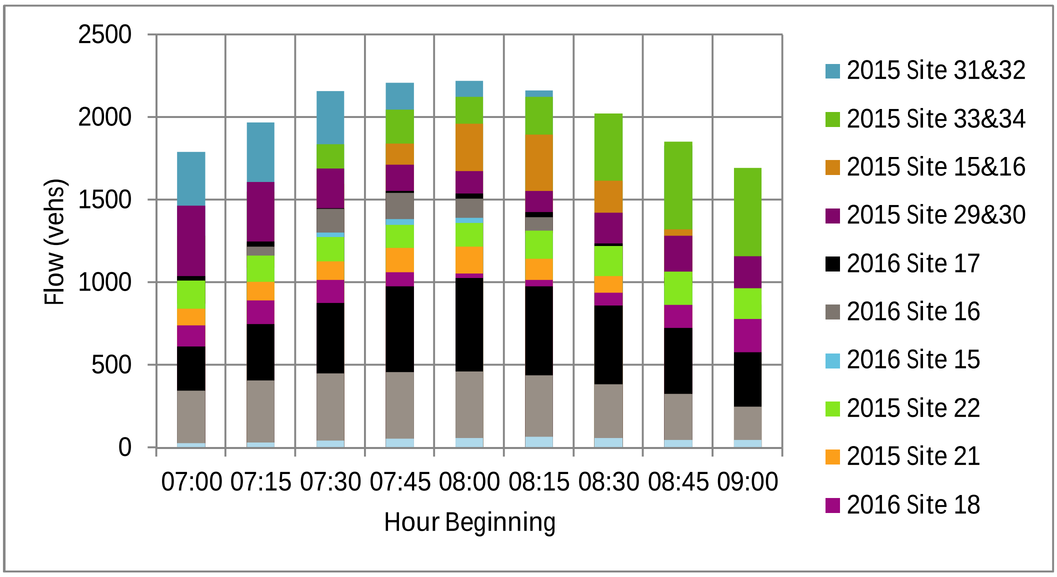

Figure 5. AM Peak Hour Analysis

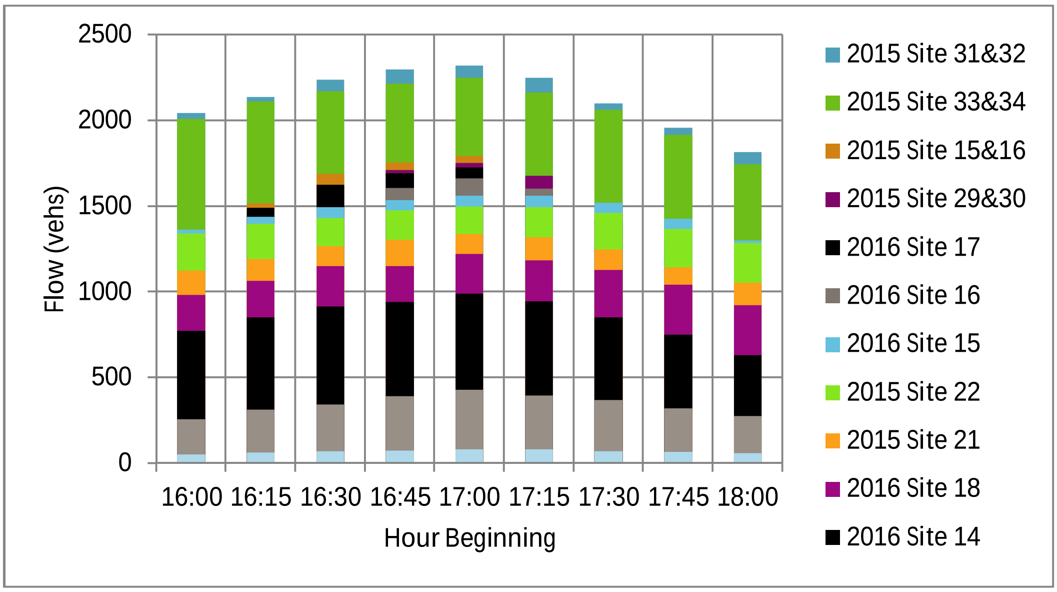

Figure 6. PM Peak Hour Analysis

Vehicle and User Classes

4.5.4 The SATURN model has been built using the three vehicle classes based on what can be separately classified in traffic survey data:

- Cars;
- Light Goods Vehicles (LGV); and
- Heavy Goods Vehicles (HGV).

4.5.5 For model assignment purposes cars are defined as being one of three trip purposes, commuting, business or other. This results in there being five user classes for highway assignment purposes as shown in Table 3 along with their corresponding vehicle class:

Table 3: Model User and Vehicle Classes

User Class	Vehicle Class	Purpose
1	1	Car Commute
2	1	Car Employer's Business
3	1	Car Other
4	2	LGV
5	3	OGV

4.5.6 Bus routes and services in and around Milton Keynes have been extracted from the Emme Public Transport Model and coded as fixed flows in the model.

4.6 Assignment Algorithm and Method

4.6.1 Assignment of trips to the highway network was undertaken using a user-equilibrium assignment according to the first of Wardrop's principles, assumed to govern the routes chosen by drivers travelling from a given origin to a given destination.

4.6.2 This principle of equilibrium is such that: 'The journey times on all the routes actually used are equal and less than those which would be experienced by a single vehicle on any unused route'.

4.6.3 User-equilibrium, as implemented in SATURN version 11.3.12, is based on the Frank-Wolfe algorithm, which employs an iterative process based on successive all-or-nothing assignments to generate a set of combined flows on links that minimise an objective function. The travel costs are re-calculated for each iteration and then compared to those from the previous iteration. The process is terminated when the costs obtained from successive iterations do not change significantly. At this point, the model is said to have converged to a pre-defined degree.

4.7 Generalised Cost Formulation and Parameter Values

4.7.1 The cost of travel is expressed in terms of generalised cost, which combines time and money, using a specified 'Value of Time' to convert money into time separately for each defined journey purpose. SATURN uses two parameters: pence per minute (PPM) and pence per kilometre (PPK), and calculates generalised cost in minutes as:

Time + PPK/PPM x Distance + toll (pence)/PPM.

4.7.2 The values of Time (VoT) and Vehicle Operating Costs (VoC) used in the base year model have been calculated from the WebTAG data book released in July 2016 and are shown in Table 4. The value of time applicable to HGV trips is uplifted by a factor of two as suggested in WebTAG Unit M3.1 paragraph 2.8.8.

Table 4: Values of Time and Vehicle Operating Costs as PPM and PPK Values

User Class	AM Peak		Inter-Peak		PM Peak	
	PPM	PPK	PPM	PPK	PPM	PPK
1: Car Commute	20.25	5.52	20.58	5.52	20.32	5.52
2: Car Employer's Business	30.20	11.82	30.56	11.82	30.63	11.82
3: Car Other	13.97	5.52	14.88	5.52	14.63	5.52
4: LGV	21.34	12.70	21.34	12.70	21.34	12.70
5: HGV	43.34	42.81	43.34	42.81	43.34	42.81

5. Calibration and Validation Data

5.1 Introduction

5.1.1 This section details the data used to build and develop the trip matrices and to calibrate and validate the base year model to represent existing conditions. Due to budget limitations existing data was used where available including the RSI surveys conducted for the previous model development in 2009. As such a gap analysis was conducted on the existing data and additional surveys commissioned where further data was required.

5.2 Review of existing Screenlines and Cordons

5.2.1 The 2009 model used the calibration cordons and screenlines indicated in Figure 7. These were defined as follows;

1. RSI Cordon
2. Outer Cordon
3. Southern Screenline
4. Canal Screenline
5. Northern Screenline
6. CMK Cordon Screenline
7. Railway Screenline

5.2.2 The Outer cordon closely followed the RSI cordon and there would seem to be little logic for these being so similar. It is also noted that there was only one calibration site located east of the M1.

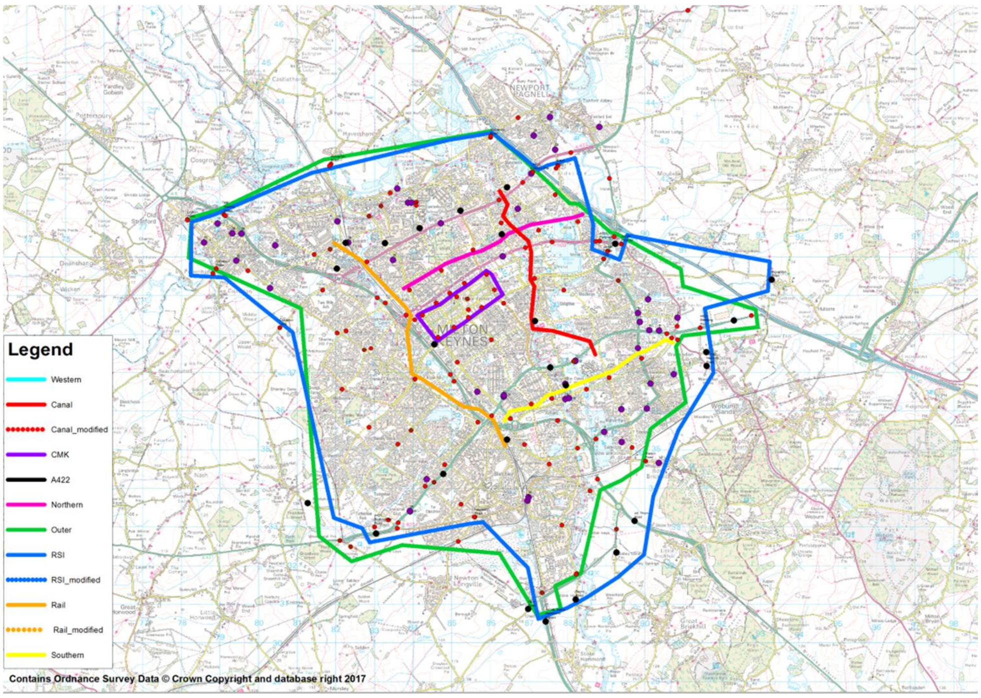

Figure 7. 2009 Calibration Cordons and Screenlines

5.2.3 Figure 8 indicates where validation sites were located in the 2009 base year model:

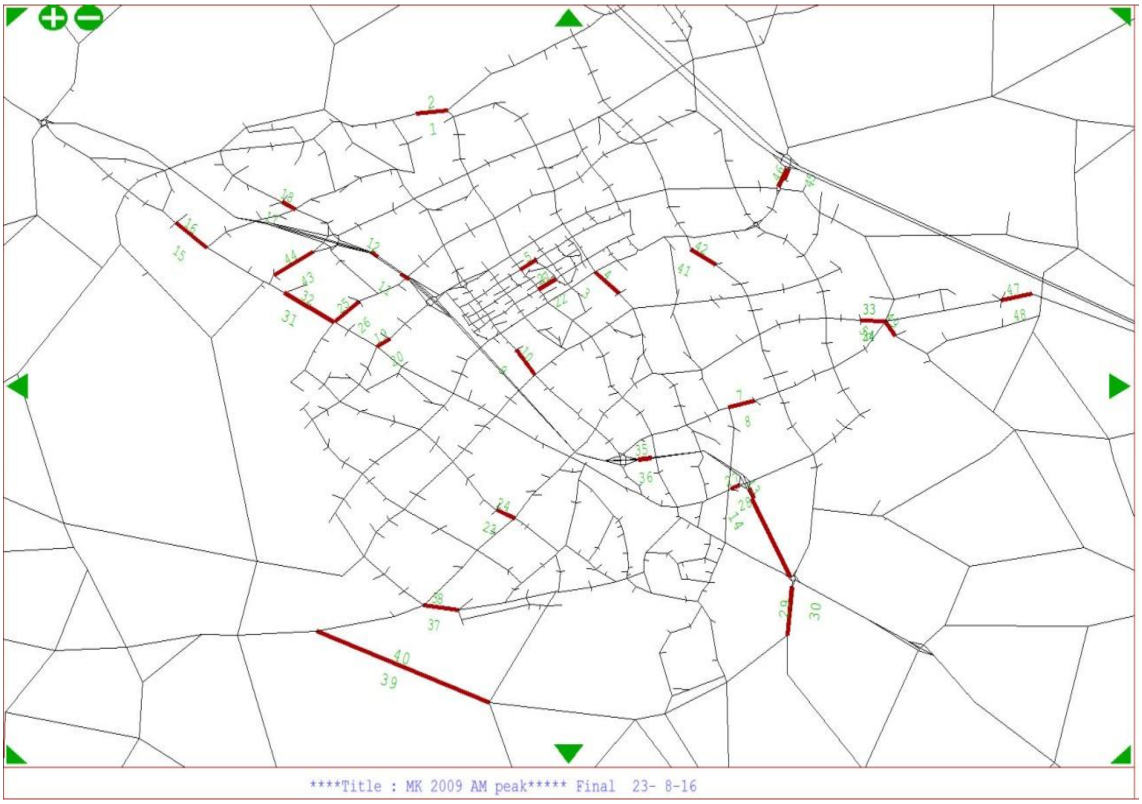

Figure 8. 2009 Validation Links

5.2.4 Based on a review of calibration and validation cordons and screenlines the following amendments were made (see Figure 9):

- The 'outer' cordon was removed as this effectively repeated the RSI cordon.
- Two new calibration screenlines were added, the 'A422' and 'Western'. This was to strengthen the model in these areas.
- The northern and railway screenlines became 'independent' validation screenlines, which means that traffic count data was excluded from developing the model.
- Some changes in the road sections included were made for the railway and canal screenlines to reflect data availability and to improve the screenline.
- A cordon of Newport Pagnell was also defined to ensure that flows into and out of Newport Pagnell could be more accurately modelled.

5.2.5 The nine screenlines and cordons are listed below and encompass 80 individual count sites.

1) A422 Screenline
2) CMK Cordon
3) Canal Screenline
4) Newport Pagnell Cordon
5) Northern Screenline (Validation)
6) RSI Cordon

7) Railway Screenline (Validation)
8) Southern Screenline
9) Western Screenline

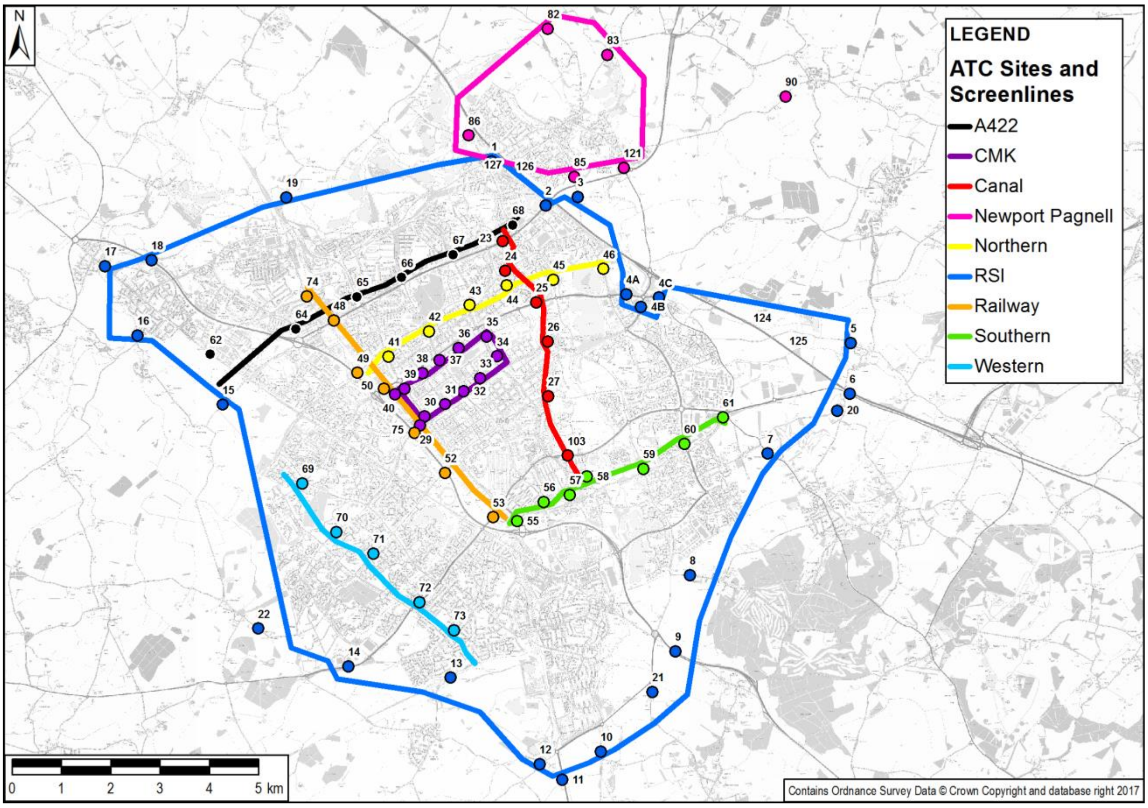

Figure 9. Revised Cordons and Screenlines

5.3 Data Requirements

5.3.1 Data was required for the following:

- Roadside Interview (RSI) expansion counts
- Calibration counts
- Validation counts
- Journey Time validation

5.3.2 For the calibration and validation cordons and screenlines the following data would generally be required if no budget constraints applied:

- 2 week ATC at the 2009 MK RSI locations
- 1 day (12 hr) MCC at the 2009 MK RSI locations
- 2 week ATC at screenline locations
- 1 day MCC at screenline locations

5.3.3 These totalled 78 sites and for budgetary and timescale constraint reasons, the decision was made to make use of existing data where possible. It was felt that in combination with new surveys the use of existing data would not compromise the model in the context to which the model was being used to test Plan:MK.

5.3.4 Much of the existing data comprised one week ATCs which were collected as part of MKCs monitoring programme as well as 21 ATCs located at the 2009 RSI sites. Note that the seven RSI's dating from 2005/6 surveys undertaken in the Bedford area and used in developing the 2009 model were not used in building the 2016 matrices.

5.3.5 Due to the extent of data availability it was assumed that relatively contemporary data from 2012 onwards could be used to update the model to June 2016. Factors to convert data collected from years other than 2016 and months other than June were derived from available continuous data. Two sets of factors were produced as shown in Table 5 and Table 6, one using data from central Milton Keynes which were then applied to the Central Milton Keynes Cordon and the other using sites across the rest of Milton Keynes. (It was the latter set which was used in the Matrix build process for the RSI counts.)

Table 5. Central Factors

Month / Year	2012	2013	2014	2015	2016
Jan	1.044	1.079	1.043	1.034	1.035
Feb	1.046	1.029	1.053	1.025	1.050
Mar	1.026	1.019	1.026	1.012	1.032
Apr	1.006	1.014	1.000	1.006	1.024
May	1.011	1.032	1.030	1.037	1.030
Jun	1.000	1.000	1.000	1.000	1.000
Jul	1.053	0.987	0.992	0.974	1.001
Aug	1.054	1.018	1.023	0.985	1.055
Sep	1.031	0.993	1.014	1.018	1.007
Oct	1.010	1.004	0.995	1.023	1.008
Nov	0.968	0.966	0.971	0.961	n/a
Dec	0.846	0.875	0.885	0.874	n/a
Yearly	0.961	0.969	0.971	0.985	1.000

Table 6. Non-Central Factors

Month / Year	2012	2013	2014	2015	2016
Jan	1.048	1.076	1.034	1.007	1.018
Feb	1.052	1.034	1.022	0.991	0.996
Mar	1.001	1.005	1.004	0.996	1.006
Apr	0.991	1.000	1.001	0.981	0.990
May	1.021	1.013	1.033	1.033	0.989
Jun	1.000	1.000	1.000	1.000	1.000
Jul	1.007	0.989	0.992	1.006	0.999
Aug	1.103	1.084	1.085	1.059	1.094
Sep	1.018	1.010	0.981	0.953	0.990
Oct	0.998	0.981	0.977	0.977	0.982
Nov	0.991	0.964	0.946	0.961	n/a
Dec	0.967	0.937	0.947	0.939	n/a
Yearly	1.116	1.098	1.064	1.024	1.000

5.4 Data Gap Analysis

5.4.1 The following sources of data were available:

- MKC Permanent ATCs – majority 1 week, a few continuous
- MKC Ad-Hoc ATCs – 1 week
- MKC Ad-hoc MCLCs – 1 day, generally peak periods
- CATAPULT ATC & MCTCs – 2 week ATC and 1 day MCC
- Highways England WebTRIS – Continuous (though some gaps)
- Highways England M1 J13-J16 surveys ATC and MCLC/MCTCs – 2 week ATC, 1 day MCC, some 14 day MCCs
- Central Beds Council data – 1 week ATCs
- East-West Rail Data – 2 week ATC and 1 day MCLCs
- Brinklow-Monkston – ATC / MCLC / MCTCs
- Crownhill & Loughton – MCTC peak hour

5.4.2 Gap analysis was completed to identify the need for additional surveys. The survey company Intelligent Data Collection was commissioned to undertake surveys at 20 locations as shown in Figure 10. Due to high traffic speeds most of these were surveyed using video cameras rather than pneumatic tubes. Survey budget limitations meant that surveys were conducted for one week rather than two weeks. Due to roadworks, including road closures, the surveys were conducted during the week beginning 26 September. Recording issues at two locations meant that the surveys were not completed until Wednesday 5 October.

5.4.3 In addition MKC undertook a number of ATC surveys at eight locations on lower speed roads. One week of data for six of these eight sites was provided.

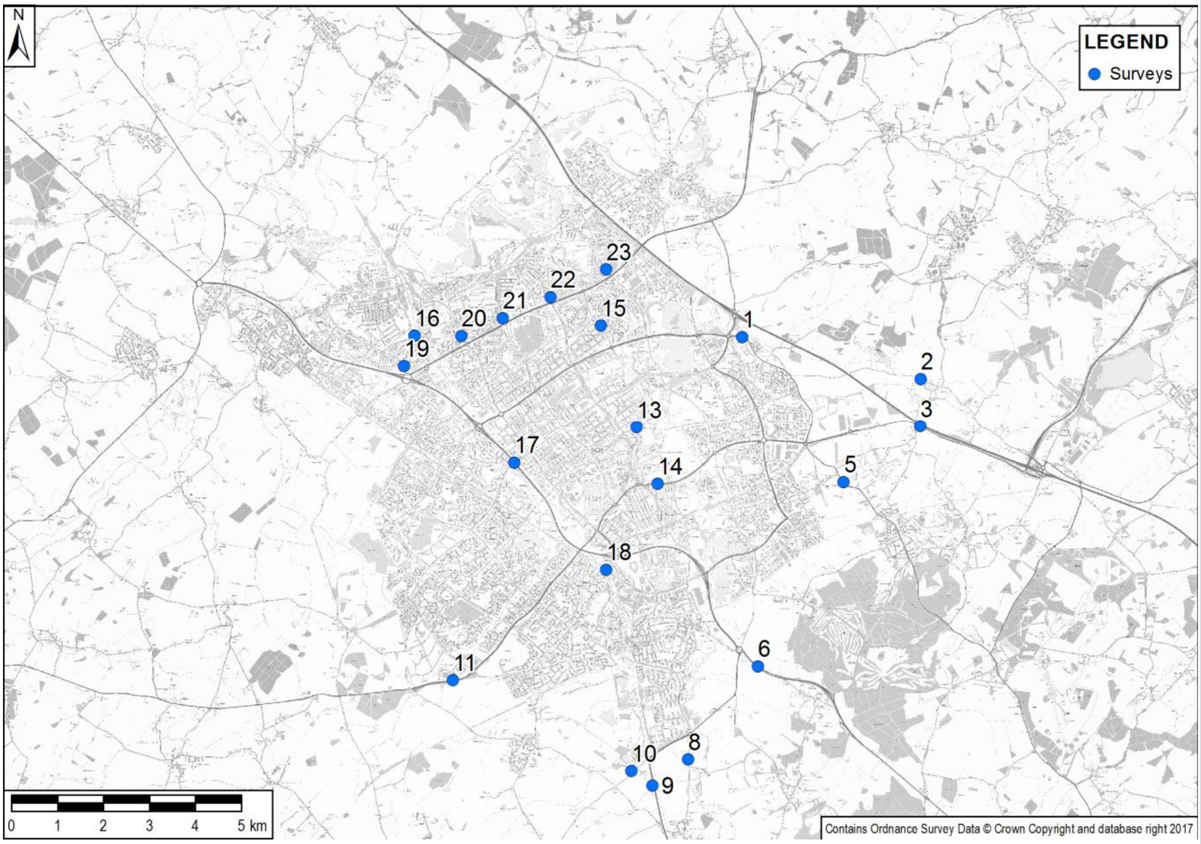

Figure 10. Additional Survey Locations - Volumetric and Classified

5.5 Highway Journey Time Data

5.5.1 2014-15 and 2015-16 Trafficmaster data was supplied to AECOM by MKC and covers the area shown in Figure 11. This coverage was sufficient for the journey time validation purposes.

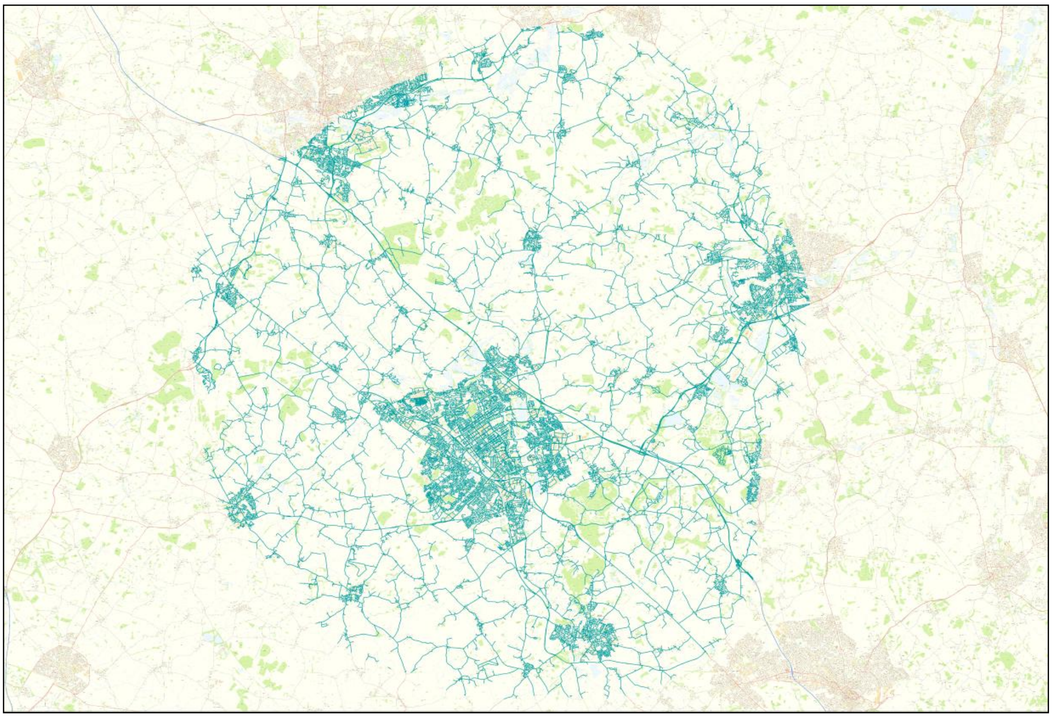

Figure 11. Trafficmaster Data Coverage

5.5.2 The journey time routes used as part of the model validation are listed in Table 7 and are displayed in Figure 12. Routes 1 to 8 were repeated from the 2009 model, while routes 9, 10, 12 and 13 were added. Route 11 (North – South via the railway level crossings at Fenny Stratford and reverse) is not listed or included in the journey time validation, as traffic volumes are very low on this route.

Table 7. Journey time Routes

Route No.	Description
1	A421 to M1 J13 and reverse
2	Old Stratford to Chicheley and reverse
3	Old Stratford to Watling, Little Brickhill and reverse
4	Portway/Fulmer St to Newport Pagnell and reverse
5	Child's way / Tattenhoe St to Moulsoe and reverse
6	A4146 / Stoke Rd to Saxon St / Newport Rd and reverse
7	M1 J13 to M1 J15 and reverse
8	Brunel Roundabout, Bletchley to Newport Pagnell and reverse
9	Brickhill Street – between A1146 and A5 (via the railway level crossings at Bow Brickhill) and reverse
10	A5130 – between A421 and A4012 (via the railway level crossings at Woburn Sands) and reverse
12	Central MK to M1 J13 via A421 and reverse
13	Central MK to M1 J13 via M1 J14 and reverse

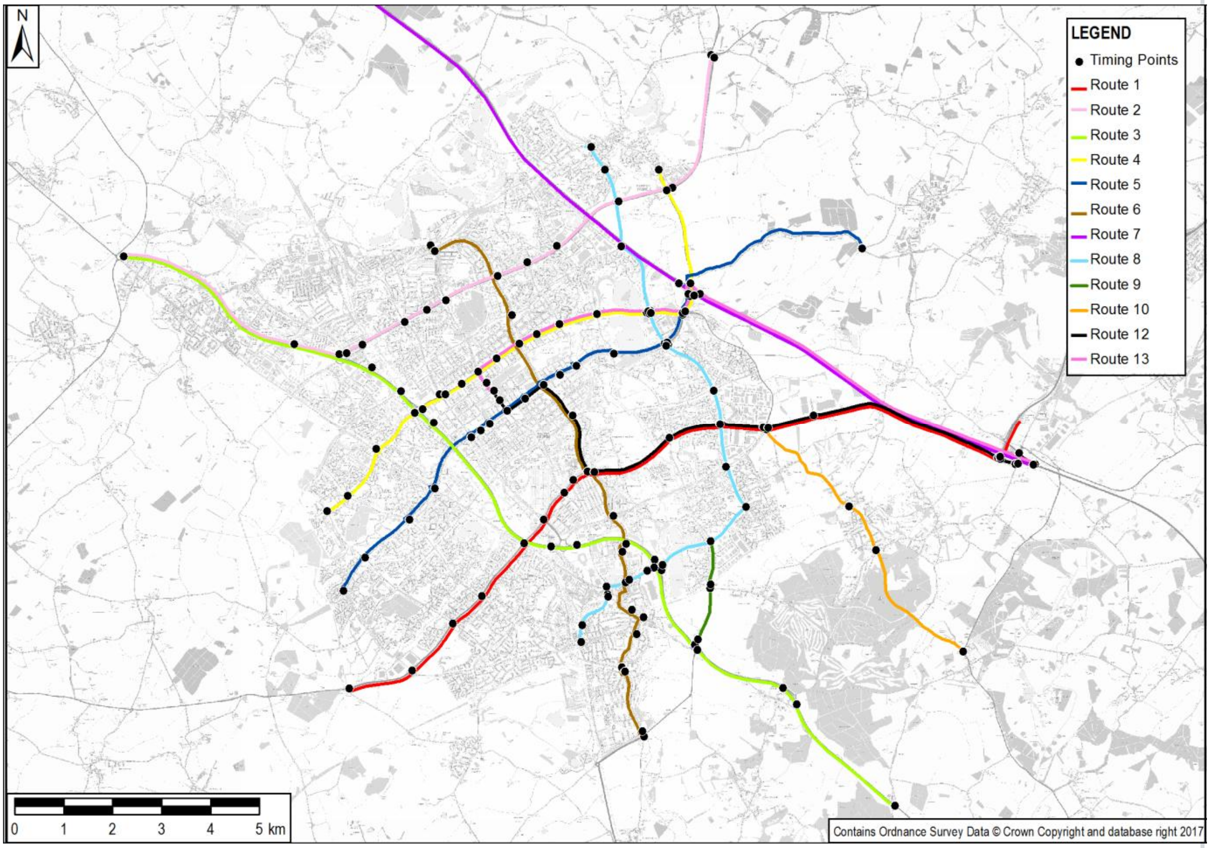

Figure 12. Journey Time Routes

5.5.3 Data was extracted from Trafficmaster data for cars and LGVs for June 2016 and June 2015, excluding school holidays. An average Monday to Thursday journey time was calculated for each of the modelled periods.

5.5.4 It was intended to use the June 2016 Trafficmaster data for all of the observed journey times. However, following a comparison of each route against comparable 2014-15 data, it was noted that there were significant differences in journey times on certain routes due to road works and non-typical signal timings occurring in June 2016. The June 2015 journey time data was therefore considered to be more representative of typical conditions for routes 4,5,6,8 and 13.

6. Network Development

6.1 Introduction

6.1.1 The existing 2009 model was used as the basis of the SATURN network. The primary amendments were to update the network from 2009 to June 2016. The simulation area was also extended.

6.2 Updates to 2016

6.2.1 Forty six changes to the highway network in Milton Keynes were identified as being implemented between 2009 and June 2016, 36 of which required coding into the network. The remainder were already included or were not modelled. Further to the amendments made so far, test network assignments were run using the 2009 matrix modified to the new zone structure to check that the network assignment and routing appears to be sensible. The more network significant changes are outlined below:

6.2.2 Highways Schemes:

- A421 Bedford to M1 J13 improvement (part of which has been coded as simulation);
- M1 J10-J13 Dynamic Hardshoulder Running;
- Kingston Roundabout improvement;
- A421 Dualling between Kingston and Eagle Farm Roundabouts;
- Part time signals Pineham Roundabout;
- V6 / Silbury Blvd – Roundabout removed, now signals; and
- Kelly’s Kitchen Roundabout (A5/A4146) now signalised.

6.2.3 New links have been added to represent new developments built since 2009, for example:

- Newton Leys; and
- Western Expansion Area.

6.2.4 Other amendments include speed limit changes, HGV bans and banned right turns, for example:

- V7 Saxon Street between H8 and H10, speed limit reduced to 40mph;
- V6 Grafton / Oldbrook Boulevard – banned right turn; and
- HGV ban on Newport Road.

6.3 Simulation Area Extension

6.3.1 A significant amount of change to the model network involved extension of the simulation area to north, east south and west. Figure 13 shows the extent of the original 2009 model simulation area in red and the extended 2016 model simulation area in blue.

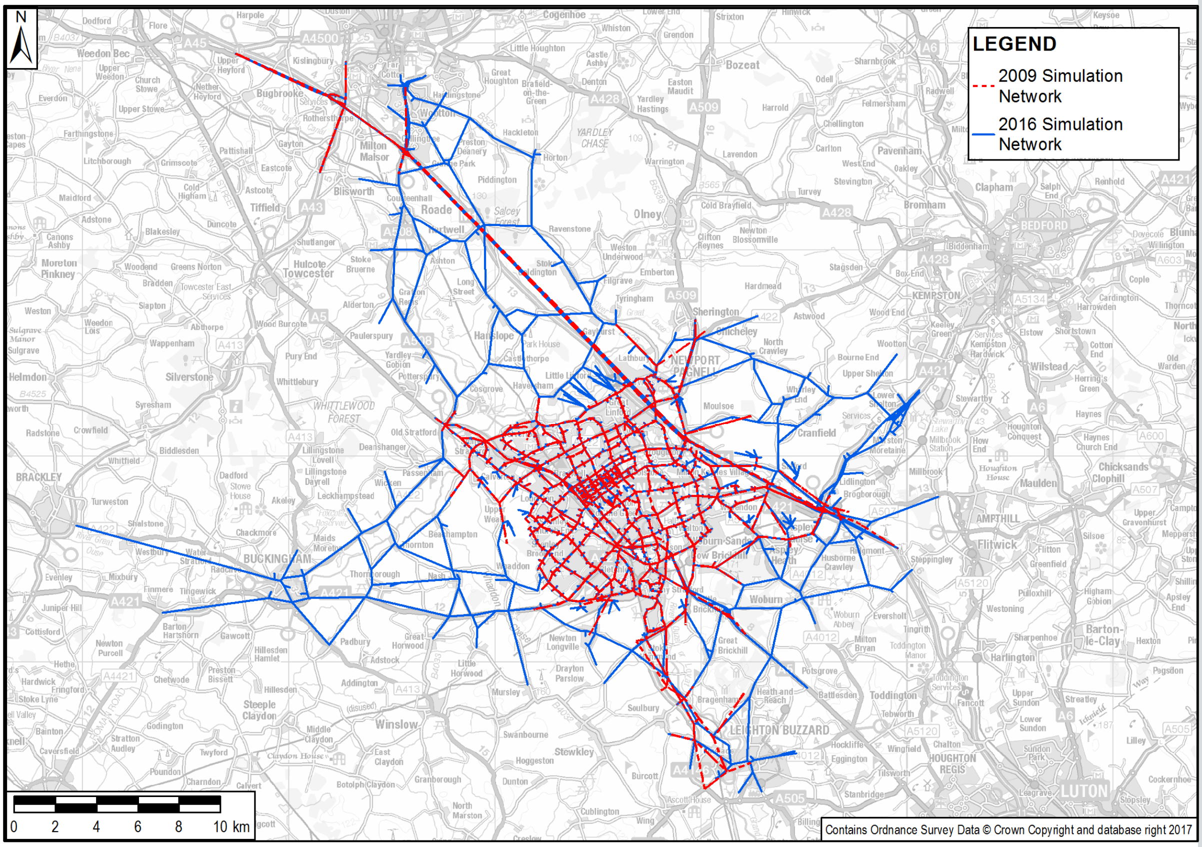

Figure 13. Extent of simulation extension

6.3.2 The Highways England Regional Model coding manual was used as a guide to network coding, to ensure consistency across the new simulation area in terms of saturation flows and roundabout capacities. Speed flow curves were applied using the default speed flow curves used for the existing simulation.

6.3.3 Zone loading was adjusted to connect to the new simulation via spigot links. Spigot links are 'dead end 'links. Zone connectors are joined to the ends of the spigots to allow traffic to enter and exit the model. This is an approach consistent with original simulation area.

6.3.4 Additional nodes were added to the network to model changes in speed limit or two adjacent junctions that were represented as a single node in the buffer network. An example of this around Roade is shown in Figure 14 with the blue links and nodes indicating the original 'buffer' coding and the red links and nodes the more detailed simulation coding.

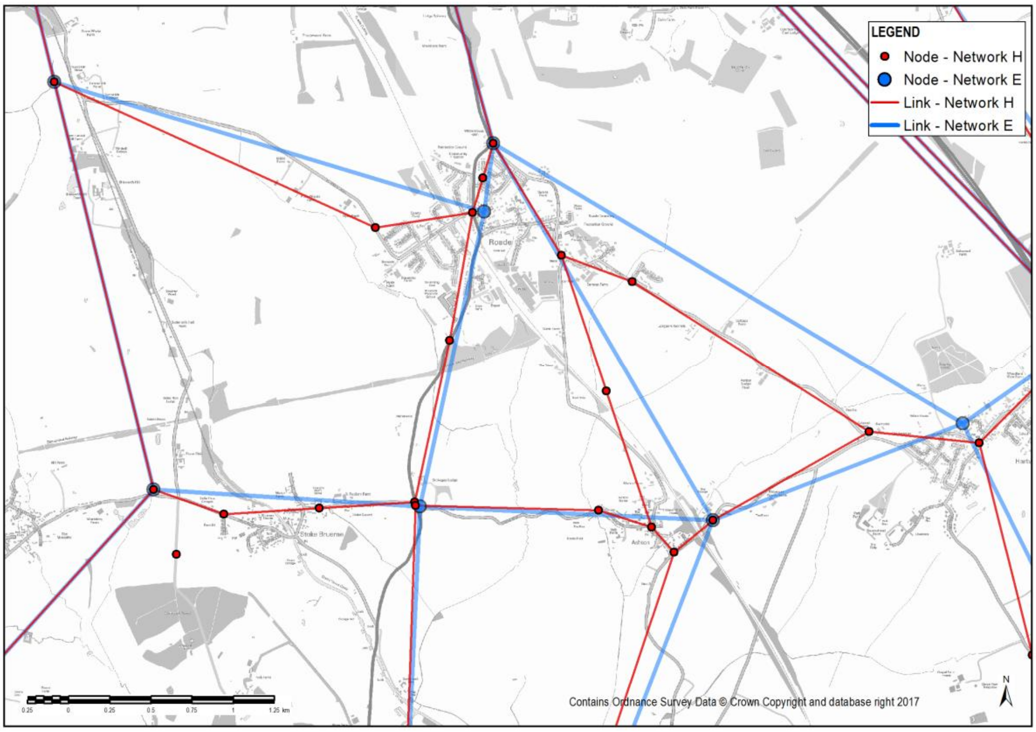

Figure 14. Example of additional nodes

6.3.5 Other notable changes included a connection made to the M1 J12 from Milton Bryan via Toddington, to provide a realistic route from south east of Milton Keynes to the M1 motorway. The Chicheley Hill roundabout (northern junction of the A509 and A422) was modelled in more detail as an 'exploded' junction with segregated left filter lane lanes rather than a single roundabout node.

6.3.6 The A5 around Little Brickhill was re-coded to make it more representative, with an additional on slip, and 'Q' nodes to better represent merge delay. This is shown in Figure 15.

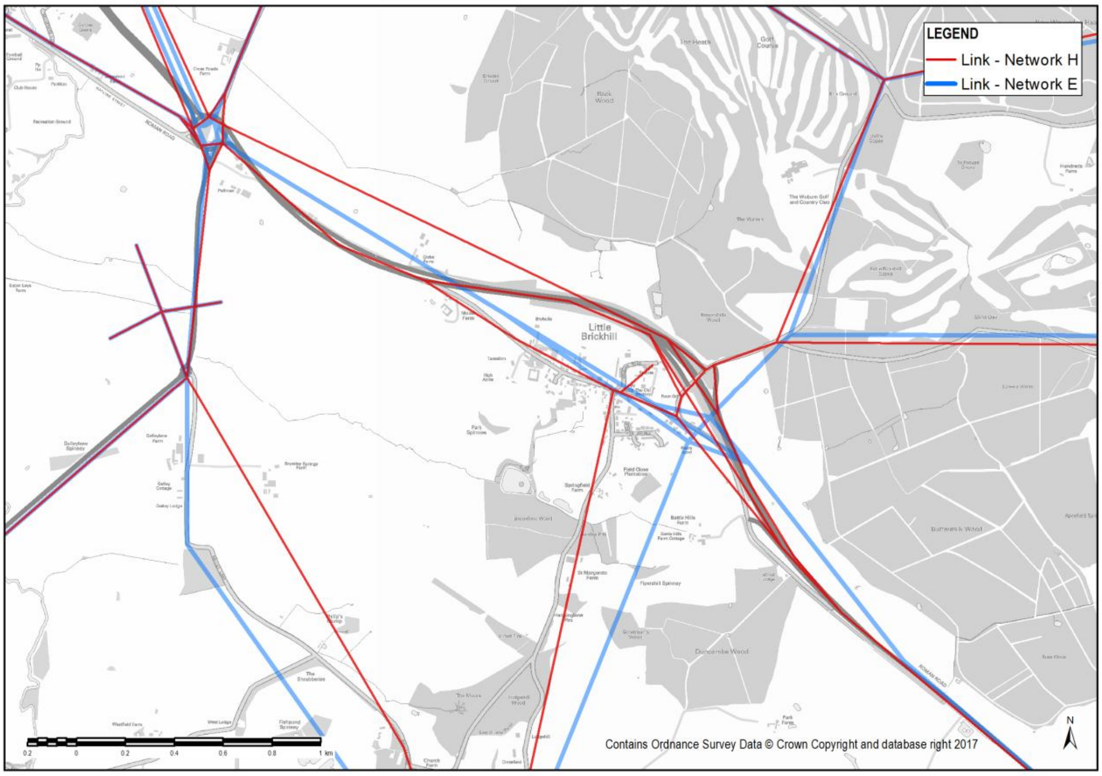

Figure 15. A5 at Little Brickhill

6.4 Speed Flow Curves

6.4.1 The use of speed flow curves in the original 2009 simulation network was limited to the M1 and the grade separated sections of the A5. As many roads across the Milton Keynes area are dual and single carriageways with 60 or 70mph speed limits it was considered that speed-flow curves should also apply to these links to better model the impacts of increased flow on link speeds. Therefore speed-flow curves were applied to all links with a speed limit over 40mph. For consistency the speed flows curves were defined using capacity indices taken from the Highways England Regional Traffic models.

6.4.2 The buffer link speed flow curves and capacity indices were not consistent in the 2009 network, some buffer links were defined with different speed flow curves but with an identical capacity index.

6.4.3 All buffer links with a speed flow curve were assigned a capacity index consistent with the simulation area. There were a number of single carriageway roads in the 2009 network with a capacity of 4,250 PCUs, which is representative of a dual carriageway. Examples of these were the A507, A4280, and the single carriageway sections of the A6 through Bedfordshire. Conversely the section of the A1 between the A428 and A421 (Black Cat) was coded as a single carriageway with a capacity of 1,640 PCUs which was acting as a major pinch point in the model. These incorrect capacities were corrected and the speed flow curves defined in the buffer were standardised with the use of the default capacity indices as applied in the simulation area.

6.5 Signal Timings

6.5.1 Signal timings were based on limited available information which did not include average observed green times. Amendments were made to reduce unrealistic delay and to better represent the observed journey times to aid journey time validation. For junctions that had been signalled between 2009 and June 2016 the green splits were based on the ratio of flows through the junctions.

6.6 Bus Lanes

6.6.1 Bus lane coding was reviewed. A number of bus only links through estates were removed from the model as they were not representative of the road network. It is assumed these were in place for the fixed bus flows, enabling the local buses to travel from one side of an un-modelled estate to the other. However as fixed bus flows have been updated using the parameter 'KANGA' which allows the buses to 'jump' from one part of the network to another they were no longer required.

6.6.2 Bus lanes were also added to model links where they existed on street. Part time bus lanes were included in the AM and PM networks but excluded from the IP network. The network was checked to ensure that there were no differences in terms of nodes other than whether or not a 'B marker' was applied to denote a bus lane.

6.7 Level Crossings

6.7.1 Signal nodes have been included to represent the level crossings on the Bletchley to Bedford railway line where the road network is modelled:

- Ridgmont
- Aspley Guise
- Woburn Sands
- Bow Brickhill
- Fenny Stratford

6.8 Network checks and adjustments

6.8.1 Throughout the model updating and continuing into the model calibration, checks of significant warnings, such as link distances and speeds being different by direction were made. Checks were also made to ensure there was no unrealistic delay in the model causing high levels of queued flow.

6.9 Buffer Network amendments

6.9.1 In addition to the speed-flow curve amendments, other edits were made to the buffer to join unconnected links and add additional detail.

6.9.2 It was found that at junction 16 of the M1 with A45 and A4500, the junction was not represented as the links just crossed over each other in the model. The same situation was noted at the A428/A45 junction in Northampton as shown in Figure 16 where there was no node where the two blue links crossed near the junction.

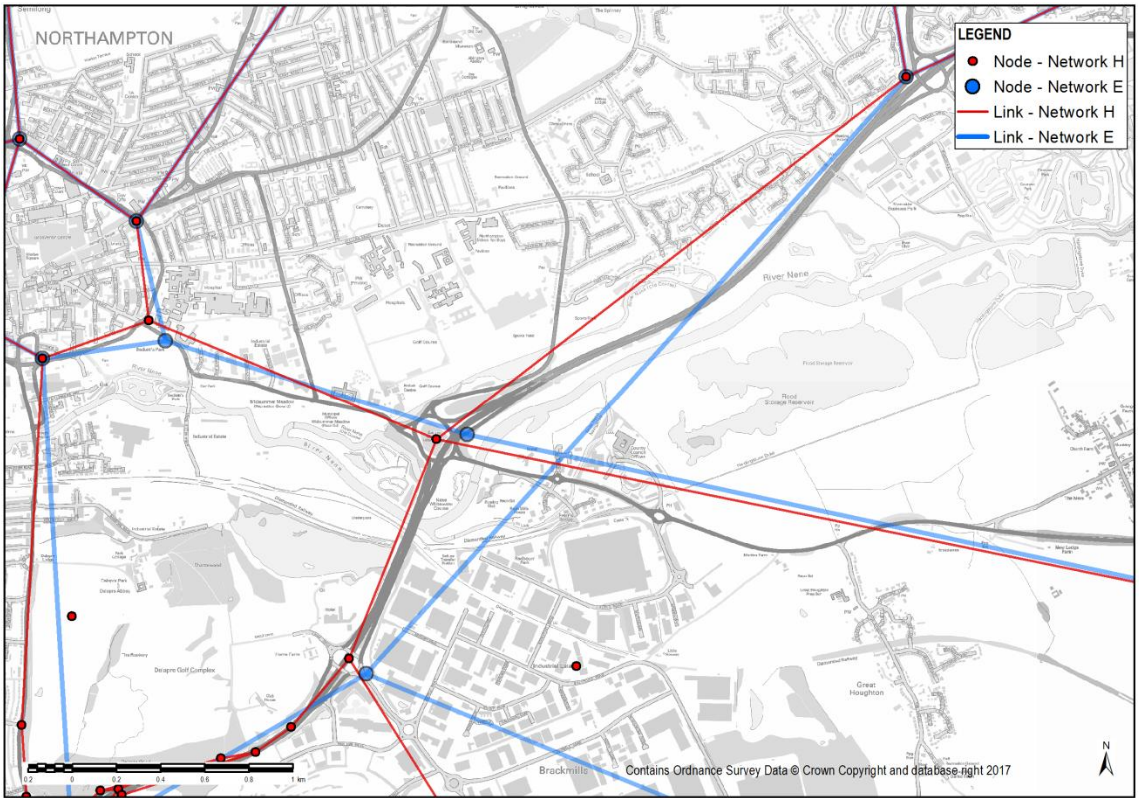

Figure 16. A45/A500 junction

6.9.3 The A603 between Bedford town centre and the A1 was added as was the B530 between Bedford and the A507 as this is a key route between Flitwick and Bedford. The Bedford Western Bypass is now modelled with some minor back lanes removed between the bypass and A422. These amendments are shown in Figure 17

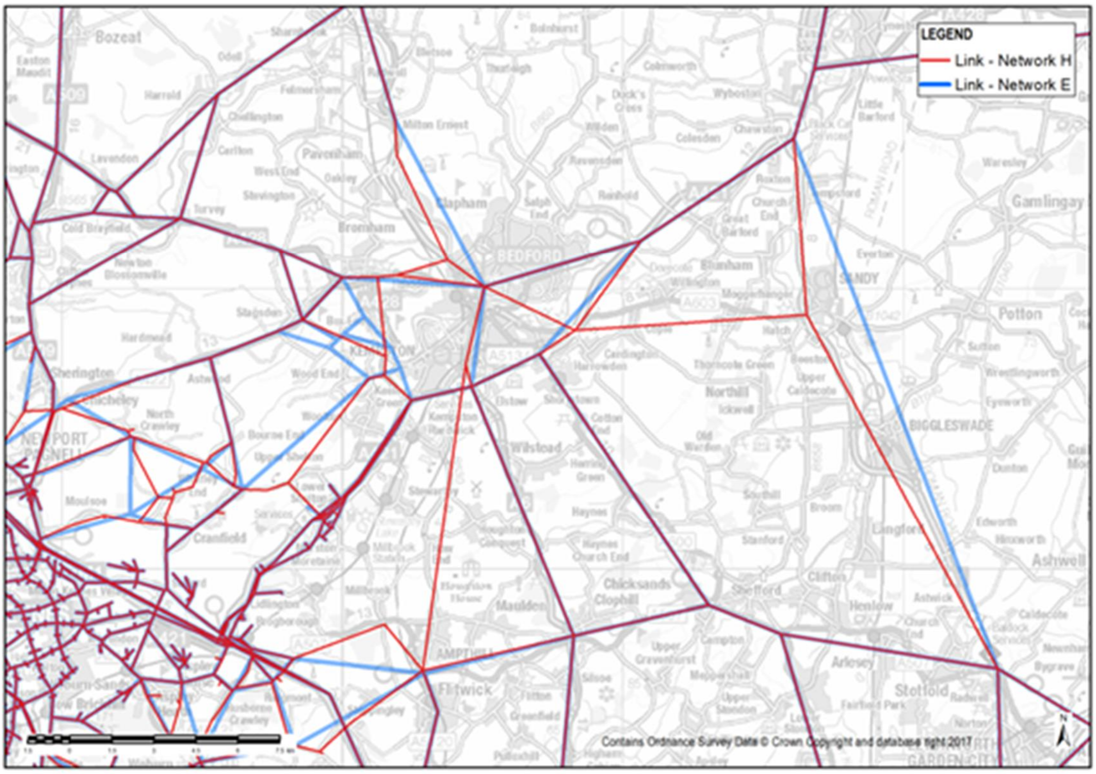

Figure 17. Buffer amendments around Bedford

7. Trip Matrix Development

7.1 Planning Data

Introduction

7.1.1 Planning data were required to determine existing trip generation and attraction across the Milton Keynes area. A source of these data is that used within NTEM. However NTEM zoning is much more aggregate than the MKMMM zone system within the Milton Keynes area and hence there was a need to obtain planning data from MKC at a more detailed geographic level. Ideally this would be in the same format as that used in the NTEM databases but this level of breakdown was not available for some of the data provided.

Residential

7.1.2 2016 dwelling data at 'settlement' level was provided by MKC and so it was possible to develop a reasonably accurate estimate of the number and location of base year households within the MKC part of the 'internal' model area (as shown in Figure 18). For the rest of the 'internal' model area the 2016 estimates were based on uplift to the 2011 census data using the 2014 mid-year estimates. Assessment of data indicated no change in average household size since 2011 and hence the Lower Super Output Area data were used to generate 2016 population estimates.

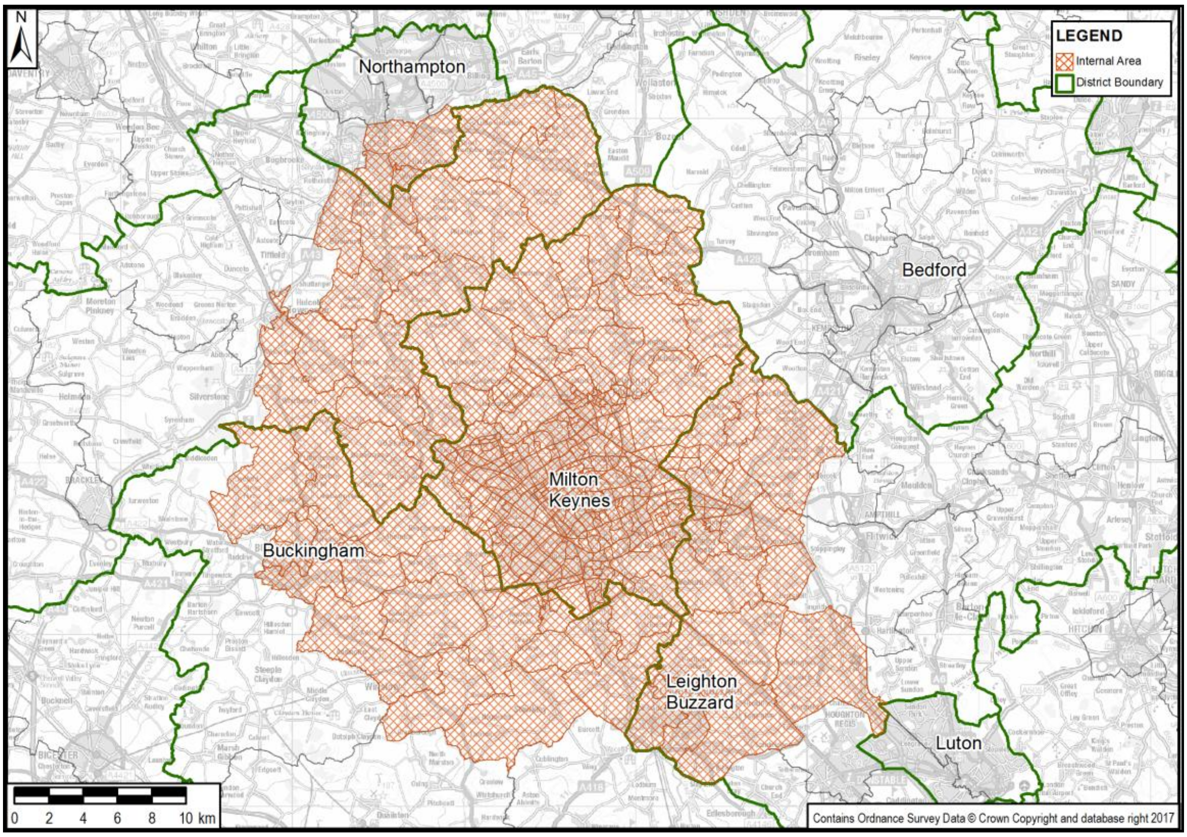

Figure 18. MKMMM 'Internal' Model Area

Employment

7.1.3 As no local post 2011 data was available the method of generating 2016 employment estimates required the use of more aggregate data. The 2011 census was used as the main source. To uplift to 2016 the Nomis database was used although this does not account for specific developments. The only specific employment data available were:

- The Quadrant: 3,000 business (E14) jobs have been assumed within zone 1216[2]
- Magna Park: a total of 3,925 jobs split between E09 (services), E10 (industry) and E14 (business) and across zones 1540, 1564 and 1565[3].

7.2 Base Year Planning Data

7.2.1 Household and population data based on estate / settlement level dwelling data was provided by MKC, whereas employment data was based largely on the 2011 Census. Possible sources of information on significant employment developments in and around Milton Keynes between 2011 and 2016 were also discussed.

7.2.2 Information was provided by MKC covering:

- Details of twelve major employment investment sites within Milton Keynes, along with the number of jobs created at these locations. This list includes The Quadrant and the developments at Magna Park on the A421.
- Successful planning application information for employment land-uses between 2011 and 2016.
- Specific information on the number of jobs created at two other locations: the Morrison's supermarket at Leisure Plaza; and the Wolverton Pool on Addington Avenue.

7.2.3 Given the large number of (around 600) planning applications provided, only those where there was a net increase in floor space of over 10,000m^2 were considered. Additional floor space for these developments was converted into an estimate of jobs using employment densities published by the Homes and Communities Agency.

7.2.4 The employment growth in zones containing these key employment developments were reviewed to ensure that the assumed growth is consistent with the information provided for these locations. Figure 19 and Figure 20 show the outturn base year population and employment densities respectively within Milton Keynes.

[2] An estimate of 3,000 jobs at The Quadrant is based on an internet search for information regarding the number of jobs at this location. All available information suggested that there were around 3,000 jobs located within The Quadrant.
[3] There is limited information on the number of jobs generated by this development. However, based on an estimate of the current floor space available at Magna Park, an indication of the likely number of jobs has been derived from work AECOM has undertaken on similar types of development elsewhere and also through the applications of employment densities specified by the Homes and Communities Agency.

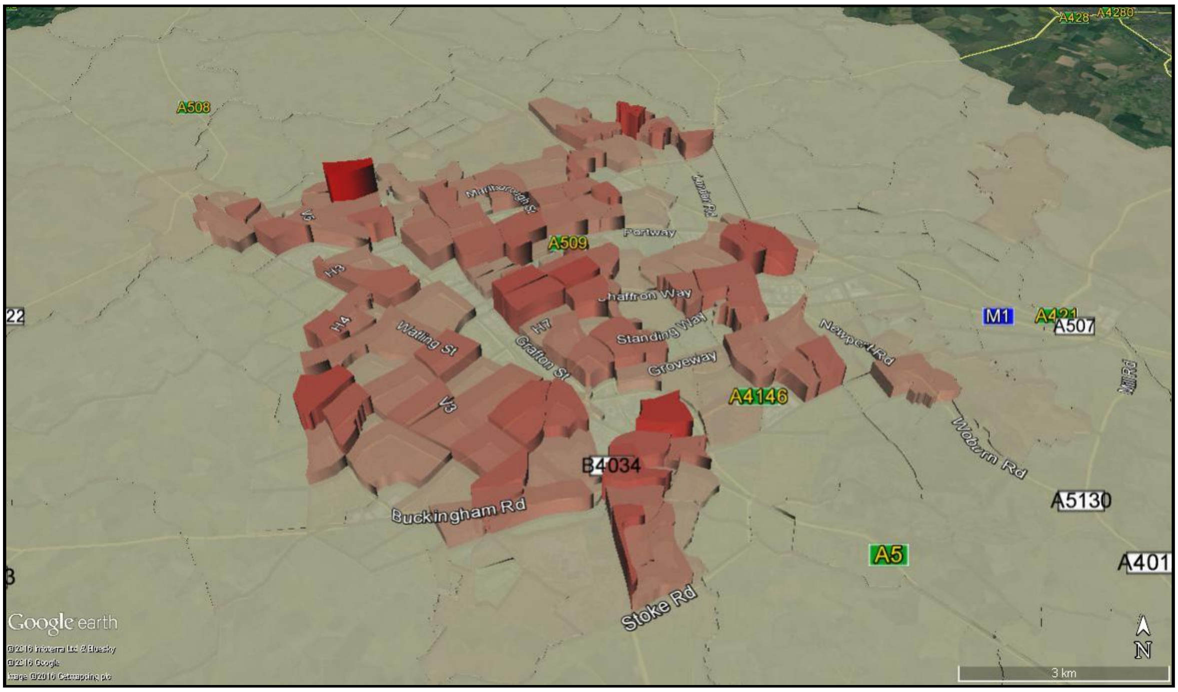

Figure 19. Base Year Population Density

Figure 20. Base Year Employment Density

7.3 Highway Matrix Build: Synthetic Process

7.3.1 Defining the "internal" area as those zones within the RSI cordon, the source of the highway demand data within the base year prior matrices was as shown in Table 8. The purpose of the synthetic demand was to provide an estimate for the demand within the urban area of Milton Keynes as no 'observed' trip O-D data were available for these zone to zone movements.

Table 8: Source of Base Year Highway Demand

	Internal	External
Internal	Synthetic	RSI data / SERTM
External	RSI data / SERTM	SERTM

7.3.2 The synthetic highway matrix build for car demand takes the trip-ends estimated based on the base year planning data and produces a matrix which reproduces the observed trip-length profiles by trip purposes taken from the National Travel Survey. The synthetic matrices were generated at a 24-hour level in production / attraction format for car person demand. Figure 21 shows the results of this calibration exercise to trip-length profiles by car trip purpose.

7.3.3 These 24-hour production / attraction car person trip matrices were then converted to assignment hour applying the following factors:

- Conversion from 24-hour to period and from production / attraction to origin / destination formation using factors from the National Travel Survey and NTEM v7.0.
- Conversion from person to vehicle matrices using occupancy factors as defined for SERTM (South-East Regional Traffic Model).
- AM and PM Peak hour matrices calculated using interim peak hour factors of 0.41 in the AM Peak and 0.38 in the PM Peak based on analysis of the RSI traffic counts only. (The Inter-Peak assignment matrix is an average over the six hour period.)

7.3.4 A similar process was undertaken for LGV traffic using trip-ends based on the base year employment data and TRICS trip-rates. As with car person demand, this produced a 24-hour synthetic demand matrix, which was converted to assignment hour using interim factors based on the RSI traffic counts.

7.3.5 For HGV demand, the BYFM (Base Year Freight Matrices) published by the DfT was used. These were disaggregated from the BYFM zone system to the MKMMM zone system using employment data.

7.3.6 Using these synthetic matrices, an initial assignment of demand onto an early version of the highway network was undertaken to review the pattern and level of flows within Milton Keynes. At this stage, no comparison against the calibration / validation screenlines and cordons was undertaken.

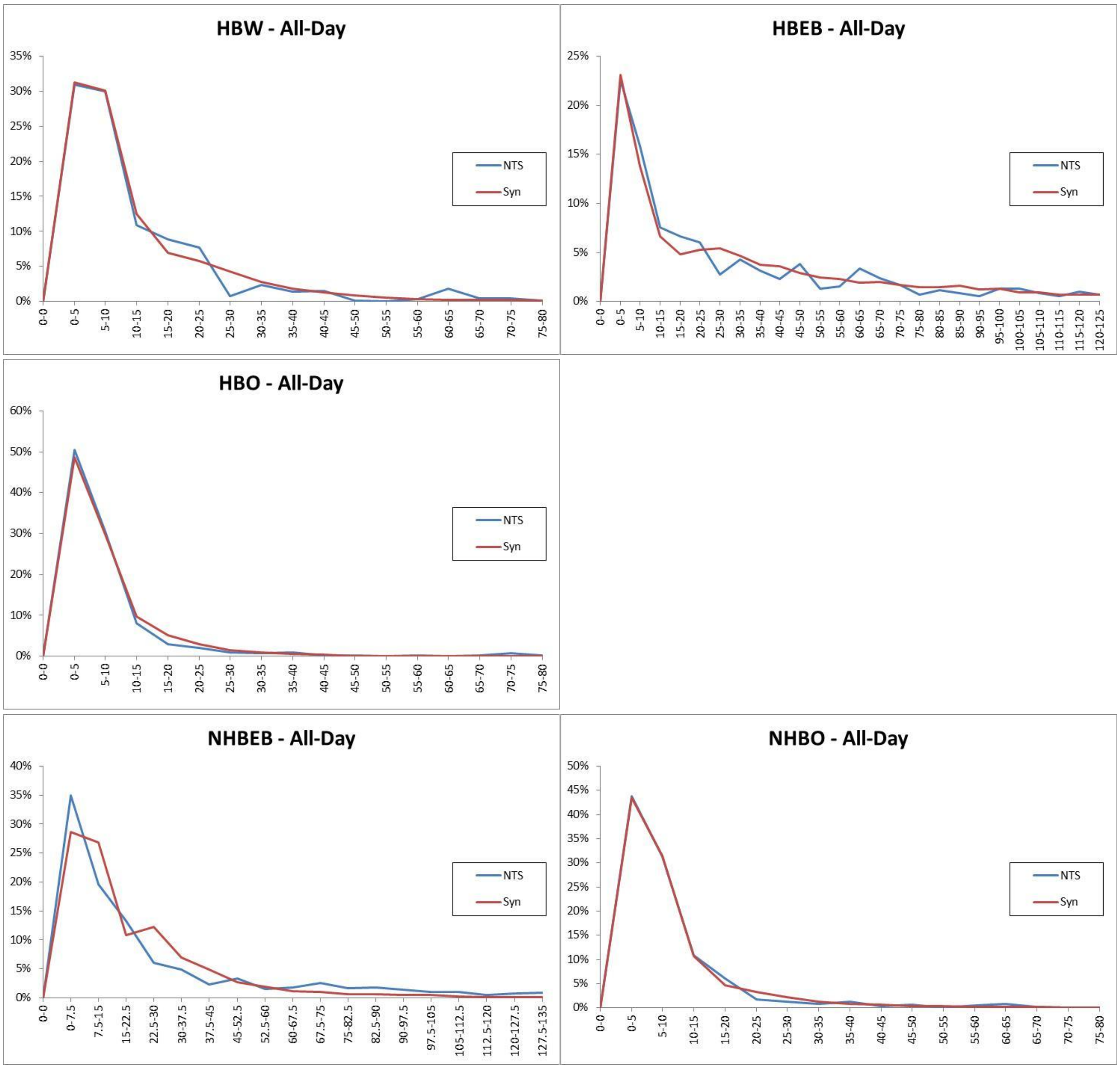

Figure 21. 24-hour Synthetic Trip-Length Profiles

7.3.7 Figure 22 to Figure 24 show the results of the assignment of the synthetic demand within Milton Keynes in the AM Peak, Inter-Peak and PM Peak hours respectively. Within these figures, the height of the bars representing the level of traffic on a given link, and the colour represents the volume-capacity ratio (yellow representing a low volume-capacity ratio, and red representing a high volume-capacity ratio).

Figure 22: AM Peak Synthetic Demand Assigned Flows

Figure 23: Inter-Peak Synthetic Demand Assigned Flows

Figure 24: PM Peak Synthetic Demand Assigned Flows

7.3.8 These figures showed that the initial assignments of the synthetic demand onto the highway network result in higher flows on the key routes into and out of Milton Keynes, and that in the two peak hours the modelled flows were around the modelled capacities in a number of locations. This demonstrated that the broad pattern and level of demand within the synthetic matrices were in line with expectations.

7.4 Highway Matrix Build: Observed Data

7.4.1 For non 'internal to internal' sector trips the highway data to build the matrices was obtained from the 2009 RSI The RSI data was expanded to the survey count data. The first stage of this processing was to review the raw survey data, undertaking a number of data and logic checks. These checks included:

- checks for missing data entries;
- checks for data entries outside of defined ranges; and
- checks on the origin / destination of trips observed.

7.4.2 Six per cent of the collected RSI records failed to meet one or more of the data cleaning checks, and were therefore removed from the dataset prior to expansion. There was a limited number of data entry errors which resulted in a given RSI record being removed, with the majority of removals due to checks on the recorded origin / destination for a trip. The records removed based on their origin / destination were reviewed to ensure that they were illogical records.

Table 9: Source of Base Year Highway Demand

Total number of raw RSI records	13,983
…removed due to high vehicle occupancies	6 (0.0%)
…removed due to missing origin	12 (0.1%)
…removed due to missing destination	60 (0.4%)
…removed due to illogical purpose	1 (0.0%)
…removed due to same origin / destination coordinates	3 (0.0%)
…removed due to same origin / destination zone	25 (0.2%)
…removed due to crow-fly distance vs. crow-fly distance via RSI site[4]	217 (1.6%)
…removed illogical origin / destination[5]	508 (3.6%)
Total number of cleaned RSI records	**13,151**

7.4.3 With the RSI records cleaned, these were firstly expanded to the recent traffic counts in the interview direction. The RSI records were then reversed to estimate the non-interview direction, and these reversed records were expanded to the reverse direction counts

7.4.4 With the RSI data expanded, a partially observed matrix was constructed for movements with an origin or destination within the RSI cordon, and this matrix was then compared with the SERTM matrices for the same movements. Based on the results of this comparison, the RSI data was used for trips to or from Milton Keynes.

7.5 Highway Trip-Rates: NTEM and TRICS

7.5.1 Considering the initial AM Peak synthetic assignment matrix, the peak hour origin trip rate per household was calculated for zones within Milton Keynes. Average trip rates were then calculated based on the percentage of land-use within a given zone which is residential and these are provided in Table 10.

Table 10: AM Peak Synthetic Trip Rates per Household

%HHs	*HH Trip Rate*
>90%	0.23
Between 80% and 90%	0.21
Between 70% and 80%	0.25
Between 60% and 70%	0.26
Between 50% and 60%	0.28

[4] This test has looked at the ratio of the direct crow-fly distance between the origin and destination versus the crow-fly distance from the origin to destination via the RSI site. Where the distance via the RSI site is more than twice the crow-fly distance, the record has been removed.
[5] This test has considered the direction of the RSI site, and compared this to the direction from the origin or destination to the RSI site. Where this is outside a defined range, the record is removed. For example, if the RSI site is eastbound (i.e. 90° from north), we would not expect the origin of the trip to be to the east of the RSI site (i.e. between 30° and 150° from the RSI site). These limits have been reviewed for each RSI site to ensure that this process does not remove 'correct' records.

7.5.2 The analysis suggests an AM Peak hour vehicle trip-rate of around 0.20 to 0.25 per household. This analysis is consistent with similar analysis from NTEM v7.0 for Milton Keynes Borough as shown in Table 11.

Table 11: NTEM v7.0 Household Trip-Rate Estimate (Milton Keynes Borough)

Households	**108,508**
Car Driver Origins	
AM Period	73,403
~AM Peak Hour (assuming 0.4 peak hour factor)	29,361
~Household AM Peak Hour Trip-Rate	0.27

7.5.3 Any new development modelled within the MKMMM will use a trip rate based on NTEM v7.0, so we would expect an AM Peak hour trip rate of around 0.25 car origins per household. Using TRICS to define a similar AM Peak hour trip rate generally results in a trip rate of around 0.4; however this depends on the nature and location of a given development.

7.6 Cordon and Screenline Traffic Volumes

7.6.1 Table 12 provides a summary of the equivalent June 2016 weekday traffic volumes for the three model time periods across the model cordons and screenlines. The outcomes were considered to be logical and uniform. Across all the screenlines the PM peak volumes are equivalent to those in the AM whereas average hourly inter-peak traffic is about 60% of that in the peak hours. Inter-peak traffic is higher where it would be expected to be greater such as around Central Milton Keynes. AM and PM volumes also indicate tidality in the direction expected, e.g. a higher volume into Milton Keynes in the AM peak at the RSI cordon and a similar volume outbound during the PM peak hour. A similar pattern occurs at the other screenlines and cordons.

Table 12: Cordon and Screenline Traffic (June 2016 Weekday Equivalent)

Screenline / Cordon	AM (Vehs)	IP (Vehs)	PM (Vehs)	IP/AM	PM/AM	IP/Peak 2-way	PM/AM 2-way
RSI Inbound Cordon	22511	9488	13762	42%	61%	56%	98%
RSI Outbound Cordon	12542	9846	20463	79%	163%		
Canal Eastbound	5716	4117	7884	72%	138%	58%	104%
Canal Westbound	8131	4058	6493	50%	80%		
CMK Inbound	9404	5254	5475	56%	58%	77%	107%
CMK Outbound	2761	4473	7537	162%	273%		
Northern Southbound	6013	2990	4644	50%	77%	59%	95%
Northern Northbound	4644	3179	5475	68%	118%		
Railway Eastbound	11180	5751	8074	51%	72%	63%	102%
Railway Westbound	7013	5809	10444	83%	149%		
Southern Southbound	4784	3195	5328	67%	111%	63%	102%
Southern Northbound	5139	3127	4783	61%	93%		
A422 Northbound	5301	4068	7850	77%	148%	59%	99%
A422 Southbound	8590	4045	5930	47%	69%		
Western Eastbound	4082	2154	2815	53%	69%	65%	98%
Western Westbound	2765	2238	3926	81%	142%		
Newport Pagnell Inbound	2736	1668	3393	61%	124%	54%	100%
Newport Pagnell Outbound	3386	1621	2719	48%	80%		
All Screenlines	**126698**	**77081**	**126995**	**61%**	**100%**		

7.7 Highway Trip Matrix Development

7.7.1 As no origin to destination data collection (such as RSIs, mobile phone data or a household survey) was commissioned as part of this update to the MKMMM, the highway matrix development has made use of available data sources. These sources were the existing 2009 RSI surveys (indicated in Figure 25) which form a cordon of Milton Keynes urban area and the ‘prior’ trip matrices from SERTM.

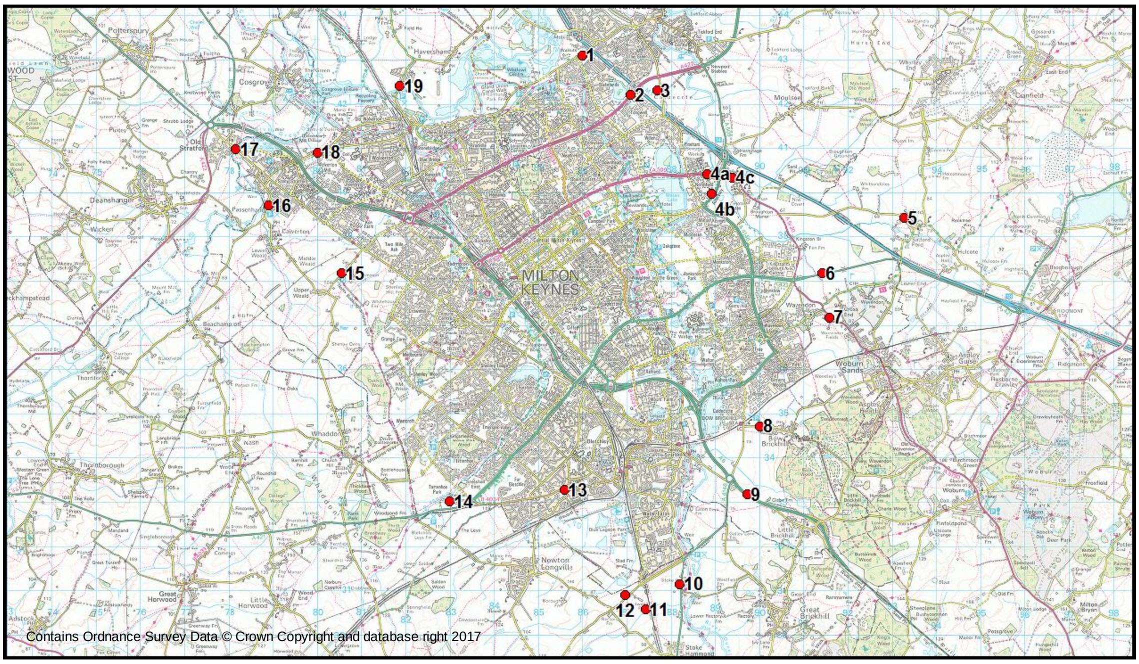

Figure 25. 2009 RSI Locations

7.7.2 The 2009 RSIs provide observed data of traffic entering and leaving Milton Keynes, but the data is seven years old compared to the new model base year. Expanding the RSIs to more recent count data accounts for changes in traffic volumes over the past seven years, but does not account for changes in travel patterns that may have occurred between 2009 and 2016. A comparison of the 2009 RSI data against the SERTM prior matrices was therefore undertaken to ascertain if there is evidence of any changes in these demand patterns.

7.7.3 In terms of processing of the 2009 RSI data, following cleaning of the data, these observations were expanded to the 2016 traffic counts collected at the RSI locations. This expansion was undertaken both in the interview direction (inbound to the cordon) and the non-interview direction (outbound from the cordon). The reversal of the RSI records has been undertaken using return time proportions taken from National Travel Survey (NTS) data.

7.7.4 Combining the records across RSI sites provides a matrix of trips entering and leaving Milton Keynes urban area, with the exception of the A5 north where the RSI was suspended. Traffic using the A5 to the north of Milton Keynes is therefore missing from the partially observed matrix at this stage.

7.7.5 This partially observed matrix was then compared with the base year matrices developed for SERTM to ascertain if there is any evidence of changes in trip patterns for trips with an origin or destination within the RSI cordon. This analysis looked at the pattern of trips at a sector level (both for sector to sector movements and trip-ends) and also the trip-length profiles within the two sets of matrices. This analysis excluded origin-destination movements which may have used the A5 to the north of Milton Keynes as this demand is missing from the RSI data but is included in the SERTM matrices.

7.7.6 In terms of the sector based analysis, a sector system was developed which consisted of:

- three sectors within Milton Keynes;
- one sector for the remainder of Milton Keynes Borough;
- separate sectors for each district which has a border with Milton Keynes borough;
- separate sectors for the remainder of each county which borders Milton Keynes borough; and
- four 'external' sectors that represent the rest of the UK in the north, south, east and west.

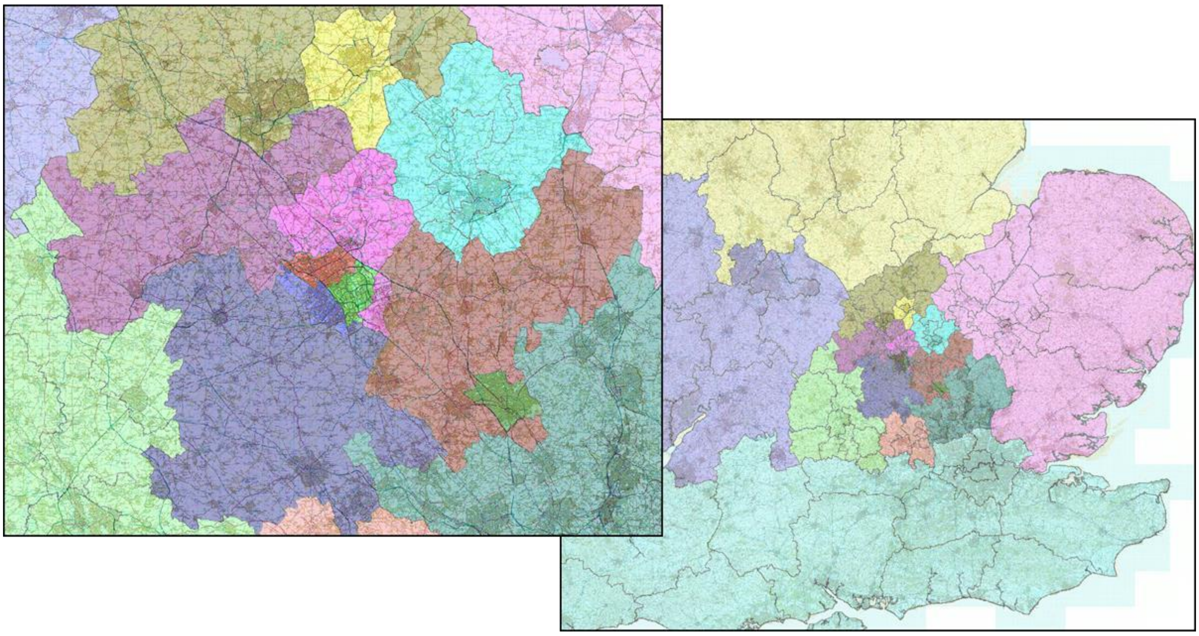

Figure 26. RSI-SERTM Comparison Sectors

7.7.7 The following table provides a summary of the analysis comparing the RSI and SERTM matrices using this sector system.

Table 13: Sector-Based Comparison of RSI and SERTM Matrices

			Origin Trip-Ends	Destination Trip-Ends	Sector-Sector Movements
AM Peak	Car	R^2	0.95	0.94	0.92
		Slope	0.60	0.56	0.56
	LGV	R^2	0.91	0.96	0.70
		Slope	0.57	0.65	0.47
	HGV	R^2	0.05	0.15	0.00
		Slope	0.24	0.36	-0.02
Inter-Peak	Car	R^2	0.89	0.91	0.88
		Slope	0.69	0.69	0.68
	LGV	R^2	0.93	0.91	0.73
		Slope	0.49	0.50	0.37
	HGV	R^2	0.28	0.30	0.01
		Slope	0.83	0.91	0.10
PM Peak	Car	R^2	0.95	0.96	0.92
		Slope	0.60	0.60	0.56
	LGV	R^2	0.95	0.95	0.63
		Slope	0.71	0.75	0.54
	HGV	R^2	0.18	0.29	0.00
		Slope	1.11	1.54	-0.12

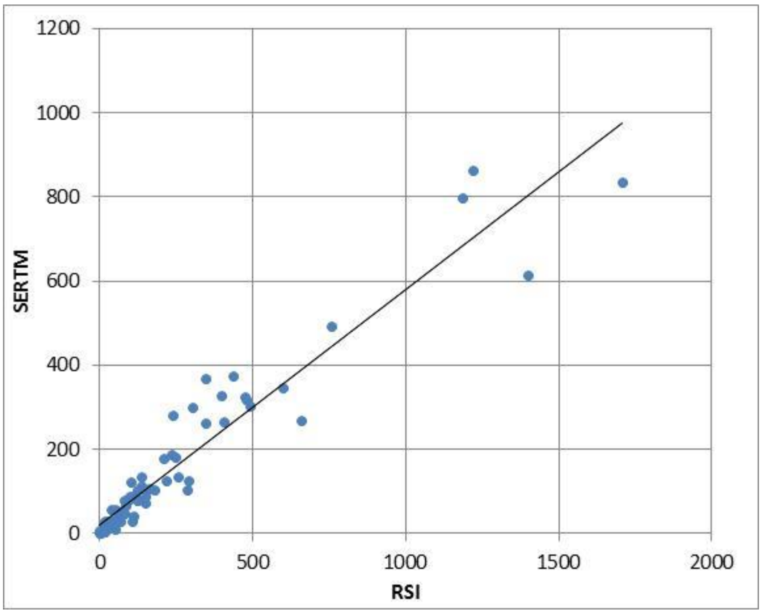

Figure 27. Comparison of AM Peak Car Matrices

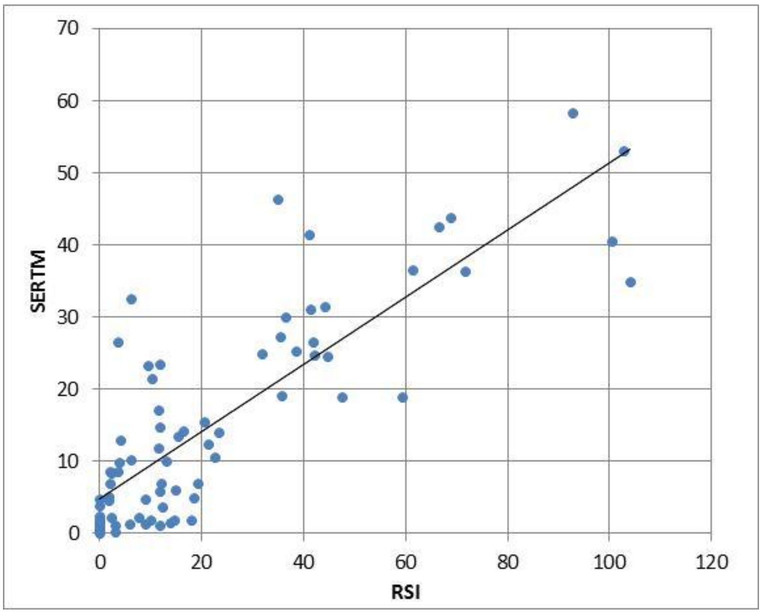

Figure 28. Comparison of AM Peak LGV Matrices

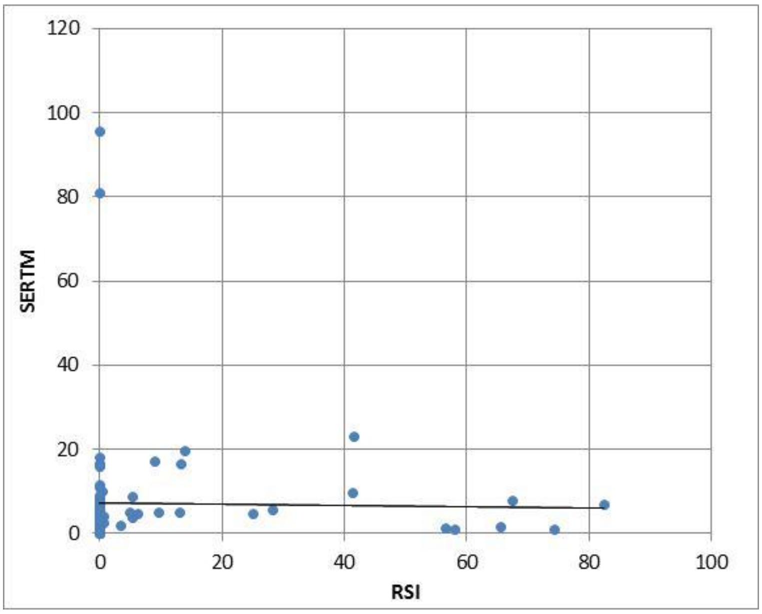

Figure 29. Comparison of AM Peak HGV Matrices

7.7.8 The key outcomes from this sector-based analysis were that:

- there was good correlation between the RSI and SERTM trip matrices for car based trips on the chosen sector system;
- there was evidence of a correlation between RSI and SERTM matrices for sector-sector movements, with a good correlation for origin and destination trip-ends for LGVs; and
- there was poor correlation between the RSI and SERTM matrices for HGVs.

7.7.9 In addition to the sectored demand analysis, analysis was also undertaken comparing the trip-length profiles within the two sets of matrices. This analysis compares the average trip-length within the two sets of matrices, and also calculates the coincidence ratio which is a measure of how similar the two trip-length profiles are. The results of this analysis are shown below.

Table 14: Trip-Length Comparison of RSI and SERTM Matrices

		AM Peak	Inter-Peak	PM Peak
Car	Avg. Trip-Length	1%	-3%	-1%
	Coincidence Ratio	0.86	0.88	0.86
LGV	Avg. Trip-Length	-11%	-26%	0%
	Coincidence Ratio	0.63	0.60	0.62
HGV	Avg. Trip-Length	-64%	-61%	-63%
	Coincidence Ratio	0.17	0.15	0.10

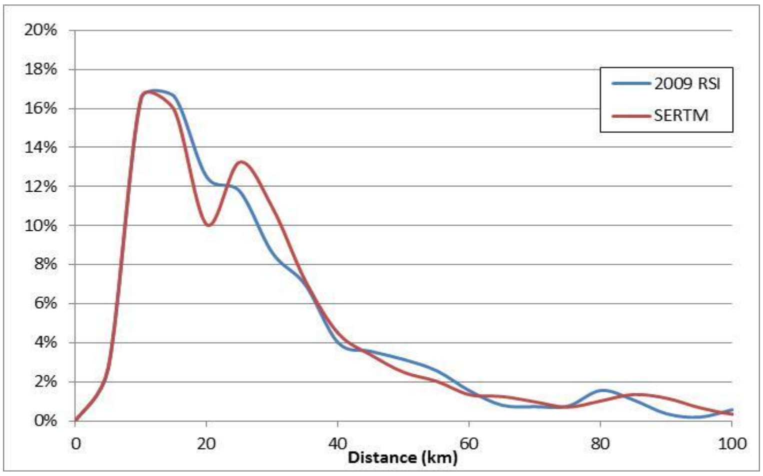

Figure 30. Comparison of AM Peak Car Trip-Length Profile

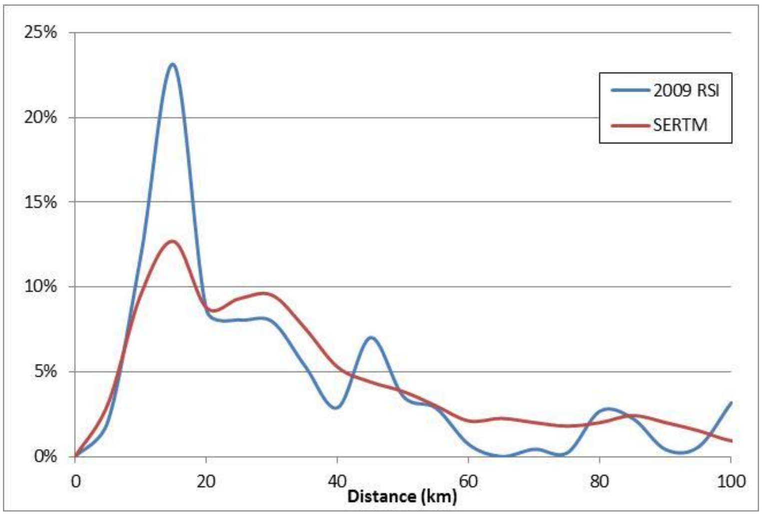

Figure 31. Comparison of AM Peak LGV Trip-Length Profile

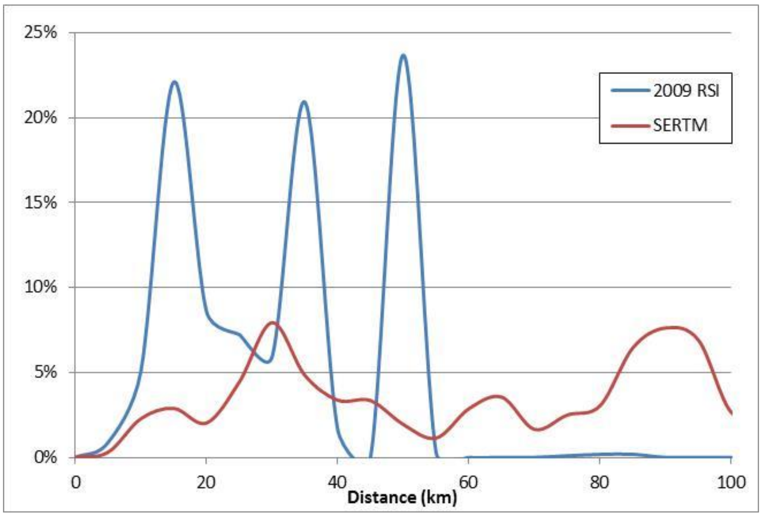

Figure 32. Comparison of AM Peak HGV Trip-Length Profile

7.7.10 The key outcomes from this trip-length analysis were that:

- there was good correlation between the trip-length profiles within the RSI and SERTM demand matrices for car demand;
- there was a correlation between the RSI and SERTM trip-length profiles for LGV demand, although this is at a lower level than for car demand; and
- there was poor correlation between the RSI and SERTM trip-length profiles for HGV demand.

7.7.11 Combining the results from both of these comparisons:

- For car demand there was a good correlation between the two data sources both in terms of sector-sector movements and trip-length profiles. This suggested that, given the available data, there was no evidence of changes in the pattern of trips from that observed in the 2009 RSIs, and these observations were therefore used for trips with an origin or destination within the Milton Keynes urban area.
- Whilst the correlation between the RSI and SERTM demand matrices for LGVs was not as strong as it was for cars, this analysis did not provide any evidence to discount the trip patterns for LGVs observed within the 2009 RSI data. The RSI data was therefore used for trips with an origin or destination within Milton Keynes.
- The analysis for HGV demand suggested that there was no correlation between the 2009 RSI data and the SERTM matrices (which were derived from BYFM data). This was likely to be as a result of the lower sample rate for HGV traffic compared to car and LGV traffic within the RSI data[6], which reduces the confidence that can be placed on the RSI data for this vehicle type. On this basis, the RSI data was not used for HGV traffic to / from Milton Keynes.

[6] Based on a 12-hour period, the sample rates within the RSI data are approximately 10% for car traffic, 7% for LGV traffic and 3% for HGV traffic.

7.7.12 Based on this analysis and the available data sources, the following table details the source of demand data for the base year highway matrices.

Table 15: Proposed Highway Demand Data Sources

	Internal Milton Keynes	Internal-External & External-Internal	External-External
Car	Synthetic	RSI data, with A5 north infilled with select link from SERTM	SERTM
LGV	Synthetic	RSI data, with A5 north infilled with select link from SERTM	SERTM
HGV	BYFM	BYFM	SERTM

7.8 'Initial' Prior Matrix Performance

7.8.1 As the matrices were developed the networks were be improved and refined. The 'Initial' Prior matrix was assigned to an interim version of the network, version E. This network includes the scheme updates between 2009 and 2016. The RSI cordon calibrated reasonably well but modelled counts were found to be too low internally in Milton Keynes itself. Points of note are:

- Modelled Car volumes were consistently around 20%-25% lower in total across the 3 time periods.
- Modelled HGV volumes looked to be about right in the IP but were around 30% high in the AM and 70% high in the PM.
- Modelled LGV volumes looked to be about right in the AM but were around 15% low in the IP and 30% low in the PM.
- At the RSI cordon the assignments were around 10% under. This generally applied to Car and LGV but HGV differences were greater in the AM and PM
- For the 'internal' cordons and screenlines the differences are greater and were in order of 20%.
- The newly created Newport Pagnell screenline had shortfalls in the AM and PM peaks of up to 45% in the non-peak direction and between 20-30% in the peak direction and during the inter-peak.

Table 16: Initial Cordon and Screenline Summary - AM

AM PEAK	Version		Cars			LGVs			HGV PCUs			HGV	Total Vehs		
	Network	Matrix	Obs	Mod	Diff	Obs	Mod	Diff	Obs	Mod	Diff	Vehs	Obs	Mod	Diff
ALL Cordons & Screenlines	E2	1b	112863	90969	-20%	9594	9940	5%	7701	9663	32%	3081	125537	104774	-16%
Excluding RSI	E2	1b	82748	64038	-23%	6293	6818	8%	4472	6319	41%	1789	90827	72990	-20%
RSI Only	E2	1b	30115	26931	-11%	3301	3123	-5%	3229	3344	4%	1292	34710	31784	-8%
Newport Pagnell Cordon	E2	1b	5470	3622	-34%	484	358	-26%	198	165	-17%	79	6032	4046	-33%

Table 17: Initial Cordon and Screenline Summary - Inter-Peak

INTER-PEAK	Version		Cars			LGVs			HGV PCUs			HGV	Total Vehs		
	Network	Matrix	Obs	Mod	Diff	Obs	Mod	Diff	Obs	Mod	Diff	Vehs	Obs	Mod	Diff
ALL Cordons & Screenlines	E2	1b	63926	48437	-24%	9055	7821	-13%	8063	7219	-5%	3225	76207	59146	-22%
Excluding RSI	E2	1b	48942	34885	-29%	6218	5149	-17%	4888	4322	-12%	1955	57115	41559	-27%
RSI Only	E2	1b	14984	13552	-10%	2838	2673	-6%	3175	2897	-9%	1270	19092	17587	-8%
Newport Pagnell Cordon	E2	1b	2677	1811	-32%	458	286	-38%	231	114	-51%	92	3238	2143	-34%

Table 18: Initial Cordon and Screenline Summary - PM

PM PEAK	Version		Cars			LGVs			HGV PCUs			HGV	Total Vehs		
	Network	Matrix	Obs	Mod	Diff	Obs	Mod	Diff	Obs	Mod	Diff	Vehs	Obs	Mod	Diff
ALL Cordons & Screenlines	E2	1b	115956	90049	-23%	8353	5990	-27%	3385	5426	75%	1354	125663	98209	-22%
Excluding RSI	E2	1b	85548	62631	-27%	5525	3393	-39%	2003	3588	79%	801	91874	67152	-27%
RSI Only	E2	1b	30408	27418	-10%	2828	2597	-8%	1382	1838	33%	553	33789	31057	-8%
Newport Pagnell Cordon	E2	1b	5459	3549	-35%	489	256	-48%	99	101	2%	40	5988	3845	-36%

7.9 Prior Matrix Refinements

7.9.1 The review of the 'initial' prior matrices highlighted four main areas for improvement in the performance of the matrices. These were:

- a shortfall of traffic within the RSI cordon compared against counts;
- the overstatement of traffic on the M1 adjacent to Milton Keynes;
- the allocation of freight demand between periods; and
- based on the performance of the Newport Pagnell cordon, a shortfall of demand outside the RSI cordon in the vicinity of the Milton Keynes urban area.

7.9.2 The remainder of this section discusses each of these areas in more detail, discussing the review and amendments applied to the processing of the base year demand data.

Traffic within Milton Keynes Urban Area

7.9.3 Traffic with an origin and a destination within the Milton Keynes urban area was taken from the synthetic matrices as there was little and certainly no comprehensive available observed data for these trips. There were a number of input assumptions and factors applied to generate these matrices and convert them for use in the assignment model. A review of all the inputs and assumptions was undertaken with a view to addressing the shortfall of demand within the urban area.

7.9.4 In terms of the inputs to the synthetic matrix build process, these were:

- base year planning data;
- NTEM v7.0 trip rates;
- trip-length profiles derived from the National Travel Survey (NTS), and;
- a distance skim from an initial version of the updated MKMMM network.

7.9.5 The base year planning data was consistent with the National Trip End Model (NTEM) version 7.0 and was based on data provided by Milton Keynes Council (MKC), so no significant adjustments were expected to this input[7]. Similarly, alternative data source for trip rates or trip-length profiles other than the NTS (which underpins the NTEM v7.0 trip rates) were not available. Whilst network refinements were made since the distance matrix was generated, it was considered that these would mostly impact on the journey times between zones and would not have a significant impact on the distances between zones.

7.9.6 This review of the input data did not suggest that there was evidence to amend any of the inputs to the synthetic matrix building process; however this process produced a 24-hour person production and attraction demand, which was converted using a number of factors into assignment hour vehicle demand in origin and destination format. The following discusses each of the factors applied in this conversion process:

- **24-hour to Period Factors:** the factors to split 24-hour demand to periods were based on the proportion of trip-ends from NTEM v7.0. These were compared with the proportion of traffic within each period observed at the RSI locations, and these factors based on counts were consistent with those derived from NTEM v7.0.
- **Production / Attraction to Origin / Destination Factors:** as with the 24-hour to period factors, the factors to convert from production and attraction to origin and destination format were based on data within NTEM v7.0. There was no alternative source of data for these factors available, and it is worth noting that these factors do not change the overall level of traffic within a given period.
- **Vehicle Occupancy Assumptions:** these were derived from analysis of the NTS, and vary by trip purpose and time period. An alternative source of local data on vehicle occupancies are the RSIs; however these only capture the vehicle occupancies for trips entering Milton Keynes, and provide no information on vehicle occupancies for trips internal to the urban area.
- The occupancies derived from the NTS were considered to be a better source of data than the RSI data due to the fact that the NTS covers ‘all’ demand and not the subset of demand captured by the RSI surveys.
- **Peak Hour Factors:** within the ‘initial’ prior matrices the peak hour factors for the AM Peak and PM Peak hours were based on the counts collected at RSI locations only. The dataset used for calculating the peak hour factors was expanded to cover all the calibration and validation counts, and marginally different peak hour factors by vehicle type were calculated.

7.9.7 The review summarised above did not identify changes to the inputs or assumptions used in the building of synthetic demand which would address the shortfall in demand observed within the Milton Keynes urban area. Therefore, consideration was given to making an adjustment to the process by which the synthetic demand was estimated.

7.9.8 The initial synthetic build process controlled the matrices to the trip-ends from NTEM v7.0 and the trip-length profiles derived from the NTS. Using the RSI data there were additional constraints which could be applied within the matrix build process which were the observed number of trips entering and leaving Milton Keynes at the RSI cordon. Taking this forward, adjustments were made to the synthetic matrix build process to include the observed sector movements from the RSIs as an additional constraint within the process.

[7] Although NTEM version 7.2 was released towards the end of the development of the Base Year models there was insufficient time in the programme to incorporate the revised data within the BY model development process.

7.9.9 In order for the revised process to converge to an acceptable solution it was necessary to make some adjustments to the RSI data processing. Analysis of the RSI data showed that there was a difference between the observed purpose splits within the RSI data and those assumed within NTEM v7.0. This was largely an understatement of home-based employers' business trips and an overstatement in non-home-based employers' business trips. To correct for this, the RSI data has been controlled to NTEM v7.0 trip purpose splits using all sites combined over a 12-hour period. This retains the variation in trip purposes across the day and by RSI location.

7.9.10 Applying these additional constraints within the synthetic matrix development resulted in around 6% to 7% additional internal-internal trips within the AM Peak and PM Peak hours, and around 3% additional internal demand in the Inter-Peak hour.

Strategic M1 Traffic

7.9.11 A comparison of the modelled flows against counts on the M1 adjacent to Milton Keynes showed that the 'initial' prior matrices overstated demand on this route. Within the development of the 'initial' prior matrices a single peak hour factor was applied to all trips based on the count data used to define the calibration and validation screenlines.

7.9.12 Analysis of the flows on the M1 near Milton Keynes suggested that the profile of demand within the two peak periods was different on the M1 compared to that observed in the Milton Keynes calibration and validation count data. Using the MK calibration and validation count dataset, there was a distinct peak hour within the urban area with the AM Peak hour being around 43% of the period and the PM Peak hour being around 39% of the period for car traffic. Similar analysis of the M1 traffic suggested that the AM Peak hour was around 33% of the period and the PM Peak hour was around 35% of the period.

7.9.13 SERTM represented an average hour within the peak periods, and analysis of count data on the M1 suggested that traffic within the MKMMM peak hours on the M1 was broadly equivalent to an average hour. Therefore, average hour demand from SERTM was used for external-external movements.

Allocation of Freight Demand

7.9.14 Within the 'initial' prior matrices, the factors applied to break down the 24-hour demand to individual time periods were based on the profile of total traffic from the count data collected for the expansion of the RSI data. This dataset was expanded to include all count data collected for the calibration and validation of the model.

7.9.15 A limitation of the calibration and validation dataset for this purpose was that classified count data was only available for the 12-hour period between 7am and 7pm, and so there was no information on the level of freight demand outside this period. To estimate the proportion of LGV and HGV demand which occurred overnight between 7pm and 7am, data from a 24-hour manual classified count undertaken on the A509 (near M1 Junction 14) during May 2015 was used.

7.9.16 With the proportion of freight demand within the off-peak defined, the calibration and validation count data were used to define the proportion of LGV and HGV traffic within the AM Peak, Inter-Peak and PM Peak periods. These revised factors were used to generate an updated set of prior matrices.

'Local' External Demand

7.9.17 SERTM demand was used for all external-external demand, i.e. all trips with an origin and destination outside the RSI cordon. This meant that the majority of demand to and from locations such as Newport Pagnell, Olney and Buckingham were taken from SERTM. Evidence from the Newport Pagnell cordon suggested that the SERTM matrices understated the level of demand within these areas.

7.9.18 The following is an extract from a Technical Note entitled *"Strengths and Weaknesses of RTM Prior Trip Matrices"* produced as part of the development of the Regional Traffic Models:

7.9.19 "In summary the prior matrices should be, in general, most reliable in representing longer distance car movements. The matrices will be less accurate in their representation of:

- *short journeys (around 5km in urban areas and 15km in rural areas),*
- *particularly within and to urban areas and where there is an appreciable public transport market share,*
- *at particular locations where night shift working is prevalent;*
- *across estuaries, and*
- *for HGV movements, particularly near major logistics sites. "*

7.9.20 This summary suggested that there may be weaknesses in the SERTM matrices within the rural areas surrounding Milton Keynes, which may be part of the reason for the poor performance of the 'initial' prior matrices against the Newport Pagnell cordon.

7.9.21 The demand from the RSIs could not be used for these movements, so the only available alternative source of data was the synthetic demand matrices. The approach adopted was therefore to use these synthetic matrices for external-external movements which were relatively 'local' to Milton Keynes urban area, such as an area bounded by Northampton, Bedford, Leighton Buzzard and Buckingham.

7.10 'Updated' Prior Matrix Performance

7.10.1 Following on from the review of the matrix build process, and the initial prior matrix performance, and updated period to peak hour factors, five updated versions of the prior matrices were produced:

- **Prior Matrices Version 1b**

  These prior matrices were an update to the initial matrices. They included a number of corrections to the matrix build processes, which largely (but not wholly) impacted on freight demand within Milton Keynes urban area. The assumptions underpinning these matrices were unchanged.

- **Prior Matrices Version 2**

  These matrices were as '1' but included the updated factors to convert from period to peak hour, and to split 24hr freight demand by time period. Overall, for internal Milton Keynes trips, this resulted in ~1.5% more demand in the AM Peak and inter-peak hours, but ~3% less demand in the PM Peak hour.

- **Prior Matrices Version 3**

  These used the same assumptions as '2', but with the vehicle occupancies used to convert from person to vehicle demand within the synthetic matrix build changed to those derived from the RSIs from those derived from NTS data. In terms of internal Milton Keynes demand, this change in occupancies resulted in around a 5% increase in demand within the AM Peak and inter-peak hours, but a 2% reduction in demand in the PM Peak hour.

- **Prior Matrices Version 4**

  This is an experimental version of the matrices, which built on '3' but used the synthetic demand for more 'local' external-external demand as opposed to SERTM. This area where synthetic demand was used was defined as a ring around Milton Keynes urban area between roughly Northampton, Bedford, Leighton Buzzard and Buckingham. The aim here was to judge whether the synthetic matrices provided a 'better' estimate of demand than SERTM for areas like Newport Pagnell.

- **Prior Matrices Version 5**

  These were based on '2' but included RSI-based sector constraints within the synthetic build, which required some adjustments to the purpose splits within the RSIs to provide greater consistency with NTEM. Updated factors to split freight demand by time period and the updated peak hour factors were also included. Peak hour factors were not applied to SERTM demand, which remained to represent an average hour (which was broadly consistent with analysis of M1 traffic flows), and SERTM demand was used for all external-external movements (i.e. the synthetic process was not used for 'local' external demand).

- **Prior Matrices Version 6**

  These were based on '5' (i.e. containing the RSI constraints within the synthetic) but the synthetic demand was used for trips with an origin and destination within a ring around Milton Keynes urban area (defined to cover Bedford, Leighton Buzzard, Buckingham and Northampton, which was slightly bigger than before).

7.10.2 Matrices 1 to 4 were assigned to network version E, and Matrices 4 and 5 assigned to network I. This network included the extended simulation and other edits as outlined in Section 6.3. Matrices 2,4,5 and 6 to network version J which uses speed flow curves as defined in the Highways England Regional Model coding manual. A screenline calibration comparison is shown in Table 19 to Table 21.

7.10.3 There was a general improvement in calibration with each new version of the matrices with a reduction in the percentage difference between modelled and observed flows.

7.10.4 The change to LGV's and HGV's (mostly occurring within Version 2 of the matrices) has resulted in their errors being in line with cars, although LGV's were -10 to -12% compared to -16 to -23% for car and -18% to -25% for HGV's.

7.10.5 Version 3 marginally reduced the shortfall of trips in the AM and IP periods but marginally increased it in the PM peak period.

7.10.6 Version 4 had the largest impact in terms of car trips as it reduced the error across the RSI, Internal and most notably the Newport Pagnell cordon, although the shortfall on this cordon was still about 5-10% greater than elsewhere in the AM and PM peak. In the IP period it was similar to the non-RSI screenlines.

7.10.7 Version 5 had the largest impact on LGVs, nudging down the percentage difference in trips for Cars with little impact on HGV flows across all screenlines and cordons.

7.10.8 Version 6 provided comparable results for LGV and HGV to version 5 but further reduced the percentage difference in flows for Car. As such Prior Version 6 matrices were taken forward.

Table 19: Cordon and Screenline Summary Comparison – AM

AM PEAK	Version		Cars			LGVs			HGV PCUs				Total Vehs		
	Network	Matrix	Obs	Modelled	Diff	Obs	Modelled	Diff	Obs	Modelled	Diff	HGV Vehs	Obs	Modelled	Diff
ALL Cordons & Screenlines (Excl M1)	E2	1b	112863	90969	-20%	9594	9940	5%	7701	9663	32%	3081	125537	104774	-16%
	E2	2a	112863	92428	-18%	9594	8632	-9%	7701	5564	-24%	3081	125537	103285	-18%
	E2	3a	112863	93762	-17%	9594	8675	-9%	7701	5575	-24%	3081	125537	104667	-17%
	E2	4a	112863	94564	-16%	9594	8566	-10%	7701	5536	-24%	3081	125537	105345	-16%
	I	4	112863	95204	-16%	9594	8429	-12%	7701	5251	-32%	3081	125537	105734	-16%
	I	5	112863	96064	-15%	9594	8817	-8%	7701	5224	-32%	3081	125537	106970	-15%
	J	2	112863	92919	-18%	9594	8538	-11%	7701	5275	-32%	3081	125537	103566	-18%
	J	4	112863	95221	-16%	9594	8451	-12%	7701	5243	-32%	3081	125537	105769	-16%
	J	5	112863	95924	-15%	9594	8862	-8%	7701	5311	-31%	3081	125537	106910	-15%
	J	6	112863	98237	-13%	9594	8795	-8%	7701	5277	-31%	3081	125537	109143	-13%
	K	6	112863	97581	-14%	9594	8777	-9%	7701	5352	-31%	3081	125537	108499	-14%
Excluding RSI	E2	1b	82748	64038	-23%	6293	6818	8%	4472	6319	41%	1789	90827	72990	-20%
	E2	2a	82748	65420	-21%	6293	5610	-11%	4472	3187	-29%	1789	90827	72305	-20%
	E2	3a	82748	66617	-19%	6293	5646	-10%	4472	3197	-29%	1789	90827	73649	-19%
	E2	4a	82748	67202	-19%	6293	5568	-12%	4472	3169	-29%	1789	90827	74027	-18%
	I	4	82748	67678	-18%	6293	5534	-12%	4472	3013	-33%	1789	90830	74417	-18%
	I	5	82748	69168	-16%	6293	5799	-8%	4472	2980	-33%	1789	90830	76159	-16%
	J	2	82748	65644	-21%	6293	5592	-11%	4472	3026	-32%	1789	90830	72447	-20%
	J	4	82748	67571	-18%	6293	5549	-12%	4472	3016	-33%	1789	90830	74326	-18%
	J	5	82748	69021	-17%	6293	5829	-7%	4472	3030	-32%	1789	90830	76062	-16%
	J	6	82748	70306	-15%	6293	5808	-8%	4472	3025	-32%	1789	90830	77324	-15%
	K	6	82748	69896	-16%	6293	5795	-8%	4472	3065	-31%	1789	90830	76917	-15%
RSI Only	E2	1b	30115	26931	-11%	3301	3123	-5%	3229	3344	4%	1292	34710	31784	-8%
	E2	2a	30115	27008	-10%	3301	3022	-8%	3229	2376	-26%	1292	34710	30980	-11%
	E2	3a	30115	27145	-10%	3301	3029	-8%	3229	2378	-26%	1292	34710	31018	-11%
	E2	4a	30115	27362	-9%	3301	2998	-9%	3229	2367	-27%	1292	34710	31318	-10%
	I	4	30115	27526	-9%	3301	2895	-12%	3229	2238	-31%	1292	34707	31317	-10%
	I	5	30115	26896	-11%	3301	3018	-9%	3229	2244	-31%	1292	34707	30812	-11%
	J	2	30115	27275	-9%	3301	2945	-11%	3229	2249	-30%	1292	34707	31120	-10%
	J	4	30115	27650	-8%	3301	2902	-12%	3229	2227	-31%	1292	34707	31443	-9%
	J	5	30115	26903	-11%	3301	3033	-8%	3229	2281	-29%	1292	34707	30848	-11%
	J	6	30115	27931	-7%	3301	2986	-10%	3229	2252	-30%	1292	34707	31818	-8%
	K	6	30115	27685	-8%	3301	2982	-10%	3229	2287	-29%	1292	34707	31582	-9%
Newport Pagnell Cordon	E2	1b	5470	3622	-34%	484	358	-26%	198	165	-17%	79	6032	4046	-33%
	E2	2a	5470	3630	-34%	484	301	-38%	198	113	-43%	79	6032	3976	-34%
	E2	3a	5470	3617	-34%	484	300	-38%	198	113	-43%	79	6032	3962	-34%
	E2	4a	5470	3943	-28%	484	281	-42%	198	108	-46%	79	6032	4267	-29%
	I	4	5470	4622	-16%	484	373	-23%	198	158	-20%	79	6032	5058	-16%
	I	5	5470	4128	-25%	484	405	-16%	198	162	-18%	79	6032	4599	-24%
	J	2	5470	4197	-23%	484	399	-17%	198	174	-12%	79	6032	4666	-23%
	J	4	5470	4527	-17%	484	377	-22%	198	169	-15%	79	6032	4972	-18%
	J	5	5470	4056	-26%	484	403	-17%	198	164	-17%	79	6032	4524	-25%
	J	6	5470	4660	-15%	484	376	-22%	198	154	-22%	79	6032	5097	-16%
	K	6	5470	4362	-20%	484	332	-31%	198	92	-54%	79	6032	4730	-22%

Table 20: Cordon and Screenline Summary Comparison – Inter-Peak

INTER-PEAK	Version		Cars			LGVs			HGV PCUs				Total Vehs		
	Network	Matrix	Obs	Modelled	Diff	Obs	Modelled	Diff	Obs	Modelled	Diff	HGV Vehs	Obs	Modelled	Diff
ALL Cordons & Screenlines (Excl M1)	E2	1b	63926	48437	-24%	9055	7821	-13%	8063	7219	-5%	3225	76207	59146	-22%
	E2	2a	63926	48049	-25%	9055	7963	-12%	8063	5775	-24%	3225	76207	58322	-23%
	E2	3a	63926	48714	-24%	9055	7959	-12%	8063	5757	-24%	3225	76207	58976	-22%
	E2	4a	63926	49509	-22%	9055	7930	-12%	8063	5683	-25%	3225	76207	59711	-21%
	I	4	63926	49053	-23%	9055	7753	-14%	8063	5444	-32%	3225	76207	58984	-23%
	I	5	63926	49365	-23%	9055	8081	-11%	8063	5464	-32%	3225	76207	59632	-22%
	J	2	63926	47759	-25%	9055	7770	-14%	8063	5562	-31%	3225	76207	57754	-24%
	J	4	63926	49239	-23%	9055	7724	-15%	8063	5542	-31%	3225	76207	59180	-22%
	J	5	63926	49451	-23%	9055	8071	-11%	8063	5559	-31%	3225	76207	59746	-22%
	J	6	63926	50329	-21%	9055	8071	-11%	8063	5516	-32%	3225	76207	60606	-20%
	K	6	63926	49965	-22%	9055	7997	-12%	8063	5576	-31%	3225	76207	60193	-21%
Excluding RSI	E2	1b	48942	34885	-29%	6218	5149	-17%	4888	4322	-12%	1955	57115	41559	-27%
	E2	2a	48942	34525	-29%	6218	5302	-15%	4888	3306	-32%	1955	57115	41149	-28%
	E2	3a	48942	35117	-28%	6218	5298	-15%	4888	3293	-33%	1955	57115	41822	-27%
	E2	4a	48942	35727	-27%	6218	5273	-15%	4888	3244	-34%	1955	57115	42226	-26%
	I	4	48942	35434	-28%	6218	5193	-16%	4888	3130	-36%	1955	57115	41879	-27%
	I	5	48942	35802	-27%	6218	5479	-12%	4888	3137	-36%	1955	57115	42536	-26%
	J	2	48942	34379	-30%	6218	5192	-16%	4888	3186	-35%	1955	57115	40846	-28%
	J	4	48942	35527	-27%	6218	5162	-17%	4888	3178	-35%	1955	57115	41960	-27%
	J	5	48942	35809	-27%	6218	5460	-12%	4888	3183	-35%	1955	57115	42541	-26%
	J	6	48942	36251	-26%	6218	5456	-12%	4888	3158	-35%	1955	57115	42970	-25%
	K	6	48942	36173	-26%	6218	5416	-13%	4888	3177	-35%	1955	57115	42860	-25%
RSI Only	E2	1b	14984	13552	-10%	2838	2673	-6%	3175	2897	-9%	1270	19092	17587	-8%
	E2	2a	14984	13524	-10%	2838	2662	-6%	3175	2469	-22%	1270	19092	17173	-10%
	E2	3a	14984	13598	-9%	2838	2662	-6%	3175	2464	-22%	1270	19092	17154	-10%
	E2	4a	14984	13782	-8%	2838	2657	-6%	3175	2439	-23%	1270	19092	17485	-8%
	I	4	14984	13619	-9%	2838	2560	-10%	3175	2314	-27%	1270	19092	17105	-10%
	I	5	14984	13563	-9%	2838	2602	-8%	3175	2326	-27%	1270	19092	17096	-10%
	J	2	14984	13380	-11%	2838	2578	-9%	3175	2376	-25%	1270	19092	16908	-11%
	J	4	14984	13713	-8%	2838	2562	-10%	3175	2364	-26%	1270	19092	17220	-10%
	J	5	14984	13643	-9%	2838	2611	-8%	3175	2377	-25%	1270	19092	17204	-10%
	J	6	14984	14077	-6%	2838	2615	-8%	3175	2358	-26%	1270	19092	17635	-8%
	K	6	14984	13793	-8%	2838	2581	-9%	3175	2399	-24%	1270	19092	17333	-9%
Newport Pagnell Cordon	E2	1b	2677	1811	-32%	458	286	-38%	231	114	-51%	92	3227	2143	-34%
	E2	2a	2677	1808	-32%	458	284	-38%	231	105	-55%	92	3227	2134	-34%
	E2	3a	2677	1863	-30%	458	285	-38%	231	105	-55%	92	3227	2189	-32%
	E2	4a	2677	2091	-22%	458	272	-41%	231	101	-56%	92	3227	2403	-26%
	I	4	2677	2181	-19%	458	290	-37%	231	114	-51%	92	3227	2516	-22%
	I	5	2677	2001	-25%	458	327	-29%	231	118	-49%	92	3227	2375	-26%
	J	2	2677	1847	-31%	458	300	-34%	231	119	-49%	92	3227	2195	-32%
	J	4	2677	2150	-20%	458	288	-37%	231	115	-50%	92	3227	2484	-23%
	J	5	2677	1968	-26%	458	323	-29%	231	118	-49%	92	3227	2339	-28%
	J	6	2677	2167	-19%	458	312	-32%	231	111	-52%	92	3227	2523	-22%
	K	6	2677	2073	-23%	458	305	-33%	231	81	-65%	92	3227	2410	-25%

Table 21: Cordon and Screenline Summary Comparison - PM

PM PEAK	Version		Cars			LGVs			HGV PCUs				Total Vehs		
	Network	Matrix	Obs	Modelled	Diff	Obs	Modelled	Diff	Obs	Modelled	Diff	HGV Vehs	Obs	Modelled	Diff
ALL Cordons & Screenlines (Excl M1)	E2	1b	115956	90049	-23%	8353	5990	-27%	3385	5426	75%	1354	125663	98209	-22%
	E2	2a	115956	90209	-22%	8353	7404	-10%	3385	2532	-18%	1354	125663	98625	-22%
	E2	3a	115956	89504	-23%	8353	7397	-10%	3385	2539	-18%	1354	125663	97917	-22%
	E2	4a	115956	89921	-23%	8353	7324	-10%	3385	2524	-18%	1354	125663	98255	-22%
	I	4	115956	89942	-22%	8353	7231	-13%	3385	2464	-27%	1354	125663	98159	-22%
	I	5	115956	93174	-20%	8353	7529	-10%	3385	2597	-23%	1354	125663	101741	-19%
	J	2	115956	90230	-22%	8353	7319	-12%	3385	2518	-26%	1354	125663	98556	-22%
	J	4	115956	90021	-22%	8353	7241	-13%	3385	2494	-26%	1354	125663	98260	-22%
	J	5	115956	93275	-20%	8353	7538	-10%	3385	2619	-23%	1354	125663	101860	-19%
	J	6	115956	94532	-18%	8353	7480	-10%	3385	2584	-24%	1354	125663	103046	-18%
	K	6	115956	94266	-19%	8353	7426	-11%	3385	2666	-21%	1354	125663	102758	-18%
Excluding RSI	E2	1b	85548	62631	-27%	5525	3393	-39%	2003	3588	79%	801	91874	67152	-27%
	E2	2a	85548	62766	-27%	5525	4852	-12%	2003	1436	-28%	801	91874	68193	-26%
	E2	3a	85548	61976	-28%	5525	4845	-12%	2003	1444	-28%	801	91874	67515	-27%
	E2	4a	85548	62293	-27%	5525	4784	-13%	2003	1433	-28%	801	91874	67723	-26%
	I	4	85548	62603	-27%	5525	4777	-14%	2003	1398	-30%	801	91874	67940	-26%
	I	5	85548	65961	-23%	5525	5033	-9%	2003	1461	-27%	801	91874	71579	-22%
	J	2	85548	63128	-26%	5525	4823	-13%	2003	1425	-29%	801	91874	68521	-25%
	J	4	85548	62701	-27%	5525	4782	-13%	2003	1414	-29%	801	91874	68048	-26%
	J	5	85548	66066	-23%	5525	5025	-9%	2003	1470	-27%	801	91874	71679	-22%
	J	6	85548	66655	-22%	5525	5001	-9%	2003	1454	-27%	801	91874	72238	-21%
	K	6	85548	66803	-22%	5525	4959	-10%	2003	1497	-25%	801	91874	72361	-21%
RSI Only	E2	1b	30408	27418	-10%	2828	2597	-8%	1382	1838	33%	553	33789	31057	-8%
	E2	2a	30408	27443	-10%	2828	2552	-10%	1382	1095	-21%	553	33789	30433	-10%
	E2	3a	30408	27528	-9%	2828	2551	-10%	1382	1095	-21%	553	33789	30402	-10%
	E2	4a	30408	27628	-9%	2828	2540	-10%	1382	1092	-21%	553	33789	30531	-10%
	I	4	30408	27339	-10%	2828	2454	-13%	1382	1066	-23%	553	33789	30219	-11%
	I	5	30408	27213	-11%	2828	2495	-12%	1382	1135	-18%	553	33789	30162	-11%
	J	2	30408	27101	-11%	2828	2496	-12%	1382	1093	-21%	553	33789	30035	-11%
	J	4	30408	27320	-10%	2828	2460	-13%	1382	1080	-22%	553	33789	30212	-11%
	J	5	30408	27209	-11%	2828	2513	-11%	1382	1149	-17%	553	33789	30181	-11%
	J	6	30408	27876	-8%	2828	2479	-12%	1382	1129	-18%	553	33789	30807	-9%
	K	6	30408	27463	-10%	2828	2467	-13%	1382	1168	-15%	553	33789	30398	-10%
Newport Pagnell Cordon	E2	1b	5459	3549	-35%	489	256	-48%	99	101	2%	40	5988	3845	-36%
	E2	2a	5459	3554	-35%	489	231	-53%	99	64	-35%	40	5988	3811	-36%
	E2	3a	5459	3599	-34%	489	231	-53%	99	64	-35%	40	5988	3856	-36%
	E2	4a	5459	3844	-30%	489	215	-56%	99	61	-38%	40	5988	4084	-32%
	I	4	5459	4247	-22%	489	254	-48%	99	78	-22%	40	5988	4532	-24%
	I	5	5459	4034	-26%	489	296	-40%	99	91	-8%	40	5988	4366	-27%
	J	2	5459	4041	-26%	489	275	-44%	99	81	-18%	40	5988	4348	-27%
	J	4	5459	4268	-22%	489	255	-48%	99	76	-23%	40	5988	4553	-24%
	J	5	5459	4035	-26%	489	286	-42%	99	86	-13%	40	5988	4355	-27%
	J	6	5459	4322	-21%	489	277	-43%	99	77	-22%	40	5988	4629	-23%
	K	6	5459	4127	-24%	489	260	-47%	99	48	-51%	40	5988	4406	-26%

7.11 Prior Matrix Factoring

7.11.1 On the basis that the Initial assignments using the prior matrix showed a shortage of traffic within the RSI cordon, it was decided to factor up trips within the RSI cordon or those crossing it. This was felt a reasonable approach given that the trips within the RSI cordon were synthetic and not based on observed data. The factors were calculated from a comparison of modelled and observed flow data within the RSI cordon using an earlier version of the network and version 6 of the prior matrices. Table 22 shows the factors used by time period and vehicle class.

Table 22: Overall Prior Matrix Adjustment Factors by Vehicle Class, Time Period and O/D

		Car		LGV		HGV	
		Internal	External	Internal	External	Internal	External
AM	Internal	1.184	1.101	1.086	1.095	1.439	1.332
	External	1.081	1.000	1.117	1.000	1.483	1.000
IP	Internal	1.353	1.085	1.148	1.106	1.446	1.415
	External	1.088	1.000	1.093	1.000	1.242	1.000
PM	Internal	1.281	1.111	1.114	1.118	1.270	1.222
	External	1.101	1.000	1.174	1.000	1.148	1.000

8. Network Calibration

8.1.1 The network calibration process was conducted to identify issues in the network causing long unrealistic delay, excessive queued flows or too much supressed demand. This was carried out in tandem with the network updates and for example identified the issue of speed flow curve capacities in the buffer network.

8.2 Stress Test

8.2.1 A final 'stress' test was carried out on the network based around artificially increasing the matrix flows to identify pinch points in the network. Trips in the prior matrix were increased by 25% and assigned to the network. In this way delays between the test run and the original prior matrix assignment could be compared and very large increases in delay at unrealistic or unexpected pinch points in the model identified. This test was carried out using the AM and PM models but not the IP model due to lower flows which may not trigger such issues in the network.

8.2.2 As shown in Figure 33 and Figure 34 there were significant increases in delay with the 25% increase in trips. However no specific issues were highlighted. The largest delay increase in the AM model was at the junction between Newport Road and the A509 just north of M1 J14, with an increase of 343 seconds, or just under 6 minutes. The largest increase in delay in the PM was Northbound on Brickhill Street at the junction with H3 Monks Way, an increase of 221 seconds, or nearly four minutes.

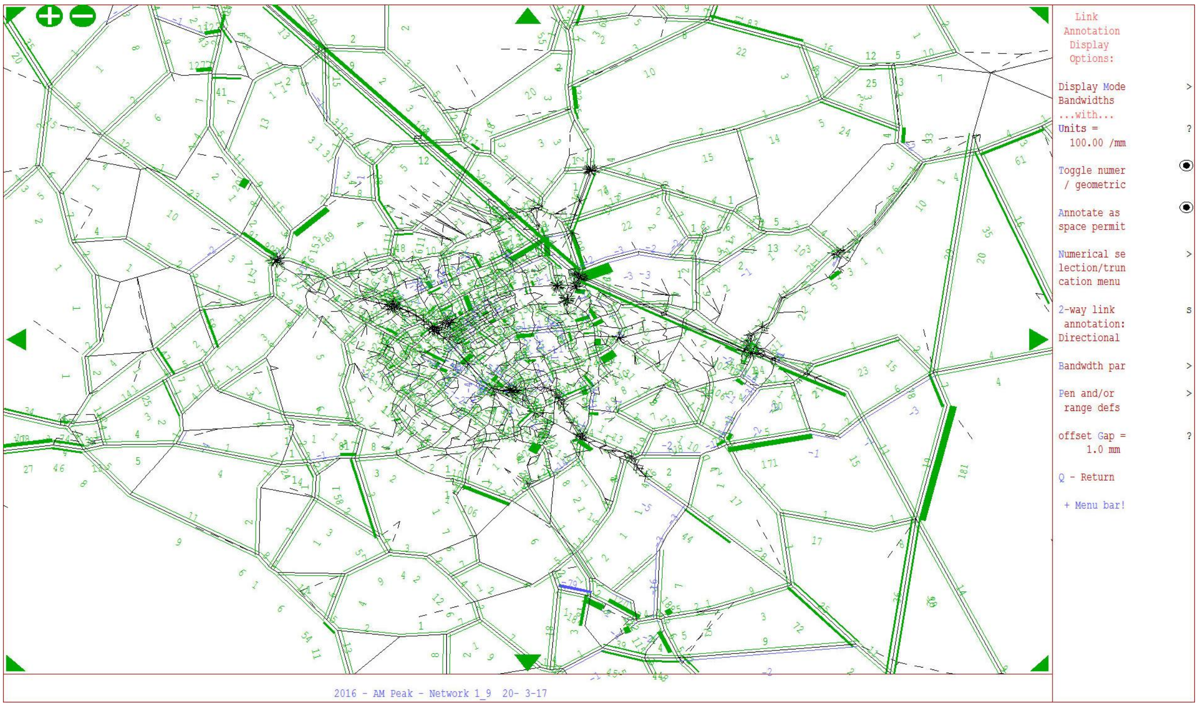

Figure 33. Total delay comparison, Stress Test – Prior - AM

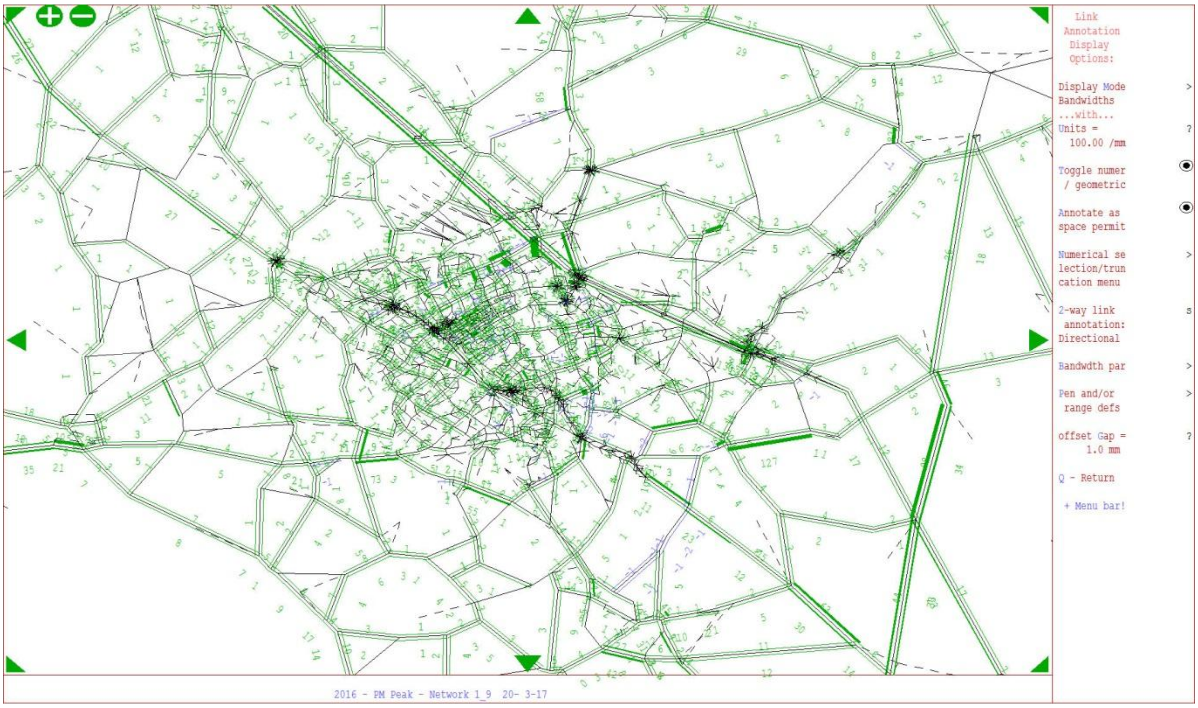

Figure 34. Total delay comparison, Stress Test – Prior - PM

9. Route Choice Calibration and Validation

9.1 Introduction

9.1.1 Further checks were made to ensure that traffic was taking sensible routes between a selection of zone pairs covering a number of key routes across and into Milton Keynes. In parallel with this exercise, flows on key roads in Milton Keynes were checked to ensure that their origins and destinations were sensible.

9.2 Route choice Calibration

9.2.1 Route choice calibration was conducted as part of the wider count and journey time calibration and validation process. Where it was thought count differences were due to inappropriate routing, measures were taken to adjust speeds or change speed flow curves as appropriate to address the routing in tandem with improving the count calibration.

9.2.2 A final check on routing calibration was conducted by using 'forest plots' between zone pairs covering a number of routes across and into Milton Keynes. The forest plots are similar to tree paths but show the percentage of assigned traffic from the matrix as the result of the iterative assignment process.

9.2.3 An example of the route choice checks is between Bedford and Milton Keynes where the A421 and A422 offer alternative route choices. Figure 35 shows the forest plot from South Bedford to Central Milton Keynes for the AM period with traffic routing via the A421. Figure 36 shows a forest plot from North Bedford to Central Milton Keynes for the AM indicating that traffic routes via the A422.

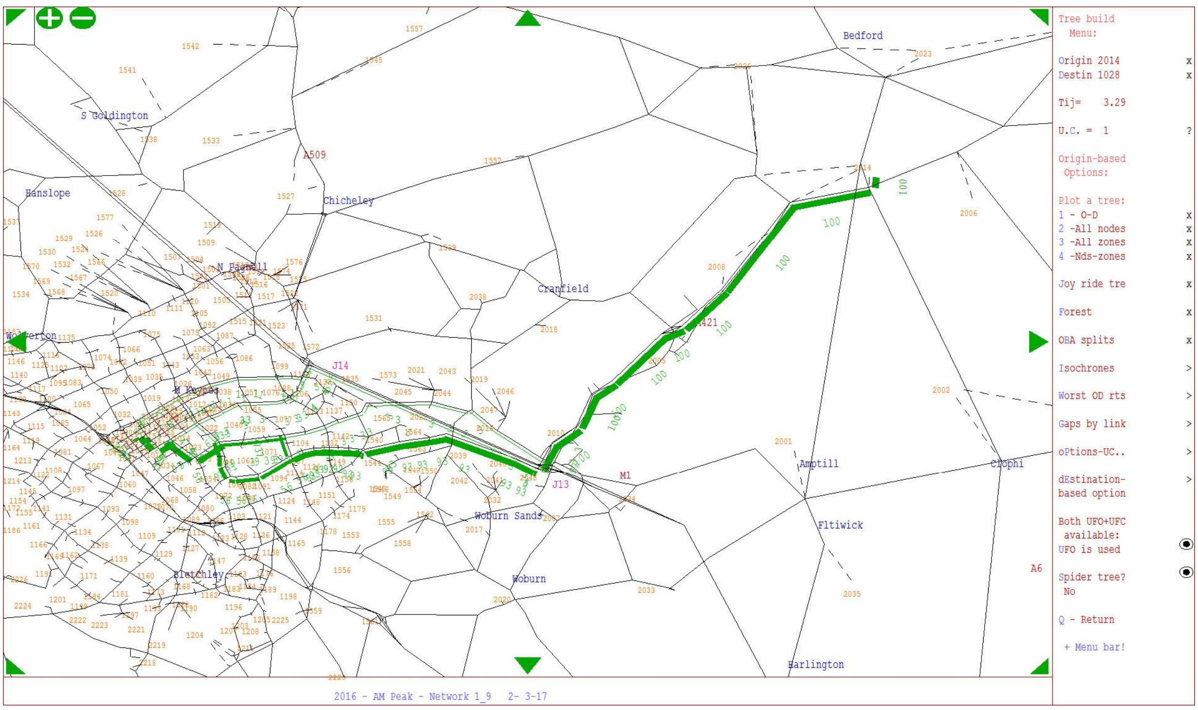

Figure 35. Forest Plot - South Bedford to Central Milton Keynes

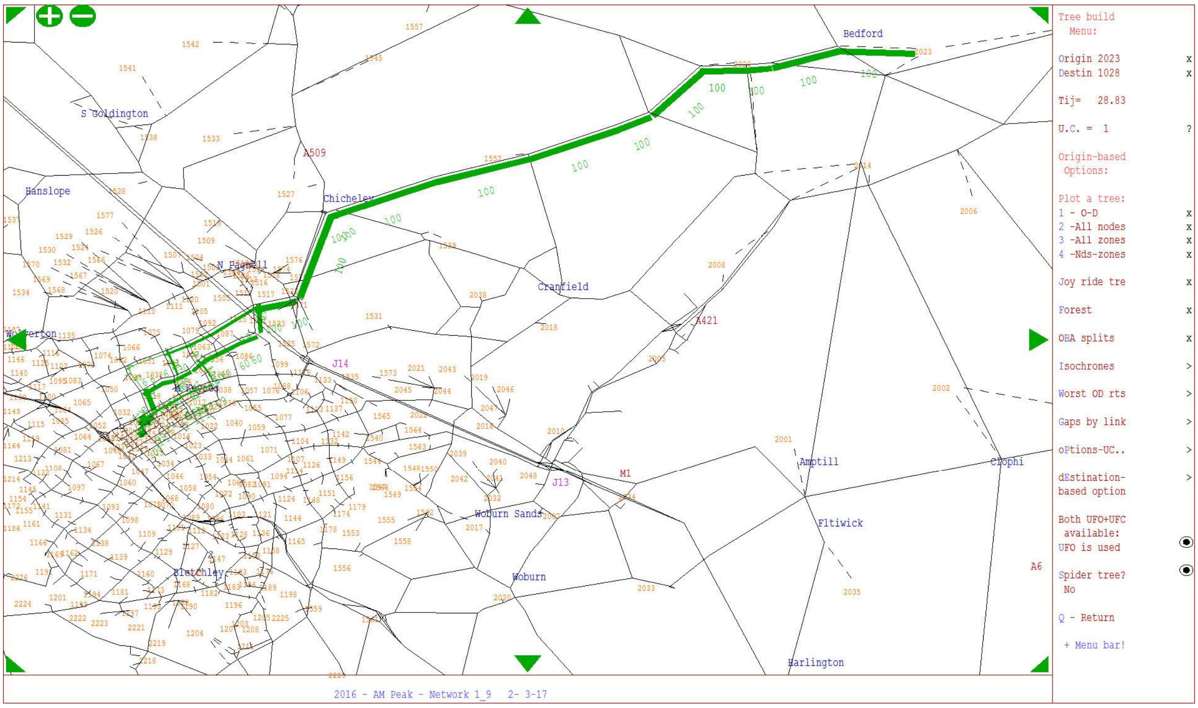

Figure 36. Forest Plot – North Bedford to Central Milton Keynes

9.2.4 All the forest plots for the final post matrix estimation (ME) assignment are shown in Appendix A. These consist of trips between the following origins and destination in each direction for each time period:

- North Bedford to central Milton Keynes
- South Bedford to central Milton Keynes
- Leighton Buzzard to central Milton Keynes
- South Buckingham to South Bedford
- North Buckingham to South Bedford
- Northampton to Luton
- Potterspury to Woburn Sands
- South Buckingham to Milton Keynes
- Bletchley to central Milton Keynes
- Wolverton to central Milton Keynes
- Newport Pagnell to Milton Keynes

9.2.5 Overall it can be seen that the model behaves realistically and gives sensible route choices.

9.3 Route Choice Validation

9.3.1 To check routing within the model a series of select link analyses were conducted on three corridors in Milton Keynes, the A421, A5 and A509. This was to check that the directions from where traffic was originating from and traveling to, were sensible.

9.3.2 Appendix B shows the results in full, with Figure 37 to Figure 39 showing an example of each select link corridor analysis for a single direction.

9.3.3 Figure 37 shows the traffic routing SB along the A5 comes from the A422, A5 to the north and A508, travelling into Milton Keynes or continuing down the A5 and A4146 all of which are sensible route choices.

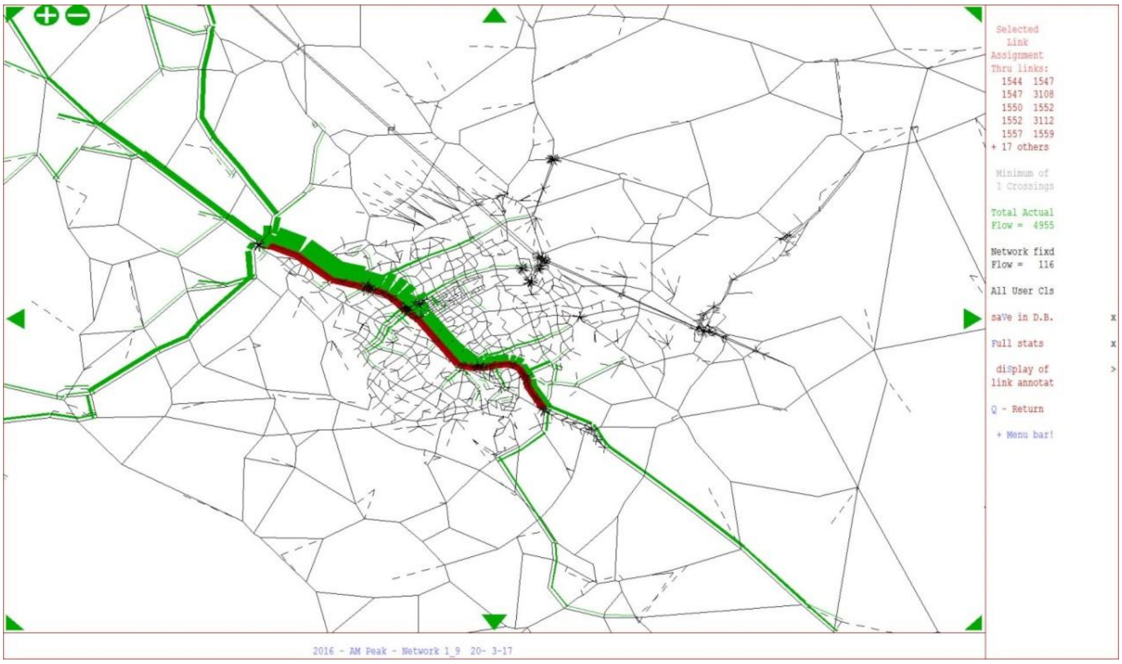

Figure 37. Select Link – A5 Corridor, SB – AM

9.3.4 Figure 38 shows the majority of traffic WB along the A421 originates east of M1 along the A421 towards Bedford and from M1 NB south of J13. Most traffic is destined towards Milton Keynes with a significant number continuing toward Buckingham.

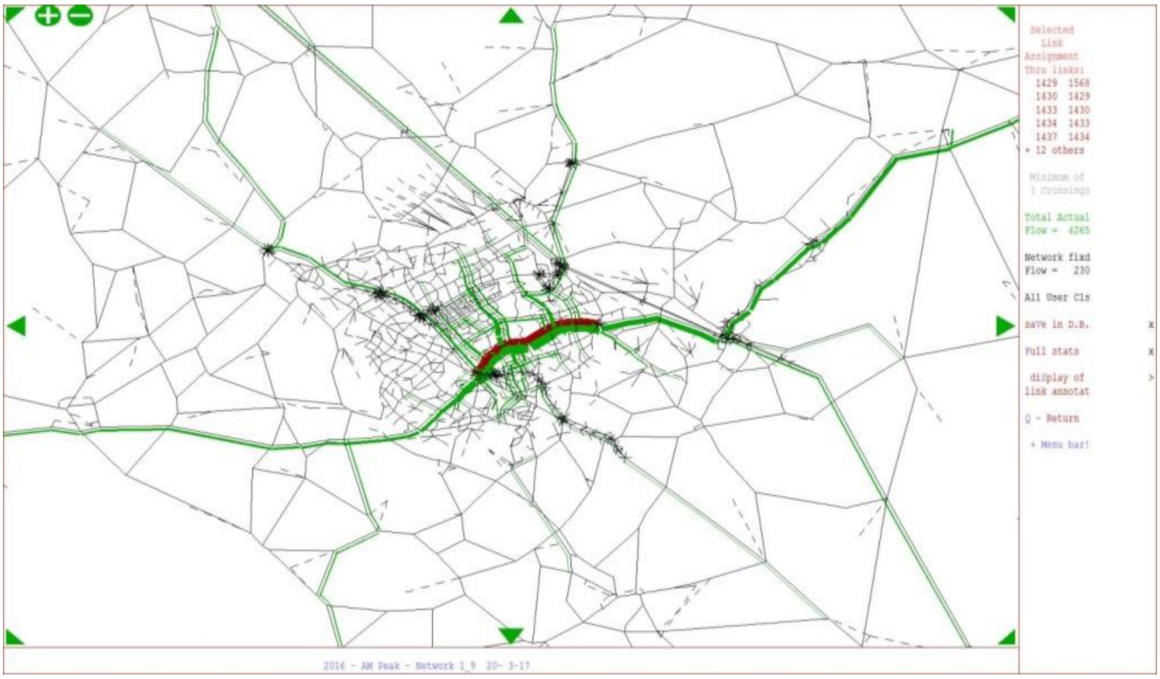

Figure 38. Select Link – A421 Corridor, WB - AM

9.3.5 It can be seen in Figure 39 that the majority of the traffic using the A509 is travelling into Milton Keynes originating from A509 to the North and the A422. Again this routing is considered appropriate.

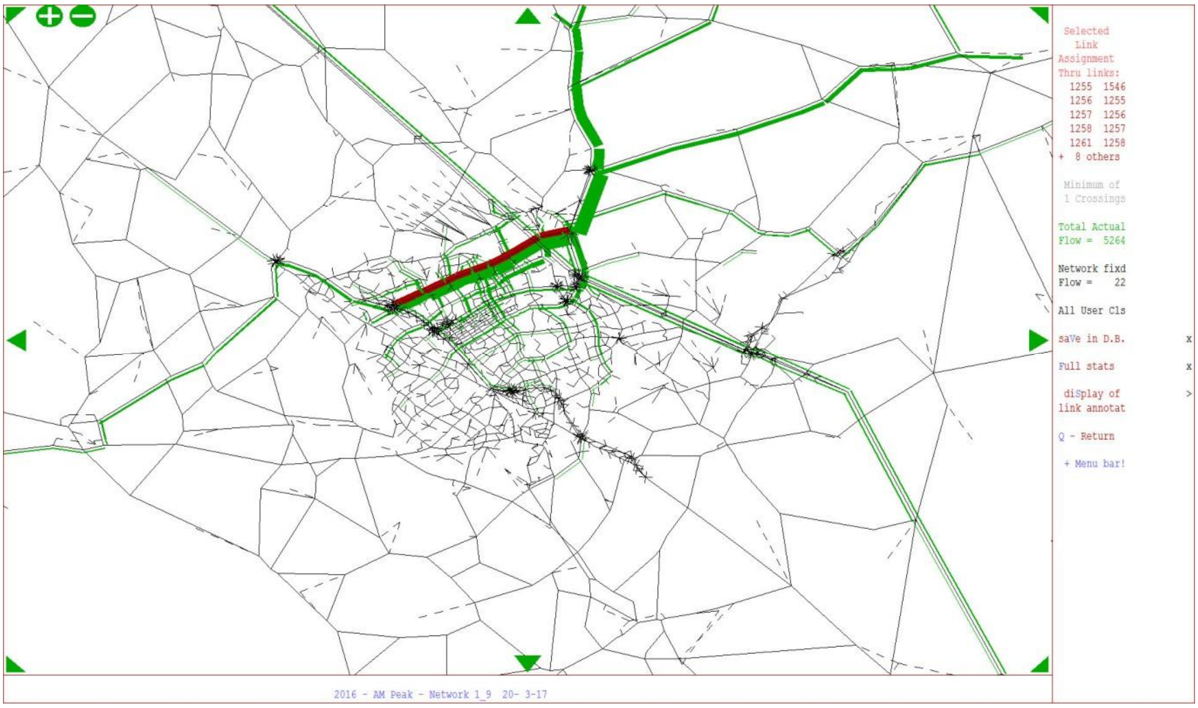

Figure 39. Select Link – A509 Corridor, WB - AM

Trip Matrix Calibration and Validation

10.1 Introduction

10.1.1 This section provides an overview of the adjustment process used to produce assignments that replicated the observed set of traffic counts on the links described in section 5 within appropriate tolerances. This followed a two staged process below;

- The network was calibrated by comparing modelled results produced using the prior matrices, using link journey times and screenline flows.
- The model was then further adjusted primarily with amendments to the matrix using Matrix Estimation (ME) but also further network edits where appropriate, so that the differences between modelled and observed data sets are within acceptable tolerances.

10.2 Matrix Estimation and Monitoring

10.2.1 Matrix estimation was conducted using the SATPIJA and SATME2 modules of the SATURN modelling package. The process adjusts the matrix by factoring origin and destination pairs to better match the observed calibration count data, with a view to better matching the validation counts also. The process is purely mathematical with no behavioural basis so ideally it should be used for refinement rather than significant changes. Hence the aim to minimise the impacts of ME to the prior matrix in line with section 4.2 of WebTAG Unit M3.1, Highway Assignment Modelling (January 2014). As such the network calibration was conducted using the factored prior matrices to a suitable point before running ME.

10.2.2 The Matrix Estimation Process is shown in Figure 40. As discussed in Section 7.11 the original prior matrices were factored up to address the general shortfall of trips within the RSI Cordon. It was these factored prior matrices that were used in the matrix estimation process.

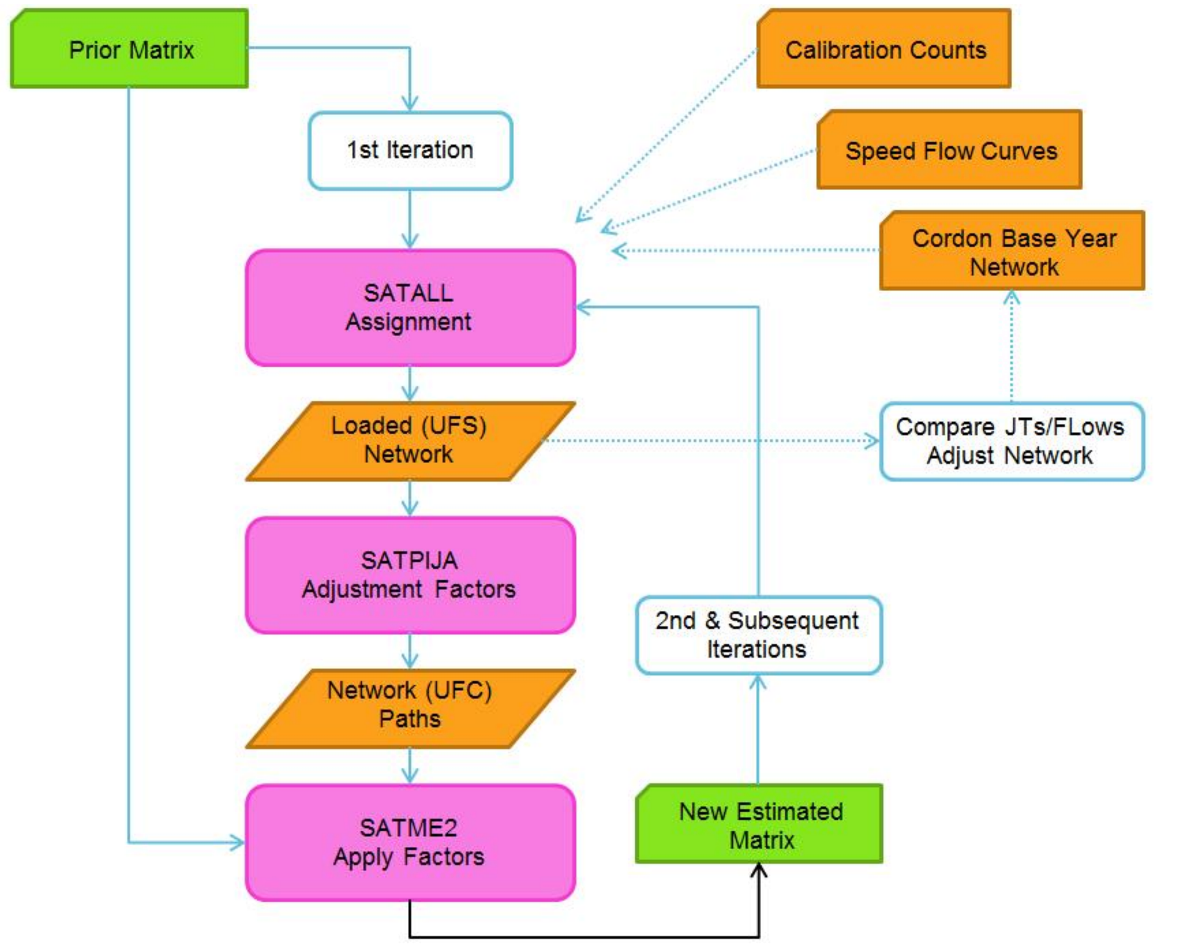

Figure 40. SATURN's 'ME2' Matrix Estimation Process

10.3 Final Results

10.3.1 To measure the impact of the ME process the following measures were used:

- Scatter plots and regression of modelled against observed flows,
- Post and factored prior ME trip length distributions,
- Post and factored prior ME trip end scatter plots and regressions statistics.

10.3.2 WebTAG guidelines (Section 3.2 TAG Unit M3.1, Highway Assignment Modelling Jan 2014) were used as a measure of the model validation.

10.4 Comparison of Modelled Flows against calibration counts

10.4.1 Modelled and observed calibration counts are compared with a linear regression trend line in Figure 41 to Figure 43. These show that calibration was to a good standard. The R2 values being 0.997, 0.999 and 0.999 for AM, IP and PM respectively with the slopes all close to a value of 1.

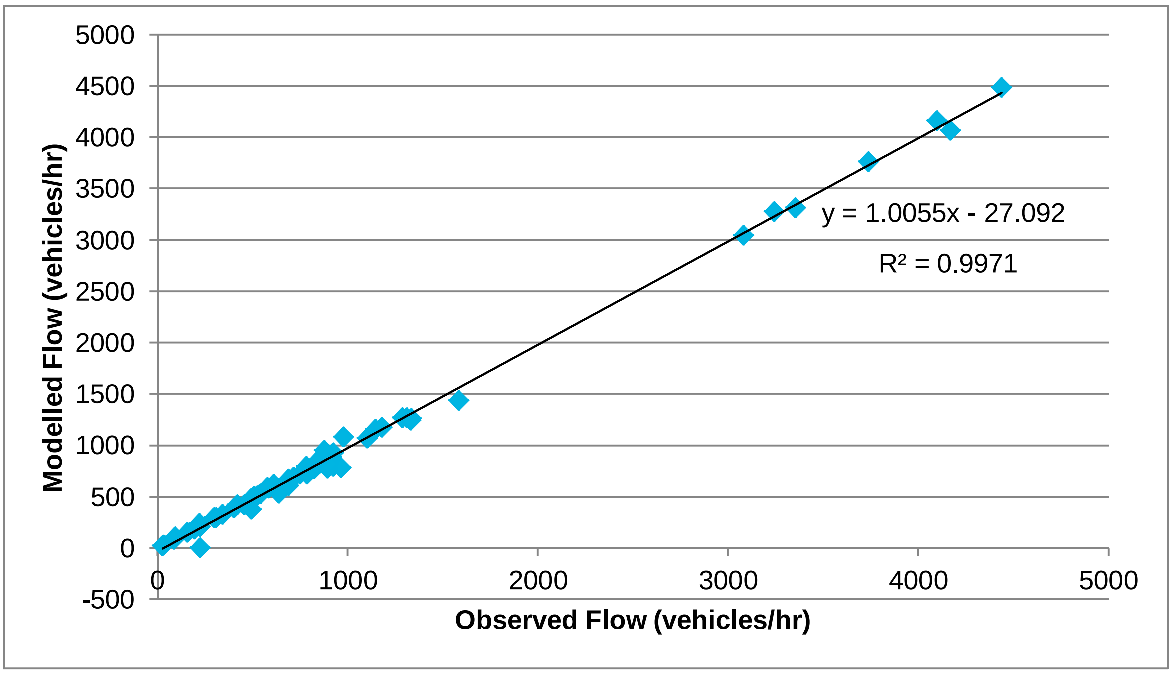

Figure 41. Comparison of Modelled against Observed Calibration Flows - AM

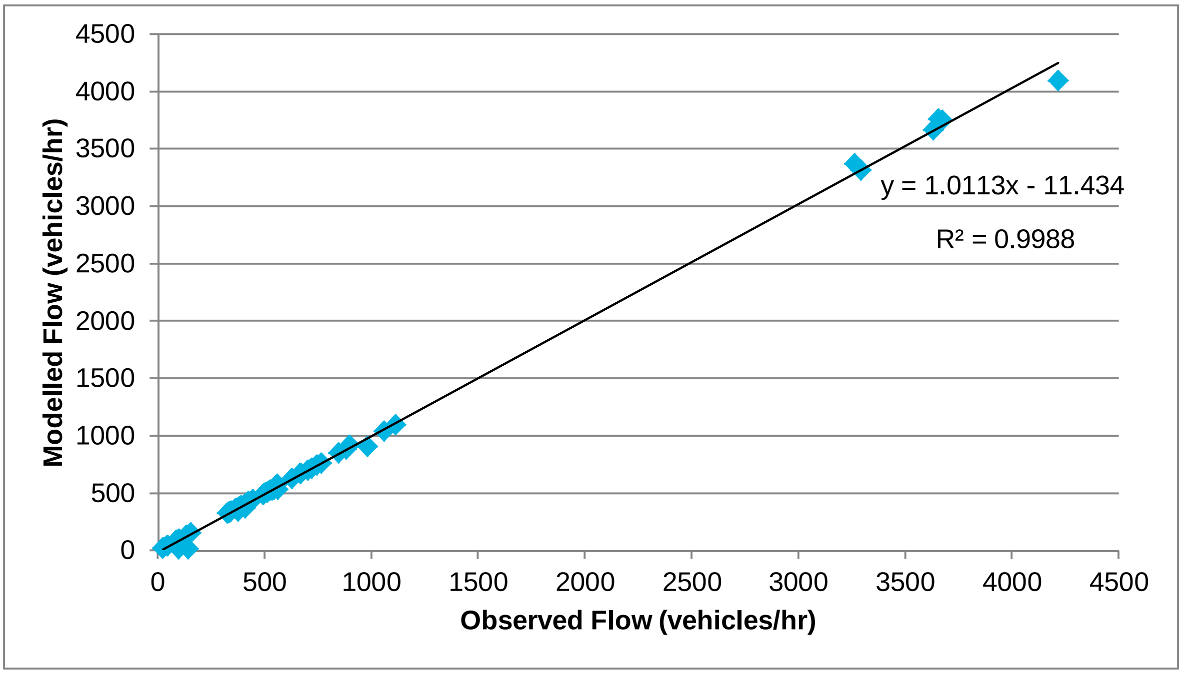

Figure 42. Comparison of Modelled against Observed Calibration Flows - IP

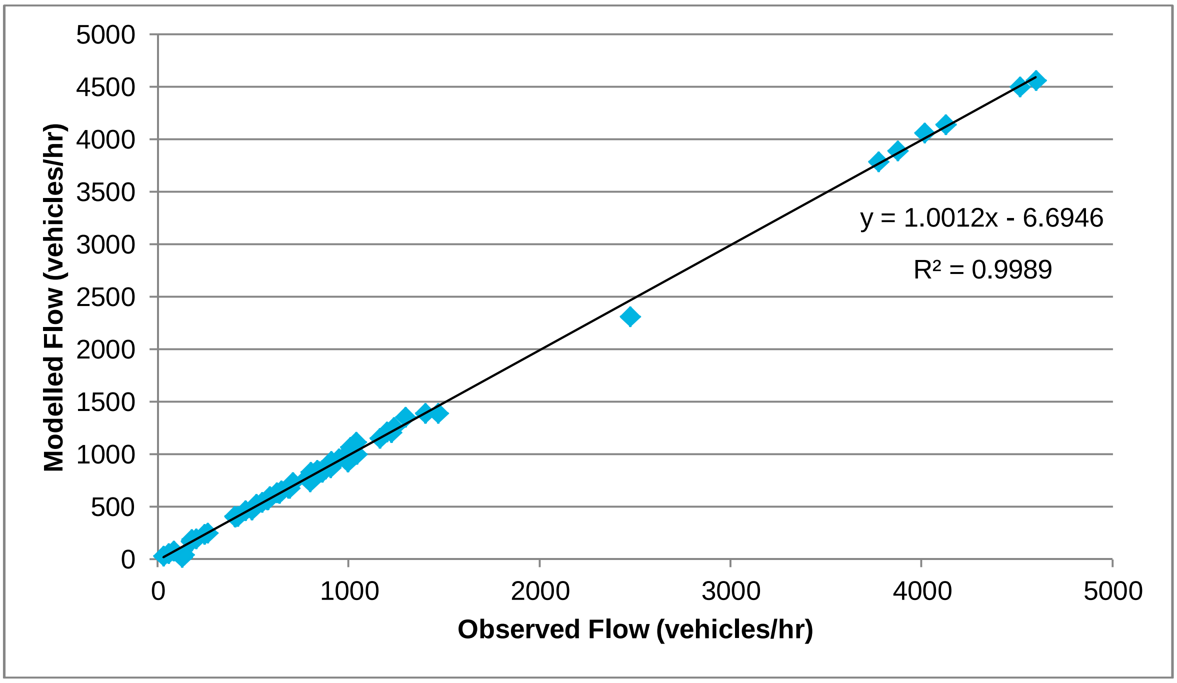

Figure 43. Comparison of Modelled against Observed Calibration Flows - PM

10.5 Post ME against prior ME Trip Length Distributions

10.5.1 Changes in trip length distribution as a result of the matrix estimation process were assessed by vehicle type to ensure the matrices had not been distorted by any adjustments applied as part of the process. To better assess the impacts the trips defined as external to external (with both origin and destination outside the RSI cordon see paragraph 7.3.1) were excluded from the analysis.

10.5.2 Figure 44 to Figure 46 show the Trip Length Distribution (TLDs) post ME against the factored pre ME assignments for the AM period for Car, LGV and HGV. The corresponding plots along with the AM plots are in Appendix C.

10.5.3 The TLD comparisons are similar for car and LGV, with an increase of shorter trips in the 10 to 15km range for car. HGV shows more variation across different trip length ranges but still with an increase in shorter distance trips. The plots for IP and PM show a similar outcome. This is considered logical as in general trips within the RSI cordon in the prior matrix assignment were low so an increase in shorter local trips would be expected.

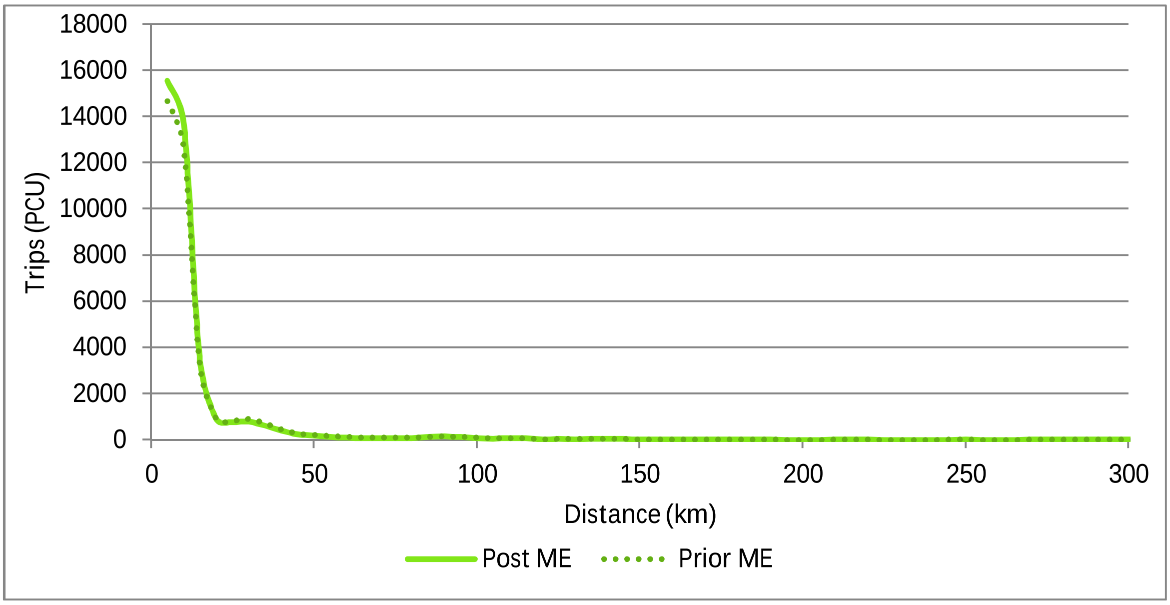

Figure 44. Trip Length Distribution Pre- and Post-ME: AM Car

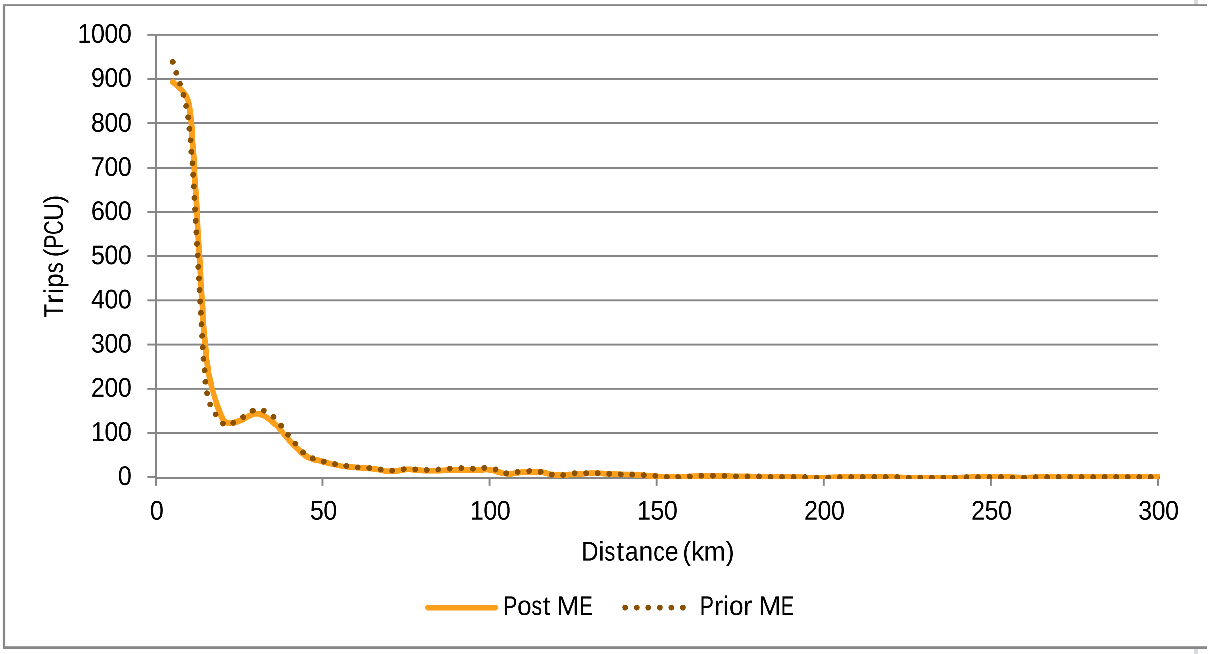

Figure 45. Trip Length Distribution Pre- and Post-ME: AM LGV

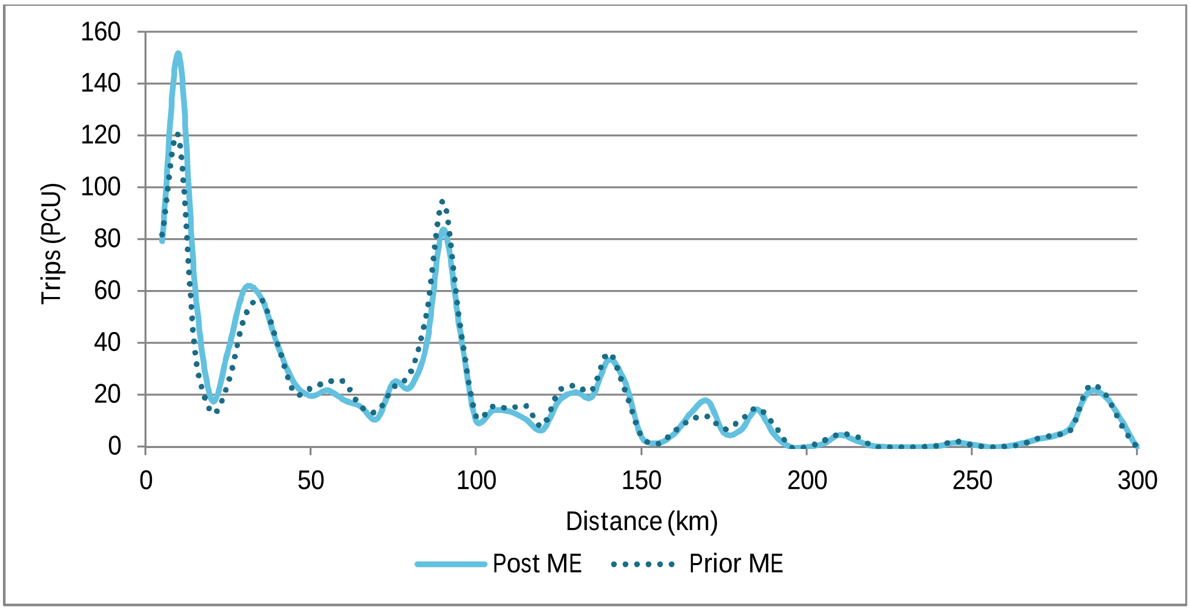

Figure 46. Trip Length Distribution Pre- and Post-ME: AM HGV

10.5.4 The mean distance travelled was calculated for both the post and prior assignments with the results shown in Table 23 to Table 25. As with the TLD plots, these tables exclude the external to external trips. The post ME averages should ideally be within 5% of the prior ME averages. The change in mean distance for car across each time period is close to this value with the AM difference being marginally greater. HGV demand has the largest change in mean trip distance which is also greater in the inter peak period. Considering the level of uncertainty in the prior matrices due to lack of observed data the results are considered satisfactory.

Table 23: Change in Average Trip Length Pre- and Post-ME (Excluding Ext Origins): AM

	Car	LGV	HGV	All Vehicles
Prior Mean Trip Length (km)	12.7	21.5	87.4	15.4
Post Mean Trip Length (km)	11.9	20.3	81.3	14.4
Percentage Change	-6.3%	-5.7%	-7.0%	-6.8%

Table 24: Change in Average Trip Length Pre- and Post-ME (Excluding Ext Origins): IP

	Car	LGV	HGV	All Vehicles
Prior Mean Trip Length (km)	12.4	20.4	88.2	16.5
Post Mean Trip Length (km)	11.6	19.5	75.1	15.5
Percentage Change	-6.0%	-4.4%	-14.8%	-6.0%

Table 25: Change in Average Trip Length Pre- and Post-ME (Excluding Ext Origins): PM

	Car	LGV	HGV	All Vehicles
Prior Mean Trip Length (km)	15.9	23.1	88.3	17.0
Post Mean Trip Length (km)	15.0	21.7	83.9	16.2
Percentage Change	-6.0%	-5.8%	-4.9%	-5.0%

10.6 Comparison of post and prior ME Matrix Totals

10.6.1 The internal and external sector totals are listed by user class for post and prior matrix estimation in Table 26 to Table 28 indicating the impacts of M.E. As anticipated the largest changes are within the internal to internal trips with minimal impact on external to external. HGV trips have the largest percentage changes but this is in part due to the lower absolute numbers.

Table 26: Change in Matrix Totals by Sector (Internal/External) Pre- and Post-ME: AM

AM		User Class Total									
		Car Commute		Car EB		Car Other		LGV		HGV	
		Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.
Prior Matrix	Int.	13,645	4,059	2,112	792	13,009	3,049	1,799	1,217	225	930
	Ext.	11,207	2,102,010	1,296	474,540	5,143	2,022,186	1,446	415,866	1,234	176,393
Post ME Matrix	Int.	14,643	3,779	2,197	767	13,689	3,179	1,839	1,191	279	892
	Ext.	11,532	2,101,933	1,294	474,361	5,101	2,022,034	1,449	415,562	1,388	174,656
Change	Int.	7.3%	-6.9%	4.0%	-3.2%	5.2%	4.3%	2.2%	-2.1%	24.0%	-4.1%
	Ext.	2.9%	0.0%	-0.2%	0.0%	-0.8%	0.0%	0.2%	-0.1%	12.5%	-1.0%

Table 27: Change in Matrix Totals by Sector (Internal/External) Pre- and Post-ME: IP

IP		User Class Total									
		Car Commute		Car EB		Car Other		LGV		HGV	
		Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.
Prior Matrix	Int.	2,683	821	1,457	699	14,532	4,815	1,826	1,164	235	1,024
	Ext.	994	722,051	682	410,352	4,397	2,857,638	1,101	400,545	1,071	170,421
Post ME Matrix	Int.	3,074	795	1,621	690	16,380	4,854	1,935	1,162	430	1,127
	Ext.	999	722,089	696	410,400	4,468	2,857,885	1,095	400,688	1,129	170,422
Change	Int.	14.6%	-3.2%	11.3	-1.3%	12.7%	0.8%	6.0%	-0.2%	83.0%	10.1%
	Ext.	0.5%	0.0%	2.1%	0.0%	1.6%	0.0%	-0.5%	0.0%	5.4%	0.0%

Table 28: Change in Matrix Totals by Sector (Internal/External) Pre- and Post-ME: PM

PM		User Class Total									
		Car Commute		Car EB		Car Other		LGV		HGV	
		Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.
Prior Matrix	Int.	10,989	7,705	2,060	900	15,465	7,880	1,574	1,112	85	367
	Ext.	3,697	1,970,865	533	497,073	5,428	2,903,276	1,174	327,349	410	111,591
Post ME Matrix	Int.	12,562	7,454	2,322	886	17,567	7,757	1,636	1,083	134	486
	Ext.	3,651	1,971,202	552	497,158	5,842	2,903,620	1,149	327,211	462	110,977
Change	Int.	14.3%	-3.3%	12.7	-1.6%	13.6%	-1.6%	3.9%	-2.6%	57.6%	32.4%
	Ext.	-1.2%	0.0%	3.6%	0.0%	7.6%	0.0%	-2.1%	0.0%	12.7%	-0.6%

10.7 Comparison of matrix trip end totals before and after ME

10.7.1 The impact of ME on the matrix trip ends is shown in Figure 47 to Figure 52 as scatter plots and regressions by time period for origins and destinations. External to External trips have been excluded from the plots to greater assess the impacts. For each plot the x-axis represents the factored prior matrix and the y axis, the post ME matrix.

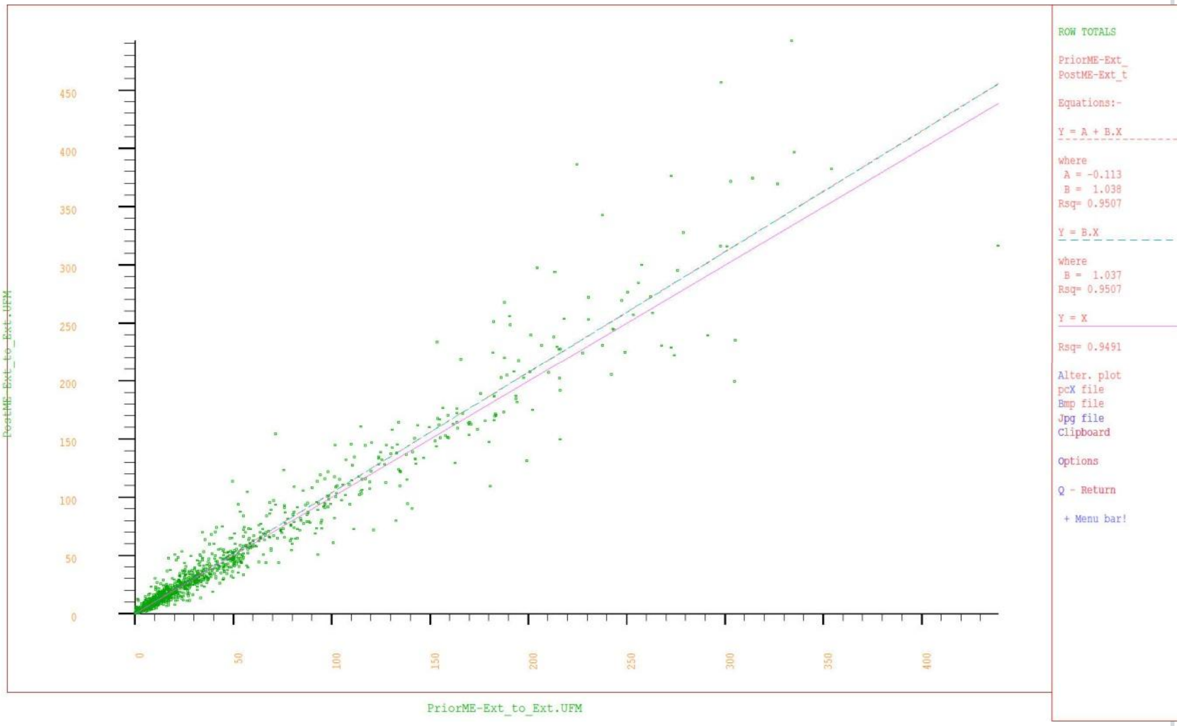

Figure 47. Trip End Changes Pre- and Post-ME (excluding External to External): AM, Origins

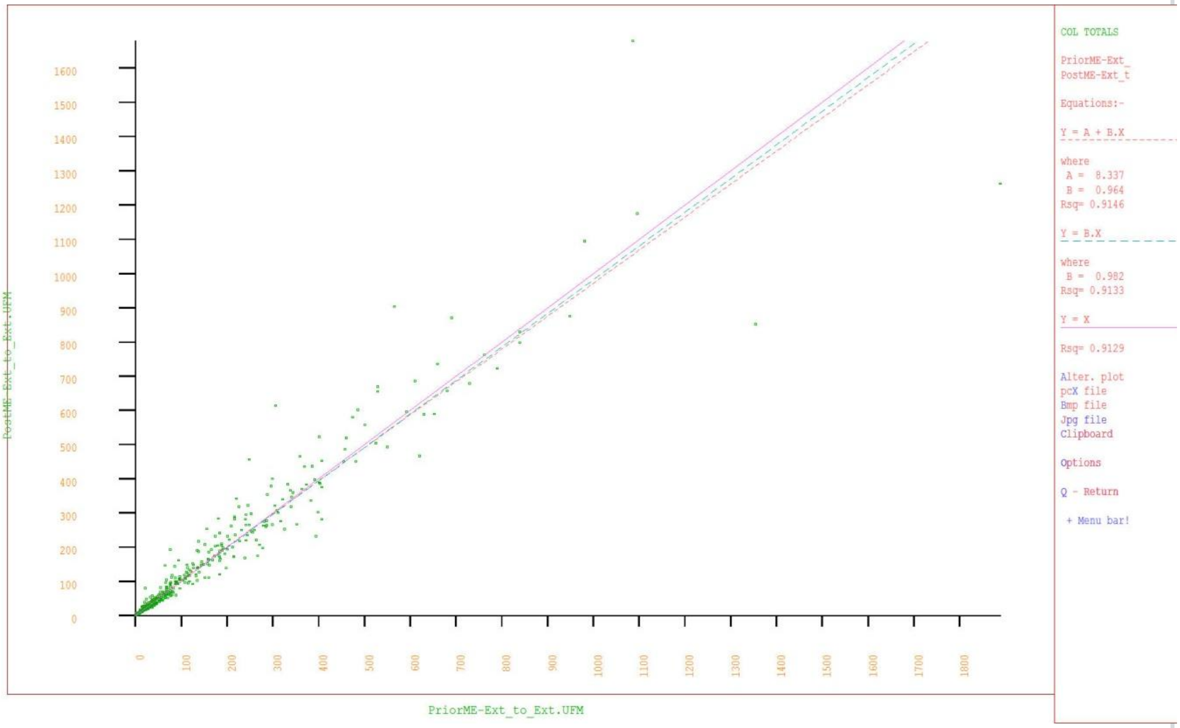

Figure 48. Trip End Changes Pre- and Post-ME (excluding External to External): AM, Destinations

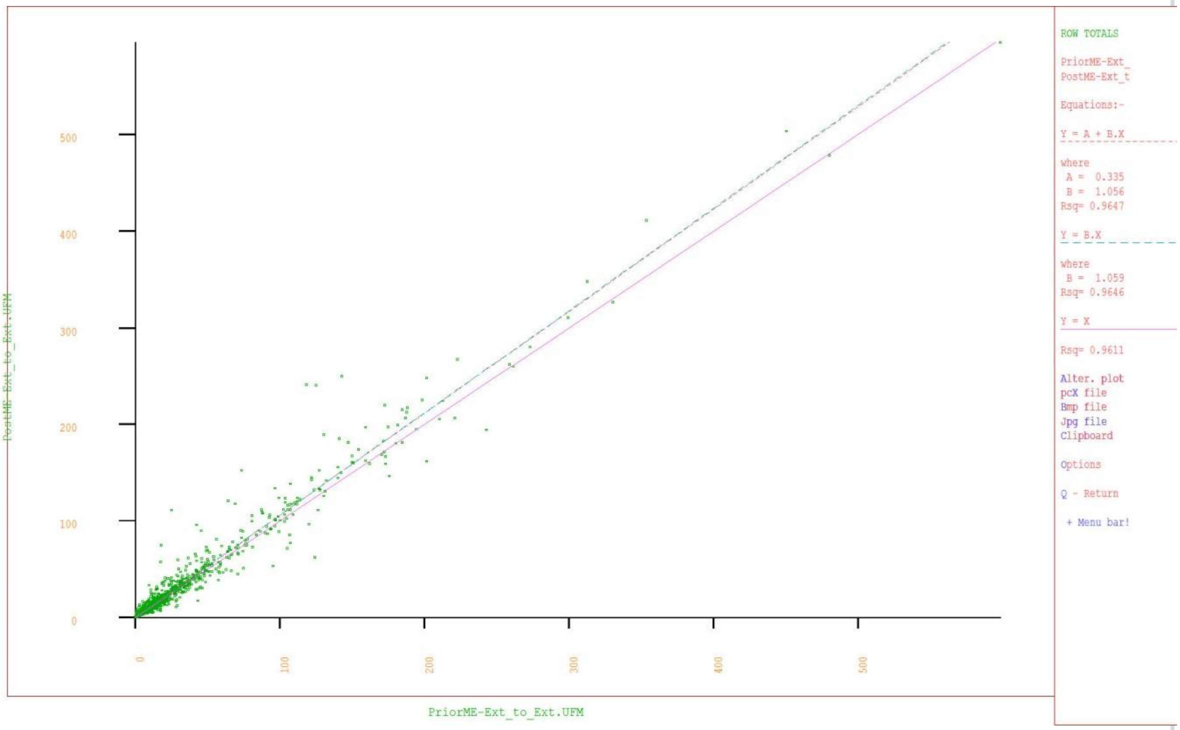

Figure 49. Trip End Changes Pre- and Post-ME (excluding External to External): IP, Origins

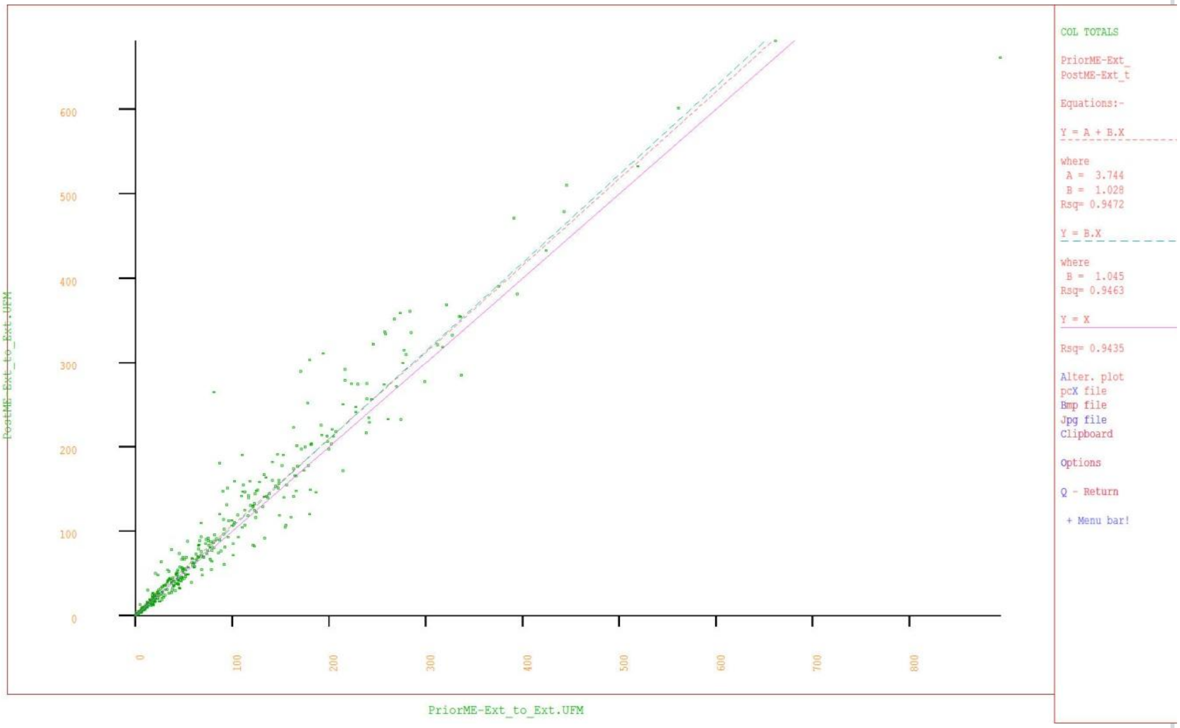

Figure 50. Trip End Changes Pre- and Post-ME (excluding External to External): IP, Destinations

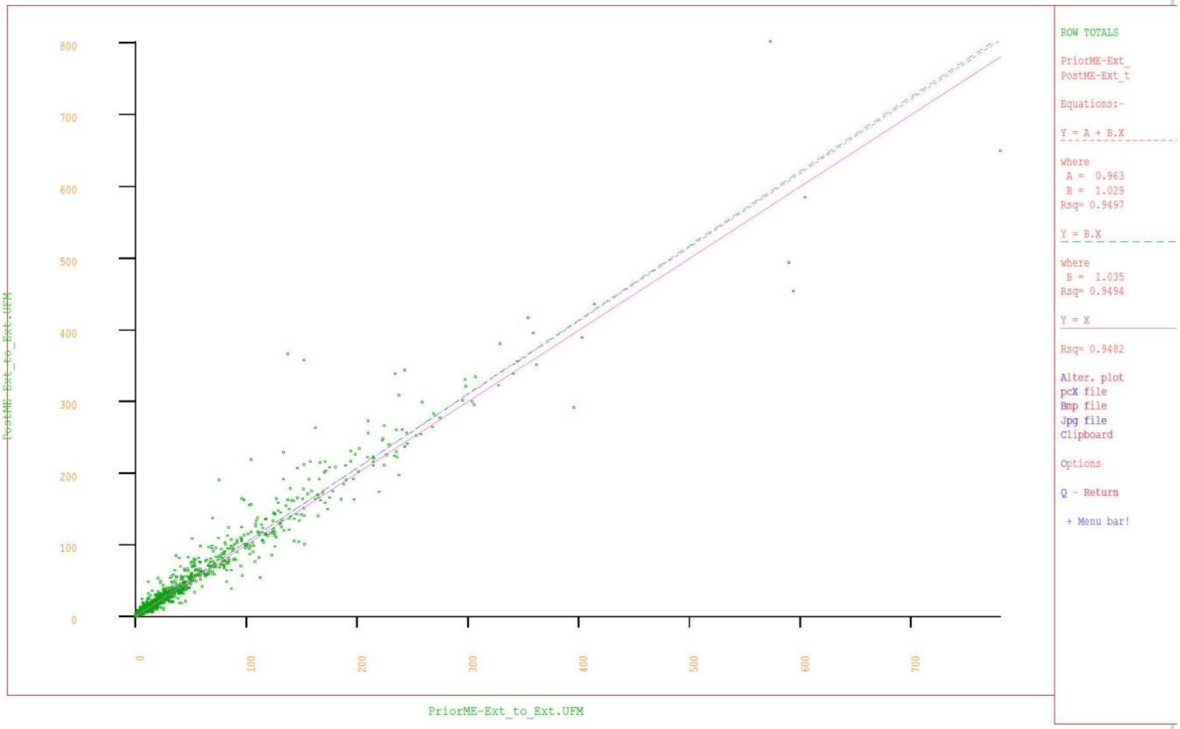

Figure 51. Trip End Changes Pre- and Post-ME (excluding External to External): PM, Origins

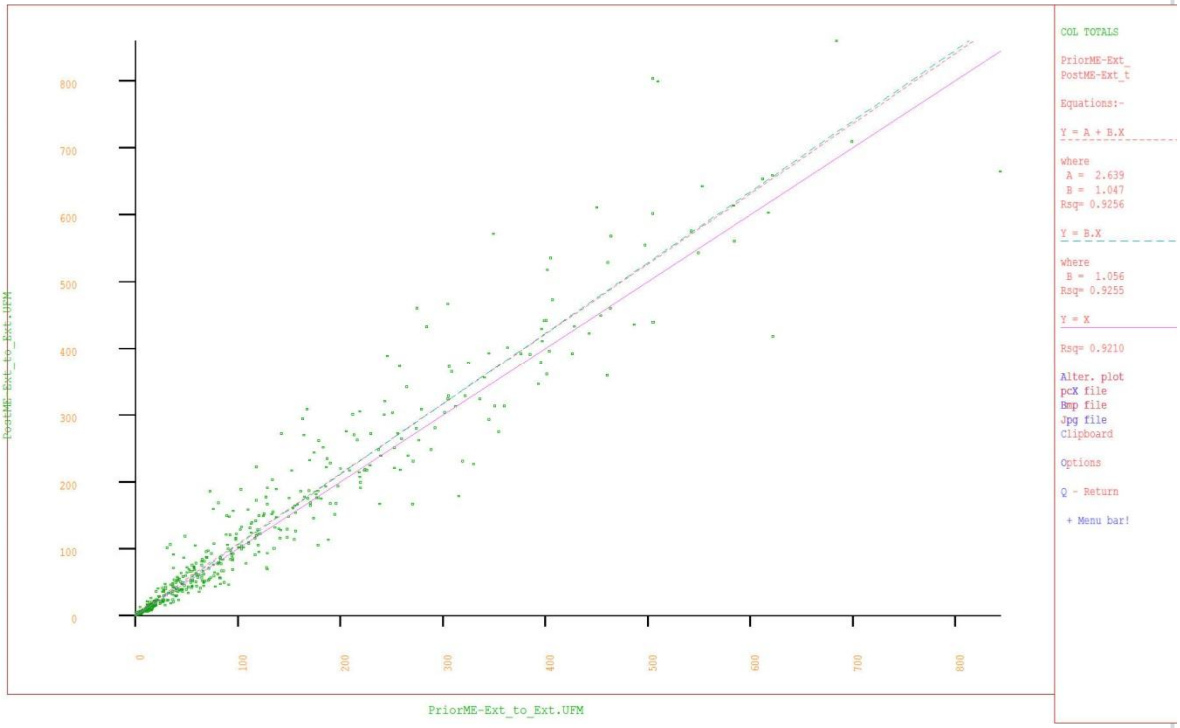

Figure 52. Trip End Changes Pre- and Post-ME (excluding External to External): PM, Destinations

10.7.2 Table 29 shows the regression statistics from the comparison of post and pre ME trip ends, excluding external to external trips. Table 5 of WebTAG Unit M3.1 specifies the following criteria: Slope within 0.99 and 1.01, Intercept near zero and R^2 in excess of 0.98). The intercepts for the origins are close to zero, with those for destinations slightly higher. The slopes are close to the criteria, with R^2 values slightly lower than the criteria specifies. Given the data sources used for the prior matrices as discussed in section 7.1 the results of the regression analysis were considered to be good.

Table 29: Regression Statistics for Matrix Trip Ends Pre and Post-ME (Excluding Ext to Ext)

Time Period	Trip Ends	Intercept	Gradient	R^2
AM	Origins	-0.11	1.04	0.95
	Destinations	8.34	0.96	0.91
IP	Origins	0.34	1.06	0.96
	Destinations	3.74	1.03	0.95
PM	Origins	0.96	1.03	0.95
	Destinations	2.64	1.05	0.93

10.8 Comparison of Matrix Cell Values before and after ME

10.8.1 Table 30 shows the regression statistics from the comparison of pre and post ME matrix cell values, excluding external to external trips, by vehicle type. Table 5 of WebTAG Unit M3.1 specifies the following guidelines for the cell variation: Slope within 0.98 and 1.02, Intercept near zero and R2 in excess of 0.95. The intercepts are all very close to zero, the gradient for car meets the criteria for AM and PM and is just over for IP. The gradients for LGV and HGV are all slightly low. The individual zone to zone regression fit is not as good as that for the trip ends. This is partly due to the trips internal to Milton Keynes being determined from a synthetic model as no observed origin-destination data was available.

Table 30: Regression Statistics for Matrix Cell Values Pre- and Post-ME (Excluding Ext to Ext)

Time Period	Vehicle Type	Intercept	Gradient	R^2
AM	Car	0.01	0.99	0.76
	LGV	0.00	0.88	0.76
	HGV	0.00	0.85	0.48
IP	Car	0.01	1.04	0.83
	LGV	0.00	0.86	0.73
	HGV	0.00	0.81	0.34
PM	Car	0.01	1.01	0.70
	LGV	0.00	0.79	0.62
	HGV	0.00	0.93	0.33

11. Assignment Calibration and Validation

11.1.1 It is important to ensure the results produced by the model are sensible when the trip matrices are assigned to the network. As such both link count and journey time data were reviewed regularly throughout the process.

11.1.2 The cordons and screenlines as discussed in Section 5 and shown in Figure 9 were monitored by direction. This section provides the results and summarises the 'pass' rate based on the WebTAG criteria detailed in Table 1.

11.2 Assignment Calibration

11.2.1 Journey time comparisons were used to help calibrate the model. Where large differences were identified at certain points along a journey time routes steps were taken to address the cause. One approach was to adjust speeds / speed flow curves to better represent the road type or speed limits in place. Where there was an issue at a particular signalised junction across time periods the saturation flows were checked and signal timings adjusted appropriately.

11.2.2 As well as looking at the flows crossing each screenline as a whole efforts were also made to ensure the modelled and observed flows at individual count sites were also close to ensure large differences were not being cancelled out along a screenline. Due to the grid system in Milton Keynes and hence the multiple route choices available this was not an insignificant task. Junction coding was reviewed and amended if observed to be causing an unrealistic delay causing trips to route elsewhere.

11.3 Assignment Validation

11.3.1 The proportion of calibration and validation links where modelled flows passed the WebTAG criteria in Table 1 was also reviewed.

11.3.2 Table 31 to Table 33 show the proportion of counts that meet the WebTAG criteria for how well the modelled and observed flows compare with each other. In all time periods the calibration counts meet the WebTAG criteria that >85% of flows meet Criteria A. Fewer validation flows satisfy Criteria A.

Table 31: Total Calibration and Validation Counts (Full Screenlines) - AM Peak

All Sites	Total no. of Counts	Counts that pass	%
Calibration Counts:	142	132	93%
Calibration Counts: GEH	142	132	93%
Calibration Counts Either	142	134	94%
Validation Counts: Flows	26	13	50%
Validation Counts: GEH	26	13	50%
Validation Counts Either	26	13	50%

Table 32: Total Calibration and Validation Counts (Full Screenlines) - Inter-Peak

All Sites	Total no. of Counts	Counts that pass	%
Calibration Counts:	142	140	99%
Calibration Counts: GEH	142	139	98%
Calibration Counts Either	142	140	99%
Validation Counts: Flows	26	9	35%
Validation Counts: GEH	26	11	42%
Validation Counts Either	26	11	42%

Table 33: Total Calibration and Validation Counts (Full Screenlines) - PM Peak

All Sites	Total no. of Counts	Counts that pass	%
Calibration Counts:	142	135	95%
Calibration Counts: GEH	142	135	95%
Calibration Counts Either	142	136	96%
Validation Counts: Flows	26	11	42%
Validation Counts: GEH	26	12	46%
Validation Counts Either	26	12	46%

11.3.3 Table 34 to Table 36 show a breakdown by vehicle class. It can be seen that LGV and HGV have a higher percentage of validation counts that pass Criteria A but this is partly due to lower volumes. Further calibration and validation detail is provided in Appendix D and Appendix E.

Table 34: Total Calibration and Validation Counts (Full Screenlines) by Vehicle Class - AM Peak

All Sites	Total no. of Counts	Car		LGV		HGV	
		Counts that pass	%	Counts that pass	%	Counts that pass	%
Calibration Counts:	142	133	94%	142	100	140	99%
Calibration Counts:	142	134	94%	136	96%	134	94%
Calibration Counts	142	135	95%	142	100	140	99%
Validation Counts:	26	12	46%	26	100	26	100%
Validation Counts:	26	12	46%	24	92%	24	92%
Validation Counts	26	12	46%	26	100	26	100%

Table 35: Total Calibration and Validation Counts (Full Screenlines) by Vehicle Class - Inter-Peak

All Sites	Total no. of Counts	Car		LGV		HGV	
		Counts that pass	%	Counts that pass	%	Counts that pass	%
Calibration Counts:	142	140	99%	142	100%	141	99%
Calibration Counts:	142	139	98%	141	99%	139	98%
Calibration Counts	142	140	99%	142	100%	141	99%
Validation Counts:	26	10	38%	26	100%	26	100%
Validation Counts:	26	11	42%	25	96%	23	88%
Validation Counts	26	12	46%	26	100%	26	100%

Table 36: Total Calibration and Validation Counts (Full Screenlines) by Vehicle Class - PM Peak

All Sites	Total no. of Counts	Car		LGV		HGV	
		Counts that pass	%	Counts that pass	%	Counts that pass	%
Calibration Counts:	142	136	96%	142	100	141	99%
Calibration Counts:	142	135	95%	142	100	141	99%
Calibration Counts	142	137	96%	142	100	142	100%
Validation Counts:	26	10	38%	26	100	26	100%
Validation Counts:	26	13	50%	26	100	24	92%
Validation Counts	26	13	50%	26	100	26	100%

11.3.4 The journey time data was also used in the model calibration and validation process. The modelled journey times was compared to the observed journey time data extracted from Trafficmaster as detailed in Section 5.5.

11.3.5 Table 37 to Table 39 show the journey time comparisons. 96% of the modelled and observed journey times are within bounds defined in WebTAG as detailed in Table 2, for each time period; this means only one route in a single direction fails to meet the criteria in each time period.

11.3.6 Figure 53 to Figure 58 show journey time comparison plots for Route 12, Central Milton Keynes to M1 junction 13 via A421 and reverse. The complete set of journey time plots can be found in Appendix F.

Table 37: Observed and Modelled Journey Times - AM Peak

Route	Route Description	Time (s)				% Error	Within Bounds?
		Observed	Range	Modelled	Error		
1EB	A421 to M1 J13	1362	204	1146	-216	-16%	No
1WB	A421 from M1 J13	1266	190	1257	-9	-1%	Yes
2EB	Old Stratford to Chicheley	790	119	823	33	4%	Yes
2WB	Chicheley to Old Stratford	1184	178	1165	-19	-2%	Yes
3SB	Old Stratford to Watling, Little Brickhill	779	117	885	106	14%	Yes
3NB	Watling, Little Brickhill to Old Stratford	905	136	923	18	2%	Yes
4EB	Portway/Fulmer St to Newport Pagnell	941	141	876	-65	-7%	Yes
4WB	Newport Pagnell to Portway/Fulmer St	1130	170	1094	-36	-3%	Yes
5EB	Moulsoe to Child's Way / Tattenhoe St.	1230	185	1167	-63	-5%	Yes
5WB	Child's Way / Tattenhoe St. to Moulsoe	1095	164	1147	52	5%	Yes
6SB	Saxon St. / Newport Rd. to A4146 / Stoke	1022	153	1105	83	8%	Yes
6NB	A4146 / Stoke Rd. to Saxon St. / Newport	1058	159	1013	-45	-4%	Yes
7SB	M1 J15 to M1 J13	1118	168	990	-128	-11%	Yes
7NB	M1 J13 to M1 J15	961	144	1012	51	5%	Yes
8SB	Newport Pagnell to Bletchley	1006	151	1030	24	2%	Yes
8NB	Bletchley to Newport Pagnell	913	137	918	5	1%	Yes
9SB	Brickhill Street Southbound	176	26	169	-7	-4%	Yes
9NB	Brickhill Street Northbound	174	26	226	52	30%	Yes
10SB	A5130 through Woburn Sands SB	444	67	414	-30	-7%	Yes
10NB	A5130 through Woburn Sands NB	466	70	446	-20	-4%	Yes
12EB	MK central to M1 J13 via A421	906	136	852	-54	-6%	Yes
12WB	M1 J13 to MK Central via A421	1071	161	1146	75	7%	Yes
13EB	MK Central to M1 J13 via M1 J14	722	108	739	17	2%	Yes
13WB	M1 J13 to MK Central via M1 J14	1006	151	1133	127	13%	Yes

Table 38: Observed and Modelled Journey Times - Inter-Peak

Route	Route Description	Time (s)				% Error	Within Bounds?
		Observed	Range	Modelled	Error		
1EB	A421 to M1 J13	963	144	875	-88	-9%	Y
1WB	A421 from M1 J13	990	148	950	-40	-4%	Y
2EB	Old Stratford to Chicheley	750	112	735	-15	-2%	Y
2WB	Chicheley to Old Stratford	791	119	767	-24	-3%	Y
3SB	Old Stratford to Watling, Little Brickhill	762	114	827	65	8%	Y
3NB	Watling, Little Brickhill to Old Stratford	800	120	859	59	7%	Y
4EB	Portway/Fulmer St to Newport Pagnell	787	118	817	30	4%	Y
4WB	Newport Pagnell to Portway/Fulmer St	800	120	818	18	2%	Y
5EB	Moulsoe to Child's Way / Tattenhoe St.	930	140	883	-47	-5%	Y
5WB	Child's Way / Tattenhoe St. to Moulsoe	914	137	872	-42	-5%	Y
6SB	Saxon St. / Newport Rd. to A4146 / Stoke	964	145	934	-30	-3%	Y
6NB	A4146 / Stoke Rd. to Saxon St. / Newport	971	146	962	-10	-1%	Y
7SB	M1 J15 to M1 J13	915	137	969	54	6%	Y
7NB	M1 J13 to M1 J15	935	140	1082	147	16%	N
8SB	Newport Pagnell to Bletchley	862	129	829	-33	-4%	Y
8NB	Bletchley to Newport Pagnell	858	129	821	-37	-4%	Y
9SB	Brickhill Street Southbound	165	25	162	-3	-2%	Y
9NB	Brickhill Street Northbound	143	22	153	10	7%	Y
10SB	A5130 through Woburn Sands SB	444	67	413	-31	-7%	Y
10NB	A5130 through Woburn Sands NB	467	70	433	-34	-7%	Y
12EB	MK central to M1 J13 via A421	884	133	828	-56	-6%	Y
12WB	M1 J13 to MK Central via A421	892	134	846	-46	-5%	Y
13EB	MK Central to M1 J13 via M1 J14	702	105	722	20	3%	Y
13WB	M1 J13 to MK Central via M1 J14	681	102	735	54	8%	Y

Table 39: Observed and Modelled Journey Times - PM Peak

Route	Route Description	Time (s)				% Error	Within Bounds?
		Observed	Range	Modelled	Error		
1EB	A421 to M1 J13	1246	187	1157	-89	-7%	Y
1WB	A421 from M1 J13	1259	189	1166	-93	-7%	Y
2EB	Old Stratford to Chicheley	900	135	934	34	4%	Y
2WB	Chicheley to Old Stratford	1023	153	942	-81	-8%	Y
3SB	Old Stratford to Watling, Little Brickhill	878	132	896	18	2%	Y
3NB	Watling, Little Brickhill to Old Stratford	1031	155	1023	-8	-1%	Y
4EB	Portway/Fulmer St to Newport Pagnell	1022	153	1007	-15	-1%	Y
4WB	Newport Pagnell to Portway/Fulmer St	1001	150	921	-80	-8%	Y
5EB	Moulsoe to Child's Way / Tattenhoe St.	1431	215	1089	-342	-24%	N
5WB	Child’s Way / Tattenhoe St. to Moulsoe	1262	189	1091	-171	-14%	Y
6SB	Saxon St. / Newport Rd. to A4146 / Stoke	1050	157	992	-58	-6%	Y
6NB	A4146 / Stoke Rd. to Saxon St. / Newport	1094	164	1037	-58	-5%	Y
7SB	M1 J15 to M1 J13	961	144	989	28	3%	Y
7NB	M1 J13 to M1 J15	982	147	1056	74	8%	Y
8SB	Newport Pagnell to Bletchley	982	147	926	-56	-6%	Y
8NB	Bletchley to Newport Pagnell	1059	159	946	-113	-11%	Y
9SB	Brickhill Street Southbound	248	37	190	-58	-23%	Y
9NB	Brickhill Street Northbound	202	30	193	-9	-4%	Y
10SB	A5130 through Woburn Sands SB	450	67	428	-22	-5%	Y
10NB	A5130 through Woburn Sands NB	451	68	437	-14	-3%	Y
12EB	MK central to M1 J13 via A421	1272	191	1141	-131	-10%	Y
12WB	M1 J13 to MK Central via A421	913	137	947	34	4%	Y
13EB	MK Central to M1 J13 via M1 J14	938	141	933	-5	-1%	Y
13WB	M1 J13 to MK Central via M1 J14	727	109	768	41	6%	Y

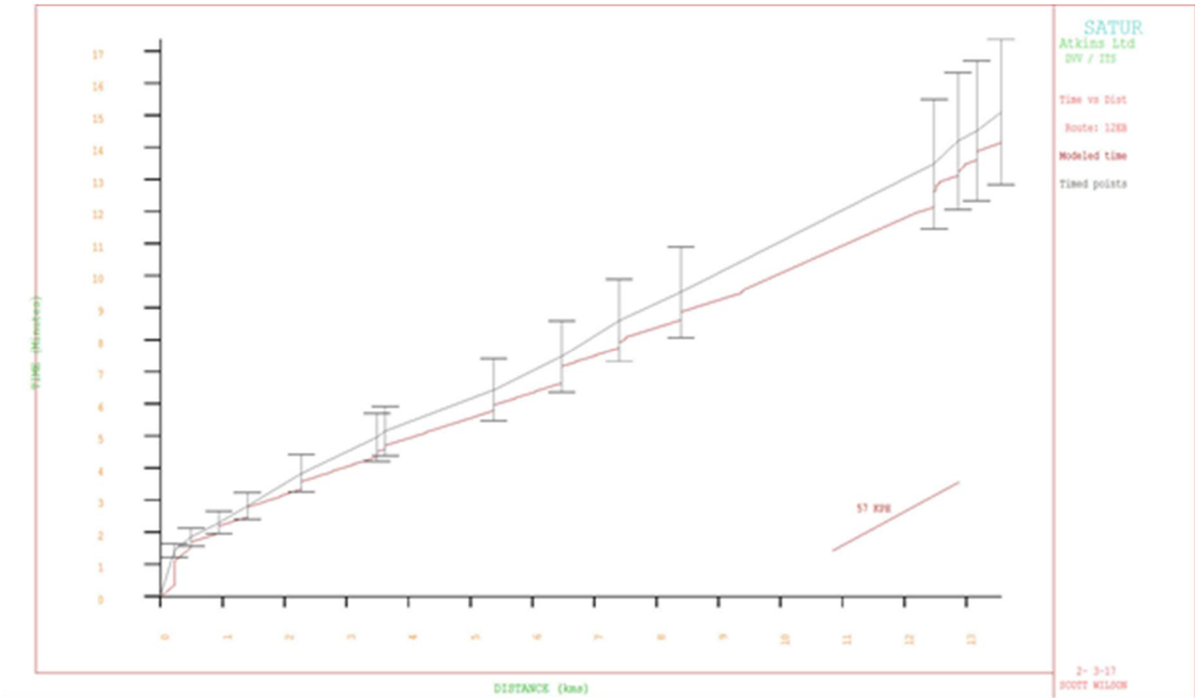

Figure 53. Journey Time Comparison – Route 12 EB, MK central to M1 J13 via A421 – AM Peak

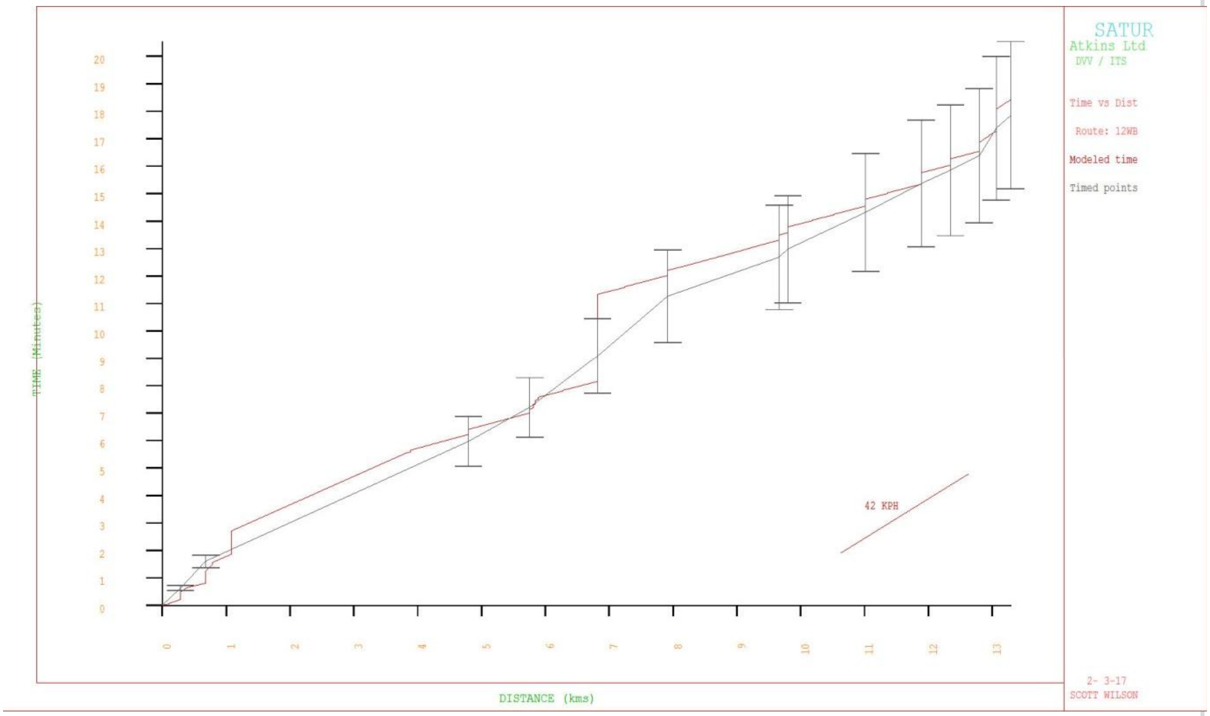

Figure 54. Journey Time Comparison – Route 12 WB, M1 J13 to MK Central via A421 – AM Peak

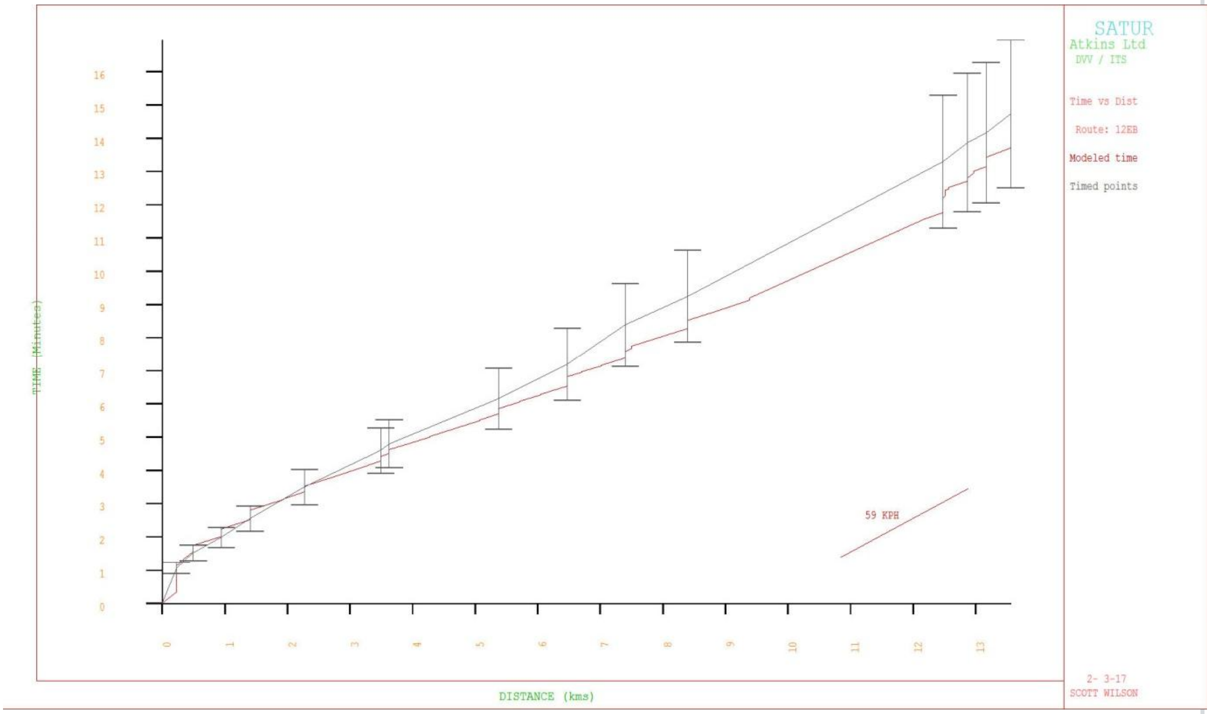

Figure 55. Journey Time Comparison – Route 12 EB, MK central to M1 J13 via A421 – Inter-Peak

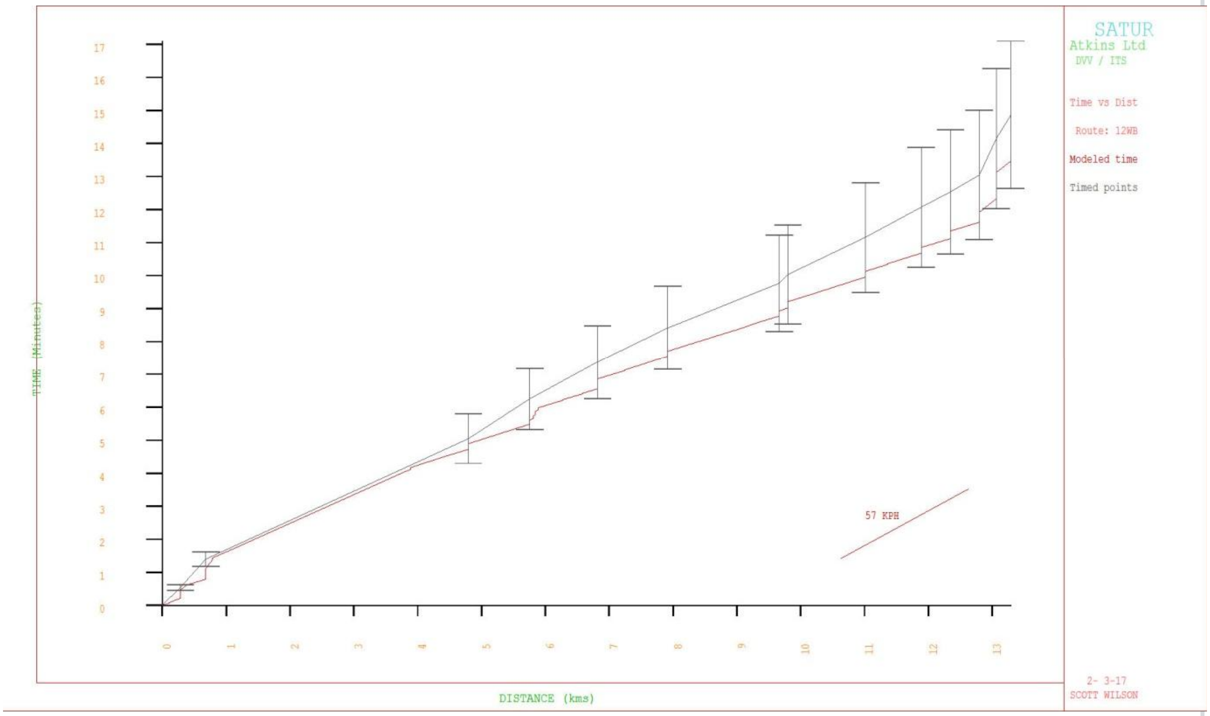

Figure 56. Journey Time Comparison – Route 12 WB, M1 J13 to MK Central via A421 – Inter-Peak

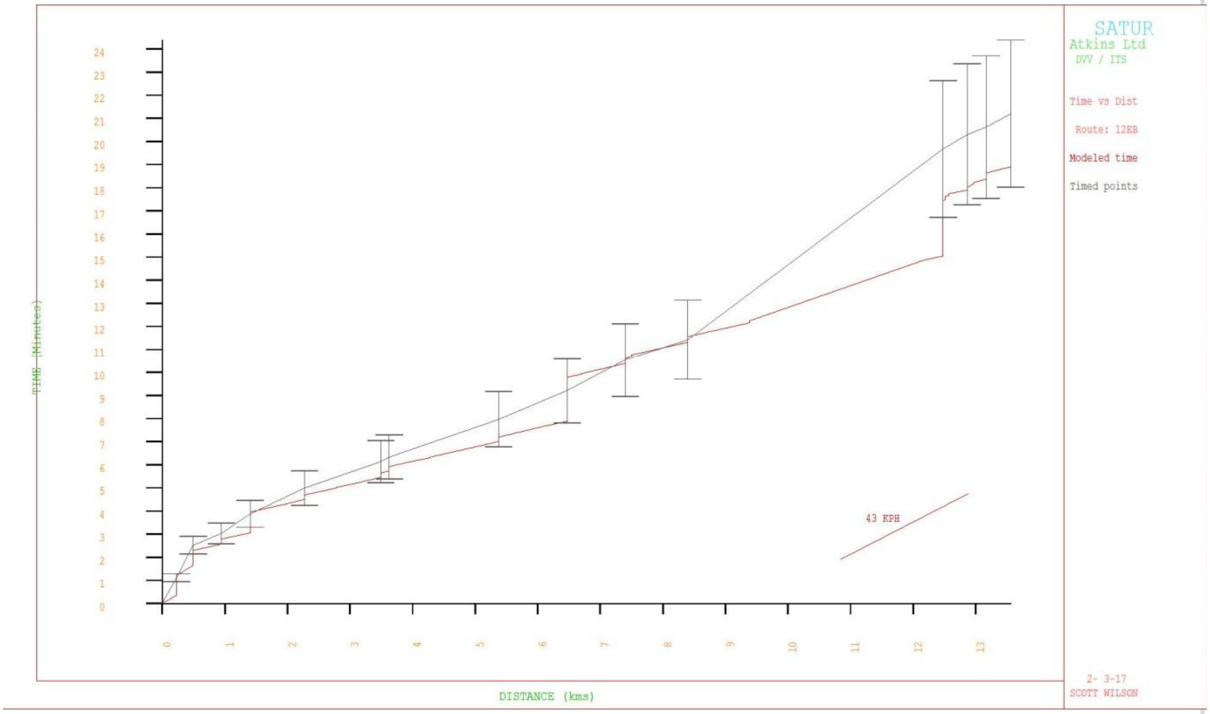

Figure 57. Journey Time Comparison – Route 12 EB, MK central to M1 J13 via A421 – PM Peak

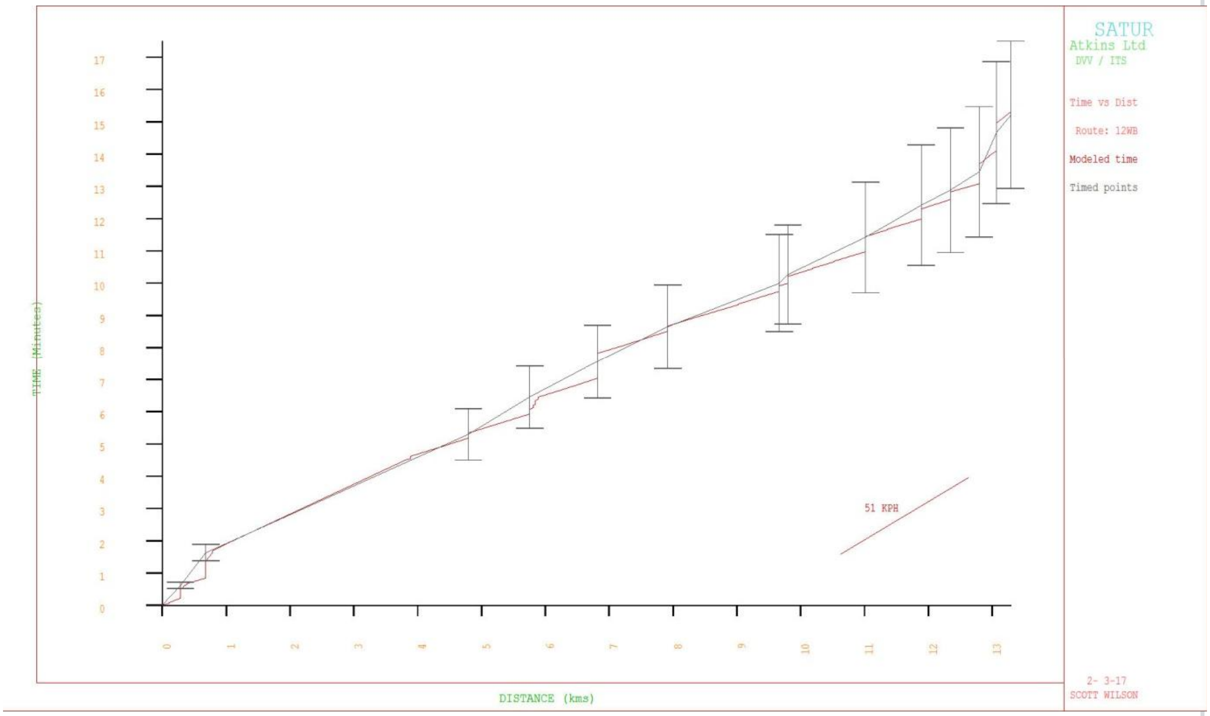

Figure 58. Journey Time Comparison – Route 12 WB, M1 J13 to MK Central via A421 – PM Peak

11.4 Model Convergence

11.4.1 The parameter %FLOW was used to assess the convergence within the SATURN assignment model. This measures the percentage of links on which flows vary by more than a pre-defined percentage between consecutive assignment iterations.

11.4.2 Convergence was improved with the use of the parameters RSTOP, PCNEAR and NISTOP which were set at 99, 1 and 4 respectively. This defined convergence as being met when link flows on 99% of all links varied less than 1% for four consecutive iterations. This is more stringent than the WebTAG criteria as shown in Table 40.

Table 40. Summary of Convergence Stats

Measure of Convergence	Base Model Acceptable Values
Delta and %GAP	Less than 0.1% or at least stable with convergence fully documented and all other criteria met
Percentage of links with flow change (P)<1%	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: WebTAG Unit M3.1

11.4.3 WebTAG provides further guidance on model stability in Appendix C of TAG unit M3.1. This recommends that the Average Absolute Difference (AAD) between consecutive iterations and also the Relative Average Absolute Difference (RAAD) in link flows between iterations. It is this which is the preferred measure with a target value of 0.1%.

11.4.4 Table 41 to Table 43 list the convergence statistics for each time period. It can be seen that %GAP is well below the 1% criteria, % FLOW meets the 99% criteria and %RAAD is well under 0.1%. So as measured against these criteria it can be said the model is well converged.

Table 41: Summary Convergence Results - AM

Assignment Loop	% GAP	AAD	RAAD	% Flows
1	0.3620			
2	0.1350	38.751	4.941	39.20
3	0.1010	9.778	1.259	53.20
4	0.0490	5.932	0.764	60.80
5	0.0420	5.873	0.757	58.30
6	0.0320	3.853	0.498	70.00
7	0.0170	3.011	0.389	71.40
8	0.0140	3.243	0.419	67.50
9	0.0150	1.717	0.222	83.00
10	0.0120	1.284	0.166	88.90
11	0.0100	1.360	0.176	84.60
12	0.0140	1.102	0.143	88.90
13	0.0100	1.137	0.147	89.80
14	0.0082	0.952	0.123	91.90
15	0.0060	0.548	0.071	95.30

Assignment Loop	% GAP	AAD	RAAD	% Flows
16	0.0049	0.853	0.110	91.00
17	0.0031	0.730	0.095	91.90
18	0.0029	0.766	0.099	90.60
19	0.0023	0.522	0.068	95.10
20	0.0016	0.457	0.059	95.30
21	0.0016	0.452	0.059	95.70
22	0.0014	0.379	0.049	97.10
23	0.0014	0.345	0.045	97.80
24	0.0010	0.239	0.031	98.40
25	0.0009	0.340	0.044	97.60
26	0.0009	0.283	0.037	97.90
27	0.0008	0.223	0.029	98.40
28	0.0006	0.238	0.031	98.30
29	0.0007	0.218	0.028	98.50
30	0.0009	0.213	0.028	98.40
31	0.0007	0.170	0.022	98.80
32	0.0004	0.091	0.012	99.50
33	0.0003	0.070	0.009	99.90
34	0.0004	0.099	0.013	99.30
35	0.0003	0.048	0.006	99.90

Table 42: Summary Convergence Results - IP

Assignment Loop	% GAP	AAD	RAAD	% Flows
1	0.0470			
2	0.0054	20.040	3.275	43.90
3	0.0077	5.104	0.838	62.20
4	0.0037	1.588	0.261	84.60
5	0.0058	1.434	0.236	85.20
6	0.0016	1.824	0.300	85.50
7	0.0007	1.198	0.197	86.30
8	0.0004	0.872	0.143	90.00
9	0.0006	0.632	0.104	93.00
10	0.0002	0.290	0.048	97.70
11	0.0001	0.390	0.064	95.40
12	0.0001	0.308	0.051	96.80
13	0.0001	0.222	0.037	98.00
14	0.0001	0.106	0.017	99.30
15	0.0000	0.049	0.008	99.80
16	0.0001	0.090	0.015	99.20
17	0.0000	0.106	0.017	99.10

Table 43: Summary Convergence Results - PM

Assignment Loop	% GAP	AAD	RAAD	% Flows
1	0.2710			
2	0.1310	37.290	4.555	39.30
3	0.0870	11.106	1.368	51.40
4	0.0530	6.322	0.779	60.10
5	0.0320	4.411	0.544	63.90
6	0.0170	4.292	0.530	63.00
7	0.0130	3.716	0.459	66.20
8	0.0110	2.210	0.273	76.80
9	0.0100	1.633	0.202	83.70
10	0.0086	1.252	0.155	87.60
11	0.0064	1.266	0.157	88.00
12	0.0042	1.294	0.160	86.70
13	0.0035	1.362	0.169	85.00
14	0.0028	1.197	0.148	89.00
15	0.0043	0.887	0.110	90.40
16	0.0019	0.773	0.096	93.10
17	0.0024	0.846	0.105	91.40
18	0.0019	0.699	0.087	93.90
19	0.0011	0.506	0.063	95.50
20	0.0010	0.442	0.055	95.40
21	0.0008	0.366	0.045	96.30
22	0.0005	0.305	0.038	97.20
23	0.0005	0.231	0.029	97.90
24	0.0005	0.241	0.030	98.00
25	0.0005	0.214	0.027	98.10
26	0.0004	0.098	0.012	99.10
27	0.0003	0.156	0.019	98.70
28	0.0003	0.144	0.018	99.10
29	0.0002	0.069	0.009	99.70
30	0.0002	0.076	0.009	99.60
31	0.0002	0.075	0.009	99.60

12. Variable Demand Model

12.1 Introduction

12.1.1 This section describes the development of the variable demand model used within the Milton Keynes Multi-Modal Model (MKMMM). The demand model works in conjunction with the trip-end, highway and public transport models, passing demand and costs between the components of the model suite.

12.2 Demand Model Structure

12.2.1 The MKMMM variable demand model was designed to estimate the effect of changes in transport infrastructure and travel cost upon patterns of demand. That is, the way travellers respond to changes in transport infrastructure, other than choosing different routes which is forecast by the highway and public transport assignment models.

12.2.2 The MKMMM demand model uses a hierarchical logit structure, with the following choice models in order of increasing sensitivity:

- trip frequency;
- motorised versus active mode (walking and cycling) choice;
- time period choice;
- car versus public transport (bus and rail) mode choice; and
- trip distribution (destination choice).

12.2.3 The choice models are applied to all person trips and to freight demand. The full hierarchy is illustrated in Figure 59. Freight trips have a simplified structure as only highway freight demand is modelled, and demand is fixed in a 'without scheme' scenario. Trips made by non-car owning households do not apply the motorised mode choice model, assuming all demand at this stage is public transport.

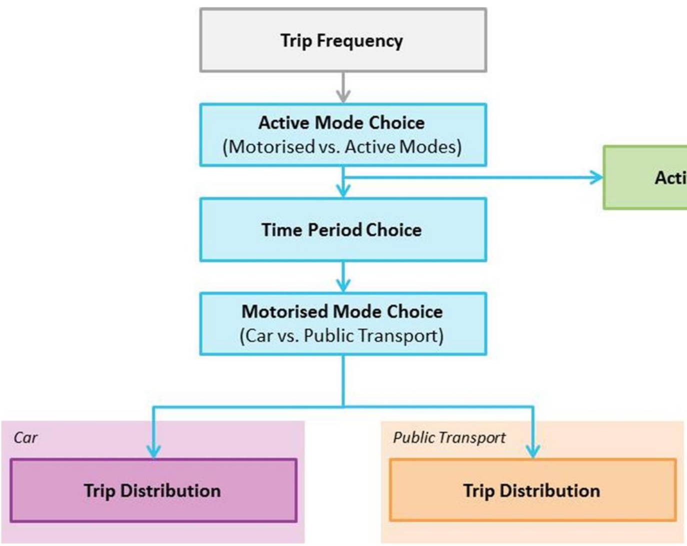

Figure 59. Demand Model Hierarchy

12.2.4 A trip frequency effect has been coded within the variable demand model; however this has been disabled by setting the sensitivity parameters to zero as all modes of travel (highway, public transport and active modes) are represented. This is in line with WebTAG guidance.

12.2.5 The trip frequency adjusts total trips from each production zone based upon the changes in the costs of travel from that zone. As discussed above, this response has been disabled and the total trips produced by a zone are fixed within the demand model.

12.2.6 For each production zone, the active mode choice model adjusts the relative proportions of demand by active (walk and cycle) and motorised (car and public transport) modes, based upon changes of travel times and costs for each mode.

12.2.7 Subsequent choice models, of increasing sensitivity, perform similar adjustments to other proportions. For example, the trip distribution model adjusts the relative proportions of demand going to each attraction zone, by production zone, mode, and time of day.

12.3 Pivoting

12.3.1 The Milton Keynes demand model is a pivot-point incremental model which estimates changes in trip patterns relative to a 'reference' matrix based upon observed data. The predicted relative changes reflect changes in travel costs and journey times. Changes in travel demand due to external factors (population, employment and personal income) are applied separately by the trip-end model to establish 'reference' matrices based on the base year matrices.

12.3.2 Therefore the MKMMM demand model seeks to forecast changes in demand in response to changes in cost, rather than attempting to estimate all demand based purely on costs of travel. This is generally considered to be practically preferable and is recommended in WebTAG Unit M2.

12.3.3 In forecasting mode, when running a 'without scheme' scenario, the MKMMM demand model pivots from the base year model, evaluating cost changes relative to the base year and adjusting the reference demand matrix. When running a 'with scheme' scenario, the MKMMM demand model pivots from the corresponding 'without scheme' forecast demand and costs. In a 'with scheme' scenario, freight demand is permitted to vary in response to changes in travel costs from the 'without scheme' scenario.

12.4 Segmentation

12.4.1 Consistent with the base year demand matrices, although segmenting employer's business and other trips by those which are home-based and non-home-based, the MKMMM demand model contains the following trip purposes:

- commuting;
- home-based employer's business;
- home-based other;
- non-home-based employer's business;
- non-home-based other;
- light goods vehicles (LGV); and
- heavy goods vehicles (HGV).

12.4.2 Within the demand model, business and other trips are considered to be either home-based (where one end of the trip is a permanent residence) or non-home-based (where neither end of trip is permanent residence). For home-based trips, from-home factors, reflecting the proportion of trips originating from home, are used to convert between origin-destination (OD) format and production-attraction (PA) format for demand and costs. These factors were produced as part of the base year matrix development.

12.4.3 Three modes of transport are modelled within MKMMM demand model: active modes (walking and cycling), car and public transport. Active mode and public transport trips are disaggregated by car ownership as follows:

- trips from non-car-owning households; and
- trips from car-owning households.

12.4.4 The demand model represents the following weekday time periods:

- AM Peak Period (07:00 – 10:00);
- Inter-Peak Period (10:00 – 16:00);
- PM Peak Period (16:00 – 19:00); and
- Off-peak Period (19:00 – 07:00).

12.4.5 Peak-hour factors are used to convert AM Peak and PM Peak period demand to individual peak hours for highway assignment. These factors were produced as part of the base matrix development.

12.4.6 No validated off-peak highway or public transport models have been produced. Off-peak models have therefore been approximated by using the Inter-Peak networks. Off-peak demand, however, was developed as part of the base year matrix development.

12.5 Generalised Cost Calculations

12.5.1 The MKMMM demand model is an incremental model that responds to changes in generalised cost. For the highway generalised cost calculations, the functions specified below are used, derived from WebTAG Unit M2. The data are expressed in minutes, pence and kilometres, unless otherwise stated.

$$\text{Fuel Cost} = F * D * i * \left(\frac{f_a}{v} + f_b + f_c v + f_d v^2 \right)$$

$$\text{Non Fuel Cost} = D * \left(n_a + \left(\frac{n_b}{v} \right) \right)$$

$$\text{GenCost}_{\text{Highway}} = \text{Pure Time} + \left(\frac{\text{Fuel Cost} + \text{Non Fuel Cost} + \text{Charges}}{\text{Value of Time} * \text{Vehicle Occupancy}} \right)$$

where:

- F is the fuel cost, in pence per litre;
- D is the assigned distance, in kilometres;

- v is the average assigned speed for the matrix cell, in kilometres per hour;
- i is the fuel efficiency improvement factor, which reduces fuel consumption over time.
- $f_{a/b/c/d}$ are the fuel cost parameters; and
- $n_{a/b}$ are the non-fuel cost parameters (assumed to be zero for non-work trips).

12.5.2 Public transport calculations use generalised costs (expressed in minutes) that are skimmed from the public transport model.

$$GenCost_{PT} = InVehicleTime + 2*WaitTime + 2*WalkTime + BoardingPenalty + \frac{Fare}{ValueOfTime}$$

12.5.3 Within the highway and public transport generalised cost calculations, the parameter values used vary by travel purpose and fuel type (an average over petrol, diesel and electric vehicles is used for car trips). The parameter values adopted are discussed within Section 9 of this technical note.

12.5.4 Demand is represented in production-attraction (PA) format. Costs for travel between productions and attractions are weighted by the proportions of trips observed travelling from and to home, thus resulting in generalised cost changes in PA format, separately for each time period.

12.5.5 The highway generalised cost matrices are derived from the MKMMM highway assignment model, which assigns five user classes: commuting, other, employer's business, LGV and HGV.

12.5.6 The public transport generalised cost matrices are derived from the public transport assignment model, which assigns public transport demand onto the bus and rail networks for each time period. The cost skims from these public transport assignments are used for all demand segments. Values of time, however, do vary, so overall generalised cost for public transport travel will vary by demand segment.

12.6 Demand Sensitivity of Longer Distance Demand Movements

12.6.1 The MKMMM demand model, in common with any model representing the whole of the UK (albeit more simply outside of the core area), contains a wide range of trip lengths, from less than 1 kilometre to over 1,000 kilometres. The sensitivity of response to a ten-minute change would be expected in reality to be larger for a 30-minute journey than a six-hour journey, but in a pure logit model this ten-minute change would result in a similar demand response irrespective of trip length.

12.6.2 The following formulation has therefore been developed to reflect the variation in response sensitivity to trip length:

$$CostDampeningFactor = \min\left(\frac{\sqrt{d_1}}{\sqrt{distance}}, 1\right)$$

where d1 is a calibrated parameter, set to 30km in the MKMMM demand model. The cost dampening function is derived from a function that was calibrated and used in the East of England Regional Demand Model (EERDM); this is consistent with advice in WebTAG Unit M2.

12.6.3 The function is plotted in the Figure 60. Cumulative generalised cost changes that are used within the demand model are multiplied by the factor implied by this function. The distance used for each movement is the assigned distance on an uncongested base year highway network. This distance matrix remains constant and is used for all modelled years and scenarios.

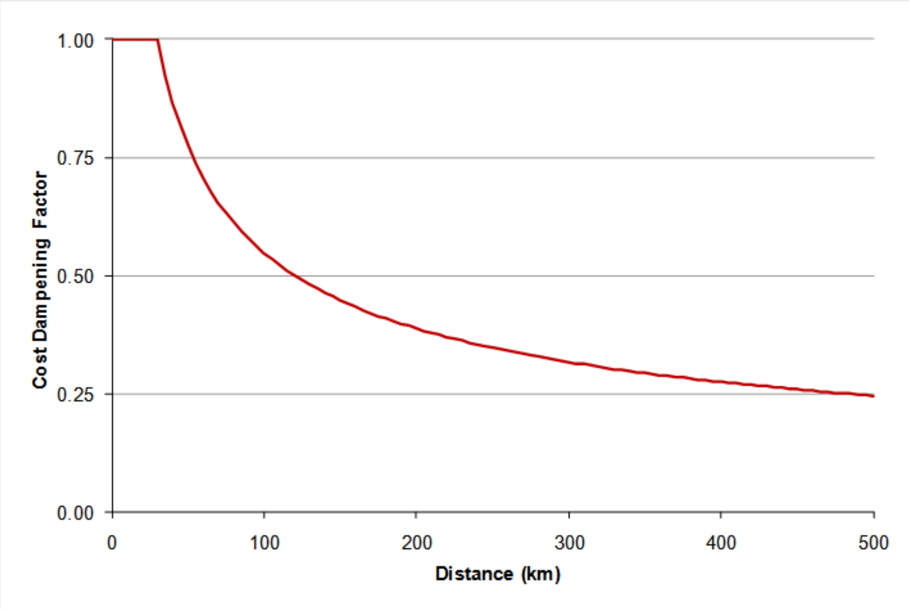

Figure 60. Cost Damping Function

12.6.4 In addition to this, a process has been introduced to modify value of time for non-work users by trip length, a second form of cost dampening, the cumulative effect of which yields plausible model sensitivity. This methodology is described in WebTAG Unit M2, Section 3.3. The non-work value of time is given by the following expression:

$$\mathrm{VoT} = \max\left(VoT_c \left(\frac{D}{D_0} \right)^{\eta_s}, VoT_c \left(\frac{D_C}{D_0} \right)^{\eta_s} \right)$$

where:

- VoT is the value of time used by the model;
- VoT_c is the central value of time given in table A1.3.2 in the WebTAG Data Book;
- D is the length of trip; and
- D_0, D_C, η_s are parameters.

Different elasticities (η_s) are used for commuting (-0.248) and other (-0.315) trips, as defined in WebTAG Unit M2.

12.6.5 In calculating these values, D has been taken as the assigned distance on an uncongested base year highway network as with the overall cost factoring discussed above. The distance skim used is static, ensuring that the value of time for any given segment for any given origin-destination pair remains the same for all MKMMM demand model tests.

12.6.6 The reason for the use of D_C is that the model contains a large number of intra-zonal trips with approximate, estimated distances, which are generally very short (<4km). It was felt that an arbitrary increase in sensitivity of these trips was undesirable. A value of 11 kilometres for D_C was thus adopted.

12.6.7 D_0 has been calibrated as 28km for car commuting and 34km for car other. These D_0 values have been calibrated to ensure that the average values of time across trip distance are approximately the central values given in the WebTAG databook, A1.3.2. An alternative approach would have been to use the D_0 values and central values of time in Appendix C to unit M2; this produces very similar functions, but we preferred to use the databook central value.

12.7 Mode Choice Model Equations

12.7.1 Sensitivity parameters (represented by lambda and theta) are applied to incremental composite travel costs, according to the travel purpose, as recommended in WebTAG Unit M2. The values used are WebTAG illustrative values which are used in the absence of locally observed behavioural data. These functions are applied to all trips using the following functions, starting with trip frequency:

$$\hat{D}_{**i*} = \sum_{tmj} D_{tmij}\, e^{\theta_f \Delta C_{**i*}}$$

with:

$$\Delta C_{**i*} = \log_e \left(\frac{\sum_{tmj} D_{tmij} e^{\theta_t \Delta C_{t*i*}}}{\sum_{tmj} D_{tmij}} \right)$$

where:

- ΔC_{tmij} is the cost change;
- D_{tmij} is the input demand;
- $\hat{D}_{ijtm}$ is the output demand;
- θ_f is the frequency theta (sensitivity parameter relative to time period sensitivity);
- θ_t is the time period choice theta (sensitivity parameter relative to main mode choice sensitivity);
- *i* is the production;
- *j* is the attraction;
- *t* is the time period (AM Peak, Inter-Peak, PM Peak or Off-peak);
- *m* is the mode (active or motorised, then car or public transport), with capital letters (A, M, C and P) representing a specific mode; and
- * is the sum (for demand) or exponential aggregation (for cost) over corresponding subscript.

12.7.2 The next level of the choice structure is the choice between active modes (walking and cycling) and motorised modes (car and public transport). This is incorporated by applying the following equation:

$$\hat{D}_{*mi*} = \hat{D}_{**i*} \frac{\sum_{tj} D_{tmij} e^{\theta_a \Delta C_{*mi*}}}{\sum_{tj} D_{tAij} e^{\theta_a \Delta C_{*Ai*}} + D_{tMij} e^{\theta_a \Delta C_{*Mi*}}}$$

with:

$$\Delta C_{*mi*} = \log_e \left(\frac{\sum_{tj} D_{tmij} e^{-\theta_t C_{tmi*}}}{\sum_{tj} D_{tmij}} \right)$$

12.7.3 The MKMMM demand model includes a demand response between time periods. The model includes functionality to reallocate trips between the modelled time periods on the basis of the respective cost changes in the different periods. The demand model does not include a mechanism to reallocate trips within a modelled time period, i.e. the MKMMM demand model includes macro time period choice, but not micro time period choice.

12.7.4 Therefore the demand model represents a demand response between the four periods defined in paragraph 12.4.4, but does not represent choice between individual hours within these four periods. Demand can be reallocated from the AM Peak Period to the Inter-Peak period for example, but it does not reallocate demand between the hours defined as the AM Peak Period (i.e. the model does not represent peak spreading).

12.7.5 Time period choice is applied through the following formulae:

$$\hat{D}_{t*i*} = \hat{D}_{**i*} \frac{\sum_{mj} D_{tmij} e^{\theta_t \Delta C_{t*i*}}}{\sum_{tmj} D_{tmij} e^{\theta_t \Delta C_{t*i*}}}$$

with:

$$\Delta C_{t*i*} = \log_e \left(\frac{\sum_{mj} D_{tmij} e^{-\theta_m C_{tmi*}}}{\sum_{mj} D_{tmij}} \right)$$

12.7.6 Motorised mode choice (car versus public transport) is forecast as a function of cost change for all non-freight and car-available demand, and is applied separately for each time period:

$$\hat{D}_{tmi*} = \hat{D}_{t*i*} \frac{\sum_{j} D_{tmij} e^{\theta_m \Delta C_{tmi*}}}{\sum_{mj} D_{tmij} e^{\theta_m \Delta C_{tmi*}}}$$

with:

$$\Delta C_{tmi*} = \log_e \left(\frac{\sum_{j} D_{tmij} e^{\lambda_d C_{tmij}}}{\sum_{j} D_{tmij}} \right)$$

12.7.7 Trip distribution is forecast as a function of cost change for all demand segments (there is no time period subscript for active mode trips; the expression is otherwise identical):

$$\hat{D}_{tmij} = \hat{D}_{tmi*} \frac{D_{tmij} e^{\lambda_d \Delta C_{tmij}}}{\sum_j D_{tmij} e^{\lambda_d \Delta C_{tmij}}}$$

where ΔC_{tmij} are cumulative generalised PA cost differences calculated directly from the highway and public transport assignment models. For active modes it is assumed that there is no change in generalised costs between the base year and any given forecast year and scenario.

12.7.8 Following guidance in WebTAG Unit M2, commuting trips are doubly-constrained, ensuring that each zone produces and attracts a fixed total number of trip-ends. All other trips are singly-constrained, with no constraint on the attractor zone. The double-constraint function is applied across all modes and time periods combined and it is iterated until the two following criteria are achieved.

$$\sum_{tmj} D_{tmij} = \sum_{tmj} \hat{D}_{tmij}$$

12.7.9 The commuting double-constraint is applied by accumulating trips to establish total trips by destination D'_{i*j*}. Segment and mode specific proportions are calculated before the double-constraint process so that the doubly-constrained output total demand matrix (total demand across all segments and modes) can be disaggregated back into demand by mode and time period, reflecting the distribution of these demand matrices before the double-constraint. These proportions are calculated using:

$$\%\hat{D}_{tmij} = \frac{\hat{D}_{tmij}}{\sum_{tm} \hat{D}_{tmij}}$$

12.7.10 The destination specific target totals are then calculated for use in the constraining process and the demand matrix is balanced to ensure that the double-constraint criteria (above) are enforced.

12.8 Convergence

12.8.1 The highway and public transport assignment models, and the demand model are run in sequence iteratively until the MKMMM demand model is deemed to have converged. The costs from the supply models and functions are fed into the demand calculations, with the resulting demand used to recalculate the costs. This process continues until convergence.

12.8.2 The measure of convergence of the demand and supply models is the demand-supply %Gap function as recommended by WebTAG Unit M2. This %Gap statistic is calculated using the following function:

$$\%Gap = \frac{\sum_{ijtcm} C(D_{ijtcm}) \cdot \left| D_{ijtcm} - D(C(D_{ijtcm})) \right| \cdot 100}{\sum_{ijtcm} C(D_{ijtcm}) \cdot D_{ijtcm}}$$

where:

- D_{ijtcm} is the current demand estimate;

- $C(D_{ijtcm})$ is the generalised cost generated by the assignment of D_{ijtcm} on the network;
- $D(C(D_{ijtcm}))$ is the demand generated by the demand model in response to cost changes created from $C(D_{ijtcm})$;
- *i* is the origin;
- *j* is the destination;
- *t* is the time period;
- *c* is the purpose; and
- *m* is the mode.

Highway and public transport modes are included in this calculation. It is also performed separately for each mode and trip purpose.

12.8.3 In calculating the %Gap, the MKMMM demand model aggregates across time periods, aiming for a %Gap target of 0.1%, across all demand segments and modes as specified in WebTAG.

12.8.4 Demand matrices are provided to the supply models, which generate costs to feed into the demand model (unaltered). This in-turn generates a new set of demand matrices, from which a %Gap is calculated prior to the application of a smoothing process. The smoothing process adjusts the output demand matrices before they are assigned in the supply models in the next demand/supply iteration to speed up the convergence of the model.

12.8.5 The demand smoothing uses the following function:

$$\hat{D}_X = \frac{2D_X}{X} + \frac{(X-2)\hat{D}_{X-1}}{X}$$

where:

- X is the current iteration of the MKMMM demand model;
- D_X is the demand matrix produced by the demand model in iteration X; and
- $\hat{D}_X$ is the averaged demand matrix used as input to the supply model in iteration X.

12.8.6 Demand smoothing is only applied from the third iteration of the model onwards. The construction of the function is such that more recent iterations are given more weight in the calculation of an averaged demand matrix than earlier iterations. It has been found in practice that this tends to result in faster convergence than a “straight” average of all previous iterations.

12.9 Generalised Costs Parameters

12.9.1 The generalised cost functions are described in Section 12.5. The parameters used in these functions are derived directly from the WebTAG databook, July 2016 in-draft, and are summarised below. They are consistent with (though not usually identical, due to differences in definitions) to those used in the highway and public transport model.

12.9.2 Person values of time are shown for the base year (2016), in Table 44. The business values of time shown are the average values of time, not the maximum. The HGV values of time are a factor of 2 higher than the WebTAG databook values, to reflect operators' rather than drivers' value of time. This adjustment is based on Department for Transport guidance and is consistent with WebTAG guidance.

Table 44. Person Values of Time, Pence per Minute, 2010 Prices, 2016 Values

Segment	Value of Time
Commuting	17.883
HB Business	26.708
HB Other	8.162
NHB Business	26.708
NHB Other	8.162
LGV	17.336
HGV	43.337

12.9.3 Vehicle operating cost parameters are shown in Table 45, again for the base year (2016).

Table 45. Operating Costs, Pence and Litres, 2010 Prices, 2016 Values

Values	Car (Petrol)	Car (Diesel)	Car (Elec)	LGV (Petrol)	LGV (Diesel)	HGV (Diesel)
Work Fuel Cost, pence per litre	87.85	91.14	13.54	87.85	91.14	91.14
Non-Work Fuel Cost, pence per litre	105.43	109.37	14.22	105.43	109.37	109.37
Fuel VOC A-Factor	1.12	0.49	0.00	1.95	1.81	2.46
Fuel VOC B-Factor	0.044	0.062	0.126	0.0345	0.327	0.492
Fuel VOC C-Factor	0.00	0.00	0.00	0.00	0.00	-0.01
Fuel VOC D-Factor	0.00000245	0.00000465	0.00	0.00000077	0.0000426	0.000056
Non-Fuel Cost A-Factor	4.95	4.95	4.95	6.35	6.35	10.50
Non-Fuel Cost B-Factor	135.95	135.95	135.95	4145944	4145944	409.91
Fleet Proportion (Petrol/Diesel)	0.47	0.53	0.00	0.03	0.97	1.00
Fuel Efficiency factor	0.88	0.87	1.00	0.97	0.85	1.00

12.10 Demand Choice Sensitivity Parameters

12.10.1 The demand model uses theta and lambda values in its choice functions, reflecting response sensitivity, the use of which are detailed in Section 12.7. The values are given here, along with discussions as to their origin.

12.10.2 Following WebTAG, lambda parameter values are specified for trip distribution. All other choice processes above distribution (frequency, mode, time period) use theta parameter values, which are scaling parameters. Theta parameters indicate the relative sensitivity of a choice process when compared with the next process down in the choice hierarchy. As the sensitivity of choice parameters should not increase when moving up the choice hierarchy, theta values will never be greater than one.

12.10.3 Sensitivity values for time period choice, trip distribution, car versus public transport mode choice, and active versus motorised mode choice are taken directly from WebTAG M2 and used unaltered. Sensitivities for trip frequency are zero as all modes of travel are represented, in line with advice in WebTAG.

12.10.4 Theta values for time period choice and active mode choice are equal to 1; that is, the models have the same sensitivity as motorised mode choice. Time period choice for freight has the same sensitivity as distribution.

Table 46. Choice Model Sensitivity Parameters

Segment	Distribution, Hwy & Active, λ	Distribution, Public Transport, λ	Mode Choice, θ	Trip Frequency, θ
Commuting	-0.065	-0.033	0.68	0.00
HB Business	-0.067	-0.036	0.45	0.00
HB Other	-0.090	-0.036	0.53	0.00
NHB Business	-0.081	-0.042	0.73	0.00
NHB Other	-0.077	-0.033	0.81	0.00
LGV	-0.030	-	-	0.00
HGV	-0.030	-	-	0.00

12.11 Demand Model Calibration

12.11.1 The validation of the MKMMM demand model is a consideration of the realism tests and recommended acceptable values or ranges of values for model sensitivity, derived from WebTAG. A number of realism tests have been undertaken to demonstrate that the modelled demand responses are plausible, both in the direction and scale of change. Data from these tests are presented below.

12.11.2 Where elasticities are discussed, these are primarily based on changes in vehicle kilometres with respect to changes in some element of cost, and are calculated via the arc-elasticity formula:

$$\text{elasticity} = \frac{\log_e\left(\frac{km_t}{km_b}\right)}{\log_e\left(\frac{v_t}{v_b}\right)}$$

where:

- km_t is the vehicle kilometres in the test case;
- km_b is the vehicle kilometres in the base case;

- v_b is the base value of the variable for which the elasticity is being calculated (fuel cost, public transport fares, journey time, etc.); and
- v_t is the test value of that variable.

12.11.3 An alternative formulation, used where specifically noted, for consistency with the data available, is that of the trip elasticity, which is given by:

$$\text{elasticity} = \frac{\log_e\left(\frac{t_t}{t_b}\right)}{\log_e\left(\frac{v_t}{v_b}\right)}$$

where:

- t_t is the total trips in the test case; and
- t_b is the total trips in the base case.

12.11.4 Elasticities have been calculated at a matrix level, using demand matrices and OD distance skims, including only demand produced in the internal area. This ensures that a complete range of trip lengths is included in the calculation but that wholly external demand, which is modelled quite simply and is of little interest, is excluded.

12.11.5 WebTAG advises that three main realism tests should be carried out:

- elasticity of car vehicle kilometres to a 10% increase in car fuel cost.
- elasticity of public transport trips to a 10% increase in public transport fare.
- elasticity of car trips to a 10% increase in car journey time (single iteration; no convergence equilibrium).

Car Fuel Cost Elasticity

12.11.6 The main measure of the model highway sensitivity is the change in car vehicle kilometres with respect to a change in car fuel cost. Car fuel cost was increased by 10%, the resulting change in car vehicle kilometres was measured, and the elasticities were calculated.

12.11.7 WebTAG Unit M2 provides guidance on car fuel cost elasticities. They are expected to be in the range of -0.25 to -0.35, at a plausible level given the modelled area's characteristics relative to the UK as a whole. The elasticity is expected to be weaker (closer to -0.25) where trip lengths are shorter than average, car driver mode shares are higher than average, and the proportion of business trips are higher than average. The elasticity is expected to be stronger (closer to -0.35) where the opposite applies.

12.11.8 We found no good reason to suggest that any of these values in the Milton Keynes area are substantially different from the national average. On this basis, the overall fuel cost elasticity is expected to be around the centre of the range defined above.

12.11.9 Table 47 shows the final car fuel cost vehicle kilometre elasticities for all trips originating in the model internal area, as derived from the test increase in car fuel cost by 10%.

Table 47. Car Fuel Cost Elasticities, Matrix, Internal Productions

Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	Annual
Commuting	-0.181	-0.200	-0.191	-0.221	-0.197
HB Business	-0.151	-0.133	-0.128	-0.149	-0.139
HB Other	-0.397	-0.396	-0.341	-0.420	-0.388
NHB Business	-0.097	-0.147	-0.125	-0.173	-0.138
NHB Other	-0.467	-0.371	-0.467	-0.404	-0.408
All Car	-0.277	-0.319	-0.280	-0.325	**-0.307**

12.11.10 Table 47 shows that for all car demand, the elasticity of vehicle kilometres with respect to a 10% increase in car fuel costs is -0.307, almost in the centre of the expected range detailed in WebTAG. The elasticities are lowest for business demand, where the value of time is highest, and conversely is highest for "other" demand where the value of time is lowest. Elasticities are also lower in the two peak periods where congestion is highest and therefore fuel costs form a smaller portion of total generalised cost.

12.11.11 The elasticity of vehicle kilometres to changes in fuel costs has also been calculated at a network level using simulation links within the highway assignment model. This analysis has been undertaken both including (Table 48) and excluding (Table 49) the links which represent the M1 within the simulation area of the model.

Table 48. Car Fuel Cost Elasticities, Network, Simulation Links (including M1)

Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	Annual
Commuting	-0.142	-0.199	-0.135	-0.227	-0.174
Business	-0.095	-0.103	-0.078	-0.154	-0.102
Other	-0.501	-0.568	-0.483	-0.638	-0.554
All Car	-0.265	-0.414	-0.297	-0.425	**-0.361**

Table 49. Car Fuel Cost Elasticities, Network, Simulation Links (excluding M1)

Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	Annual
Commuting	-0.132	-0.152	-0.117	-0.172	-0.142
Business	-0.035	-0.079	-0.036	-0.085	-0.061
Other	-0.293	-0.362	-0.306	-0.397	-0.346
All Car	-0.176	-0.271	-0.198	-0.272	**-0.235**

12.11.12 Table 48 shows that when including all links within the simulation area, the outturn vehicle kilometre elasticity is marginally above the WebTAG range at -0.361, whereas when excluding the M1 from this analysis the elasticity drops to -0.235, slightly below the expected WebTAG range. This analysis shows the significant impact that demand on the M1 has in terms of this measure of the model sensitivity. The traffic on the M1 is likely to be longer in nature than local traffic, and therefore more sensitive to changes in fuel costs.

12.11.13 Finally, WebTAG advises demonstrating the need for cost damping mechanisms where these are used. Accordingly, fuel cost elasticities have been reproduced with only value of time variation modelled (Table 50), and also without both value of time variation and cost change dampening with trip distance (Table 51). Both of these tests show that without one or more of the cost dampening mechanisms, the outturn sensitivity of the model to changes in fuel costs is outside WebTAG guidelines.

Table 50. Car Fuel Cost Elasticities, Value of Time Variation Only, Internal Productions

Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	Annual
Commuting	-0.276	-0.333	-0.298	-0.355	-0.313
HB Business	-0.352	-0.292	-0.288	-0.370	-0.319
HB Other	-0.634	-0.606	-0.504	-0.655	-0.597
NHB Business	-0.163	-0.215	-0.184	-0.302	-0.208
NHB Other	-0.740	-0.609	-0.675	-0.663	-0.645
All Car	-0.446	-0.505	-0.424	-0.520	**-0.485**

Table 51. Car Fuel Cost Elasticities, No Cost Damping, Internal Productions

Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	Annual
Commuting	-0.361	-0.455	-0.400	-0.469	-0.418
HB Business	-0.330	-0.232	-0.248	-0.368	-0.283
HB Other	-0.839	-0.784	-0.643	-0.842	-0.772
NHB Business	-0.153	-0.160	-0.149	-0.308	-0.164
NHB Other	-0.973	-0.832	-0.852	-0.891	-0.859
All Car	-0.574	-0.648	-0.538	-0.668	**-0.621**

Public Transport Fare Elasticities

12.11.14 WebTAG Unit M2 states that public transport fare elasticity test is required in all cases where changes in public transport generalised costs, including changes in fares, are modelled. Accordingly, the elasticities of public transport trips to fare have been calculated, for trips originating in the model internal area, where fares were increased by 10% for this test. The overall elasticity is within the suggested range of -0.20 to -0.90, although at the extreme lower end.

12.11.15 Accordingly, the elasticities of public transport trips to fare have been calculated, and are presented in Table 52. The overall elasticity of public transport demand to a 10% increase in fares is -0.237, which is within the WebTAG range, and at the lower end of this range.

Table 52. Public Transport Fare Elasticities, Matrix Internal Productions

Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	Annual
Commuting	-0.346	-0.162	-0.303	-0.276	-0.284
HB Business	-0.300	-0.205	-0.237	-0.227	-0.251
HB Other	-0.147	-0.157	-0.232	-0.282	-0.180
NHB Business	-0.551	-0.354	-0.599	-0.386	-0.449
NHB Other	-0.751	-0.343	-0.674	-0.701	-0.538
All	-0.292	-0.178	-0.308	-0.298	**-0.237**

Car Journey Time Elasticities

12.11.16 WebTAG also requires calculation of elasticity of car demand (at the trip level) to journey times. Here the requirement is merely that the elasticities do not exceed 2 in magnitude, and that they are negative (as is logical). Journey times were increased by 10% for this test, and the demand and supply models were not iterated to convergence but run for a single iteration only, as advised in WebTAG M2. The results of this test are shown in Table 53.

Table 53. Car Journey Time Elasticities, Matrix, Internal Productions

Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	Annual
Commuting	-0.056	-0.027	-0.105	-0.024	-0.054
HB Business	-0.079	-0.048	-0.053	-0.022	-0.053
HB Other	-0.094	-0.060	-0.113	-0.055	-0.075
NHB Business	-0.078	-0.089	-0.106	-0.034	-0.088
NHB Other	-0.051	-0.030	-0.179	-0.029	-0.063
All Car	-0.074	-0.050	-0.116	-0.043	**-0.063**

12.11.17 The overall elasticity of car demand to a 10% increase in journey times is -0.063, which is within the WebTAG range of being negative and no greater in magnitude than 2. The elasticities are higher in the two peak hours, reflecting the additional congestion in these time periods and is lowest in the off-peak when congestion is at its lowest.

12.12 Demand Model Conclusions

12.12.1 The MKMMM is a fully functioning variable demand model, designed to follow latest WebTAG guidance. The sensitivity of the MKMMM is consistent with WebTAG guidance. The demand elasticities of the model to changes in car fuel cost, journey time and public transport fares are credible, varying by demand segment and time of day.

13. Summary and Conclusions

13.1 Model Development

13.1.1 The Milton Keynes highway assignment model network was based on the 2009 SATURN network. The network was updated to represent 2016 and the simulation area extended to the north, east, south and west.

13.1.2 The 2009 zone system was updated to be in line with NTEM zones external to the Milton Keynes area and larger zones in proposed development areas were disaggregated. New trip matrices were created using the 2009 RSI data, a synthetic model and trips from SERTM.

13.1.3 Additional surveys were conducted where existing data was unavailable, for use in the matrix building and model calibration and validation. Trafficmaster data was also used for the journey time validation.

13.2 Standards Achieved

13.2.1 The validation of the calibration counts for the highway assignment model is good. Post Matrix estimation, the calibration sites that pass the flow or GEH criteria across the 142 sites that make up the calibration screenlines and cordons are as follows:

- AM: 134, 94%
- Inter-Peak: 140, 99%
- PM: 136: 96%

13.2.2 These compare favourably with the criteria that 85% of counts pass this flow test.

13.2.3 The model was validated using data independent from the matrices and assignments. Out of the 26 validation sites the following counts passed the flow or GEH criteria:

- AM: 13, 50%
- Inter-Peak: 11, 42%
- PM: 12, 46%

13.2.4 Although these are less than the WebTAG guidance, the overall screenline comparisons were within 15%. The grid system in Milton Keynes makes representation of observed flows particularly challenging. Due to the limited observed data, traffic survey and signal timings, the limited timescale and the strong flow calibration and journey time validation these results are acceptable.

13.2.5 The convergence criteria in WebTAG M3.1 is a %GAP of <0.05%. The highway model has the convergence statistics, including the %GAP values, shown in Table 54. These indicate that model converges well in all three time periods.

Table 54: Highway Model Convergence Results

Assignment Loop	% GAP	AAD	RAAD	% Flows
AM Peak	0.0003	0.048	0.006	99.90
Inter-Peak	0.0000	0.106	0.017	99.10
PM Peak	0.0002	0.075	0.009	99.60

13.3 Demand Model Realism Testing

13.3.1 The demand model was calibrated such that demand elasticities are appropriate for the 10% fuel cost change realism test that was undertaken.

13.4 Model Suitability

13.4.1 This report has demonstrated that the Milton Keynes traffic model is sufficiently robust to be taken forward into the forecasting process at a strategic level. The report has shown that the model has been able to replicate traffic volumes and travel times to a reasonable standard of accuracy. It is important to note that the model was not designed for use in a scheme specific economic assessment for which it is recommended the model would be recalibrated with additional and more recent data and targeted to reflect a more specific geographical focus of resources and modelling effort.

13.5 Future Improvements

13.5.1 Observed origin and destination data for the internal area of Milton Keynes (within the RSI Cordon) would improve the robustness of the demand matrices. Observed signal timing data should not only improve the modelled journey times accuracy but would help route choice in the model. If it is not possible for average timings to be obtained from the signal controllers, then observed average green time surveys would be required. Consideration should also be given to micro time of period choice within the demand model to enable the modelling of peak spreading effects.

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