



BSTM2 Highway Assignment Model Development and Validation Report

Buckinghamshire Council

22/07/2026

BUCKINGHAMSHIRE STRATEGIC TRANSPORT MODEL 2

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1. Introduction

AtkinsRéalis, the framework consultants to Buckinghamshire Council (BC), has been commissioned to undertake the upgrade of the Buckinghamshire Strategic Transport Model (BSTM) which was developed by Jacobs in 2021. The new version of the model is the BSTM2 and it utilises the PTV VISUM 2021 software suite.

The BSTM is a highway assignment model (HAM) with fixed demand adopting the base year 2019. It was built following the Department for Transport's (DfT) Transport Appraisal Guidance (TAG) but does not fully comply with its requirements for link validation, screenlines or journey times with enhancements needed in several key urban areas. In addition, the BSTM doesn't have components of public transport modelling and variable demand modelling.

Following the review of the BSTM by AtkinsRéalis, the below improvements were suggested:

- The addition of variable demand modelling (VDM);
- The addition of public transport elements; and
- The enhancement of the model validation in selected urban areas (Aylesbury, High Wycombe, Marlow, Bourne End and Buckingham).

The purpose of the model update is to develop a new version of the BSTM that better meets the relevant TAG standards in the above-mentioned urban areas and includes the provision of a VDM component.

Similar to the BSTM, the BSTM2 retains a 2019 base year and extends across the Buckinghamshire boundary, capturing movements on the unitary authority borders in areas including Milton Keynes, Bicester, Slough, and West Drayton. In order to better reflect traffic movements across and within key areas of Buckinghamshire, the coding of highway network and zoning elements has been enhanced in the BSTM2 specifically in Aylesbury, High Wycombe, Marlow, Bourne End and Buckingham. In addition, local model recalibration was undertaken in the above-mentioned areas to achieve better compliance to TAG for all counts, screenlines and journey time routes.

In addition to the highway assignment element, the BSTM2 includes a proxy representation of a public transport model (PRPT) using fixed skim matrices derived from TRACC¹ and a VDM component that enables more realistic estimation of demand responses to proposed schemes and developments in Buckinghamshire. A key shortcoming with PRPT is that only global parameters of public transport can be altered and tested (e.g., fares) while specific network attributes at a service or corridor level are fixed and assumed to be 'broadly' the same between a base case and a test scenario.

The primary uses of BSTM2 will be testing highway network interventions, changes in global factors in public transport services, the impacts of development proposals, as well as growth and transport strategies and the development of the local plan.

¹ TRACC is a travel time analysis tool developed by BaseMap which produces travel time catchments and contours for a range of travel modes. It can be used to analyse the effectiveness of proposed schemes and interventions, particularly with regards to those involving active Modes and PT where the location of walk/cycle routes and bus stops may be important.

This HAM Model Development and Validation Report (HAM MDVR) details the updates to the HAM only. Development of the Variable Demand Model and PRPT will be detailed in a separate report.

1.1 Use cases

In developing BSTM2, it was important to recognise the proposed uses of the model in terms of the scenarios to be forecasted and interventions to be tested. At the outset, it was determined that the updated model should be able to:

- Provide a robust evidence base to support the Buckinghamshire Council (BC) Local Plan review, this includes informing site selection and assessment of alternative development scenarios;
- Support in Outline Business Cases and Full Business Cases for highway schemes, as the need arises in future (with appropriate forecasting techniques and assumptions applied);
- Support infrastructure planning for potential longer-term housing/employment development in key areas of Aylesbury, High Wycombe, Marlow, Bourne End and Buckingham;
- Support BC in the development of related transport schemes which are currently being progressed and forecasting its impact; and
- Support the implementation of the transport strategies including key proposed initiatives such as demand management.

It is noted that the BSTM2 is not suitable to test and assess the impact of developing an improved public transport network since building a detailed representation and assignment model of public transport in BSTM2 is beyond the scope of the current commission.

1.2 Report structure

Following this introduction, the report is structured as follows:

- Chapter 2 outlines the review of existing models;
- Chapter 3 outlines the Base Model Specification;
- Chapter 4 details the calibration and validation data;
- Chapter 5 outlines the Base Model update;
- Chapter 6 describes the trip matrix update;
- Chapter 7 defines the standards against which the model is validated;
- Chapter 8 describes the calibration of the highway assignment models;
- Chapter 9 covers the model validation results; and
- Chapter 10 concludes with a summary of the model performance.

2. Review of existing models

The BSTM2 is an updated version of the BSTM equipped with VDM, PRPT and enhanced coding of the highway network in Aylesbury, High Wycombe, Marlow, Bourne End and Buckingham along with improved calibration and validation in these areas for a 2019 base year. In addition, the BSTM2 adopts the zoning system of the Aylesbury Town Model (ATM) in Aylesbury which is more granular compared to the BSTM. A brief overview of the BSTM and ATM is presented below.

2.1 Buckinghamshire Strategic Transport Model

The BSTM was developed by Jacobs, in partnership with Systra, for BC. It was originally scoped to have a 2020 base year but due to the impacts of COVID-19, pre-existing data from multiple sources prior to 2020 were used and a 2019 base year model was developed.

The model was developed using the PTV VISUM 2021 software suite with network and zoning similar to the earlier Countywide Transport Model but more detailed in areas of Aylesbury, High Wycombe, Buckingham and Iver. The movements across the unitary authority borders in bulge areas of Milton Keynes, Bicester, Slough and Uxbridge were also reflected in the model. The model has 900 zones in total where 700 zones are in the area of detailed modelling, which covers the entire unitary authority.

The BSTM was developed as a fixed demand highway-only model using data from an average neutral weekday in 2019 for the key times periods of AM peak hour (08:00-09:00), PM peak hour (17:00-18:00) and average interpeak hour (10:00-16:00). Trip matrices were created by merging observed travel patterns from Mobile Network data and synthetic matrices, which were calibrated against Census journey to work data and National Travel Survey data. The highway assignments were calibrated and validated in line with the DfT's TAG guidance but did not fully meet the criteria for link validation, screenlines or journey times.

A single forecast scenario (reflective of a reference case for 2040) was built following advice set out in TAG unit M4 for the development of a fixed demand forecast. The forecast was built without any specific assessment in mind but established the process for when a scheme was identified. With regards to business case submissions, the BSTM was considered appropriate only for a Strategic Outline Business Case (SOBC). A more detailed local model or a local revalidation of the BSTM would have been required for Outline and Full Business Case submissions. The LMVR for the BSTM has been provided in Appendix O.

2.2 SEALR (Aylesbury Town Model)

The South-East Aylesbury Link Road (SEALR) model was developed by Jacobs for BC, by updating the ATM, to support a full business case for the SEALR scheme. SEALR is a highway-only, cordon model of the Countywide Transport Model, built on data collected for the year 2017 for the AM peak hour, PM peak hour and average interpeak hour time periods. The ATM was too small to build a VDM and the Buckingham Countywide Transport Model did not have enough detail in Aylesbury to be used directly. Due to these two considerations a decision was taken to use a tiered approach with the Production-Attraction based VDM feeding demand to a more detailed local assignment model which in turn is used to update link and turn delay functions in a less detailed wider area assignment model which informs the VDM. No PT assignment elements were added in the model given the nature of the scheme and the low level of PT share in the modelled area.

The network was created using Integrated Transport Network (ITN) data, an Ordnance Survey dataset, representing the transport network in Great Britain in a links and nodes structure. The zoning of the Countywide model is an aggregation of Census Output Areas (OA's) but within the urban areas it splits the existing OA boundaries to more granular zones especially in the South-East of Aylesbury to assess the impact of SEALR more accurately.

Trip matrices were created by the merging of observed travel patterns from Mobile Network data procured from Telefonica and synthetic matrices, which were created using demographic data. The synthetic matrices were calibrated against Census journey to work data and National Travel Survey data.

The base highway assignments were calibrated and validated to a reasonable degree to meet the DfT's TAG criteria. Two initial forecast model runs were built for the business case submission, one for the scheme opening year, 2021, and one for 15 years after the scheme opening year, i.e. 2036. Further forecast model runs were also built for the business case submission for years 2024 and 2039. The LMVR for the SEALR model has been provided in Appendix P.

2.3 BSTM2 Model Updates

Following the review of existing models and ensuing discussions with BC, the following actions were agreed with BC to update the BSTM:

1. Parameters update: This comprises updating the following parameters in BSTM:
 - Values of time (VOT) and vehicle operating costs (VOC) based on TAG Data book version 1.22 released on November 2023;
 - Goods vehicles traffic growth factors based on the National Road Traffic Projections released in year 2022 (RTP22); and
 - Population and Employment growth factors based on the National Trip End Model (NTEM) version 8.0 (Core Scenario). These factors will be used in deriving the potential future demand for travel if the model will be serving studied assessed by DfT.
2. Highway network updates: This involves undertaking the following enhancements for the BSTM highway network model in five key model improvement areas in Buckinghamshire (MIAs): Aylesbury, High Wycombe, Marlow, Bourne End and Buckingham:
 - Fixing the coding of exploded roundabouts where each merge node is given a control type as roundabout. This impacts the calculation and true reflection of delays on traffic merging points within the roundabout. The best practice is to code each merge node with a yield control type (priority junction).
 - Fixing the zone connectors that are directly loading onto road junctions. This way of coding causes a misrepresentation of the traffic flows on the nearby road network and consequently a misrepresentation of traffic delays on the roads and junctions near the zone connectors.
3. Zoning system updates: This involves the review of the BSTM zoning system in MIAs and making updates where necessary. If any local model of MIAs contains more granular zoning compared to BSTM (e.g., as is the case for Aylesbury), then the more granular zones are



adopted in BSTM2. The base year trips are to be distributed as per the town model but constrained to BSTM demand.

4. Better TAG compliance: This includes the following:
 - Performing checks on all the counts data used in the BSTM2 calibration and validation and ensuring they are allocated to the proper links in the model;
 - Local model recalibration in the five MIAs mentioned above to achieve better compliance to highway network model validation criteria outlined in TAG;
 - Addition of screenlines for Marlow and Bourne End using available traffic count data for year 2019; and
 - Addition of journey time routes for Marlow and Bourne End.
5. Development of VDM and public transport representation: This involves adding a VDM component which enables more realistic estimation of demand responses to the schemes being tested. As the VDM requires costs skimming from competing modes, a representation of the public transport network and services is needed. It was decided to postpone the development of public transport network assignment model and restrain it to a PRPT by developing the needed public transport skims using TRACC¹ software acknowledging the shortcomings of this modelling technique.
6. Development of model forecast: This involves the development of a baseline forecast scenario model run for a 2045 horizon year (BSTM2 2045) to act as the point of reference for treatment of uncertainty in relation to supply and demand changes. All the future land use development and future highway network schemes are taken from the latest uncertainty logs issued by BC. As mentioned in point '1' above, the RTP22 forecasts will be adopted for goods vehicles.

3. Base model specification

3.1 Software

The BSTM2 has been developed using the PTV VISUM 2021 transport modelling software suite. VISUM is a proprietary software suite able to encompass strategic transport modelling at a regional level down to the assessment of individual junction at the simulation level. VISUM is capable of analysing even relatively minor changes in the network such as traffic management and provides detailed analysis of traffic behaviours at junctions. It is an industry respected assignment modelling tool used widely for the assessment of highways schemes and can provide robust analysis of small to large infrastructure developments.

3.2 Geographic Coverage

In determining the geographic coverage of the model, it is usual to consider a detailed inner area in which all transport behaviours are modelled, and outer area(s) in which there is progressively less detail, and few transport responses are represented. For the HAM, TAG Unit M3.1 states that the geographic coverage generally needs to:

- Allow for strategic re-routing impacts of interventions;
- Ensure that areas outside the main area of interest, which are potential alternative destinations, are properly represented; and,
- Ensure that the full lengths of trips are represented for the purpose of deriving costs.

From the Demand Model element, TAG Unit M2.1 (Section 2.4) advises that the model is divided into an internal area, in which all travel demand is modelled, and an external area, in which only trips to/from the internal area are considered.

Table 3-1 gives details of the model functionality by area type, and Figure 3-1 to Figure 3-2 show the extent of the Area of Detailed Modelling (AoDM) and Fully Modelled Area (FMA). The network density in Bulge Areas lying just on the edge of the Buckinghamshire unitary authority boundary is higher compared to Rest of Fully Modelled Area (RoFMA), enabling the movements to and from these areas into Buckinghamshire to be correctly reflected.

Table 3-1 - Geographical coverage and model functionality by area type

Area Type	Areas Covered	HAM
Internal:		
Area of Detailed Modelling	Within the Buckinghamshire unitary authority boundary	This is the area over which significant impacts of interventions are certain and the modelling detail in this area would be characterised by: representation of all trip movements; small zones; very detailed networks; and junction modelling using Intersection Capacity Analysis (ICA);
Bulge Area	Milton Keynes, Bicester, Slough, West Drayton	Areas that lie on edge of AoDM and have higher network density than compared to RoFMA. The characteristics of network elements are same as RoFMA.
Rest of Fully Modelled Area	Outside and nearby the Buckinghamshire unitary	Area over which the impacts of interventions are considered to be quite likely, but relatively weak in

Area Type	Areas Covered	HAM
	authority boundary (average distance 20 km)	magnitude and would be characterised by: representation of all trip movements; somewhat larger zones and less network detail than for the Area of Detailed Modelling; the traffic delay calculation is only based on volume delay function (VDF) at links;
Wider External Area	Rest of Country	Area where impacts of interventions would be so small as to be reasonably assumed to be negligible and would be characterised by: a buffer network representing a large proportion of the rest of Great Britain, a partial representation of demand (trips to, from and across the Fully Modelled Area); large zones; skeletal networks and fixed speed modelling.

Figure 3-1 – BSTM2 Area of Detailed Modelling

A map of the area of detailed modelling covering Buckinghamshire and highlighting the five Model Improvement Areas.

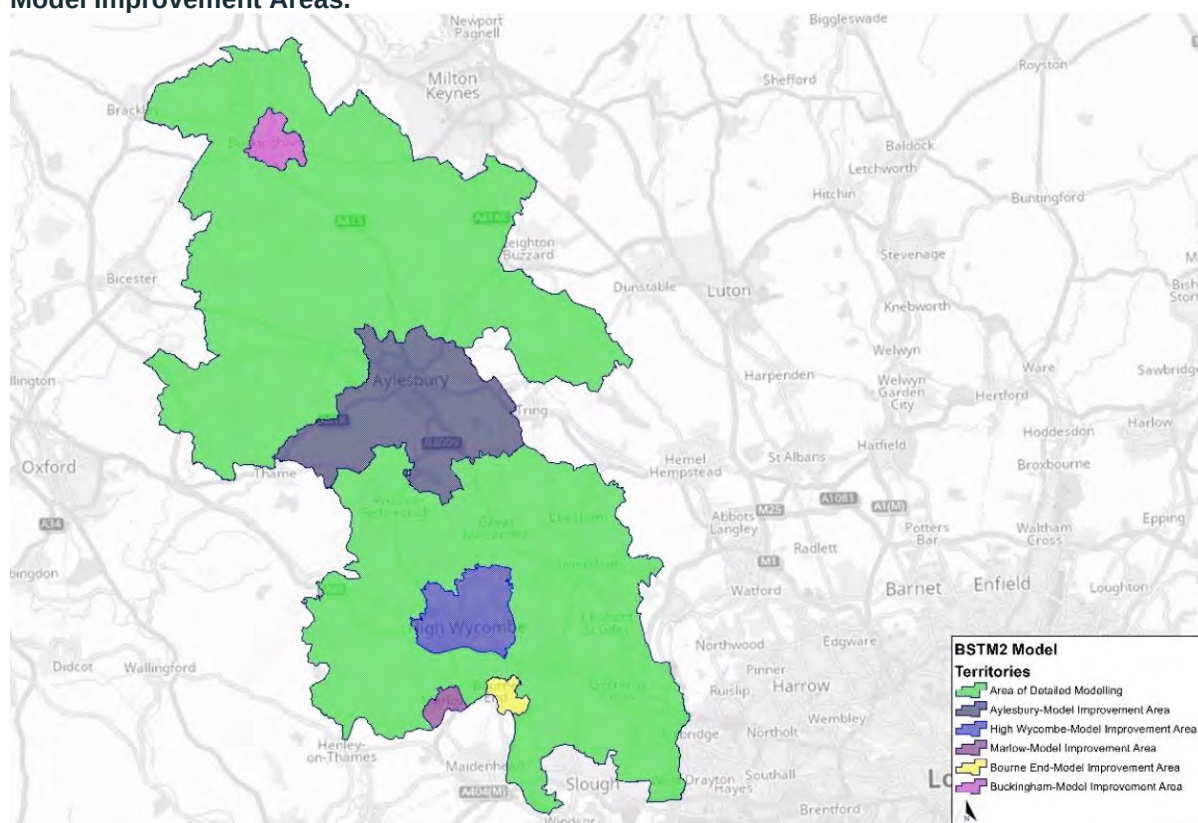
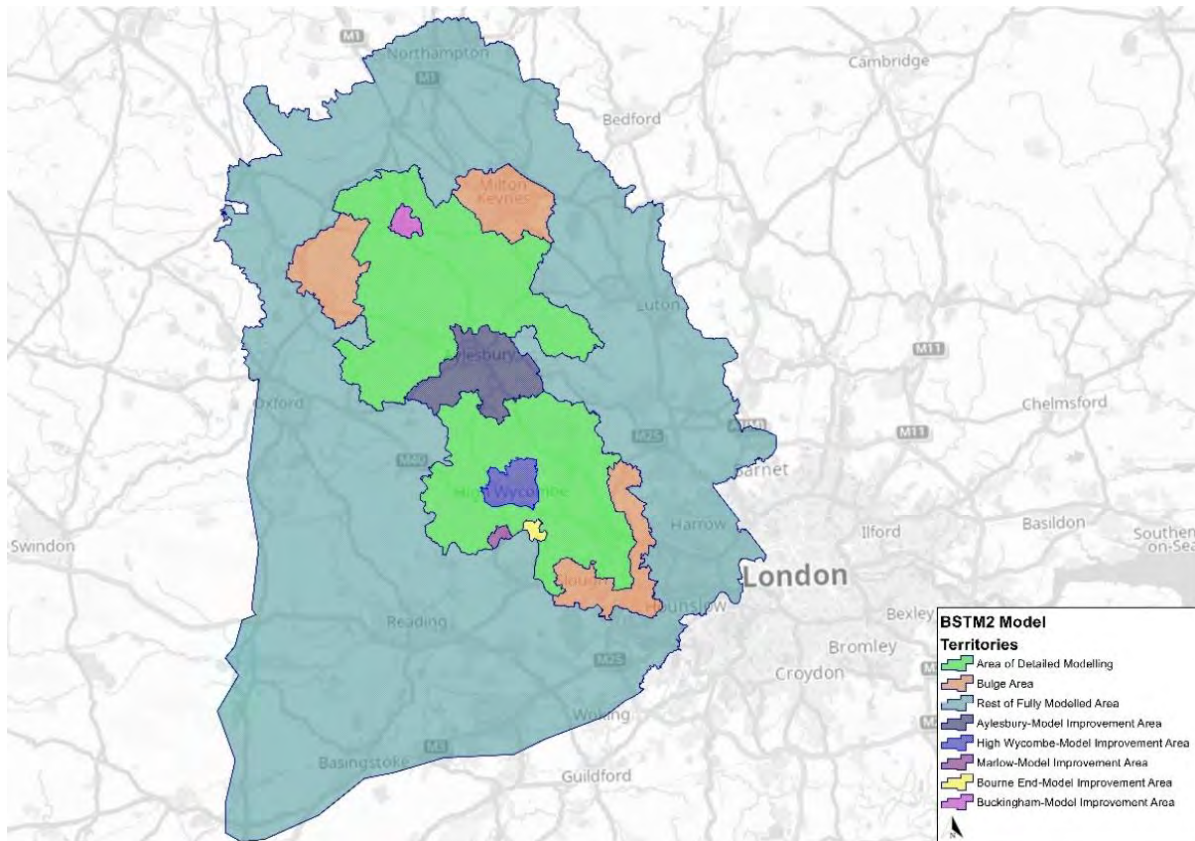


Figure 3-2 – BSTM2 Fully Modelled Area



3.3 Zoning system

The BSTM2 adopts the existing BSTM traffic zoning system for the FMA except for Aylesbury where the SEALR model provides more granular zoning. BSTM2 traffic zones for Aylesbury have been taken from the SEALR model where trips were distributed as in SEALR but constrained to the BSTM demand. In addition, within the AoDM, 10 zones were split to generate 8 new zones representing park and ride (P&R) sites near to train or bus station to be used in modelling the Bus and Rail Park and Ride modes.

Further details on the zone disaggregation in Aylesbury is presented in section 5.3. The BSTM2 zoning system is consistent across the HAM, PRPT, and VDM elements of the model. The zoning system of BSTM2 constitutes a total of 1050 zones divided into the model area types as shown in Table 3-2 and Figure 3-3 to Figure 3-5. The zoning system includes 138 vacant zones which act as placeholders for future year developments. These are empty in the base year model, and not geographically assigned so that they can be located where needed.

The adopted sectoring system in BSTM2 is shown in Table 3-3, Figure 3-6 and Figure 3-7.

Table 3-2 - BSTM2 zoning system

Modal Area	Number of zones
Area of Detailed Modelling	738
Bulge Areas	28
Rest of Fully Modelled Area	84
External	62
Vacant Zones for Future Developments	138
Total	1050

Figure 3-3 – BSTM2 Model Zoning System- AoDM

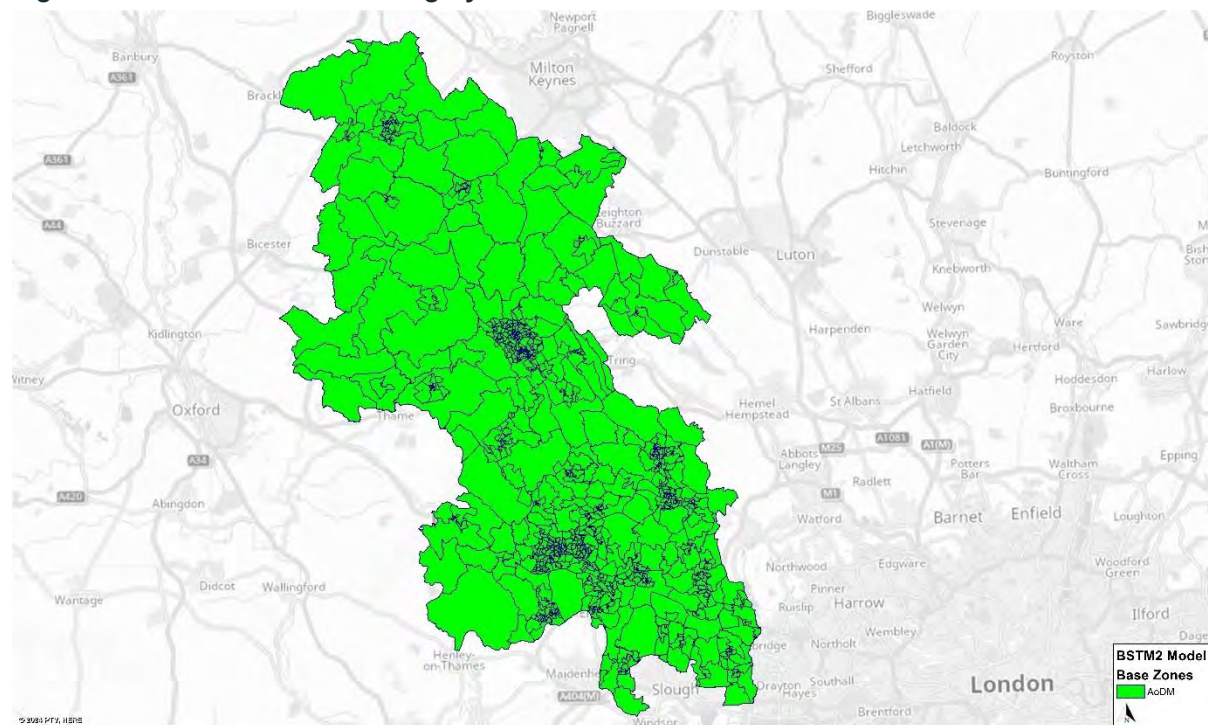


Figure 3-4 – BSTM2 Model Zoning System - FMA

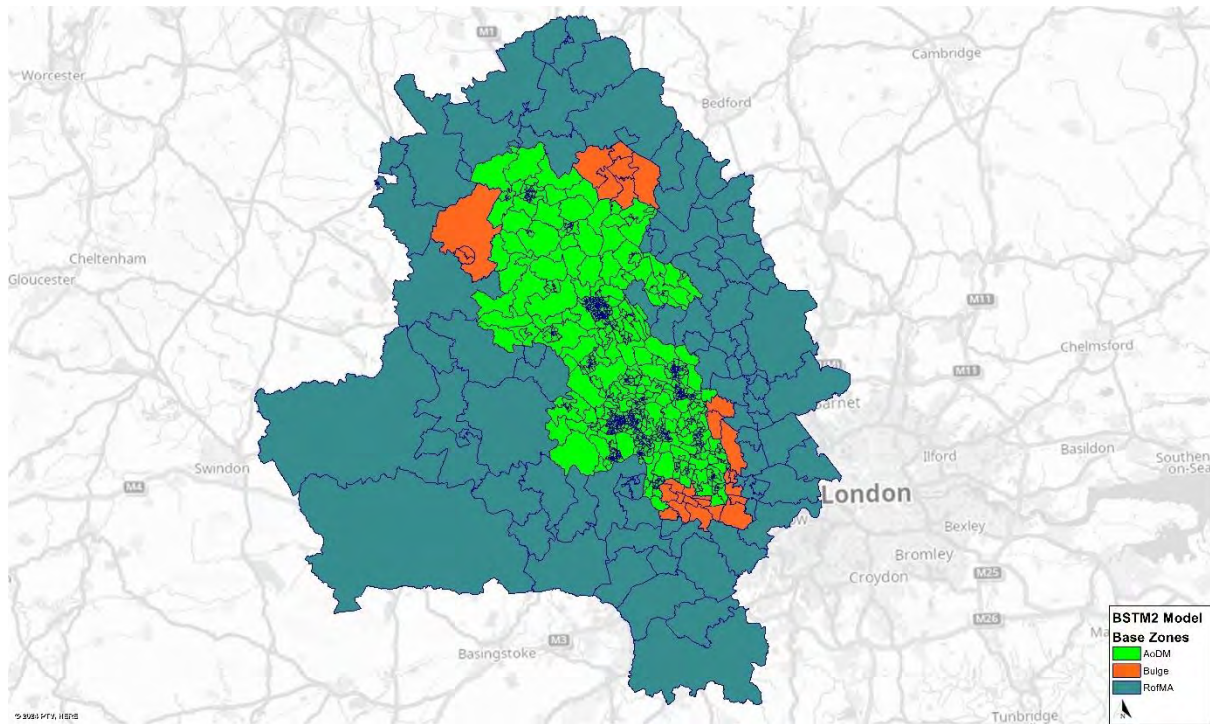


Figure 3-5 – BSTM2 Model Zoning System

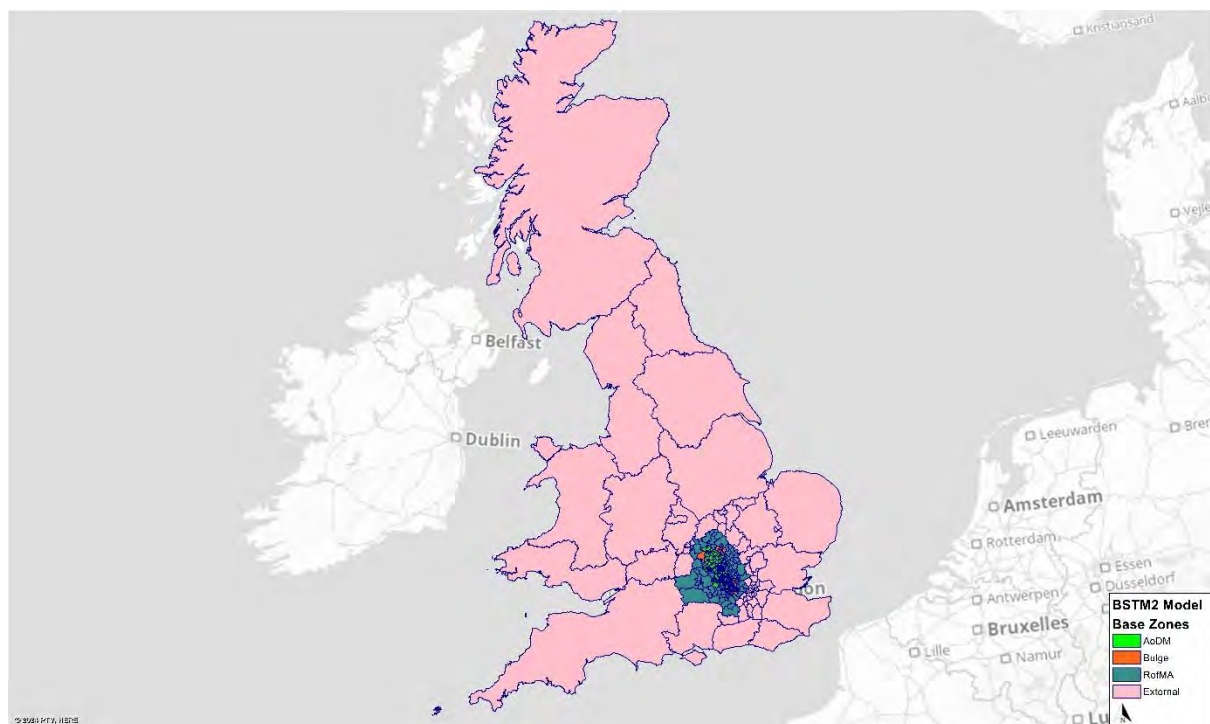


Table 3-3 - Summary of BSTM2 Sector Systems

Sector Number	Sector Name	Number of Zones	Sector Number	Sector Name	Number of Zones
101	Aylesbury North	94	308	Northamptonshire	10
102	Aylesbury Central	91	309	Bedford	1
103	Aylesbury South	71	401	Hampshire	1
104	Wycombe North-West	63	402	Berkshire	5
105	Wycombe Central and East	123	403	Oxfordshire	2
106	Wycombe South	64	404	Cambridgeshire	2
107	Chiltern North	104	405	East of England	1
108	Chiltern South	34	406	Essex	1
109	South Bucks West	44	407	Hertfordshire	7
110	South Bucks East	50	408	Kent	1
111	Milton Keynes	8	409	Surrey	11
112	Uxbridge	3	410	West Sussex	1
113	Slough	8	411	East Sussex	1
114	Bicester	3	412	Oxford	1
201	Central and North West London	15	413	West Berkshire	1
202	South and West London	5	414	Watford	2
203	East London	5	901	South West	2
301	Bedfordshire	14	902	West Midlands	3
302	Dacorum	9	903	East Midlands	6
303	Three Rivers	7	904	North West	1
304	Hillingdon South	9	905	Yorkshire and The Humber	1
305	Windsor and Maidenhead	10	906	North East	1
306	South Oxfordshire	5	907	Wales	2
307	Cherwell	8	908	Scotland	1

Figure 3-6 – BSTM2 Sector System

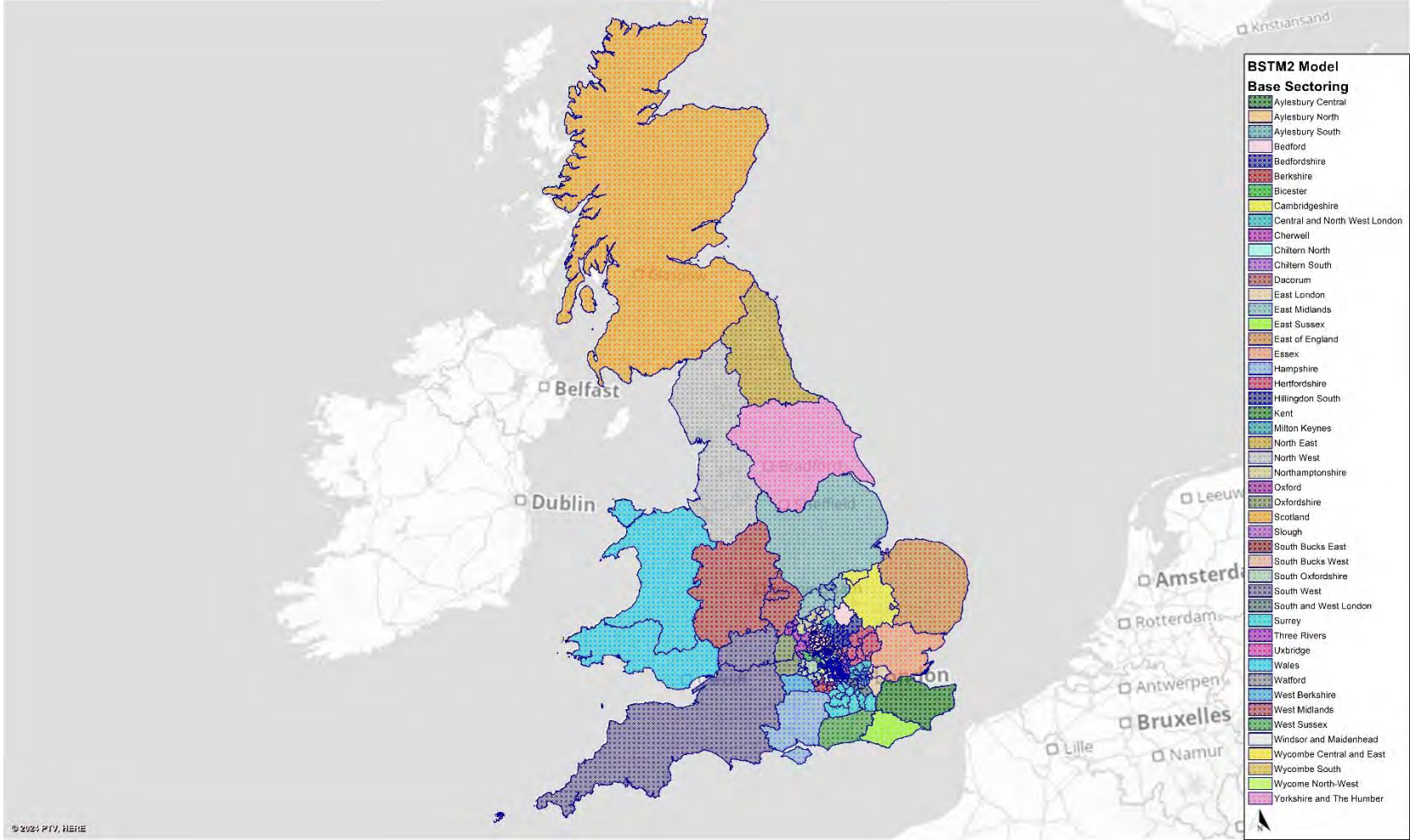
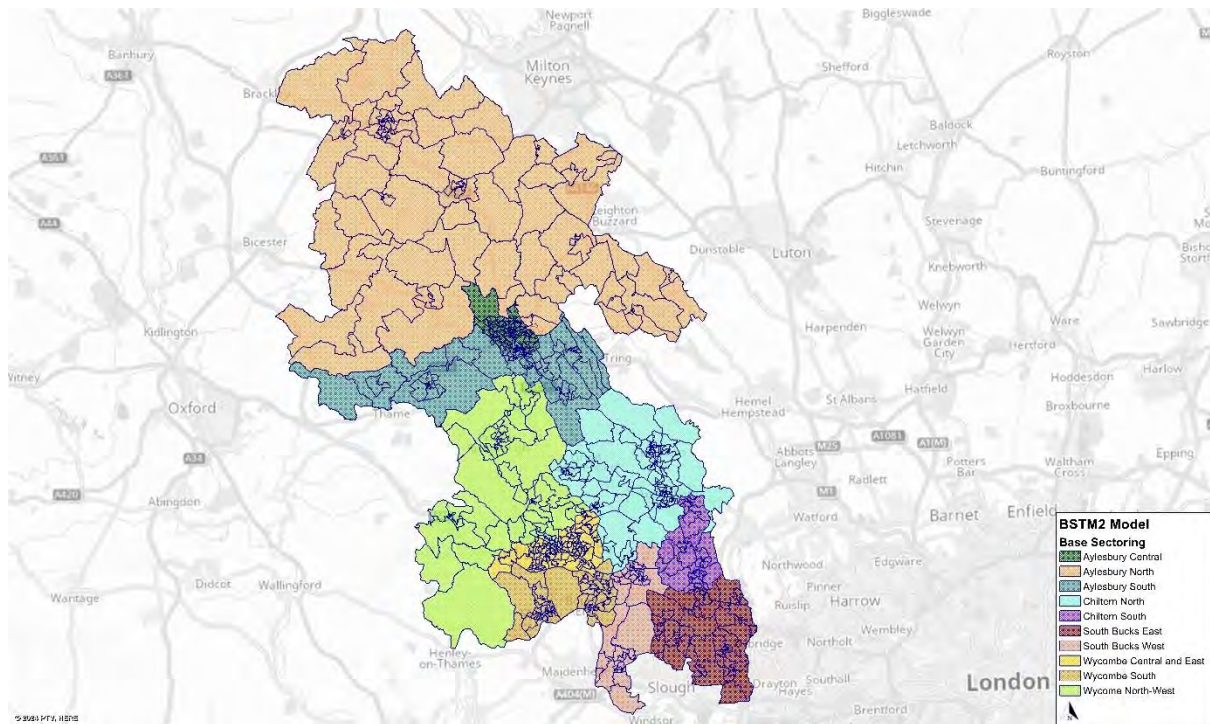


Figure 3-7 – BSTM2 Sector System Zoomed in to AoDM



3.4 Network structure

The highway network structure in the BSTM2 has been kept consistent with the BSTM. The sources of the model network were digital mapping databases such as ITN digital map for areas within Buckinghamshire and Meridian open-source digital maps for areas outside the Buckinghamshire unitary authority boundary. The highway classes within Buckinghamshire included in the network are:

- Motorways;
- A Roads;
- B Roads;
- Minor Roads; and
- Local Roads and Ancillary Roads where considered important for facilitating traffic movement.

For Bulge areas and RoFMA, only major roads were included. About 100 link types were defined in the model to classify roads, following guidance from COBA volume 13, Part 5 based on road class, number of lanes, speeds and modes allowed. These have been presented in Appendix A. Figure 3-8 shows the network structure across different areas of the model. Consistency in road links was maintained across different time periods, except in a few cases where link speeds were adjusted to reflect existing ground conditions that are not modelled.

BSTM2 Model Network Links

Territories

- Area of Detailed Modelling
- Aylesbury-Model Improvement Area
- High Wycombe-Model Improvement Area
- Marlow-Model Improvement Area
- Bourne End-Model Improvement Area
- Buckingham-Model Improvement Area

3.5 Temporal scope

The BSTM2 represents an average weekday (Tuesday to Thursday) in a neutral month of 2019. The HAM has the following time periods:

- AM Peak hour 08:00 to 09:00 – representing the busiest hour of the AM peak period across the study area;
- Inter-peak 10:00 to 16:00 – an average hour representation across 6 hours of the day; and
- PM Peak hour 17:00 to 18:00 – representing the busiest hour of the PM Peak period across the study area.

3.6 User classes

The HAM represents highway demand with five user classes:

- UC1 – Car Commute;
- UC2 – Car Employer’s Business (EB work);
- UC3 – Car Other;
- UC4 – Light goods vehicles; and
- UC5 – Heavy goods vehicles.

3.7 HAM vehicle types

The five user classes in the HAM are represented by three vehicle types. Passenger car units (PCUs) are used as the standard unit for demand and capacities rather than vehicles. This allows the effects of longer/slower vehicles that occupy more road space and take longer to clear junctions to be represented. The conversion factors used for the vehicle types are summarised below in Table 3-4 in line with TAG M3.1 Section E.7.

Table 3-4 - PCU Factors

Vehicle Type	Description	PCU Factor
Car	Private car	1
Light Goods Vehicle	Goods vehicle using car-based chassis	1
Heavy Goods Vehicle	OGV1 and OGV2 rigid	2
Bus	Scheduled coach and local bus service.	2

3.8 Assignment methodology

The assignment method used for the BSTM2 is known as “Assignment with ICA”. Typically, assignments use Volume Delay Functions (VDFs) for links and turns to model the delays (impedances) that increase with increasing volumes. In urban network models turns are of importance, since the junctions affect the network performance to a much greater extent than links do. Intersection Capacity Analysis (ICA) can represent instances, at signalised, priority and roundabout junctions, where the turn impedances do not solely depend on the volume itself but also from the volumes of the conflicting flows i.e. the volumes of other turns via the same node. ICA is a method of calculating the capacities and associated delays based on detailed geometric features of the junction.

The effects of junctions in terms of the delays experienced by vehicles are a key determinant of route choice. This approach is consistent with the latest TAG guidance.

3.9 HAM generalised cost

Generalised cost is a combined measure of time and money cost, and potentially distance, on which travellers make choices. The generic term in VISUM is the impedance value. The HAM uses distance and time information to provide the generalised cost of travel along different routes in the highway network and for each user class makes route choice on this basis.

The generalised cost function used for the HAM is shown below:

$$GC = (VOC/VoT * distance) + travel\ time$$

where VoT and VOC are the pence per second and pence per metre per vehicle

For the HAM, in accordance with TAG Unit M3.1, the values of time (VoT) and vehicle operating costs (VOC) are applied to each modelled user class. The figures used are derived using functions and parameters from TAG Data book version 1.22 released on November 2023 and are presented in Table 3-5 to Table 3-7 for the modelled time periods. For VOC calculations, an average network speed of 54kmph and 50:50 split between OGV1 and OGV2 was assumed.

Table 3-5 - VOT / VOC values - AM Peak

Morning Peak (08:00:09:00)	VoT per vehicle (pence per second)	VOC per vehicle (pence per metre)
Car Commute	0.3510	0.0063
Car Business	0.5233	0.0127
Car Others	0.2421	0.0063
LGV	0.3892	0.0139
HGV	0.8130	0.0401

Table 3-6 - VOT / VOC values – Inter-Peak

Inter Peak (10:00:16:00)	VoT per vehicle (pence per second)	VOC per vehicle (pence per metre)
Car Commute	0.3567	0.0063
Car Business	0.5363	0.0127
Car Others	0.2579	0.0063
LGV	0.3892	0.0139
HGV	0.8130	0.0401

Table 3-7 - VOT / VOC values - PM Peak

Evening Peak (17:00:18:00)	VoT per vehicle (pence per second)	VOC per vehicle (pence per metre)
Car Commute	0.3522	0.0063
Car Business	0.5309	0.0127
Car Others	0.2536	0.0063
LGV	0.3892	0.0139
HGV	0.8130	0.0401

3.10 Traffic delay calculation

3.10.1 Nodes Delay

In the urban networks of strategic transport models, junction coding is significant as it affects the network performance to a greater extent than link coding where the junction delay is considered a key determinant in formulating the vehicle route choice. As explained in section 3.9, ICA is a method of calculating the junctions' turn capacities and associated delays in the BSTM2. Since ICA works on the turn level, it can represent instances, at signalised, priority and roundabout junctions, where the turn impedances do not solely depend on the volume of the turn flow itself but also on the volumes of the conflicting turns flow i.e. the volumes of other turns flow via the same node.

3.10.1.1 Priority Junction

Priority junctions in ICA are modelled based on gap acceptance theory. This basic idea is to calculate potential capacity for each movement and then deduct capacity based on the opposing flows. In order to model priority junctions (otherwise known as Two-way stops in VISUM) the ICA module requires the following data:

- The priority arrangement of turning movements i.e. which movements give-way to the opposing flow;
- The number of lanes on each approach;
- The permitted turns for each lane; and
- Critical Gap and Follow-up time parameters.

The priority arrangement is donated by the major arms of the junction i.e. the movement with priority. This is referred to as the 'Major Flow' in VISUM and is not related to the volume of traffic making the movement. The movement with priority is the most important attribute as this denotes which vehicles are required to give-way to other vehicles, with delays calculated according to this hierarchy. Figure 3-9 illustrates for a typical give-way junction that the east to west movements have priority (denoted by the black arrows) while the southern arm would give-way.

Further attributes, Critical Gap and Follow-up time, were pre-set to values of 2 and 3 seconds respectively and were the main levers to modify available capacity at priority junctions, some of which were adjusted during network calibration. Priority junctions in the AoDM of BSTM2 are shown in Figure 3-10.

Figure 3-9 – Typical priority junction major flow

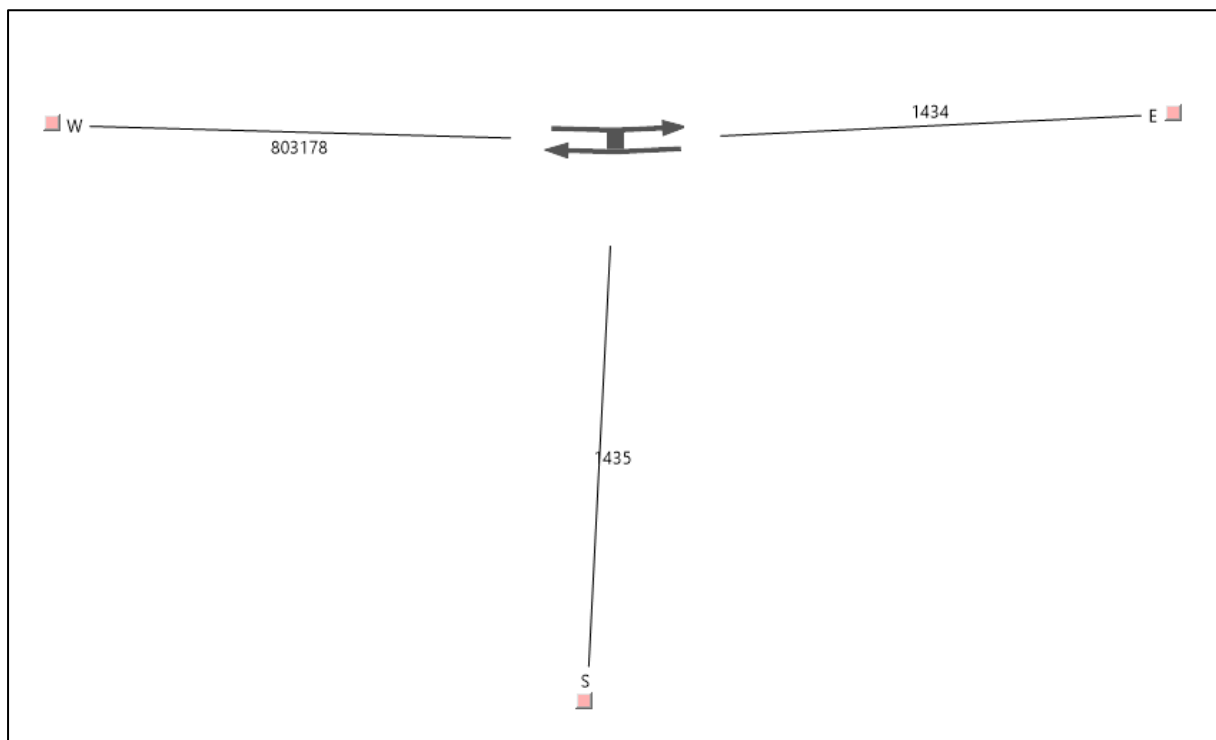
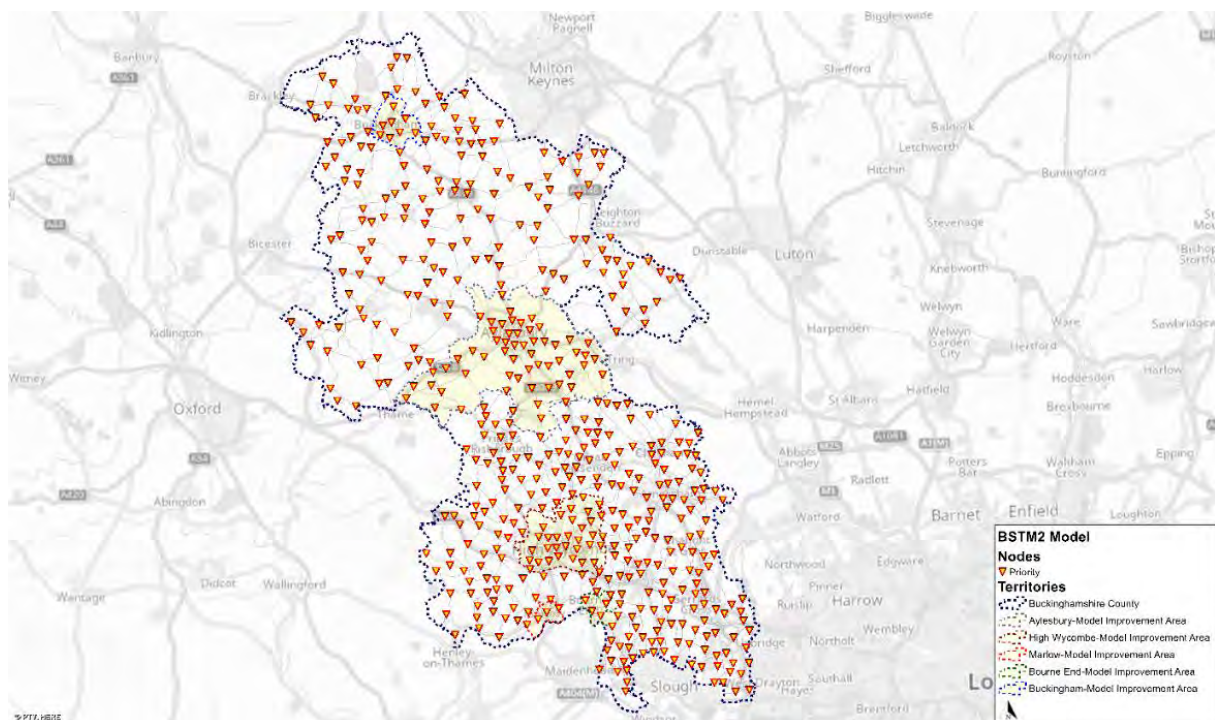


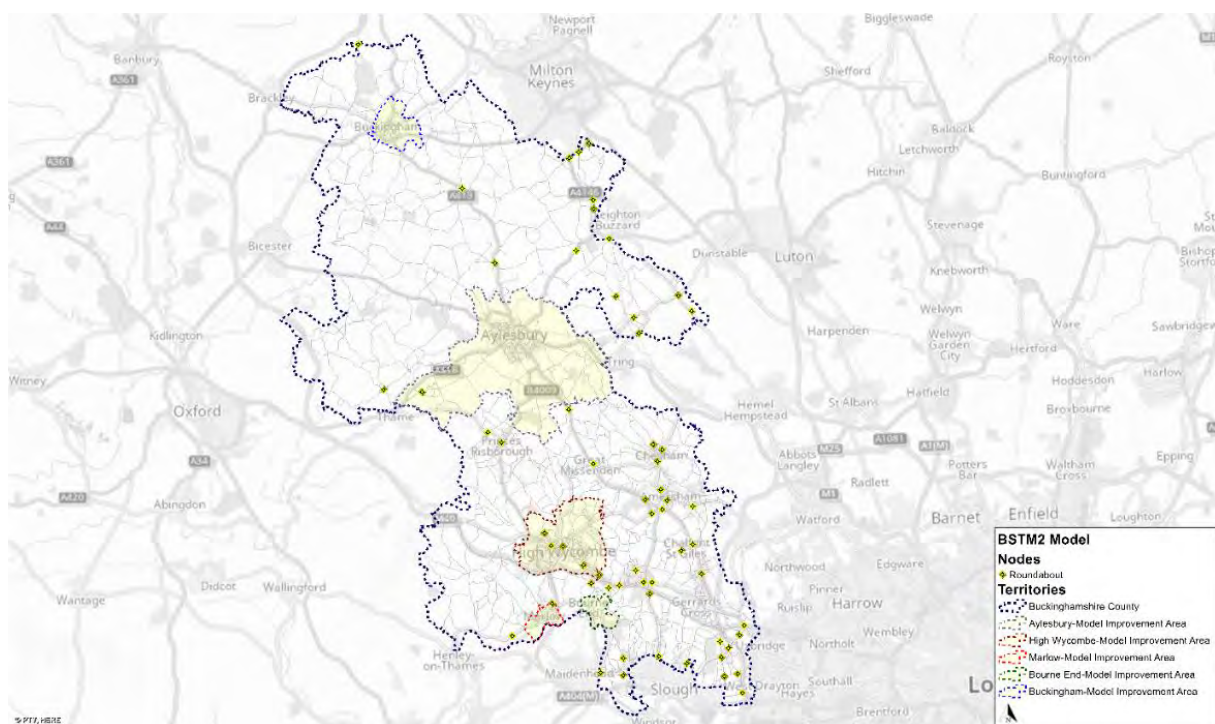
Figure 3-10 – BSTM2 Priority junctions in AoDM



3.10.1.2 Roundabout Junctions

In the BSTM, the majority of roundabouts were coded as a series of expanded nodes with the exception of a few mini roundabouts. As part of BSTM2, no new roundabouts were coded freshly into the model but all the merge nodes coded as roundabouts were converted to two-way yield within MIA's, which is explained in detail in section 5.1. Figure 3-11 presents the roundabouts in AoDM of BSTM2.

Figure 3-11 – BSTM2 Roundabout junctions in AoDM



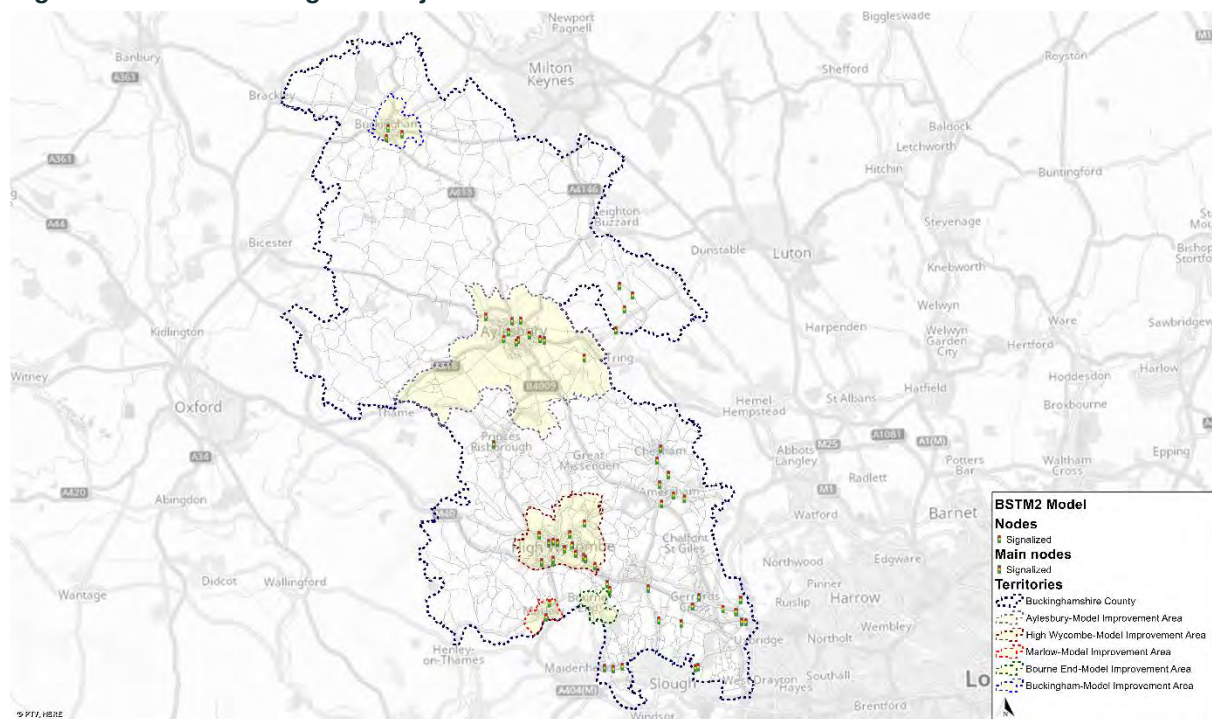
3.10.1.3 Signalised Junctions

There are 140 nodes and 35 main nodes which are signalised within the AoDM. The modelling of signalised junctions using ICA requires the following data to be coded:

- Number of lanes for all junction approaches;
- Turning movement allocations to lanes;
- Signal staging and timing data; and
- Saturation flows.

For the BSTM, signal timings were based on signal data extracted from Transport for Buckinghamshire's Urban Traffic Control system as part of Countywide Model Development study with base year 2013 and then further modified to reflect 2019 base year. As part of BSTM2, no new signalised junctions were coded freshly in the model and the existing ones were retained as is. Figure 3-12 presents the signalised junctions in AoDM of BSTM2.

Figure 3-12 – BSTM2 Signalised junctions in AoDM



3.10.2 Links Delay

In VISUM, the flow related delay on a link is modelled by Volume Delay Functions (VDF), which control the average travel speeds with respect to traffic volume. To allocate VDFs to each link, the link attributes such as road width, number of lanes, vehicular restrictions and level of development(urban/suburban/rural) were considered. For each link type, the relationship between vehicle flow and average speed were derived from COBA Volume 13, Part 5. The formulation used in BSTM for VDF was an adjusted BPR function developed by US bureau of Public Roads as below

$$t_{cur} = \begin{cases} t_0 \left(1 + a \cdot \left(\frac{q}{q_{max} \cdot c} \right)^b \right), & \frac{q}{q_{max} \cdot c} \leq 1 \\ t_0 \left(1 + a \cdot \left(\frac{q}{q_{max} \cdot c} \right)^{b'} \right), & \frac{q}{q_{max} \cdot c} > 1 \end{cases}$$

Where:

t_{cur} is the calculated link travel time;

t_0 is the link travel time at free flow conditions;

q is the flow on the link;

q_{max} is the link capacity; and

a , b , b' and c are parameters specific to each link type.

The curves developed in the BSTM were retained in the BSTM2. These curves for the BPR2 VDF for motorways, rural all-purpose highways, urban, suburban, rural and small-town link types are presented in Appendix B.

4. Calibration and Validation Data

The base year of the BSTM2 is 2019, in line with the BSTM. The counts for the calibration and validation of BSTM2 are taken from following sources.

- Existing count data used in the BSTM development;
- Existing count data used in the SEALR model development and falling on the new screenlines and cordons;
- New count data that has been used to fill gaps on the new screenlines and cordons, and to enhance the model validation near sites of proposed future developments.

4.1 Count data from the BSTM

A major portion of count data used in the BSTM2 is inherited from the BSTM. Table 4-1 summarises various types of count data by their source and year from the BSTM. 354 out of 368 BSTM counts were carried over into BSTM2 for building screenlines, with the majority collected in 2018, 2019, and early 2020 before the lockdown, providing a high level of confidence. Only a small number of counts from 2015, 2016 and 2017 were used and adjusted accordingly to fill gaps where no more recent counts were available.

Table 4-1 - Observed Count Data from BSTM model

Count Source	No. of						Total Number of Counts
	2020 (pre-lockdown)	2019	2018	2017	2016	2015	
WebTRIS	0	17	1	0	0	0	18
Survey – ATC ²	10	105	59	7	2	2	185
Survey – MCC ³	2	78	70	2	0	6	165
DfT	0	0	4	3	0	0	7
Total	12	200	134	12	2	8	368

Figure 4-1 presents the location of counts inherited from the BSTM model.

² Automatic Traffic Count

³ Manually Classified Traffic Count

BSTM2 Model

BSTM Count Links

— BSTM Counts

Territories

- Buckinghamshire County
- Aylesbury-Model Improvement Area
- High Wycombe-Model Improvement Area
- Marlow-Model Improvement Area
- Bourne End-Model Improvement Area
- Buckingham-Model Improvement Area

In the BSTM, in order to adjust counts collected prior to the base model year i.e., 2019, adjustment factors were derived from the DfT count data. Also, to adjust counts for neutral month flows, seasonality factors were calculated using a consistent set of count data from 2015 to 2019. These factors have been inherited from the BSTM and used in the BSTM2 model. The count adjustment factors and seasonality factors are presented in Table 4-2 and Table 4-3 respectively.

Table 4-2 - Count Adjustment Factors

Year	Uplift Factors to 2019	
	Minor Road	Major Road
2015	1.042	1.022
2016	1.037	1.019
2017	1.032	1.016
2018	1.026	1.006

Table 4-3 - Seasonality Factors

Month	Factor	Month	Factor
Jan	1.052	Jul	1.035
Feb	1.066	Aug	1.249
Mar	1.000	Sep	1.000
Apr	1.135	Oct	1.000
May	1.090	Nov	1.000
Jun	1.000	Dec	1.218

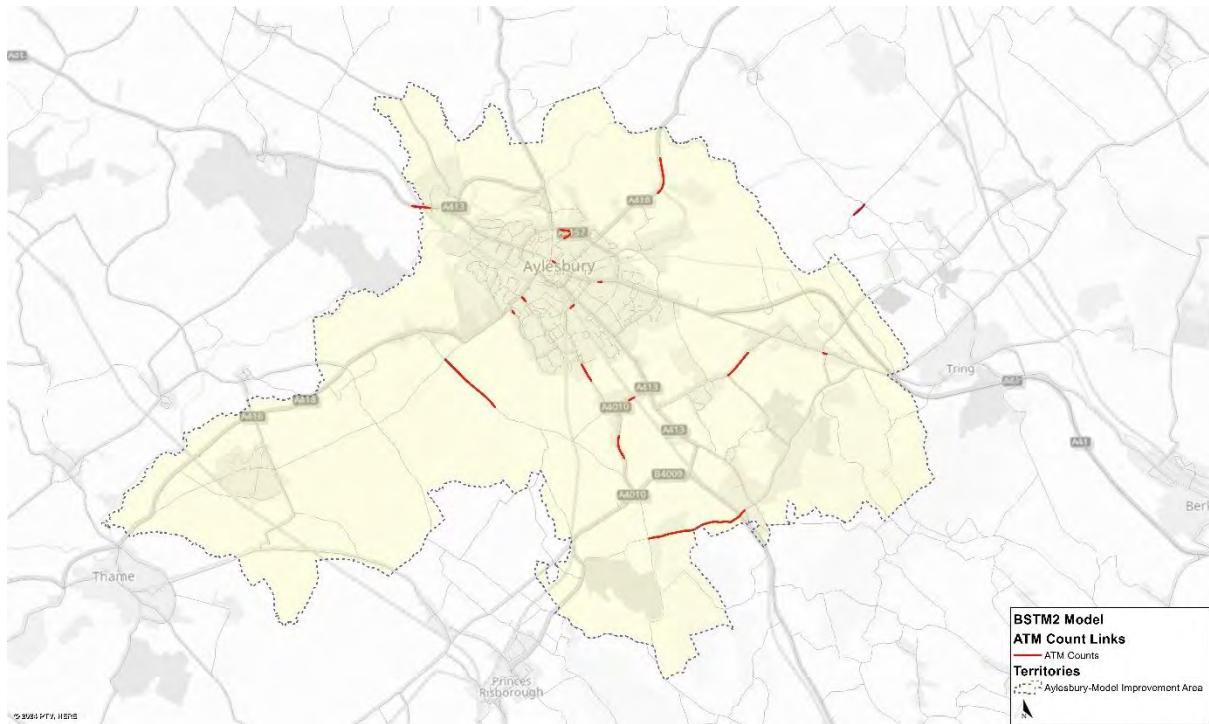
4.2 Count data from SEALR (ATM)

Counts from the SEALR model that lie on the screenlines developed for the BSTM2 were considered in this study. Overall, 34 counts were taken from the SEALR model into the BSTM2 model. SEALR counts have been considered wherever there is no available BSTM or TagMaster's data (web portal providing access to traffic monitoring data in Buckinghamshire) to fill the gaps on screenlines. Most of the SEALR counts used were collected in year 2017 and are considered quite reliable. Only 5 SEALR counts that are collected in the years 2013 and 2014 were used and uplifted to 2019 following checks on their consistency with other nearby counts. Count adjustment and seasonality factors presented in Table 4-2 and Table 4-3 were applied to convert the counts to a neutral month of 2019. The details on types of count data and year of observation are provided in Table 4-4. Figure 4-2 presents the geographic location of the SEALR counts that were used in BSTM2.

Table 4-4 - Observed Count Data from ATM model

Count Source	2017	2014	2013	Total Number of Counts
Total	24	6	4	34

Figure 4-2 – Location of counts taken from SEALR (ATM)



4.3 New Data from BC

In order to fill in gaps on screenlines new count data was requested from BC. These included ATC's and CTC's⁴. The majority of ATC's were downloaded from TagMaster while CTC's were provided by BC.

A total of 96 new counts were processed and taken into the BSTM2 for calibration and validation of the model. Similar to the BSTM, the Tuesday to Thursday average was considered to arrive at weekday average traffic volumes. Data for neutral months in 2019 was utilised where possible, but in cases where such data was not available, count adjustment and seasonality factors from Table 4-2 and Table 4-3 were used to arrive at a neutral month traffic flow for 2019. For counts where a classified volume was not available, the vehicle type split from the nearest count with similar road conditions was considered to arrive at a classified volume. Table 4-5 provides a summary of counts by their type and year of observation.

Table 4-5 - New Count data from BC

Count Source	No. of		Survey	Counts by	Collection	Year	Total Number of Counts
	2020 (pre-lockdown)	2019	2018	2017	2016	2015	
WebTRIS	0	17	1	0	0	0	18
Survey – ATC ⁵	10	105	59	7	2	2	185

⁴ Classified Traffic Count

⁵ Automatic Traffic Count

Survey – MCC ⁶	2	78	70	2	0	6	165
DfT	0	0	4	3	0	0	7
Total	12	200	134	12	2	8	368

Overall, a total of 484 counts have been used in the calibration and validation of the BSTM2. Table 4-6 summarises all the sources of counts in each of the MIA's and Figure 4-4 to Figure 4-8 provides the geographic location of these counts by each MIA. Figure 4-3 provides the geographic location of new counts considered in the BSTM2.

⁶ Manually Classified Traffic Count

BSTM2 Model New Count Links

— ATC Counts
— CTC Counts

Territories

- Buckinghamshire County
- Aylesbury-Model Improvement Area
- High Wycombe-Model Improvement Area
- Marlow-Model Improvement Area
- Bourne End-Model Improvement Area
- Buckingham-Model Improvement Area

Table 4-6 - Collated traffic survey sources for BSTM2

Count Type	Aylesbury	High Wycombe	Marlow	Bourne End	Buckingham	Rest of Buckinghamshire	Total
BSTM Counts	54	54	12	4	10	220	354
SEALR Counts	34	0	0	0	0	0	34
New ATC	22	10	0	0	2	4	38
New CTC	10	6	0	12	30	0	58
Total	120	70	12	16	42	224	484

Out of the of 388 counts from the BSTM and SEALR, 344 counts were checked for their location and direction with available raw data. A sense check was also made to verify if the data had been processed correctly, and the count had been assigned to the correct road location and traffic direction. There were 44 counts (34 from the BSTM and 10 from SEALR) where the raw data was not available for checking.

Figure 4-4 to Figure 4-8 shows the geographic locations of counts in BSTM2 MIAs.

Figure 4-4 – Location of count data in MIA of Aylesbury

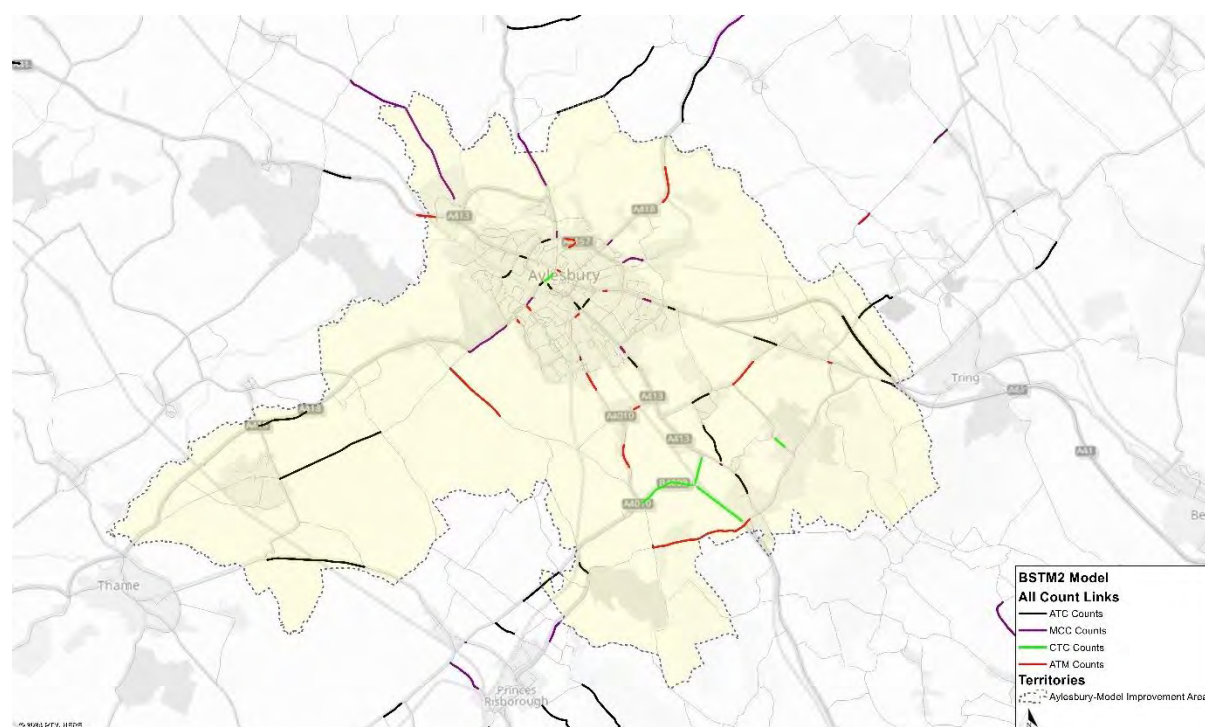


Figure 4-5 – Location of count data in MIA of High Wycombe

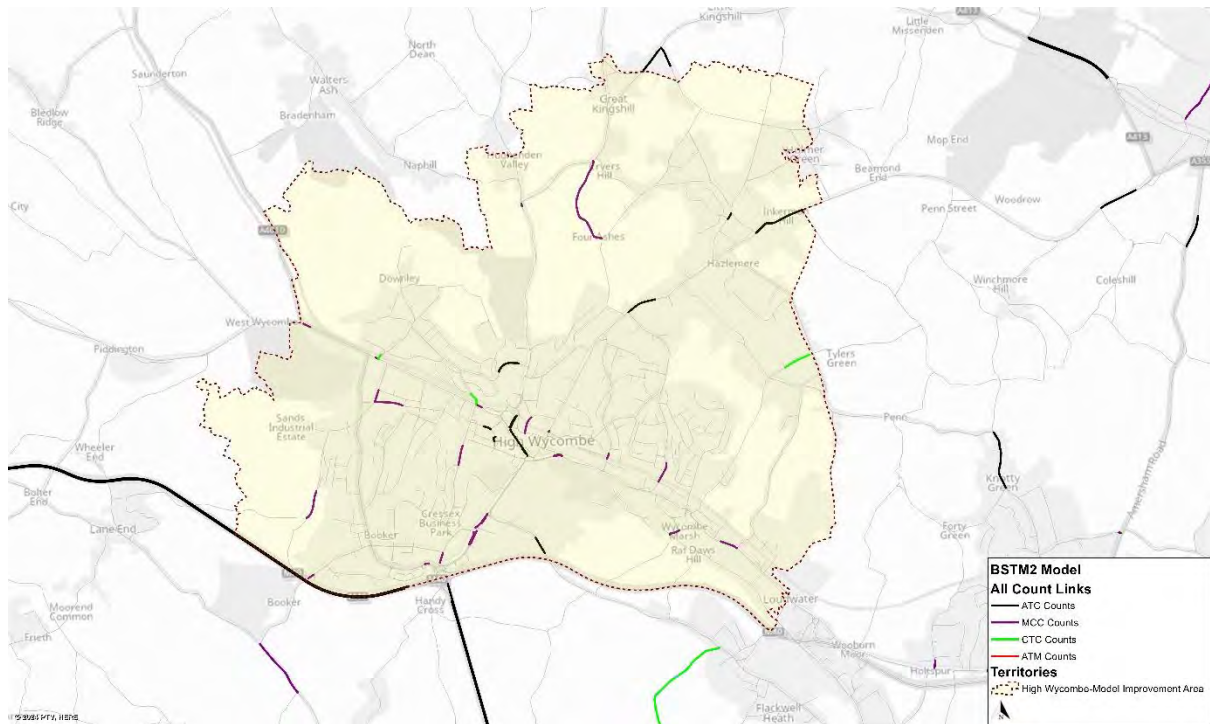


Figure 4-6 – Location of count data in MIA of Marlow

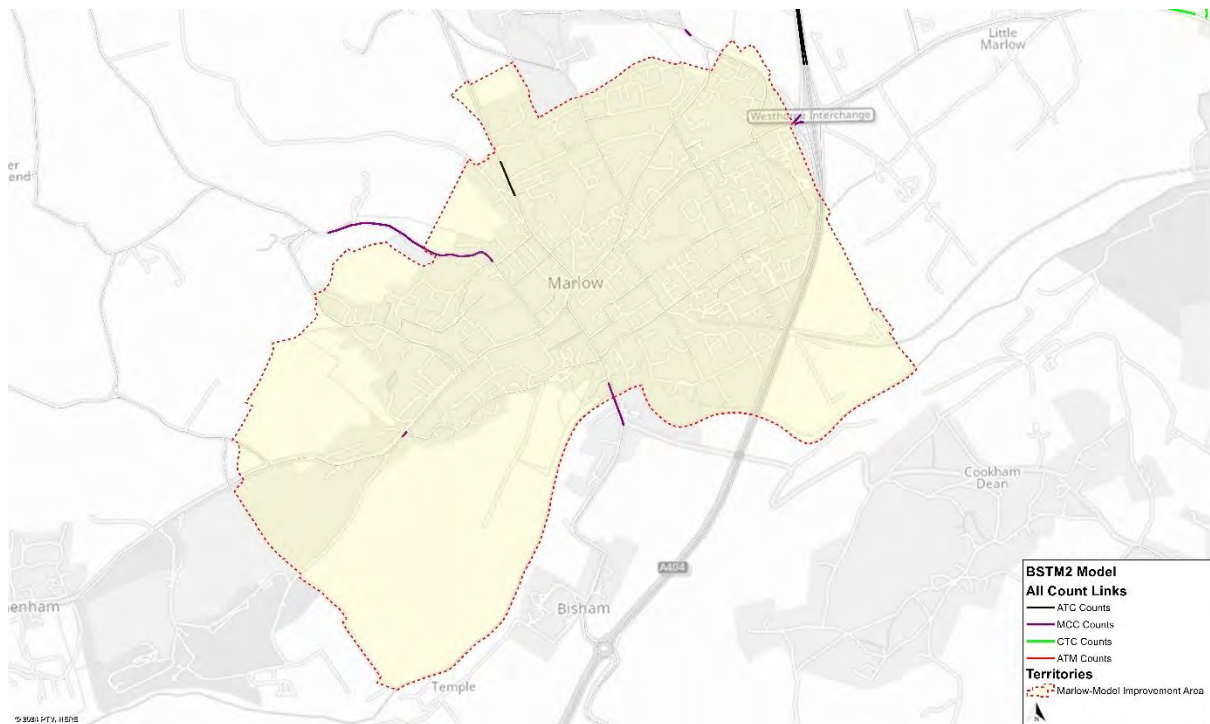


Figure 4-7 – Location of count data in MIA of Bourne End

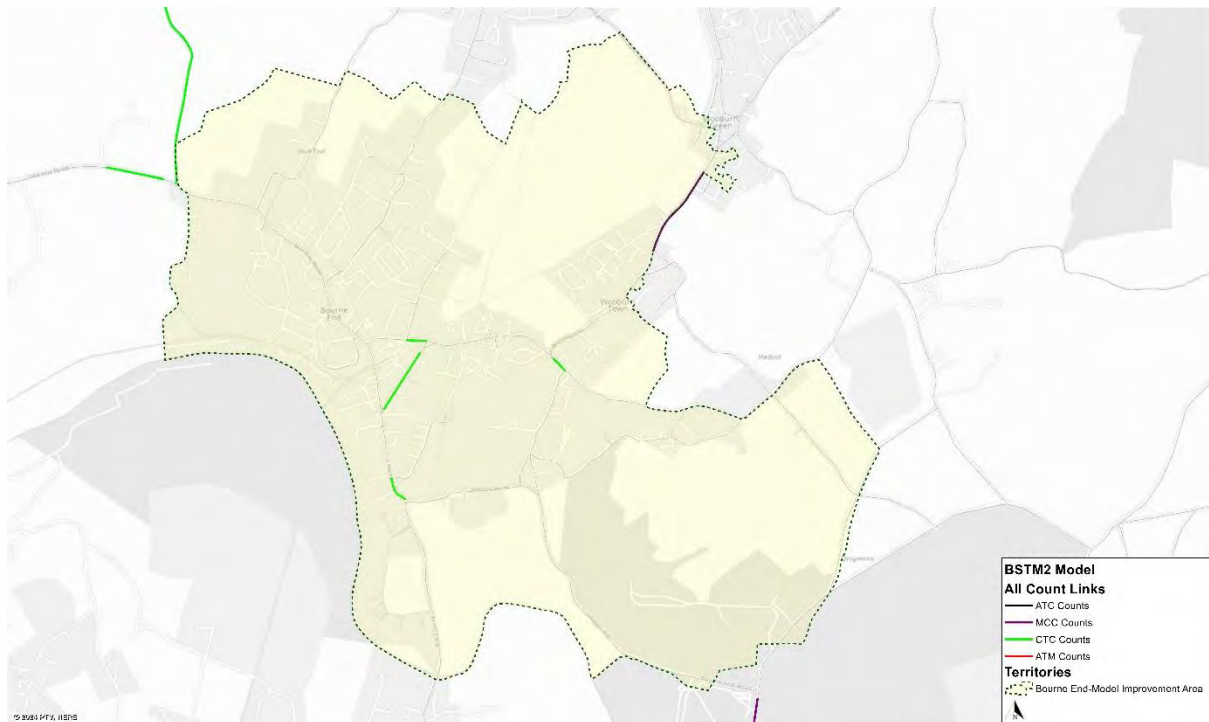
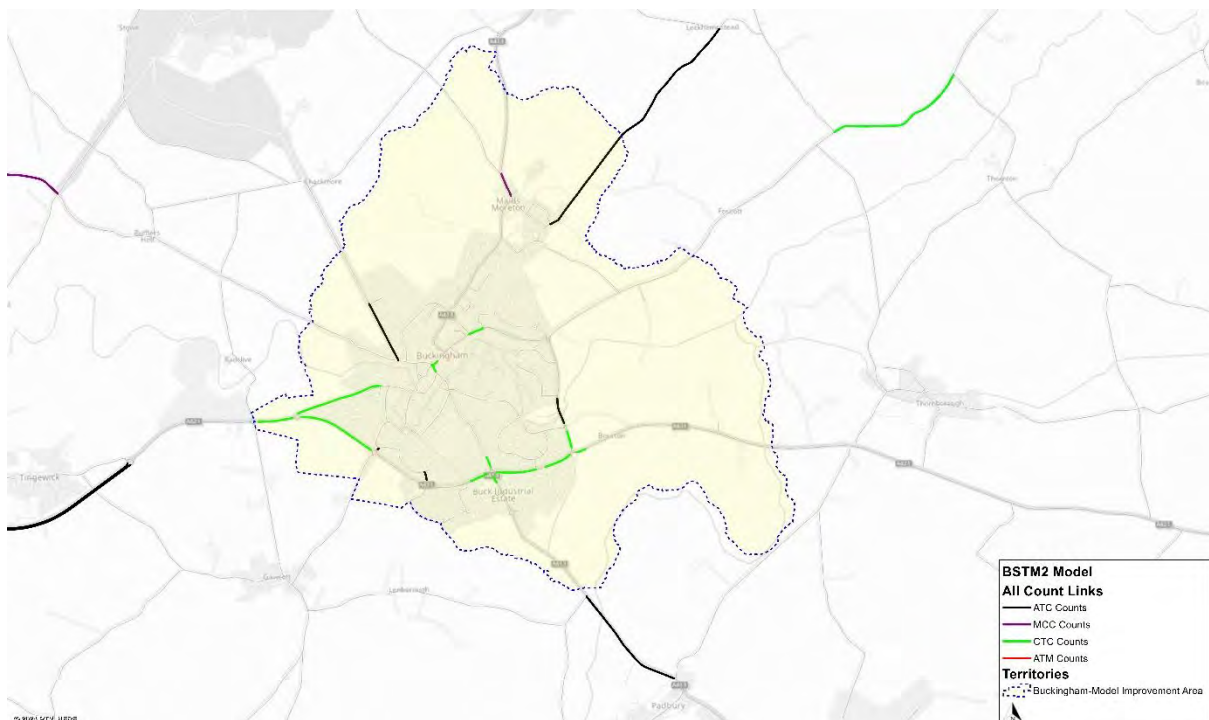


Figure 4-8 – Location of count data in MIA of Buckingham



5. Base Model Update

In the MIA's of Aylesbury, High Wycombe, Marlow, Bourne End and Buckingham, various model enhancements were made in the BSTM2 to improve the level of calibration and validation, as detailed in this chapter.

5.1 Junction Coding

As highlighted in the BSTM model review in section 2.3, the merge nodes in exploded roundabouts have been given the control type 'roundabout'. This modelling approach can give unrealistic saturation flows at each of these merges negating the true reflection of junction delays on the roundabout approaches.

In order to mitigate this issue, the control type of merge nodes in exploded roundabouts within the MIA's have been altered to 'Priority' to function as priority junctions in the BSTM2. Major flows on these junctions are assigned to the circulatory flows and a review of turns at each junction is done to allow only legitimate turning movements. The type and capacity values for each turn have been updated in line with standards. Geometric features such as the numbers of lanes, flares and cross walks have been checked and updated if needed. For each link joining the node, the transport systems have also been checked. Further attributes such as the critical gap and follow-up time, have been pre-set to give the appropriate level of capacity based on the number of lanes and flares on the approach. These parameters have been adjusted during network calibration to better represent observed operation of the junction.

As part of the zone connectors review (discussed in the next sub-section), new priority junctions have also been added so that zones are loading onto stubs rather than directly loading onto junctions. Table 5-1 summaries the new priority junctions added in the BSTM2. Figure 5-1 to Figure 5-5 present the location of nodes that are edited in each of the MIA's.

Table 5-1 - Priority Junctions in BSTM2

Areas	Merge Nodes Recoded	Link Splits	Total
Aylesbury	258	52	310
High Wycombe	158	20	178
Marlow	23	8	31
Bourne End	9	6	15
Buckingham	67	24	91

Figure 5-1 – Nodes edited in MIA of Aylesbury

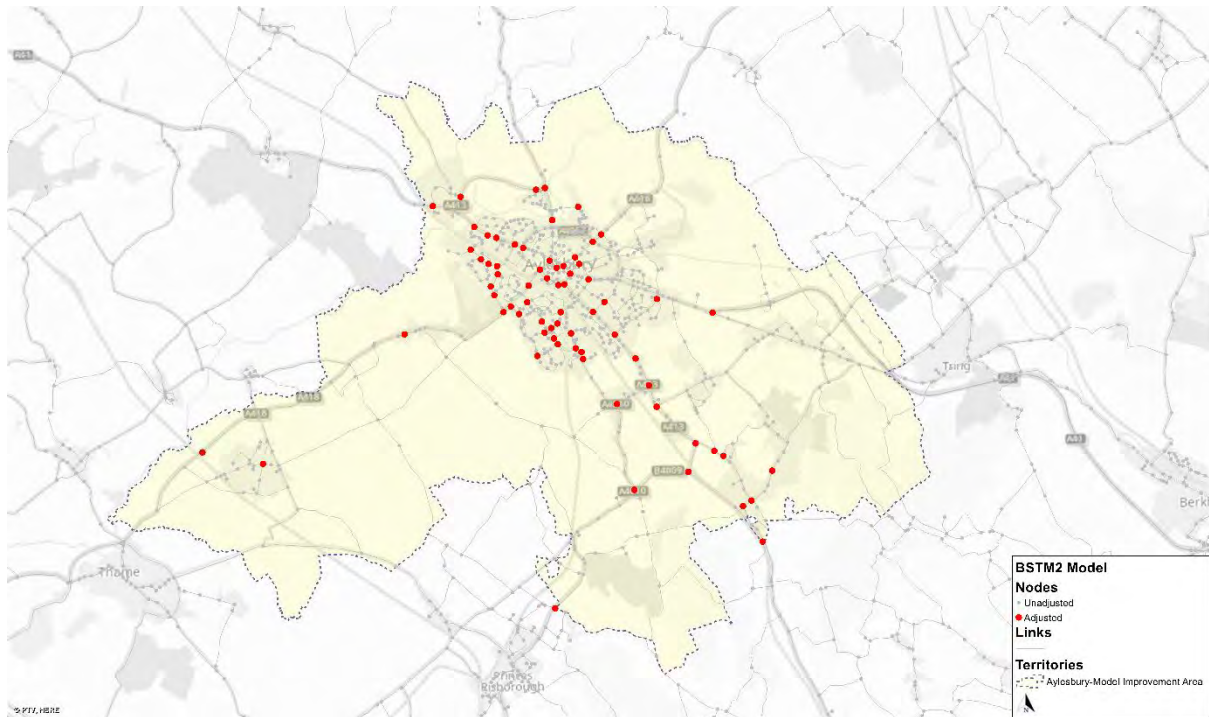


Figure 5-2 – Nodes edited in MIA of High Wycombe

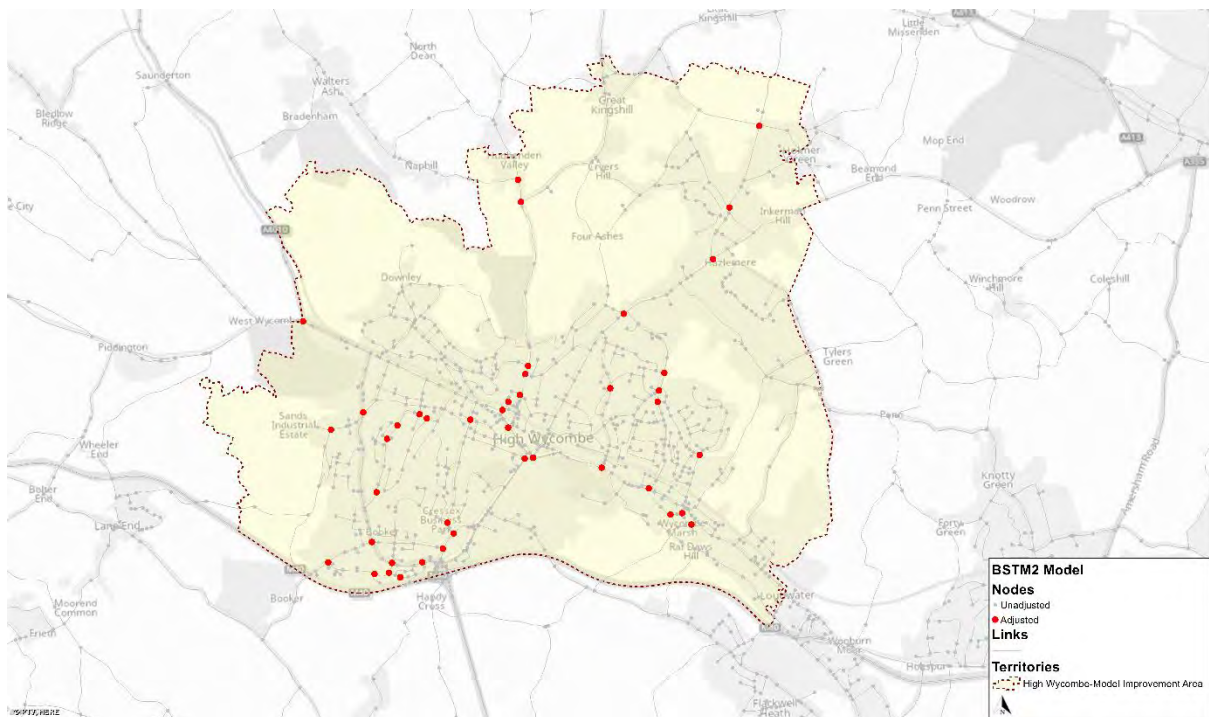


Figure 5-3 – Nodes edited in MIA of Marlow

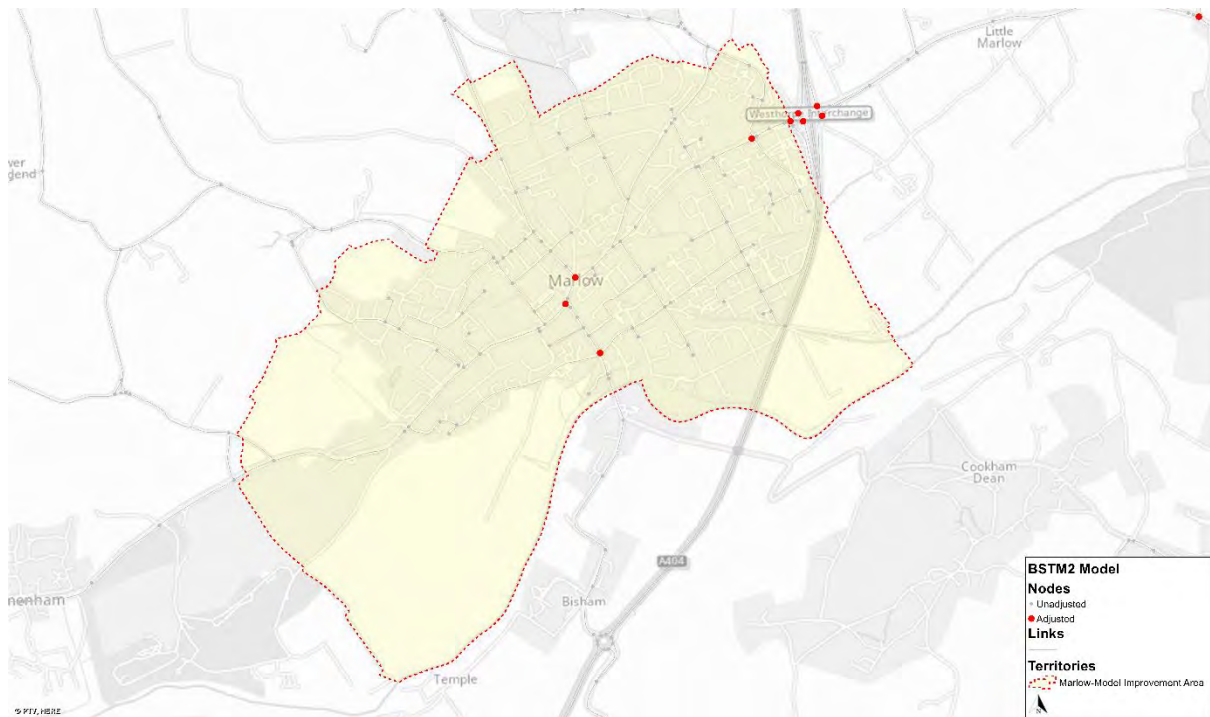


Figure 5-4 – Nodes edited in MIA of Bourne End

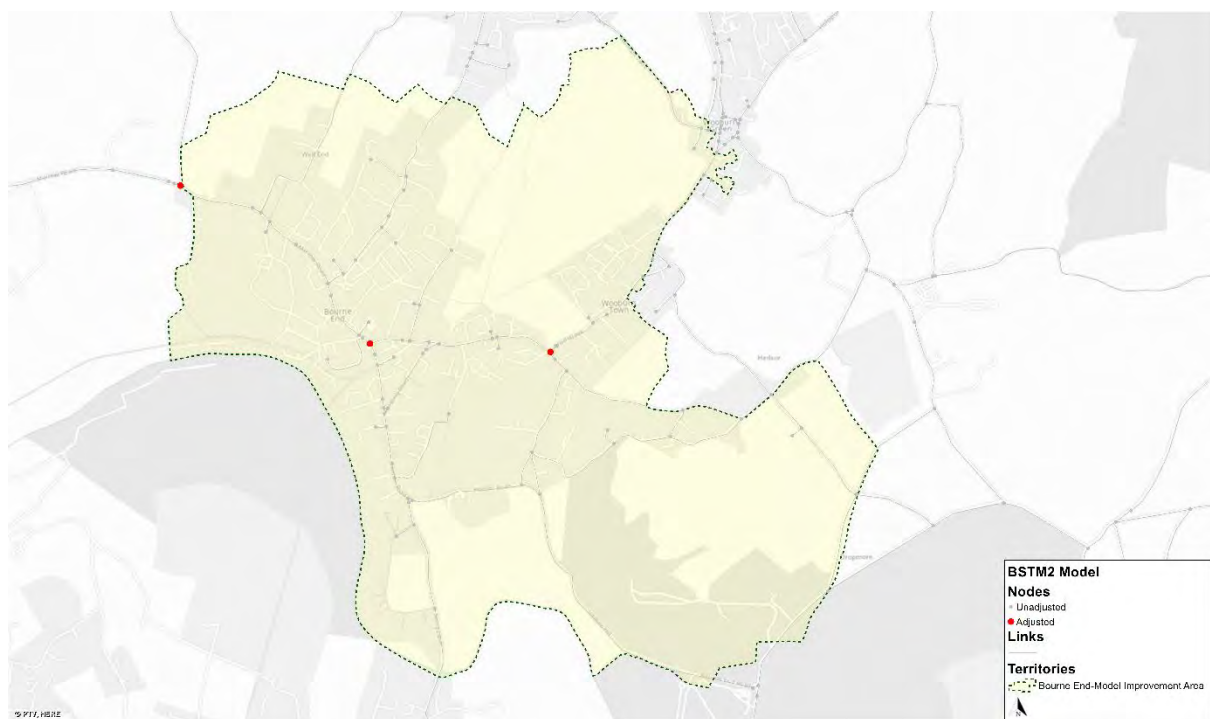
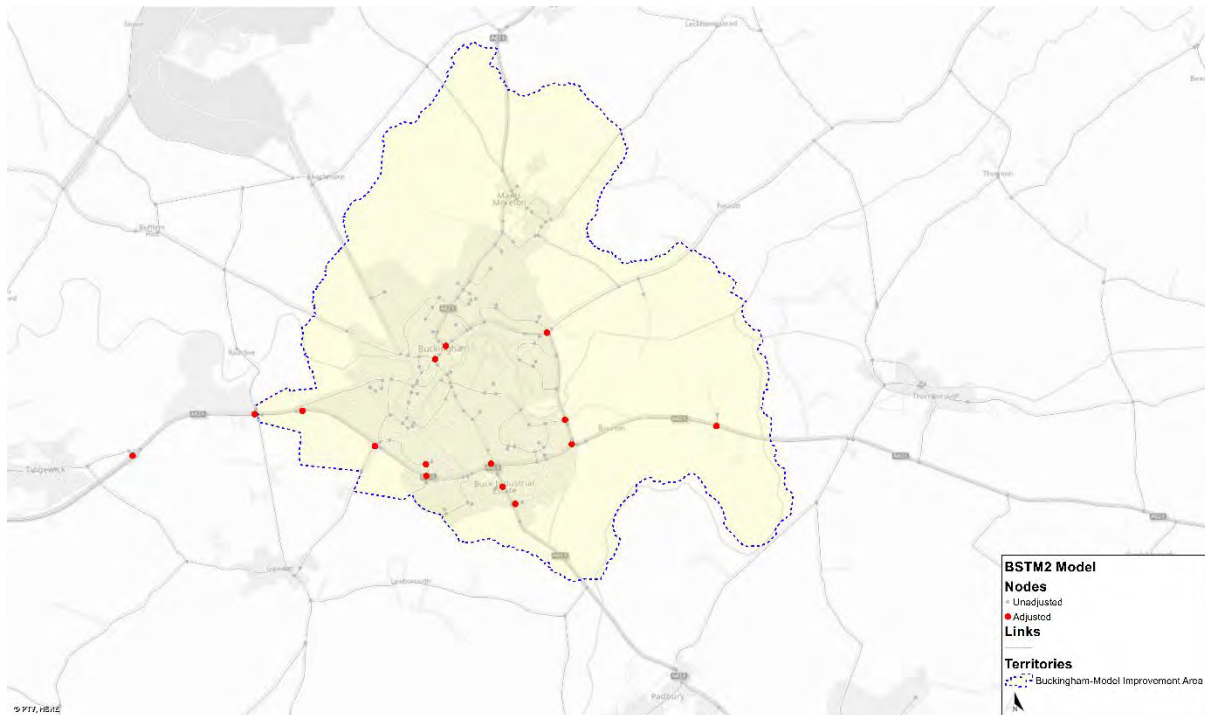


Figure 5-5 – Nodes edited in MIA of Buckingham



5.2 Zone disaggregation

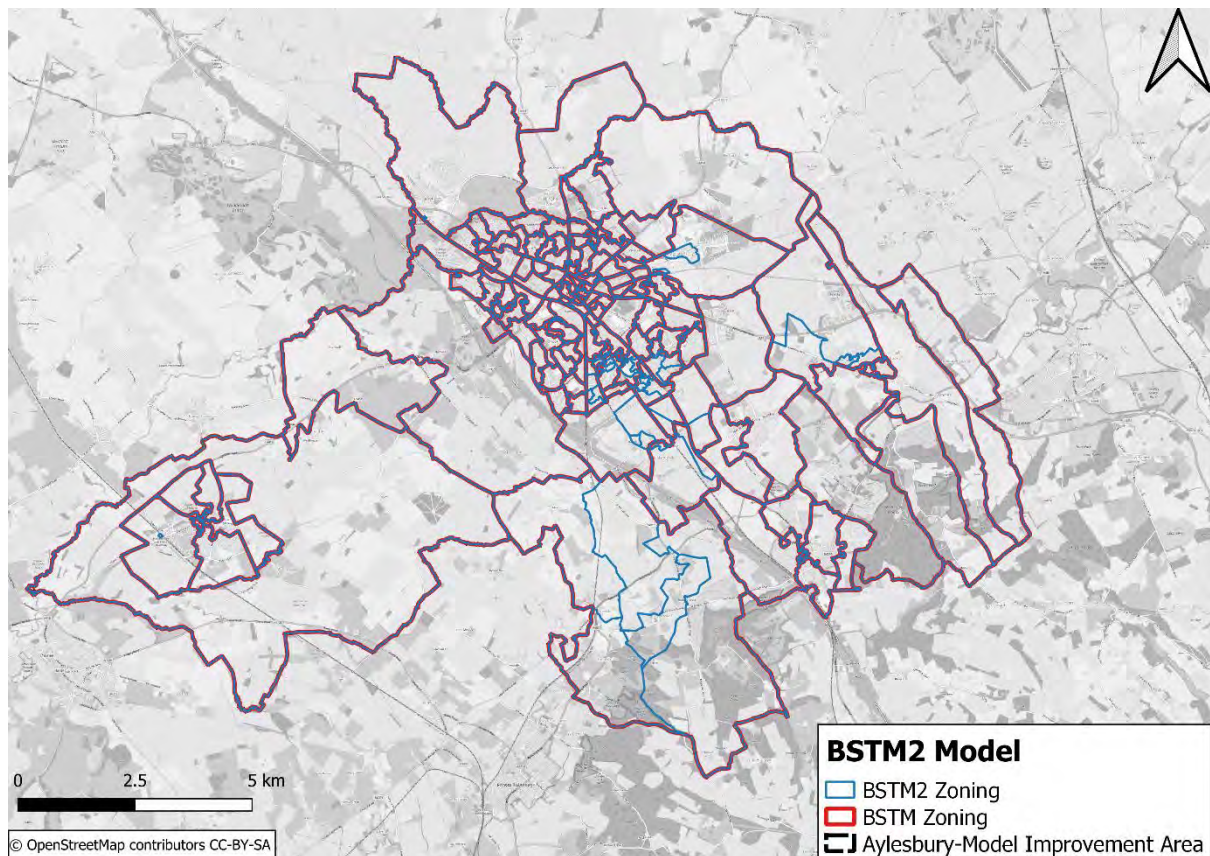
A review of the available town models in Buckinghamshire indicated that only the SEALR model for Aylesbury had more granular zoning which could be incorporated into the BSTM2. A brief review of the SEALR model is provided in section 2 and the model validation report of SEALR (ATM) is provided in Appendix P.

The BSTM and SEALR base models have 870 and 200 zones, respectively. Among the 200 SEALR zones, 168 zones are internal and 32 are external zones to the cordon. When the BSTM and SEALR zone plans were intersected in GIS, it was observed that the boundaries of 13 BSTM zones coincided with the boundaries of 46 SEALR zones with only two cases needing correction as described below:

- The intersection of SEALR zones 1765, 1767, 1768, and 1769 with BSTM zone 467 left a portion of zone 467 separated. This area was taken as a new zone in BSTM2 and given a zone number 8044; and
- SEALR zones 2010, 2009 and 1061 intersected with BSTM zone 61. The aggregated trip ends for the three SEALR zones were constrained to the demand of BSTM zone 61, and their boundaries were fixed to comply with the boundary of BSTM zone 61.

With these updates, a total of 47 disaggregated zones were added in BSTM2 replacing 13 parent zones of BSTM. The newly added zones are numbered between 8001 to 8047 and the correspondence between BSTM2 zones to BSTM zones is provided in Appendix C. Figure 5-6 shows the zone structure in Aylesbury town in the BSTM2.

Figure 5-6 – Zone structure for Aylesbury in BSTM2



5.3 Park And Ride Sites

In the AoDM, 23 railway stations and one bus station have park and ride (P&R) facilities. Stations with an average daily entry/exit of over 4,000 passengers, along with two parkway stations (Haddenham & Thame Parkway Rail Station and Aylesbury Vale Parkway Rail Station), were designated as separate park and ride zones. Consequently, seven rail P&R sites and one bus P&R site were coded as exclusive P&R zones in the model

Table 5-2 presents details of the P&R sites and Figure 5-7 presents the location of these sites. P&R demand was calculated as a percentage of average station entry/exit passengers. It has been assumed that the split between boarding and alighting will be 50% of passenger entry/exit volume per day. Out of this, 35% is assumed to be P&R demand. (E.g. For High Wycombe Rail station, 12,042 is average passenger entry/exit volume. Out of these 6,021 passengers (50%) is assumed as boarding passengers and other 6,021 as alighting passengers. Out of this 2,107(35%) is assumed to be P&R demand).

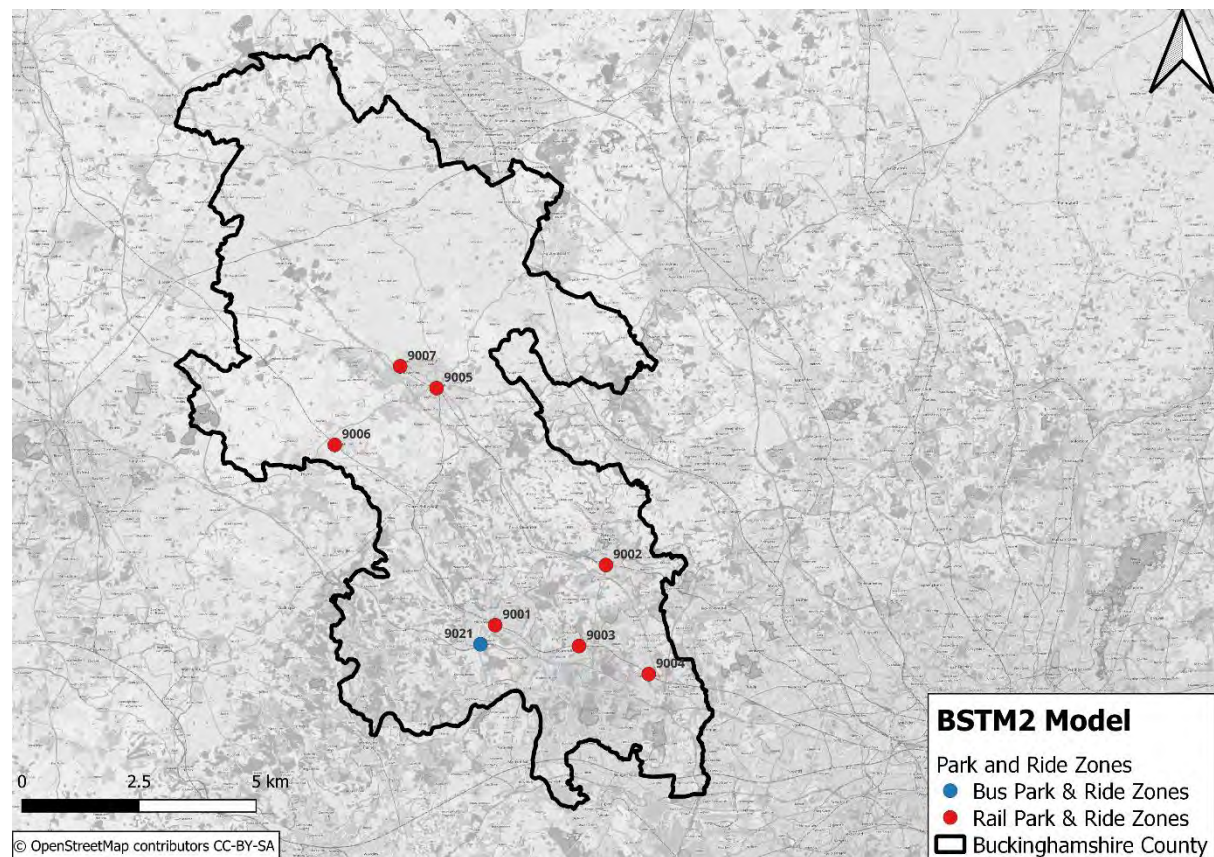
It is to be noted that the demand for the P&R sites has been deducted from the BSTM2 parent zones where they are located. For the Handy Cross Park and Ride car park presented in the Table 5-2, there weren't any available counts data to record actual usage, and no new counts were collected as per project scope of the work. Therefore, a portion of the parent zone demand was reallocated to the Handy Cross Park and Ride (P&R) facility, based on comparisons made with other surveyed bus park and ride sites.

Table 5-2 - P&R sites in BSTM2 model

Park and Ride Sites	Mode	Station Entry/Exit Passengers (Avg/day)	BSTM2 New Zone No
High Wycombe Rail Station	Rail	12,042	9001
Amersham Rail Station	Rail	7,811	9002
Beaconsfield Rail Station	Rail	6,381	9003
Gerrards Cross Rail Station	Rail	5,929	9004
Aylesbury Rail Station	Rail	4,844	9005
Haddenham & Thame Parkway Rail Station	Rail	3,769	9006
Aylesbury Vale Parkway Rail Station	Rail	797	9007
Handy Cross Park and Ride car park	Bus	401*	9021

*Presents the total parking spaces

Figure 5-7 – Location of P&R Sites



5.4 Centroid connectors

Traffic loads onto the model network from zones via “centroid connectors”. Centroid connectors are designed to realistically represent the way in which traffic joins and leaves the road network. Centroid connectors therefore join the network through specific junctions representing explicit access roads. The

number of connectors per zone is dependent on several factors including the size of the zone, the amount of traffic generated by the zone and the number of access roads into and out of the zone.

A review was carried out to check the representation of centroid connectors in the network and it was found at many locations that zones were directly loaded onto a junction. Best practice suggests to always load a zone via connectors through a stub link. Hence in MIA's, zones which were directly loaded onto junctions were fixed to load via a new stub link.

Nodes connecting the newly added stub link to the existing network were coded as priority junctions, with major flows along the existing network. For the newly split zones as per SEALR in Aylesbury, the connector demand shares were taken from the SEALR model if available, while for other zones the connector shares are retained as in the BSTM. Furthermore, free flow time (t_0) on all connectors have been set to reflect a speed of 50 kmph for private modes and 4 kmph for walk mode, ensuring a realistic representation. Table 5-3 presents the number of added stub links and fixed connectors in each of the MIA's. Appendix D includes maps showing the adjusted connectors in each of MIA's.

Table 5-3 - Number of new stubs and connectors added in MIA's of BSTM2

Areas	Stubs	Connectors
Aylesbury	104	226
High Wycombe	40	66
Marlow	8	10
Bourne End	6	6
Buckingham	18	20

6. Trip Matrix Update

This chapter discusses the development of the highway matrices. The prior matrices, inherited from the existing BSTM model, were developed using the following data sources:

- Aggregated and anonymised mobile network data (MND) obtained from Telefonica;
- National Travel Survey data (NTS), 2011 Census Journey to Work (JTW), National Trip End Model (NTEM v7.2) and bespoke synthetic matrices to augment the MND and to correct for known biases; and
- South East Regional Transport Model (SERTM), with a base year of 2015 to obtain the movements for Heavy Goods Vehicles (HGVs) and Light Goods Vehicles (LGV). These were uplifted to 2019 using DfT's Road Traffic Forecast (Scenario 1) and converted to the BSTM zoning system.

Further details on the BSTM trip matrix development can be found in chapter 9 of the BSTM LMVR. The BSTM prior matrix totals by time period and purpose are presented in Table 6-1.

Table 6-1 - Prior Matrices for BSTM (Vehicles)

Vehicle Class	AM (08:00 - 09:00)	IP (Average Hour 10:00 - 16:00)	PM (17:00 - 18:00)
Car Commute	167,062	47,050	155,718
Car Business	25,974	17,564	25,819
Car Others	205,070	149,696	223,923
LGV	576,358	555,261	460,339
HGV	275,258	263,319	173,252
Total	1,249,722	1,032,890	1,039,051

These prior matrices were assigned to the BSTM2 network, and the assigned flows were compared against observed flows across screenlines. This revealed that the prior matrices needed further refinements. Hence at key points of divergence between observed and assigned volumes, flow bundles were taken, and the prior matrix was adjusted to match the observed volume. This process was undertaken at screenline level to begin with and then at individual link level if needed, before running the Matrix Estimation (ME) process. The adjusted prior matrix totals by period and purpose are presented in Table 6-2.

Table 6-2 - Adjusted Prior Matrices for BSTM2 (Vehicles)

Vehicle Class	AM (08:00 - 09:00)	IP (Average Hour 10:00 - 16:00)	PM (17:00 - 18:00)
Car Commute	172,470	48,059	158,071
Car Business	27,245	17,961	26,263
Car Others	210,019	151,989	226,226
LGV	575,690	555,887	460,855
HGV	271,774	263,465	173,405
Total	1,257,198	1,037,361	1,044,821

The post ME matrices were subjected to all the checks as outlined in TAG to ensure that the adjustments did not change underlying travel patterns significantly and all the details are provided in section 8.3. The final post ME matrix totals by period and purpose are presented in Table 6-3.

Table 6-3 - Final Post ME Matrices for BSTM2 (Vehicles)

Vehicle Class	AM (08:00 - 09:00)	IP (Average Hour 10:00 - 16:00)	PM (17:00 - 18:00)
Car Commute	172,349	50,147	161,858
Car Business	27,195	18,870	27,322
Car Others	209,350	159,315	230,993
LGV	575,868	556,205	459,155
HGV	271,645	260,616	171,073
Total	1,256,407	1,045,153	1,050,401

It is suggested in TAG Unit M3.1 that the numbers of trips to and from individual zones within the AoDM should be approximately the same and that the numbers of trips should be between 200 or 300 per hour. Limiting the number of zones with large trip volumes avoids unrealistically high loadings onto the network, although it is noted that zones could legitimately exceed the 300 trips i.e. large superstore or shopping centre, so proportionality is needed.

A histogram showing the count AoDM zones according to the total trip ends is shown in Figure 6-1.

Figure 6-1 – BSTM2 Zones with more than 300 trips

BSTM2	Count of Zones					
	Origins			Destinations		
Number of Trips	AM	IP	PM	AM	IP	PM
0 to 100	387	551	423	443	550	376
100 to 200	254	153	205	181	156	261
200 to 300	77	30	73	65	26	83
300 to 400	16	19	16	22	19	13
400 to 500	4	9	17	13	9	6
500+	174	150	178	188	152	173
NA	0	0	0	0	0	0
Total	912	912	912	912	912	912

Figure 6-1 shows that the vast majority of zones have less than 200 origin or destination trips which is acceptable. Those zones with more than 500 trips tend to be in the suburban and rural areas of the AoDM where zones are larger and contain a number of rural settlements.

7. Model Standards

This chapter describes the standards that the HAM needs to achieve in line with TAG Unit M3.1, Highway Assignment Modelling.

7.1 Assignment Process

The assignment procedure used for the BSTM2 involves an interaction between subordinate assignment and a junction delay calculation. Visum's 'Assignment with Intersection Capacity Analysis (ICA)' is the method bringing these two elements together. Assignment with ICA is the standard method in Visum for managing the convergence challenges presented by the inclusion of detailed junction modelling. The approach for the subordinate assignment model in BSTM was a Local User-Cost Equilibrium (LUCE) based assignment for both prior and post matrices. The approach for the subordinate assignment with ICA was changed to Equilibrium assignment for post matrices in BSTM2 to significantly reduce run times during variable demand model runs. The procedure is illustrated below:

- First, Equilibrium assignment is used to calculate route choice through the network using default turn standards to calculate turn traffic volumes;
- After the assignment a blocking back calculation ensures that volumes used for ICA are realistic i.e. queues are taken into account;
- ICA is then executed to calculate the turn capacities and turn delays for those assigned turn traffic volumes;
- The delays calculated by ICA for individual turns are used in the next equilibrium assignment to calculate a new route solution and volumes; and
- The process repeats until convergence of the equilibrium assignment is reached.

7.2 Validation Criteria and Acceptability Guidelines

The below text quoted from TAG unit M3.1 summarises the validation criteria for the HAM, which should include comparisons of the following:

- *"Assigned flows and counts totalled for each screenline or cordon, as a check on the quality of the trip matrices;*
- *Assigned flows and counts on individual links and turning movements at junctions as a check on the quality of the assignment; and*
- *Modelled and observed journey times along routes, as a check on the quality of the network and the assignment".*

Similarly, TAG unit M3.1 states that validation is to be carried out for the trip matrix, network and services, and finally assignment.

7.3 Network Validation

The process of highway network calibration and validation includes the following:

- Checks to ensure that free flow speeds, signal phasing and timings, saturation flows and turn capacities are appropriate;

- Checks where the traffic count data exceeds the capacity of the link;
- Reviewing junction capacity parameters and the locations of zone connectors; and
- Checks on the routes taken through the network by selected traffic movements.

7.4 Trip Matrix Validation

For trip matrix validation, the measure that should be used is the percentage difference between modelled flows and observed flows from counts. Comparisons at long screenlines and cordons provide information on the quality of the trip matrices. TAG Unit M3.1 describes the validation criterion and acceptability guideline for highways as shown in Table 7-1.

Table 7-1 - Screenline Flow Validation and Acceptability Guideline

Criteria	Acceptability Guideline
Differences between modelled flows and counts should be less than 5% of the counts	All or nearly all screenlines (i.e. 95% of cases)

Regarding screenline validation, the following should be noted:

- Screenlines should normally be made up of five links or more;
- The comparisons for screenlines containing high flow routes such as motorways should be presented both including and excluding such routes;
- The comparison should be presented separately (a) where data were used to inform matrix development, (b) for screenlines used as constraints in matrix estimation; and (c) screenlines used for independent validation;
- The comparisons should be presented by vehicle type (cars, LGVs and other goods vehicles); and
- The comparisons should be presented separately for each modelled period.

7.5 Link Flow and Turning Movement Validation

Two measures are used for individual highway link validation: flow difference; and the Geoffrey E Haver (GEH) measure. The flow difference is based on the relative flow difference between modelled flows and observed counts, with three different criteria set depending on the scale of observed flows. The GEH measure uses the GEH statistic as defined below:

$$GEH = \sqrt{\frac{(M - C)^2}{\frac{1}{2}(M + C)}}$$

Where:

- GEH is the GEH statistic
- M is the modelled flow
- C is the observed flow.

TAG Unit M3.1 describes the link flow and turning movements validation criteria and acceptability guidelines as shown in Table 7-2.

Table 7-2 - 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

Regarding flow validation, the following should be noted:

- The above criteria should be applied to both link flows and turning movements;
- The guidance may be difficult to achieve for turning movements;
- The comparisons should be presented for cars and all vehicles but not for light and other goods vehicles (unless sufficiently accurate link counts have been obtained);
- The comparisons should be presented separately for each modelled period;
- It is recommended that comparisons using both measures are reported in the model validation report; and
- These two measures are broadly consistent and link flows that meet either criterion should be regarded satisfactory.

Consistent with a large strategic model, no turning movements were utilised within the HAM.

7.6 Journey Time Validation

In order to validate the highway journey times, the percentage difference between modelled and observed journey times is compared subject to an absolute maximum difference. These criteria and guidelines are described in TAG Unit M3.1 as shown in Table 7-3.

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

Table 7-3 - Journey Time Validation Criteria 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

7.7 Convergence Criteria and Standards

The advice on HAM convergence for the highway assignment is set out in TAG Unit M3.1 and is reproduced in Table 7-4.

Table 7-4 - Summary of Convergence Measures and Base Model Acceptable Values

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 (P1) < 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)

The measures above are defined as follows:

- Delta or the percentage GAP is the difference between the costs along the chosen routes and those along the minimum cost routes, summed across the whole network, and expressed as a percentage of the minimum costs.
- P1 and P2 are the percentage of links with changes in flow and cost, respectively, less than 1% between successive iterations.

It should be noted that the guidance requires that the criteria for the GAP and either P1 or P2 is met. However, to ensure that the best possible level of model convergence and stability is achieved, the criteria has been targeted for all three metrics in BSTM2.

7.8 Impact of Matrix Estimation (ME)

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

- Regression analysis of matrix zonal cell values, prior to and post ME (slopes, intercepts and R² values);
- Regression analysis of zonal trip ends, prior to and post ME (slopes, intercepts and R² values);
- Trip Length Distributions, prior to and post ME, with means and standard deviations; and Sector to sector level matrices, prior to and post ME, with absolute and percentage changes.

The changes introduced by the application of ME should not be significant and are assessed using TAG Unit M3.1, as shown in Table 7-5.

Table 7-5 - Significance of ME Changes

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

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

The comparisons should also be presented separately for each modelled time period or hour.

7.9 Interpretation of the Guidelines

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

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

8. Highway Model Calibration

This chapter provides details regarding the techniques used and the changes made as part of the model calibration process, and the results achieved. A two-stage process was taken to the calibration process. The first stage involved calibration of an initial base year assignment, based on the initial network and matrices.

Analysis of the initial base year assignment provided the opportunity to demonstrate the robustness of the initial model development activities, and enabled errors in the network, matrix and count data to be identified and remedied at an early stage. The second stage of calibration involved the application of matrix estimation to fine-tune the trip matrices in order that the assigned traffic flows matched the surveyed counts.

8.1 Model Convergence

A summary of the highway model equilibrium assignment convergence statistics is shown in Table 8-1

Table 8-1 - Summary of BSTM2 Model Convergence

Time Period	Assignment Iterations	% Flow (P1)	% Cost (P2)	% Gap
AM Peak	14	96.8	99.0	0.01
	15	97.3	99.1	0.01
	16	97.9	99.3	0.01
	17	98.3	99.3	0.01
Inter-peak	6	93.2	99.1	0.01
	7	95.7	99.4	0.01
	8	97.3	99.5	0.00
	9	97.2	99.5	0.00
PM Peak	12	96.9	99.1	0.01
	13	98.0	99.2	0.01
	14	98.1	99.3	0.01
	15	98.2	99.3	0.01

Table 8-1 demonstrates that all 3 base model assignments reach acceptable convergence levels, with four consecutive iterations of greater than 98% for cost changes and close to 98% for flow changes between iterations which meets the TAG guidance criteria - and with the GAP values significantly lower than the guidance. The flow and cost criteria demonstrate that the model is behaving in a stable manner while the GAP value demonstrates that the model convergence is very good indicating the difference between the costs along the chosen routes and those along the minimum cost routes are very close.

8.2 Calibration of the Initial Assignment

Calibration of the initial base year assignment focussed on reviewing, fine-tuning and rectification of network and routing issues. As part of model calibration, junction capacities were varied where modelled journey times exceeded observed values (i.e. where modelled junction delays were higher than observed with the appropriate level of traffic flow), where turn capacities were lower than observed turning movements, and where modelled links/turns were operating in excess of capacity

when the link/turn is known to operate below this level in reality. Routeing checks were carried out (for the routes discussed in Section 9.4) to ensure that vehicles were routeing in a realistic manner.

Count data was checked for consistency between counts on adjacent links. Typically, the main source of inconsistency between neighbouring counts arises as a result of the counts being carried out on different dates. Differences can also arise where neighbouring counts have been carried out using different survey techniques, for example, where an ATC is compared with a manual classified count on an adjacent link. Where inconsistencies were identified, the issue was addressed through smoothing of the count data.

Traffic flows and patterns across a number of screenlines were reviewed to ensure that they closely matched the observed data. Once calibration of the initial base year assignment had been satisfactorily completed, matrix estimation was applied to the prior matrix to fine-tune the demand in the trip matrices to ensure that the assigned flows match the observed link and junction counts.

8.3 Prior Matrix Link Flow and Screenline Calibration

Table 8-2 shows the level of link flow calibration for the prior matrices for the three time periods. There are 404 link counts used in the model calibration as shown in Figure 8-1.

Table 8-2 - Prior Matrix Link Flow Validation

	AM	IP	PM
Total vehicles	82% (331 out of 404)	62% (251 out of 404)	55% (224 out of 404)
Cars	85% (344 out of 404)	65% (263 out of 404)	54% (219 out of 404)

Table 8-2 shows a satisfactory level of prior matrix link validation with 82%, 62% and 55% of links to achieve post matrix link validation close to TAG criteria, set out in Chapter 7, for total vehicles in the AM, Inter-Peak and PM peak hours, respectively. The validation for cars is higher compared to total vehicles with 85%, 65% and 54% for the AM, Inter-peak and PM peak hours, respectively. The prior matrix screenline calibration is provided in Appendix E.

The locations of the screenlines is shown in Figure 8-1. The following can be observed:

- In the AM peak hour, 33 out of 74 screenlines have modelled flows within 5% of observed counts;
- In the Inter-Peak, 11 out of 74 screenlines have modelled flows within 5% of observed counts; and
- In the PM peak hour, 12 out of 74 screenlines have modelled flows within 5% of observed counts.
- For modelled flows within 10% of observed counts 62, 20 and 34 out of 74 screenlines are meeting the criteria for AM peak, Inter-peak and PM Peak providing good screenline calibration.

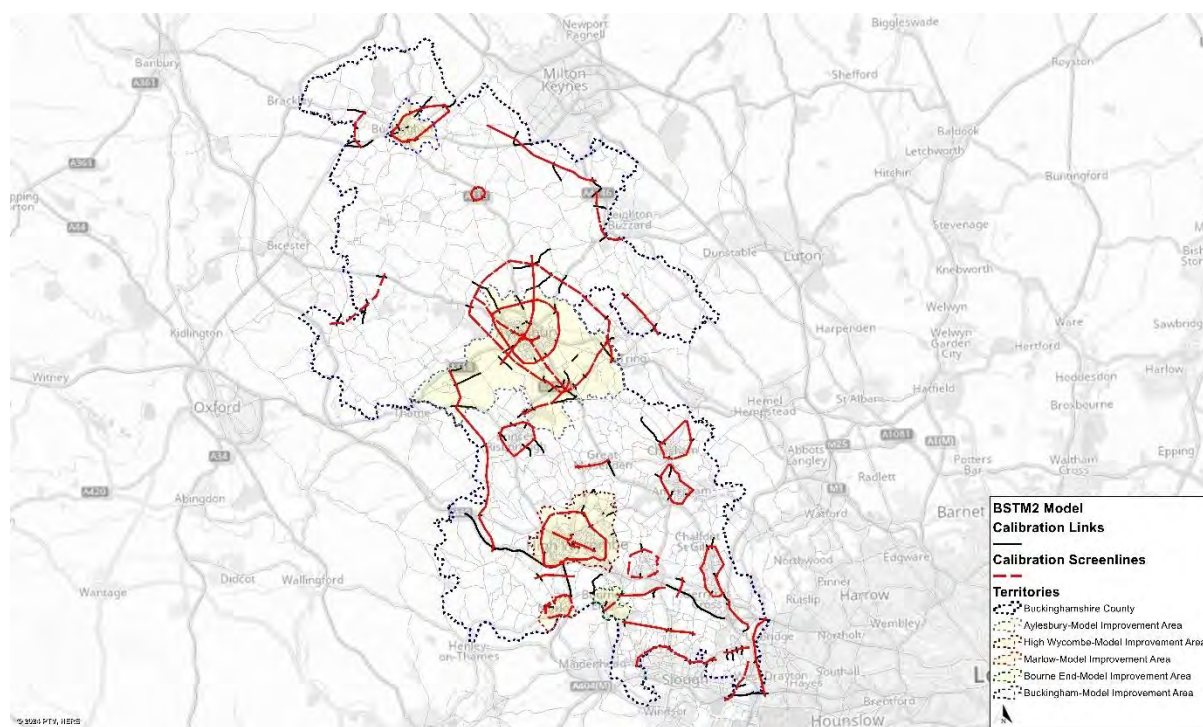
The prior matrix screenline calibration demonstrates that 45%, 15% and 16% of screenlines are within 5% of observed volumes for the AM, Inter-peak and PM peak hours, respectively. Considering screenlines that are within 10% of observed, the results improve to 84%, 27% and 46% for the AM, Inter-peak and PM peak hours respectively.

TAG advises that the prior matrix should be assigned and evaluated against validation criteria to form a satisfactory basis for proceeding with matrix estimation. It also stresses that matrix estimation must

not introduce significant changes to the prior matrices to maintain compliance with validation standards. To justify this, Table 8-3 highlights the differences between the prior and post matrices, showing that no significant changes have occurred, which is a key factor in ensuring accurate matrix estimation though the prior matrices calibration results are significantly lower.

The screenline calibration for the prior matrices is good for the AM peak but significantly lower for the Inter Peak and PM peak which is likely to be due to weaknesses in the Mobile phone data used to create the prior matrices as discussed later in Section 8.4.3.

Figure 8-1 – BSTM2 Calibration Screenlines and Links



8.4 Matrix Estimation Process

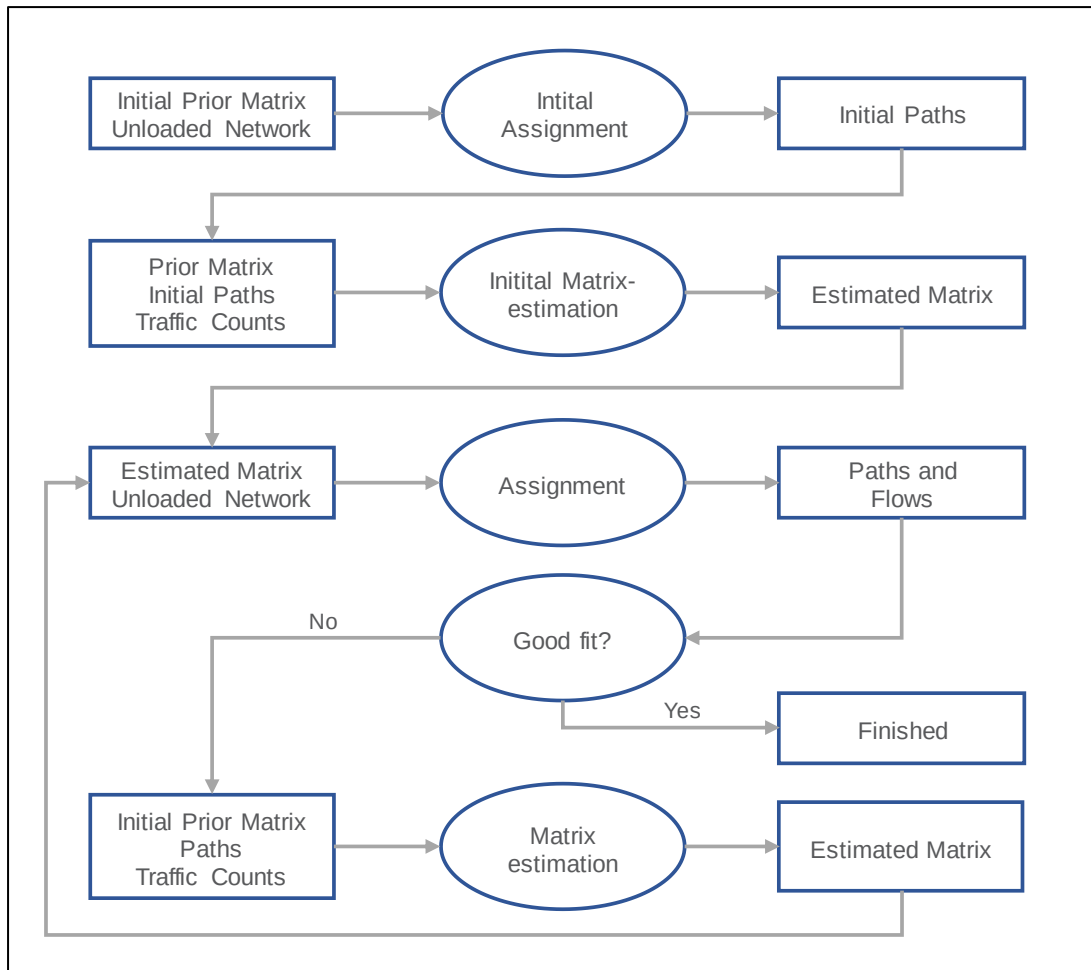
The matrix estimation process is an integral part of the model calibration. It has been undertaken within VISUM using the Least Squares procedure for each vehicle type separately. The function of matrix estimation is to produce an updated matrix using traffic counts. Trips are adjusted in the matrix to produce an estimated matrix that is consistent with the traffic counts. The counts used for calibration are shown in Figure 8-6 and include 74 screenlines and 404 individual link counts.

This process is dependent on several factors including the quality of the prior matrix, traffic routeing, and the order and consistency of the observed traffic counts. It is, therefore, essential that the process be monitored closely to ensure the following:

- The trip matrix is converging to a stable solution;
- Trip length distributions are reasonable; and
- Travel patterns at a sector level are reasonable.

Figure 8-2 shows the matrix estimation process as a flow chart.

Figure 8-2 – Matrix Estimation Process



8.4.1 Matrix Estimation Impact

Table 8-3 shows the change in user class total trips for each time period due to matrix estimation.

Table 8-3 - Matrix Trip Totals – Pre and Post Matrix Estimation Totals (vehicles)

User Class	AM	Peak	Hour	Inter	Peak	Hour	PM	Peak	Hour
	Pre-ME (Vehs)	Post-ME (Vehs)	% Diff	Pre-ME (Vehs)	Post-ME (Vehs)	% Diff	Pre-ME (Vehs)	Post-ME (Vehs)	% Diff
Car Commuting	172,470	172,349	-0.07%	48,059	50,147	4.34%	158,071	161,858	2.40%
Car Business	27,245	27,195	-0.19%	17,961	18,870	5.06%	26,263	27,322	4.03%
Car Other	210,019	209,350	-0.32%	151,989	159,315	4.82%	226,226	230,993	2.11%
LGV	575,690	575,868	0.03%	555,887	556,205	0.06%	460,855	459,155	-0.37%
HGV	271,774	271,645	-0.05%	263,465	260,616	-1.08%	173,405	171,073	-1.34%
Total	1,257,198	1,256,407	-0.06%	1,037,361	1,045,153	0.75%	1,044,821	1,050,401	0.53%

It can be observed from Table 8-3 that the matrix estimation changes the overall matrix totals by - 0.06%, 0.75% and 0.53% in the AM, Inter-Peak and PM peak hours, respectively. The matrix totals for cars change by -0.21%, 4.73% and 2.34% for the AM, Inter-Peak and PM peak hours, respectively.

In analysing changes between prior and post matrix estimation matrices, TAG guidance recommends that the statistics shown in Table 7-5 are used to determine if the changes are significant. The guidance states that all exceedances of these criteria should be examined and assessed for their importance for the accuracy of the matrices in the Fully Modelled Area or the area of influence of the scheme to be assessed.

8.4.2 Changes to Zonal Cell Values

Table 8-4 shows the change brought about by matrix estimation for each time period at the zonal cell level for each peak hour.

Table 8-4 - BSTM2 Zonal Cell Values Regression Statistics

Time Period	Vehicle Type	Slope	Intercept	R-square
AM	Car	0.9999	-0.0007	0.9999
	LGV	1.0000	0.0002	1.0000
	HGV	1.0000	-0.0001	1.0000
	Total	1.0000	-0.0007	1.0000
IP	Car	1.0009	0.0092	0.9990
	LGV	1.0000	0.0003	1.0000
	HGV	1.0000	-0.0026	1.0000
	Total	1.0000	0.0071	1.0000
PM	Car	1.0001	0.0087	0.9996
	LGV	1.0000	-0.0015	1.0000
	HGV	1.0000	-0.0021	1.0000
	Total	1.0000	0.0051	1.0000

It can be observed from Table 8-4 that the regression statistics for zonal cell values are in line with guidance for cars, LGV's, HGV's and total vehicles for all time periods.

8.4.3 Change in Trip Ends Values

Change brought about by matrix estimation at the zonal trip origin and destination level are presented in Table 8-5 and Table 8-6 for origins and destinations, respectively.

Table 8-5 - BSTM2 Zonal Origin Regression Statistics

Time Period	Vehicle Type	Slope	Intercept	R-square
AM	Car	0.9969	0.3990	0.9998
	LGV	0.9999	0.2152	1.0000
	HGV	0.9999	-0.0856	1.0000
	Total	0.9995	-0.1839	1.0000
IP	Car	1.0008	9.6681	0.9985
	LGV	0.9997	0.4535	1.0000
	HGV	0.9983	-2.2848	1.0000
	Total	0.9988	8.5805	1.0000
PM	Car	1.0010	8.7570	0.9994
	LGV	0.9996	-1.4315	1.0000
	HGV	0.9982	-1.9288	1.0000
	Total	0.9984	6.8908	1.0000

Table 8-6 - BSTM2 Zonal Destination Regression Statistics

Time Period	Vehicle Type	Slope	Intercept	R-square
AM	Car	0.9967	0.4750	0.9998
	LGV	0.9999	0.2024	1.0000
	HGV	0.9999	-0.0992	1.0000
	Total	0.9996	-0.3021	1.0000
IP	Car	1.0007	9.6779	0.9987
	LGV	0.9997	0.4436	1.0000
	HGV	0.9991	-2.4854	1.0000
	Total	0.9993	8.1536	1.0000
PM	Car	0.9986	9.7131	0.9994
	LGV	0.9995	-1.4214	1.0000
	HGV	0.9987	-2.0112	1.0000
	Total	0.9986	6.7198	1.0000

The regression statistics for origins and destinations are very close to guidance for all user classes and total vehicles for all time periods. Slope and R square values meet the TAG criteria but the intercept values are outside the guidance values for cars and total vehicles in the Inter-Peak and PM peak hours. The reason for this can be attributed in part to the nature on the prior matrix build, being based on mobile phone data rather than roadside interviews and expansion techniques from which viewpoint the guidance has been developed. Simply applying these criteria to matrices developed from new data sources such as mobile phone data can lead to misinterpretation. There are several points associated with this:

- Traditional prior matrix building techniques, using roadside interview surveys (RSI), fuse data from different areas and datasets to produce a matrix of observed trips, with these parts of the matrix considered fully observed. The application of constraints in the matrix estimation then ensures the fully observed elements are not modified, giving strong correlations between prior and post. Matrices developed from Mobile phone data could be considered as entirely fully observed therefore matrix estimation is equally valid when applied to any cell in the matrix.
- Traditional matrix building uses small movement samples from RSI data which are expanded to total traffic counts, the expanded data is then combined to represent all traffic crossing a screenline or cordon. In this way the Origin-Destination survey data has been expanded to represent the total traffic count, therefore it is expected that the counts and assigned flows would match well. Mobile phone data is expanded based on population and mobile phone operator market share, without any relation to the traffic counts. Consequently, it is far less likely that the assigned flows would compare favourably to the screenline and cordon counts. Therefore, it may be necessary to allow matrix estimation to make more changes to a prior matrix, based on mobile phone data, in order to reproduce counted flows.

8.4.4 Trip Length Distribution

A comparison of the trip length distribution of the prior and post ME matrices, for total vehicles for the three modelled time periods is shown in Figure 8-3 to Figure 8-5 respectively. Appendix F presents the comparison of trip length distribution for all user classes and for all time periods.

Figure 8-3 – AM Total Vehicles - Trip Length Distribution

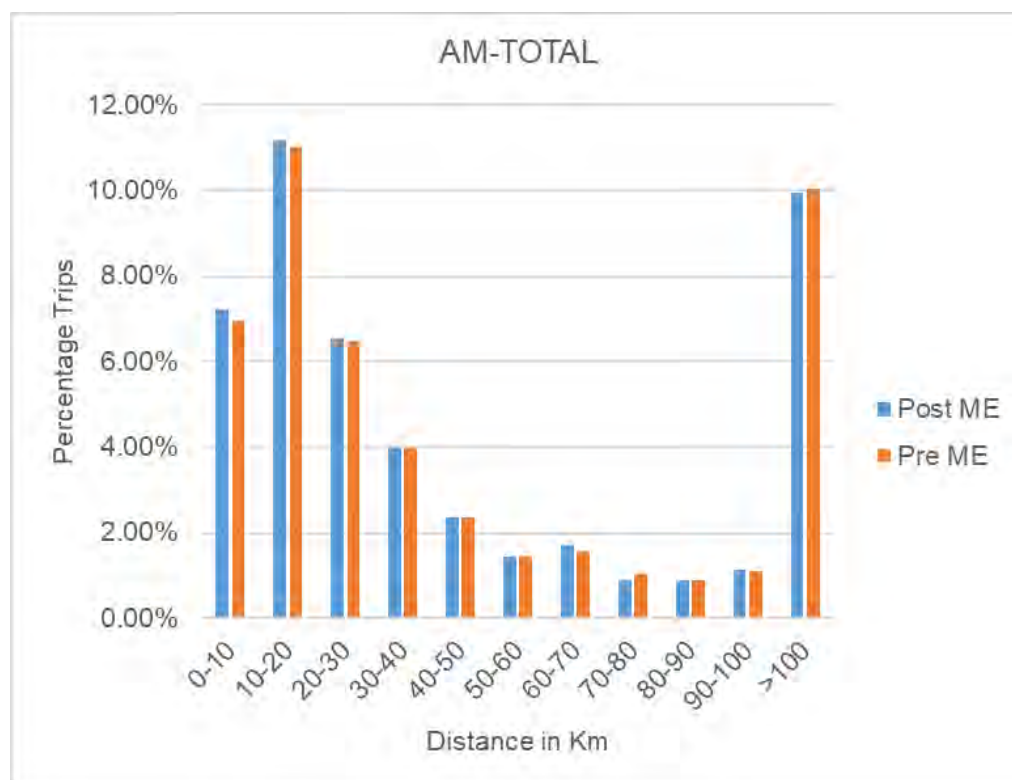


Figure 8-4 – IP Total Vehicles - Trip Length Distribution

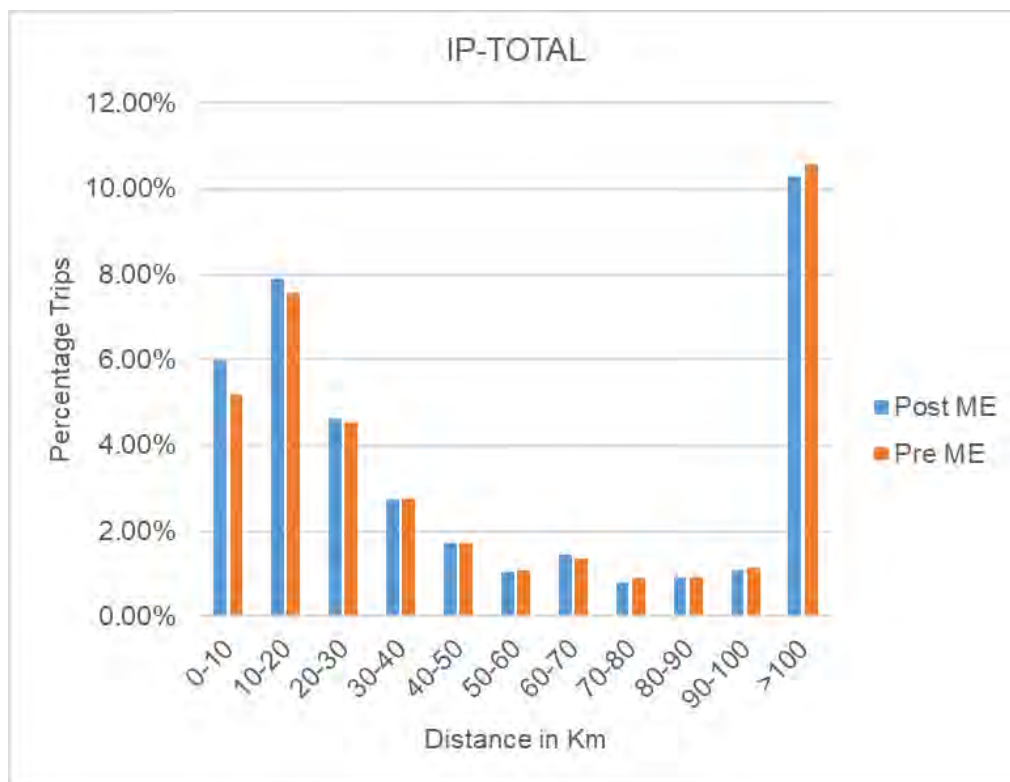
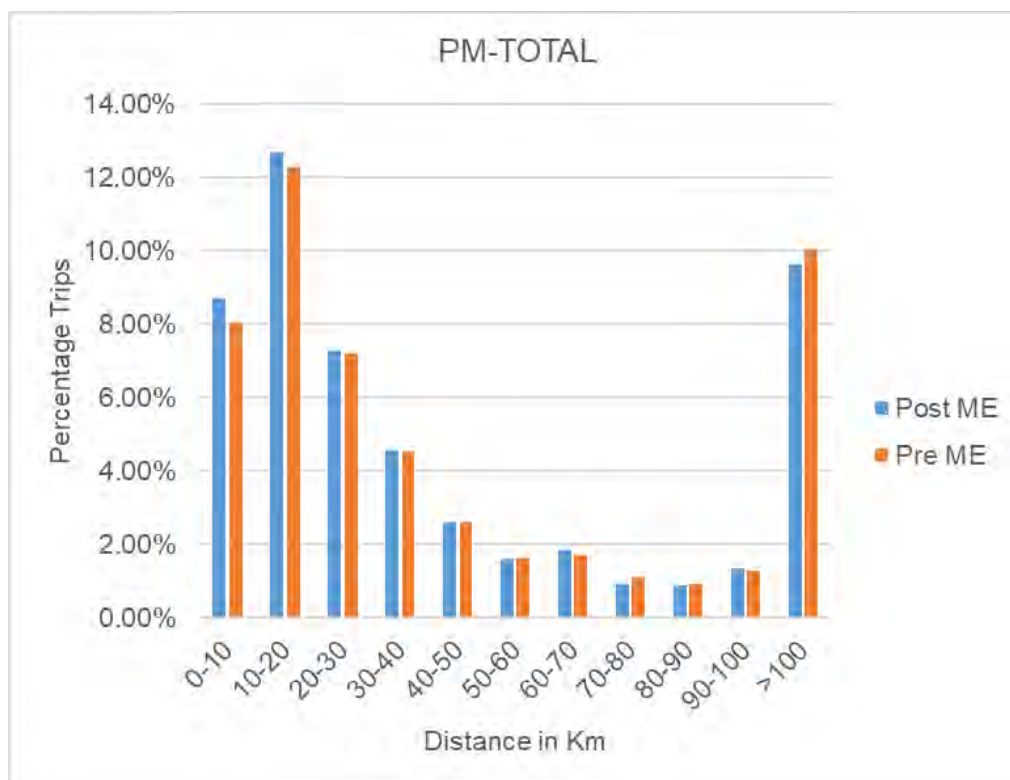


Figure 8-5 – PM Total Vehicles - Trip Length Distribution



It can be observed from Figure 8-3 to Figure 8-5 and Appendix F that the matrix estimation does not result in a significant change in the trip length distribution of the matrices for the three time periods.

Table 8-7 shows the mean and standard deviation for the change in trip length distribution, prior to and post matrix estimation for total vehicles, cars, LGVs and HGVs for the AM, Inter-peak and PM peak.

Table 8-7 - Average Trip Length Comparison

Time Period	Vehicle Type	Prior	Distance (Kms)	Post	Distance (Kms)	Change	(%)
		Mean	Std	Mean	Std	Mean	Std
AM	Car	37.09	30.80	36.73	30.50	-0.95%	-0.97%
	LGV	19.61	45.57	19.57	45.39	-0.22%	-0.40%
	HGV	54.49	59.38	54.41	59.26	-0.16%	-0.21%
	Total	32.85	39.47	32.69	39.23	-0.49%	-0.61%
IP	Car	43.17	31.42	41.82	30.48	-3.11%	-3.00%
	LGV	17.70	45.31	17.50	44.68	-1.14%	-1.39%
	HGV	56.05	60.10	54.96	59.90	-1.94%	-0.33%
	Total	32.79	39.93	32.15	39.20	-1.94%	-1.83%
PM	Car	38.98	31.18	38.31	30.84	-1.72%	-1.08%
	LGV	20.46	46.94	20.14	46.45	-1.60%	-1.04%
	HGV	57.63	61.22	56.57	61.49	-1.84%	0.45%
	Total	33.91	40.34	33.34	40.09	-1.68%	-0.61%

Table 8-7 demonstrates that the change in average trip length and standard deviation between the prior and post matrices are within 5% for total vehicles and for car, LGV and HGV individually for all three time periods demonstrating that there is not a significant impact on average trip lengths due to matrix estimation.

8.4.5 Sector Analysis

For the purposes of sector analysis, the model zoning system has been grouped into 48 sectors as presented in Table 3-3 and Figure 3-6. A comparison of the percentage changes in trip levels between sectors, prior to and post matrix estimation, are presented in Appendix G for the AM, Inter-peak and PM peaks. The GEH values are also provided as this statistic takes account of the number of trips and can, therefore, provide a better indication of significant changes than the percentage change, especially where sector totals represent low numbers of trips.

Table 8-8 presents a summary of the percentage of sector-to-sector pairs with GEH change less than 5, GEH change within 5 to 10 and those with GEH change greater than 10 brought about by ME.

Table 8-8 - Sector-to-sector ME changes in GEH ranges

User Class	GEH	AM	IP	PM
Commute	< 5	100.00%	99.71%	99.42%
	5 to 10	0.00%	0.29%	0.58%
	> 10	0.00%	0.00%	0.00%
Employers' Business	< 5	100.00%	99.96%	100.00%
	5 to 10	0.00%	0.04%	0.00%
	> 10	0.00%	0.00%	0.00%
Other	< 5	100.00%	99.04%	99.29%
	5 to 10	0.00%	0.79%	0.67%
	> 10	0.00%	0.17%	0.04%
LGV	< 5	100.00%	99.75%	99.42%
	5 to 10	0.00%	0.25%	0.58%
	> 10	0.00%	0.00%	0.00%
HGV	< 5	100.00%	99.08%	99.42%
	5 to 10	0.00%	0.87%	0.58%
	> 10	0.00%	0.04%	0.00%

It can be observed from the comparisons that most sectors do have GEH changes less than 5 in the three time periods, indicating that the majority of changes are not significant and ME doesn't change the underlying trip patterns significantly.

From Appendix G it can be observed that the majority of the sector movements where changes are high are outside the area of model improvements.

8.5 Screenline Calibration Results

74 screenlines were selected for the calibration of the model, as shown in Figure 8-1. As detailed in Chapter 7, guidance requires that all or nearly all (>95%) of model screenline flows are within 5% of observed flows. Appendix H shows the screenline calibration results for total vehicles and by user class following matrix estimation for the AM, Inter-Peak and PM peak hours, respectively.

The results by user class also shows a high level of calibration and provide confidence that the vehicle split in the matrices is accurate. The GEH has also been considered as this takes into account the volume of traffic flow on the screenline, although it is noted that this is no longer part of the TAG criteria.

Table 8-9 and Table 8-10 present the screenline calibration for total vehicles and cars respectively in the full model and all MIA's. The GEH has also been considered as this takes into account the volume of traffic flow on the screenline, although it is noted that this is no longer part of the TAG criteria.

Table 8-9 - Post ME Screenline Calibration - Total Vehicles in all model improvement areas

Area	Counts	AM		Peak		Inter		Peak		PM		Peak	
		Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4	Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4	Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4
Aylesbury	14	86%	100%	100%	93%	86%	100%	100%	100%	86%	93%	100%	93%
High Wycombe	10	90%	100%	100%	100%	90%	100%	100%	100%	70%	90%	90%	90%
Marlow	2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Bourne End	2	50%	100%	100%	100%	50%	100%	100%	100%	100%	100%	100%	100%
Buckingham	2	100%	100%	100%	100%	50%	100%	100%	100%	100%	100%	100%	100%
Outside MIA	44	84%	95%	98%	98%	45%	73%	86%	80%	52%	75%	82%	80%
BSTM2 Area (all)	74	85%	97%	99%	97%	61%	84%	92%	88%	65%	82%	88%	85%



Table 8-10 - Post ME Screenline Calibration - Cars in all model improvement areas

Area	Counts	AM		Peak		Inter		Peak		PM		Peak	
		Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4	Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4	Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4
Aylesbury	14	86%	93%	100%	93%	86%	100%	100%	100%	86%	93%	100%	93%
High Wycombe	10	90%	100%	100%	100%	90%	100%	100%	100%	70%	90%	90%	90%
Marlow	2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Bourne End	2	50%	100%	100%	100%	50%	100%	100%	100%	50%	100%	100%	100%
Buckingham	2	100%	100%	100%	100%	50%	100%	100%	100%	100%	100%	100%	100%
Outside MIA	44	91%	95%	98%	98%	45%	70%	91%	86%	55%	70%	84%	82%
BSTM2 Area (all)	74	89%	96%	99%	97%	61%	82%	95%	92%	65%	80%	89%	86%



The following can be observed from Table 8-9 and Table 8-10:

- For Aylesbury, 86% of screenlines pass in the AM Peak, Inter-peak and PM peak, respectively, with a flow difference of less than 5% for total vehicles. For cars also, 86% of screenlines pass for all three time periods. However, the screenline calibration is 100% in the AM Peak and Inter-peak with 93% in PM peak, respectively with a flow difference of less than 7.5% for total vehicles. For cars, the screenline calibration is 93% in the AM Peak, 100% in the Inter-peak and 93% in PM peak, respectively, with a flow difference of less than 7.5%. This demonstrates a high level of calibration for the Aylesbury area.
- For High Wycombe, 90%, 90% and 70% of screenlines pass in the AM Peak, Inter-peak and PM peak, respectively, with a flow difference of less than 5% for total vehicles and cars. The screenlines calibration for cars and total vehicles is 100%, 100% and 90% in the AM Peak, Inter-peak and PM peak if a criteria of flow difference of less than 7.5% or GEH<4 is considered which demonstrates a high level of calibration for the High Wycombe area.
- For Bourne End, one of the two screenlines meets the TAG criteria in all time periods for cars and in the AM Peak, Inter-peak for total vehicles. Both screenlines meets the TAG criteria in AM Peak for for total vehicles . Both screenlines have a flow difference of less than 7.5% or GEH<4 for cars and total vehicles for all three time periods indicating that the screenlines which fails is close to passing. This is mainly due to the lower number of counts links on the screenlines which is acceptable.
- For Marlow, both screenlines meet the TAG criteria in the AM, Inter-peak and PM Peak for cars and total vehicles flow difference of less than 5%.
- For Buckingham, both screenlines meet the flow difference TAG criteria for the AM and PM peak hours. In the Inter-Peak one of the screenlines does not meet the TAG criteria but it does have a flow difference of less than 7.5% or GEH<4 which means it is close to passing.
- At overall model level, the screenline calibration is 85% in the AM peak, 61% in the Inter Peak and 65% in the PM peak for the flow difference of less than 5% criteria for total vehicles whereas this increases significantly to 97% in the AM peak, 88% in the Inter Peak and 85% in the PM Peak if a GEH < 4 criteria is considered which demonstrates that the screenlines are not failing significantly. It is predominantly the low flow screenlines which are just outside the TAG criteria with a small absolute difference in vehicles between modelled and observed. Further, the screenline calibration is 99% in the AM peak, 92% in the Inter Peak and 88% in the PM peak for the flow difference of less than 10% criteria for total vehicles. This indicates that the screenline calibration shows a good correlation between modelled flows and observed flows.
- Overall, considering the condition of the survey data used in BSTM2 development, the model performed best in calibration compared to TAG criteria and suggests that for the screenlines failing, most do not exhibit a significant difference between modelled and observed flows which is clear considering flow differences less than 7.5% or GEH<4.

8.6 Link Flow Calibration Results

The locations of the counts used in the link flow calibration are shown in Figure 8-6. The link calibration results for total vehicles and cars only are summarised in Table 8-11 and Table 8-12, respectively. The tables show the number of links which meet the TAG criteria (refer to Table 7-2) stating that all the links should have:

- Individual flows within 100 veh/h of counts for flows less than 700 veh/h;
- Individual flows within 15% of counts for flows from 700 to 2,700 veh/h;
- Individual flows within 400 veh/h of counts for flows more than 2,700 veh/h or;
- GEH<5 for individual flows for at least 85% of count links.

Details of individual link calibration by vehicle type is provided in Appendix I.

Figure 8-6 – Calibration Count Locations

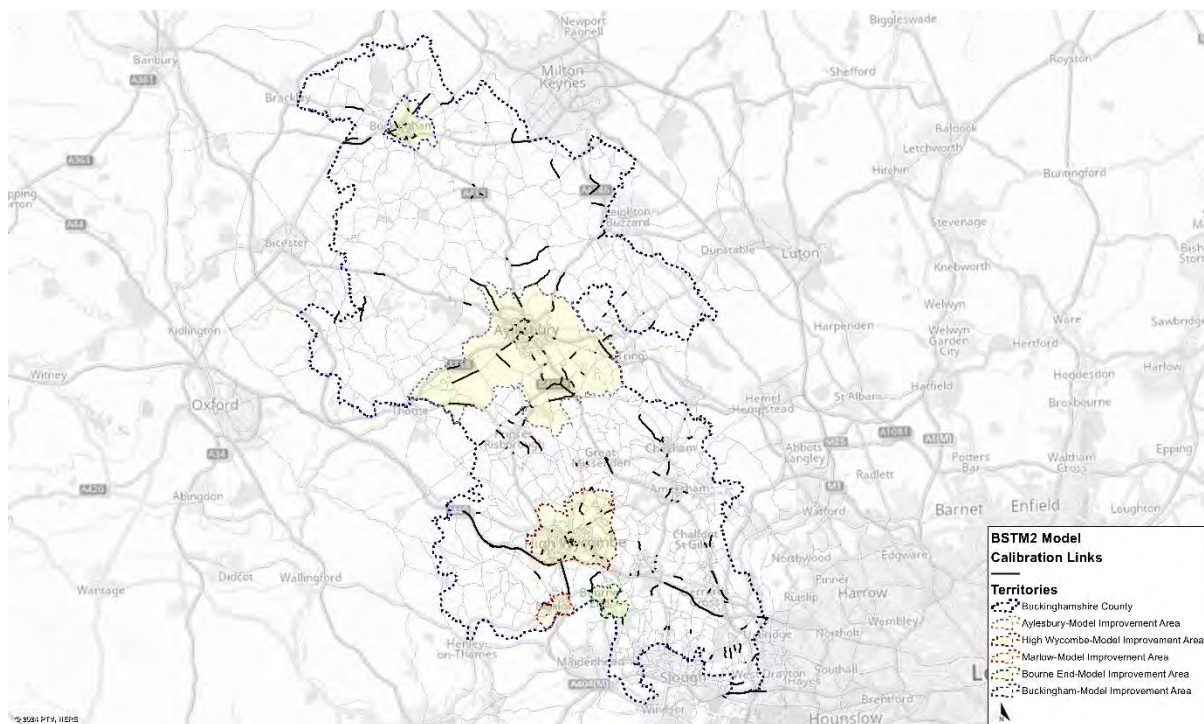


Table 8-11 - Post-ME Link Calibration (Total Vehicles)

	AM	IP	PM
Cordon / Screenline links	95% (339 out of 358)	96% (344 out of 358)	92% (330 out of 358)
Individual Ad-hoc links	96% (44 out of 46)	98% (45 out of 46)	93% (43 out of 46)
Total calibration links	95% (383 out of 404)	96% (389 out of 404)	92% (373 out of 404)

Table 8-12 - Post-ME Link Calibration (Cars)

	AM	IP	PM
Cordon / Screenline links	96% (343 out of 358)	98% (350 out of 358)	92% (330 out of 358)
Individual Ad-hoc links	96% (44 out of 46)	98% (45 out of 46)	96% (44 out of 46)
Total calibration links	96% (387 out of 404)	98% (395 out of 404)	93% (374 out of 404)

Table 8-11 and Table 8-12 show that a high level of calibration has been achieved for total vehicles and for cars only for all three time periods, meeting or exceeding the TAG criteria. Given the high number of counts used this demonstrates a good level of correlation between modelled and observed flows throughout the model.

Figure 8-7 to Figure 8-24 show the link pass/fail results for the AM, Inter-Peak and PM peak hours, both for the model extent and the areas of model improvement. Here, 'pass' is considered if the TAG criteria are fully met (i.e. GEH<5 or the flow difference criteria is met), 'near pass' if the TAG criteria is not met but GEH<7.5 and 'fail' if the TAG criteria are not met and GEH>7.5.

Again, the figures confirm there is broadly very good parity between modelled results and observed counts for all MIA's. Table 8-13 and Table 8-14 present the link calibration for total vehicles and cars respectively in all MIA's.

Table 8-13 - Post ME Link Calibration - Total Vehicles in all model improvement areas

Area	Counts	AM Peak	Inter Peak	PM Peak
		GEH (<5)	or	Flow Diff<5%
Aylesbury	102	98%	97%	95%
High Wycombe	60	83%	95%	95%
Marlow	12	92%	100%	92%
Bourne End	16	94%	94%	88%
Buckingham	32	100%	100%	100%
Outside MIA	182	96%	96%	89%
BSTM2 Area (all)	404	95%	96%	92%

Table 8-14 - Post ME Link Calibration - Cars in all model improvement areas

Area	Counts	AM Peak	Inter Peak	PM Peak
		GEH (<5)	or	Flow Diff<5%
Aylesbury	102	98%	99%	96%
High Wycombe	60	87%	95%	93%
Marlow	12	92%	100%	92%
Bourne End	16	94%	94%	94%
Buckingham	32	100%	100%	100%
Outside MIA	182	97%	98%	89%
BSTM2 Area (all)	404	96%	98%	93%

Table 8-13 and Table 8-14 demonstrate that there is a high level of link calibration for cars and total vehicles in Aylesbury, Marlow, Bourne End and Buckingham in all time periods, with over 90% of links meeting the TAG criteria.

There is a high level of link calibration in High Wycombe for the Inter-Peak and PM peak hour with more than 93% of links meeting the TAG criteria for both cars and total vehicles. In the AM peak hour there is a slightly lower level of calibration with, 83% and 87% of links meeting the TAG criteria for total vehicles and cars, respectively. However, 100% meet the criteria with a GEH of 7.5 which indicates that those which are failing are close to meeting the criteria.

BSTM2 Model
AM PEAK (08:00 - 09:00)
Calibration Links

Pass/Fail (Total Vehicles)

- PASS
- NEAR PASS
- FAIL

Territories

- Buckinghamshire County
- Aylesbury-Model Improvement Area
- High Wycombe-Model Improvement Area
- Marlow-Model Improvement Area
- Bourne End-Model Improvement Area
- Buckingham-Model Improvement Area

Figure 8-8 – Link Flow Calibration AM Peak- Aylesbury

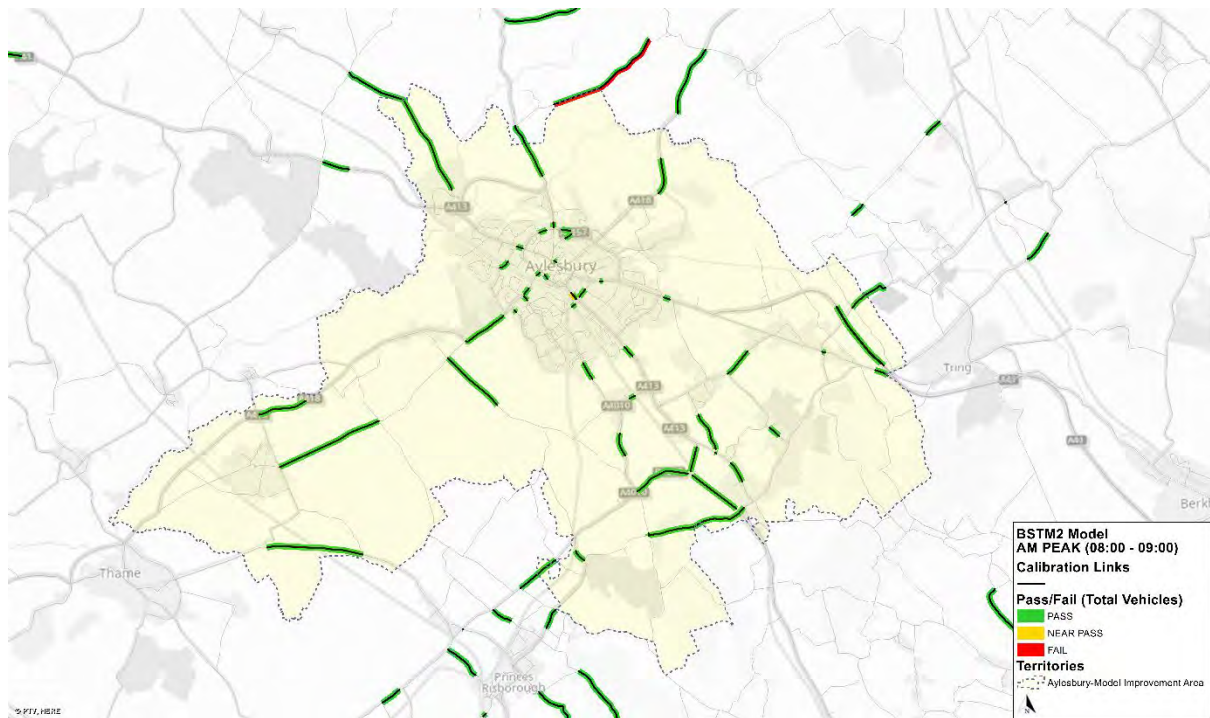


Figure 8-9 – Link Flow Calibration AM Peak- High Wycombe

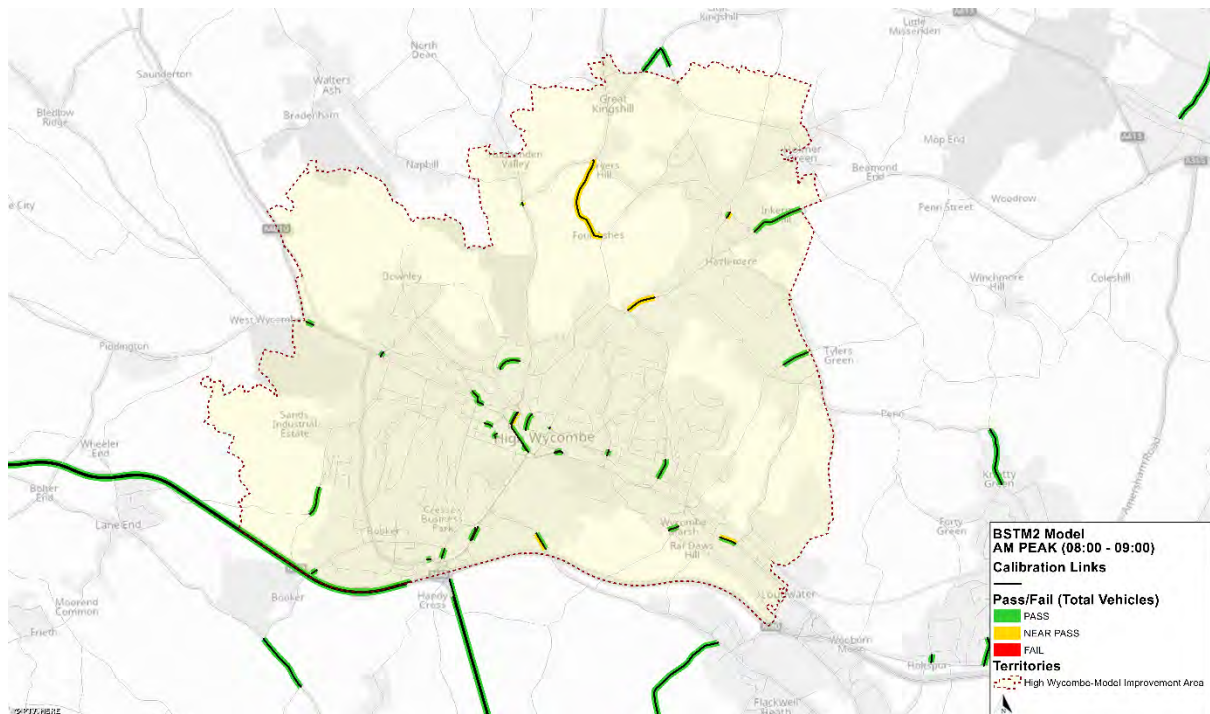


Figure 8-10 – Link Flow Calibration AM Peak- Bourne End

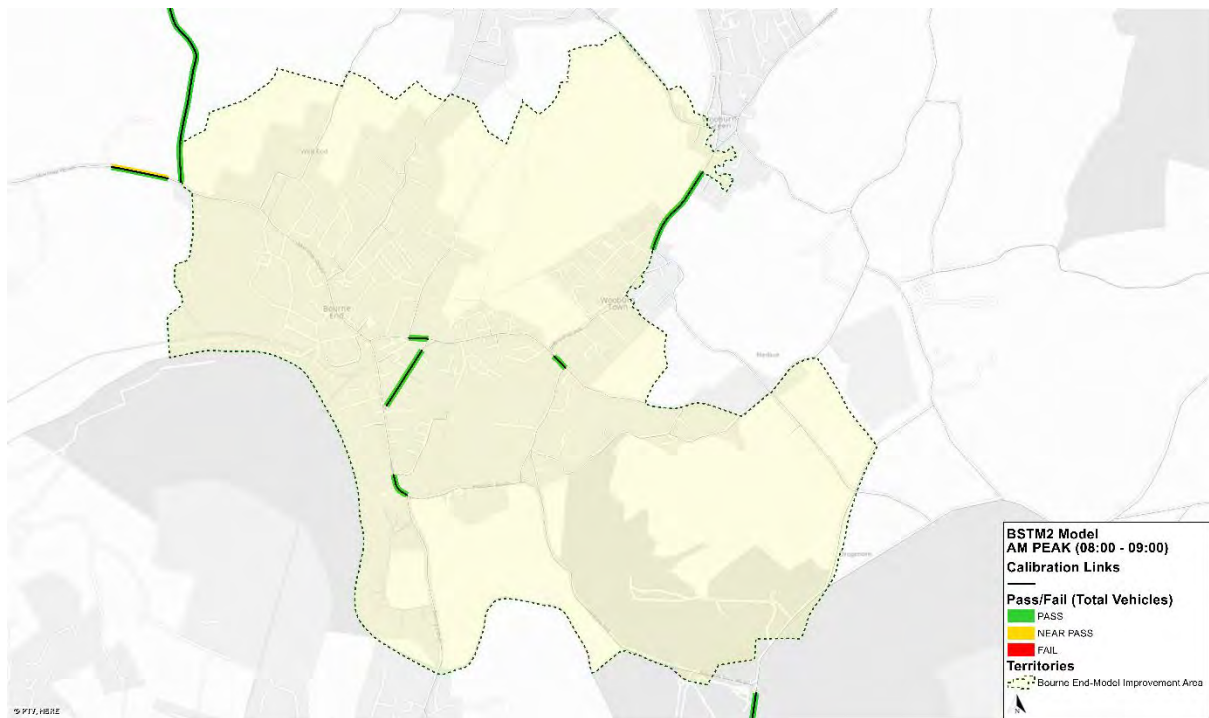


Figure 8-11 – Link Flow Calibration AM Peak- Marlow

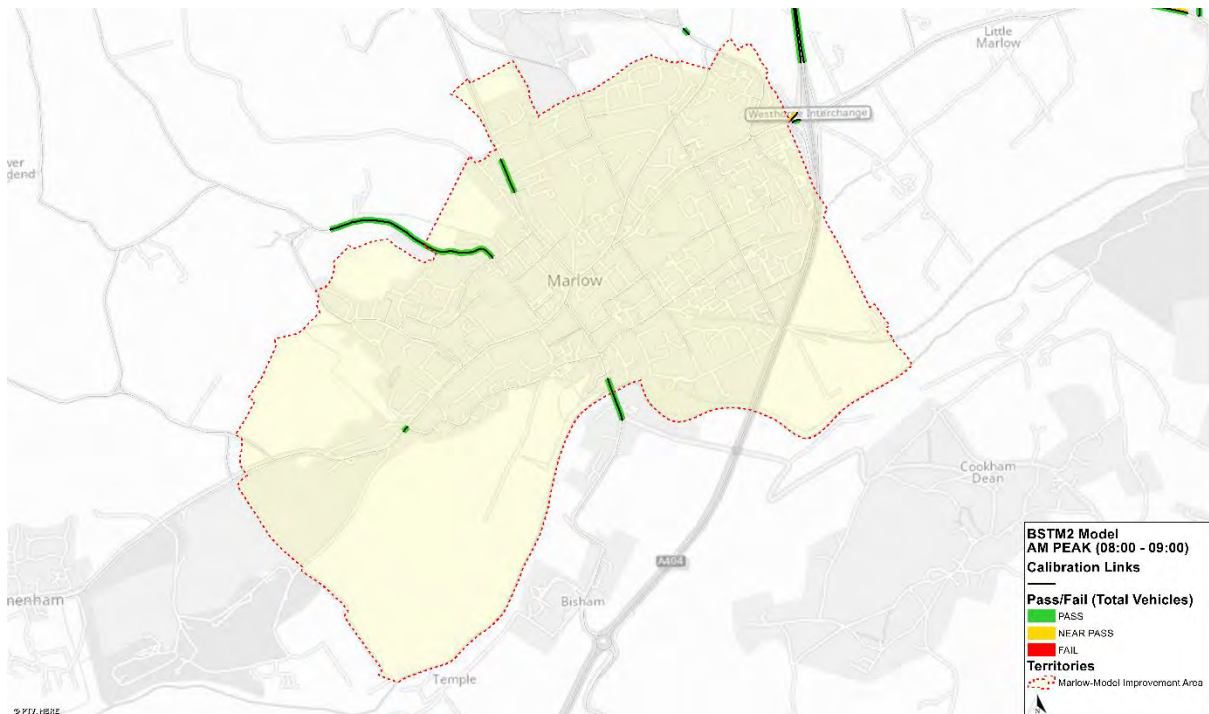


Figure 8-12 – Link Flow Calibration AM Peak- Buckingham

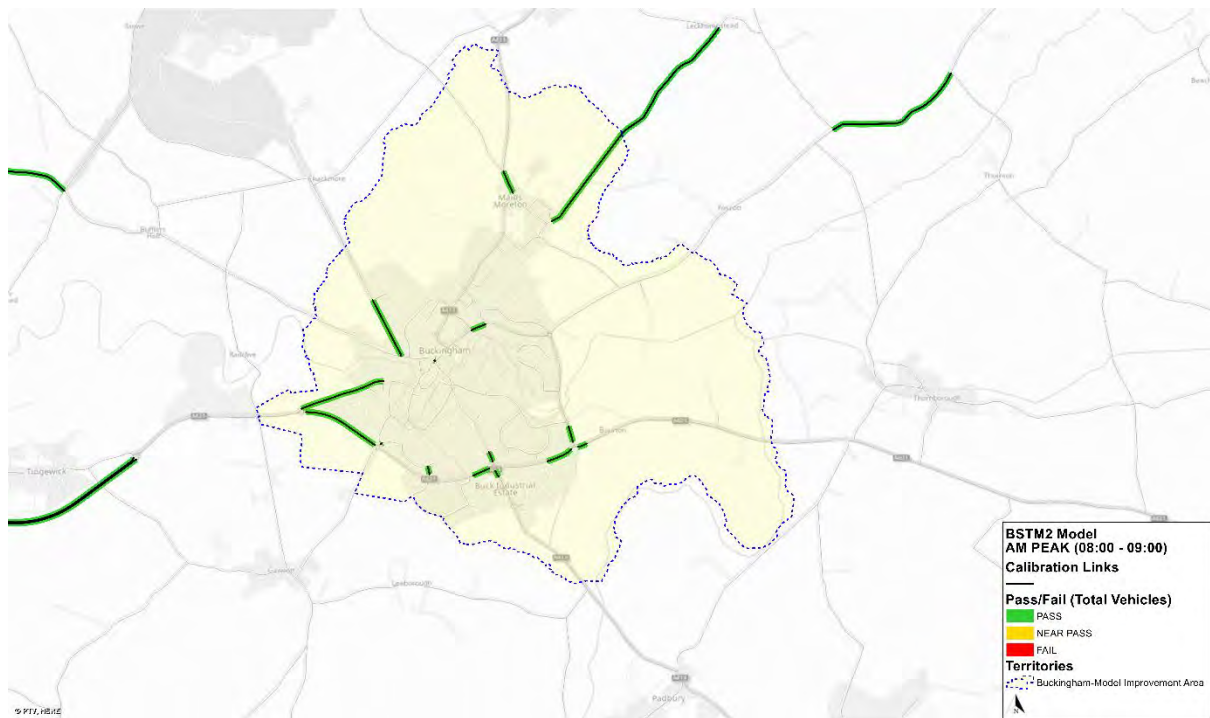


Figure 8-13 – Link Flow Calibration Inter-peak- Model Extent

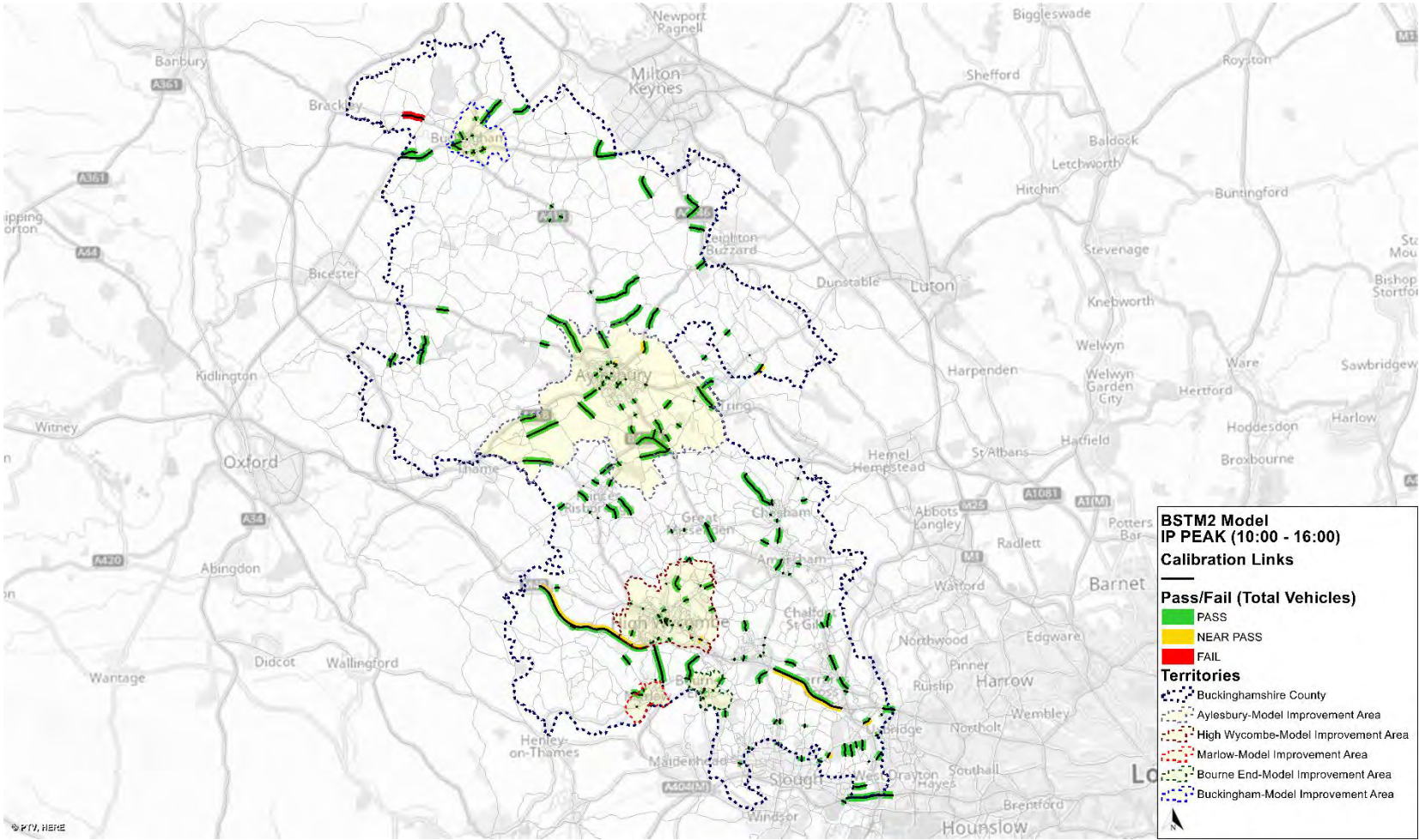


Figure 8-14 – Link Flow Calibration Inter-Peak- Aylesbury

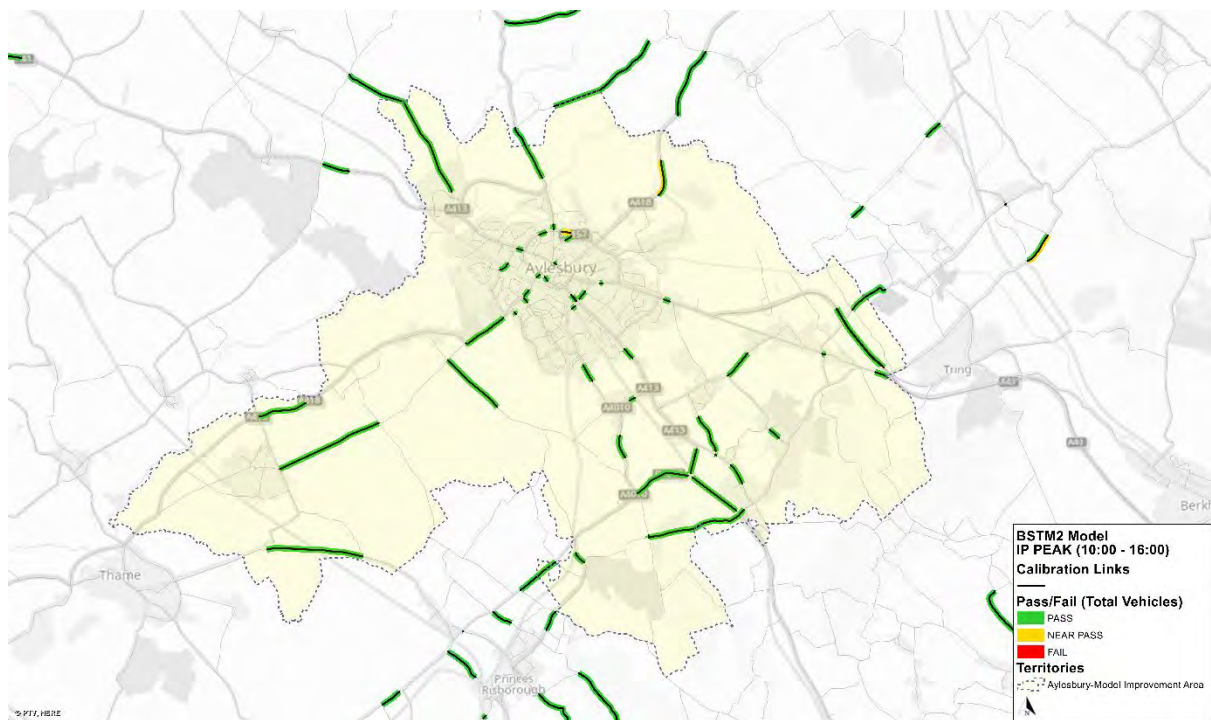


Figure 8-15 – Link Flow Calibration Inter-Peak- High Wycombe

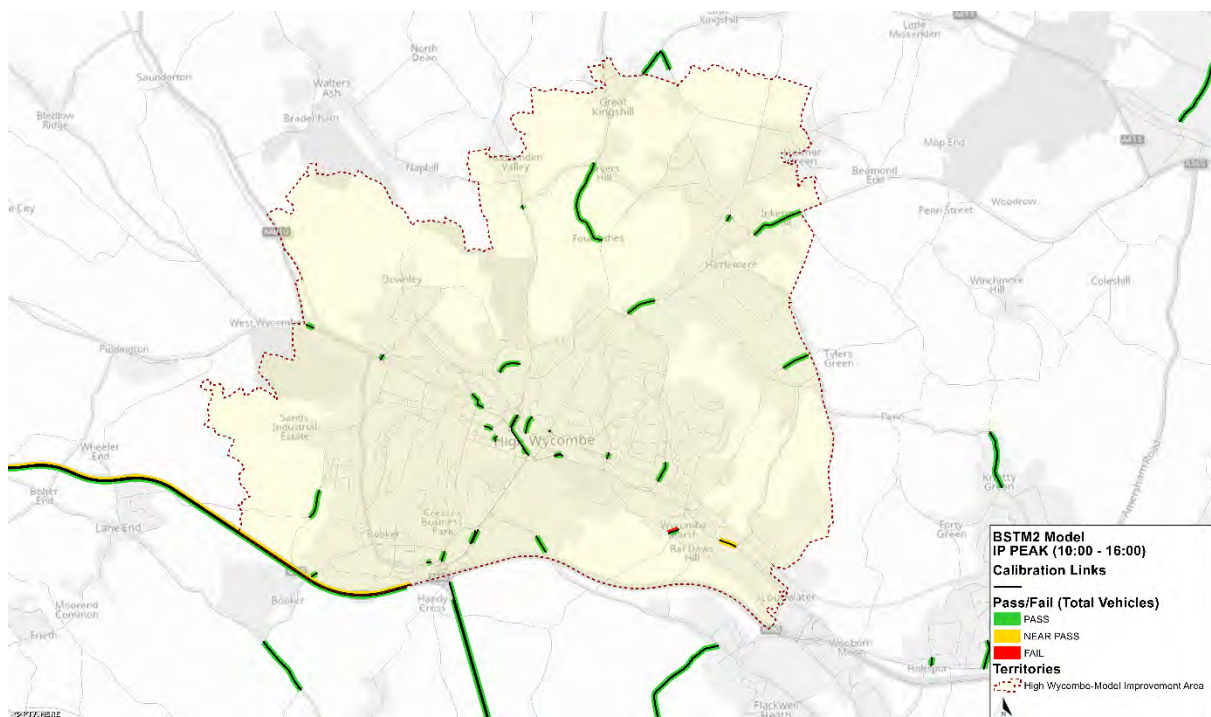


Figure 8-16 – Link Flow Calibration Inter-Peak- Bourne End

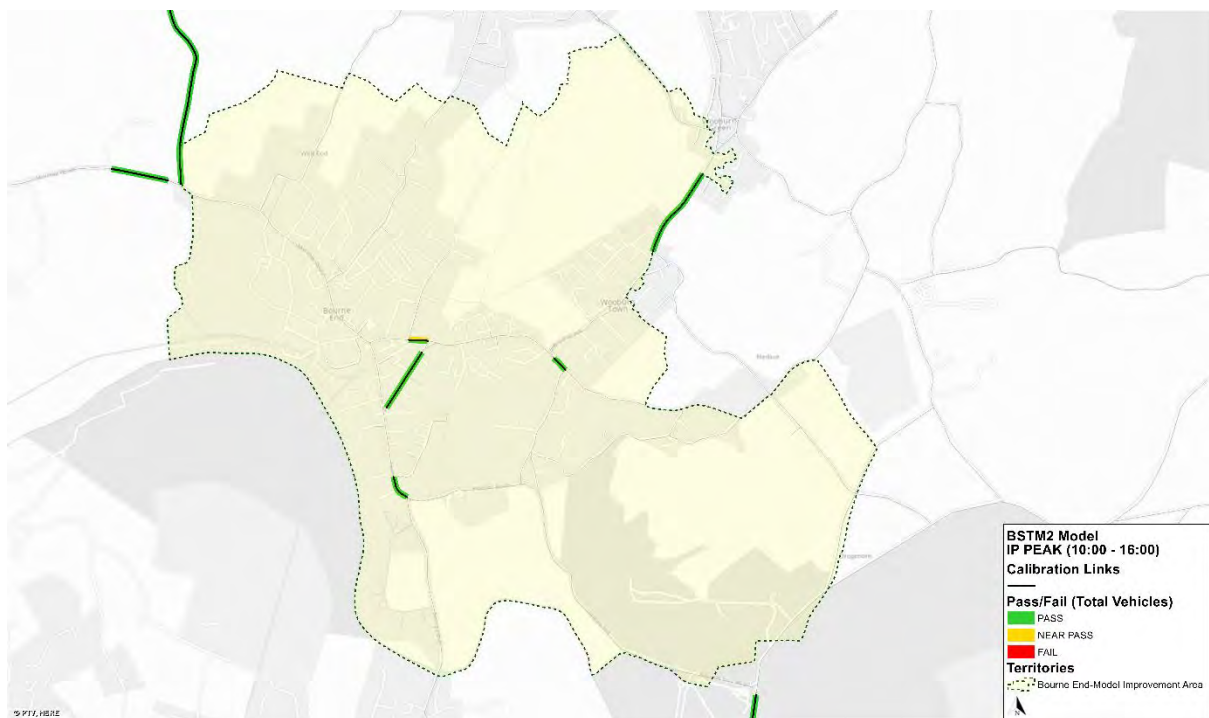


Figure 8-17 – Link Flow Calibration Inter-Peak- Marlow

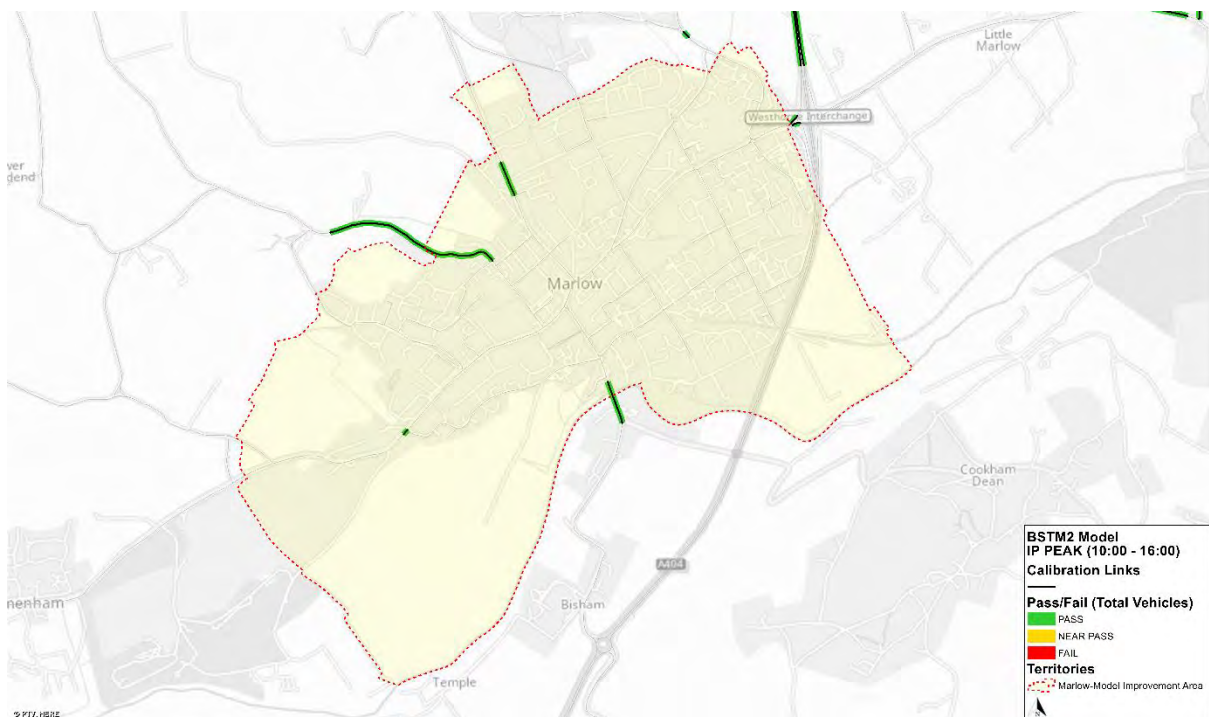
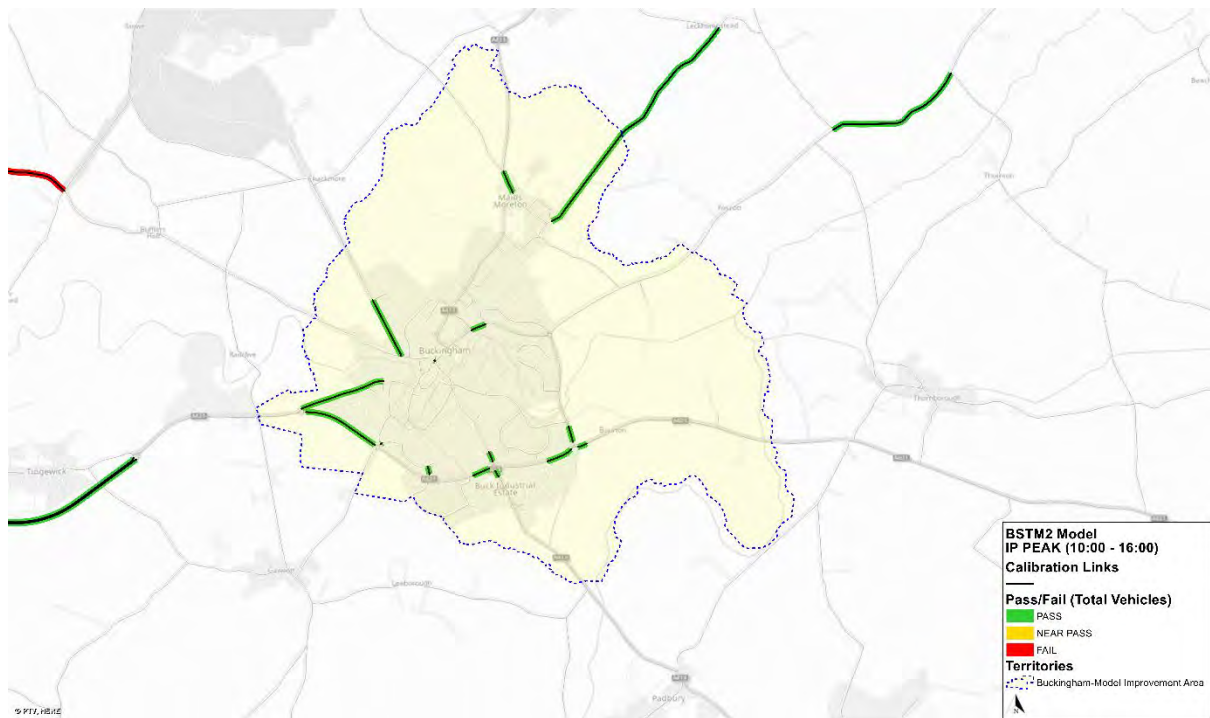


Figure 8-18 – Link Flow Calibration Inter-Peak- Buckingham



**BSTM2 Model
PM PEAK (17:00 - 18:00)
Calibration Links**

Pass/Fail (Total Vehicles)

- PASS
- NEAR PASS
- FAIL

Territories

- Buckinghamshire County
- Aylesbury-Model Improvement Area
- High Wycombe-Model Improvement Area
- Marlow-Model Improvement Area
- Bourne End-Model Improvement Area
- Buckingham-Model Improvement Area

Figure 8-20 – Link Flow Calibration PM Peak- Aylesbury

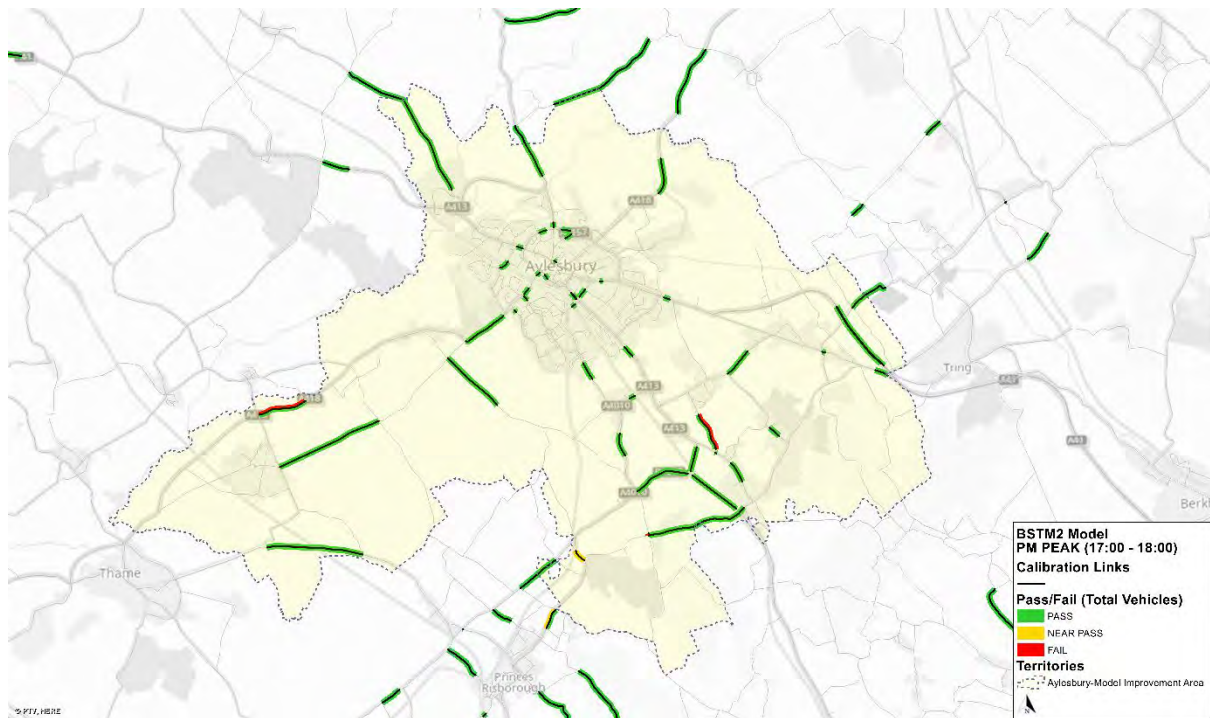


Figure 8-21 – Link Flow Calibration PM Peak- High Wycombe

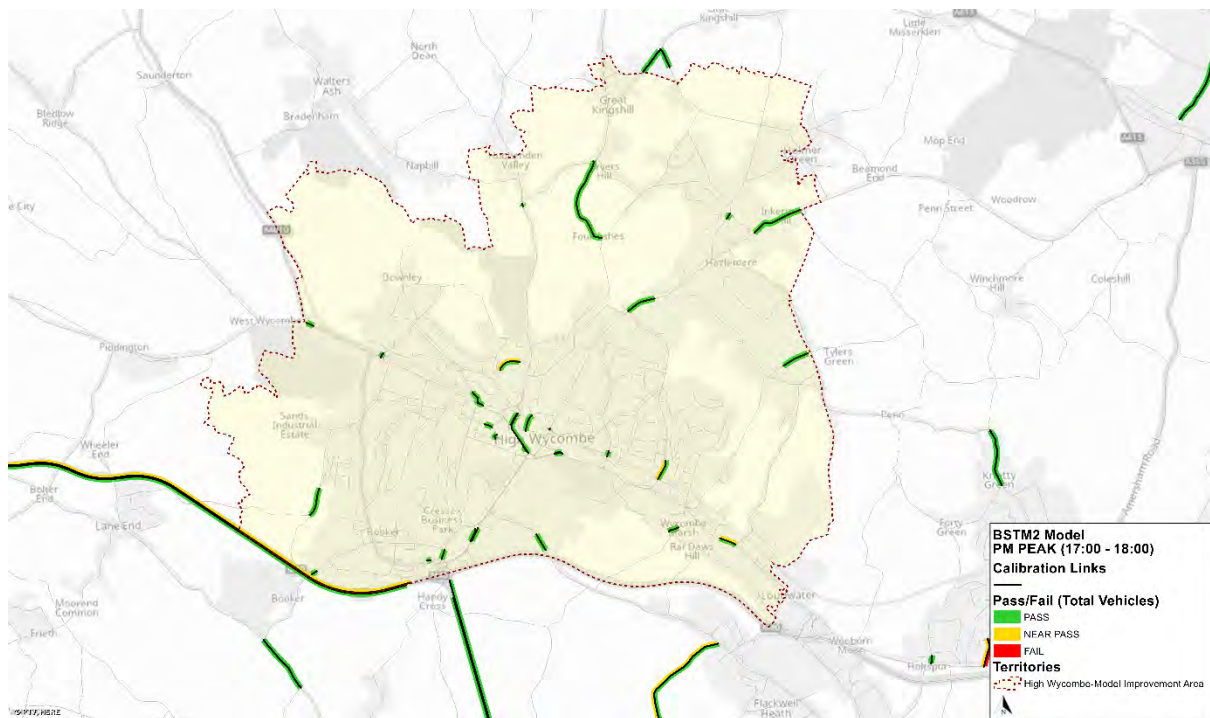


Figure 8-22 – Link Flow Calibration PM Peak- Bourne End

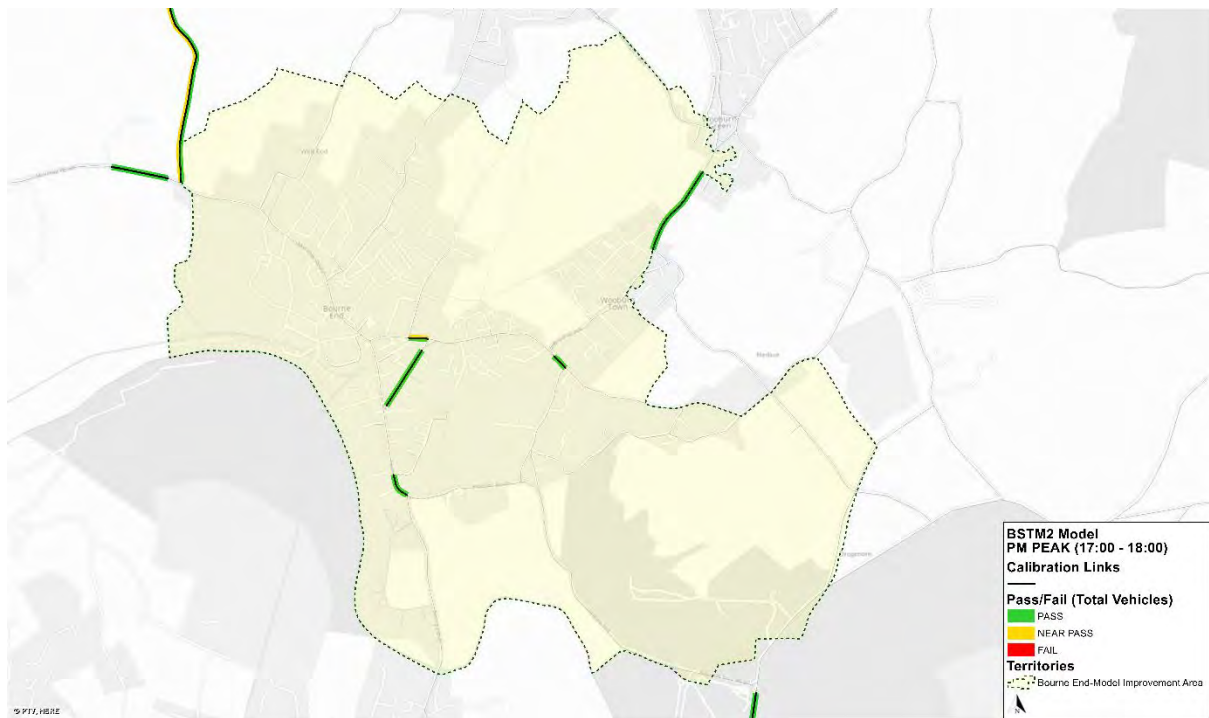


Figure 8-23 – Link Flow Calibration PM Peak- Marlow

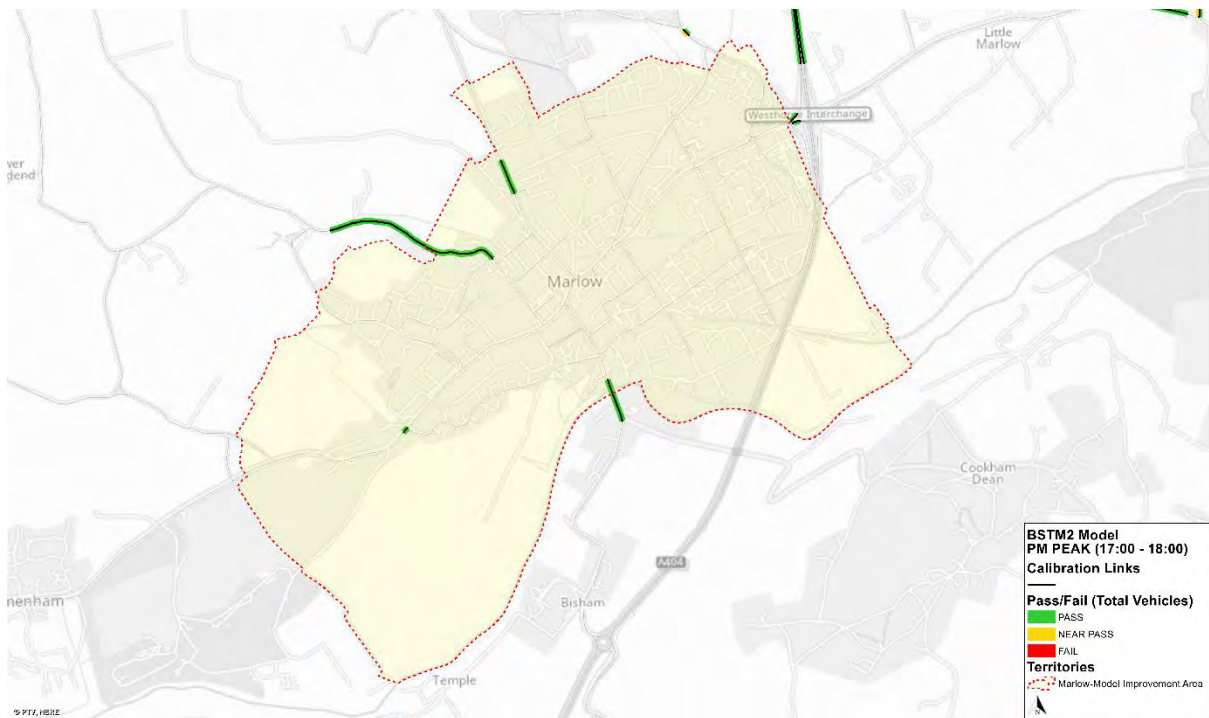
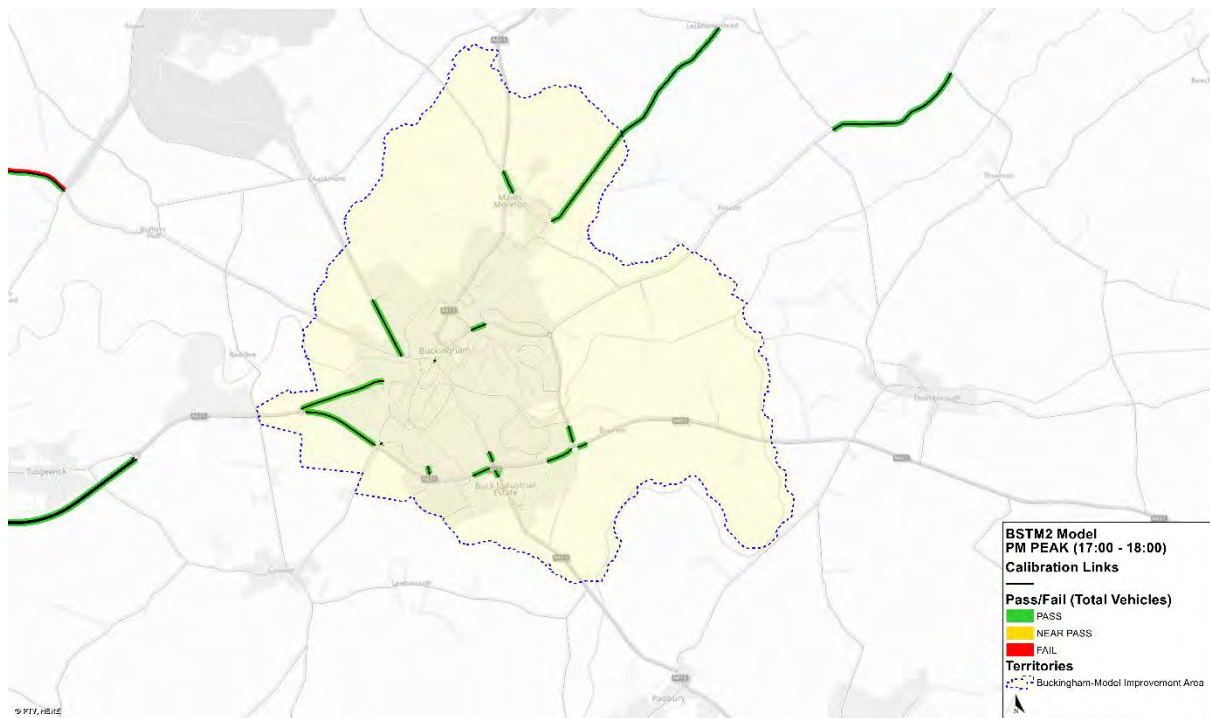


Figure 8-24 – Link Flow Calibration PM Peak- Buckingham



9. Highway Model Validation

Model validation is a comparison of model output data with an independent set of observed data to assess the accuracy of the calibrated model and establish its suitability as a basis from which to prepare forecasts. The TAG guidance criteria used in this process is summarised in Chapter 7.

Validation of the BSTM2 has involved the following aspects:

- Individual link flow validation;
- Journey time validation; and
- Trip routing for key movements.

9.1 Screenline Validation Results

Fourteen screenlines were selected for the validation of the model, as shown in Figure 9-1.

Figure 9-1 – BSTM2 Model Screenlines for Validation

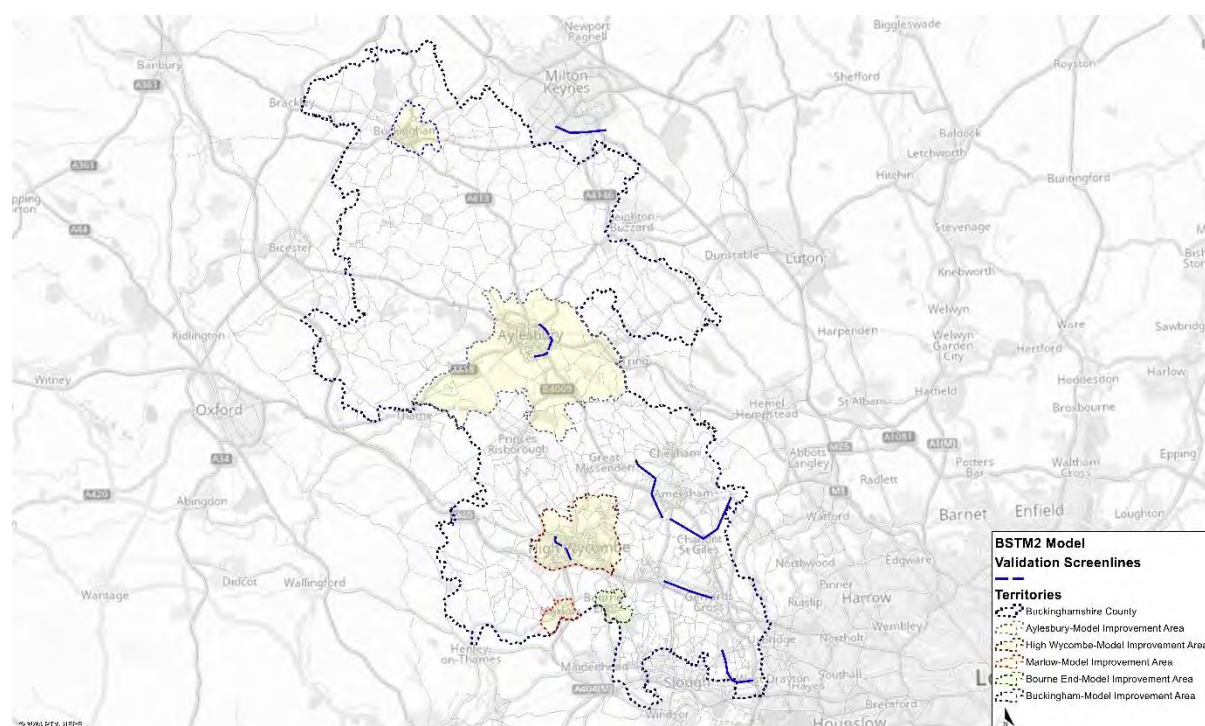


Table 9-1 to Table 9-3 show the screenline validation results for total vehicles following matrix estimation for the AM, Inter-Peak and PM peak hours, respectively. The screenline validation results by vehicle type are included in Appendix J.

Table 9-1 - Post ME Screenline Validation AM Peak Hour; Total Vehicles

Cordon / Screenline	Direction	No of Links	Observed	Post ME		Flow Diff (%)	GEH	TAG (within 5%)
				Modelled	Modelled - Observed			
Aylesbury NewVal	WB	5	3,515	3,715	200	5.70%	3	Fail
Aylesbury NewVal	EB	5	3,333	3,056	-277	-8.31%	5	Fail
Iver 1 (within)	EB	4	2,922	2,863	-59	-2.01%	1	Pass
Iver 1 (within)	WB	4	2,784	2,514	-270	-9.70%	5	Fail
Amersham 1 (west of) *A413	EB	4	2,219	2,263	44	1.98%	1	Pass
Amersham 1 (west of) *A413	WB	4	1,646	1,762	117	7.10%	3	Fail
Beaconsfield / Gerrards Cross *A355	NB	2	1,978	2,065	87	4.38%	2	Pass
Beaconsfield / Gerrards Cross *A355	SB	2	2,247	2,274	26	1.17%	1	Pass
Milton Keynes 1 (south of)	NB	2	3,981	4,427	446	11.21%	7	Fail
Milton Keynes 1 (south of)	SB	2	2,250	2,334	83	3.70%	2	Pass
High Wycombe 1 (within)	EB	5	3,349	3,342	-7	-0.20%	0	Pass
High Wycombe 1 (within)	WB	5	3,962	3,971	10	0.25%	0	Pass
Amersham 2 (south of) *A413	NB	3	2,108	2,103	-5	-0.26%	0	Pass
Amersham 2 (south of) *A413	SB	3	2,113	2,276	163	7.71%	3	Fail

Table 9-2 - Post ME Screenline Validation Inter-Peak Hour; Total Vehicles

Cordon / Screenline	Direction	No of		Post	ME		GEH	TAG (within 5%)
		Links	Observed	Modelled	Modelled - Observed	Flow Diff (%)		
Aylesbury NewVal	WB	5	2,637	2,744	107	4.05%	2	Pass
Aylesbury NewVal	EB	5	2,737	2,767	30	1.10%	1	Pass
Iver 1 (within)	EB	4	1,740	1,896	155	8.93%	4	Fail
Iver 1 (within)	WB	4	1,723	1,751	28	1.64%	1	Pass
Amersham 1 (west of A413)	EB	4	1,168	1,172	4	0.34%	0	Pass
Amersham 1 (west of A413)	WB	4	1,239	1,232	-7	-0.56%	0	Pass
Beaconsfield / Gerrards Cross *A355	NB	2	1,386	1,756	370	26.71%	9	Fail
Beaconsfield / Gerrards Cross *A355	SB	2	1,368	1,888	519	37.96%	13	Fail
Milton Keynes 1 (south of)	NB	2	2,253	2,776	524	23.24%	10	Fail
Milton Keynes 1 (south of)	SB	2	2,032	1,992	-40	-1.96%	1	Pass
High Wycombe 1 (within)	EB	5	2,573	2,894	321	12.49%	6	Fail
High Wycombe 1 (within)	WB	5	2,797	3,005	208	7.44%	4	Fail
Amersham 2 (south of A413)	NB	3	1,587	1,616	30	1.86%	1	Pass
Amersham 2 (south of A413)	SB	3	1,506	1,738	232	15.38%	6	Fail

Table 9-3 - Post ME Screenline Validation PM Peak Hour; Total Vehicles

Cordon / Screenline	Direction	No of		Post	ME		GEH	TAG (within 5%)
		Links	Observed	Modelled	Modelled - Observed	Flow Diff (%)		
Aylesbury NewVal	WB	5	3,721	4,120	399	10.72%	6	Fail
Aylesbury NewVal	EB	5	3,578	3,553	-24	-0.67%	0	Pass
Iver 1 (within)	EB	4	2,550	2,508	-42	-1.66%	1	Pass
Iver 1 (within)	WB	4	2,628	2,609	-19	-0.72%	0	Pass
Amersham 1 (west of A413)	EB	4	1,553	1,664	110	7.11%	3	Fail
Amersham 1 (west of A413)	WB	4	2,201	2,026	-174	-7.92%	4	Fail
Beaconsfield / Gerrards Cross *A355	NB	2	1,766	1,862	96	5.42%	2	Fail
Beaconsfield / Gerrards Cross *A355	SB	2	1,692	2,154	463	27.34%	11	Fail
Milton Keynes 1 (south of)	NB	2	2,690	2,500	-190	-7.05%	4	Fail
Milton Keynes 1 (south of)	SB	2	3,480	3,264	-216	-6.22%	4	Fail
High Wycombe 1 (within)	EB	5	3,758	3,951	194	5.15%	3	Fail
High Wycombe 1 (within)	WB	5	3,992	3,907	-85	-2.12%	1	Pass
Amersham 2 (south of) *A413	NB	3	2,713	2,181	-532	-19.62%	11	Fail
Amersham 2 (south of) *A413	SB	3	1,982	2,243	261	13.18%	6	Fail

It can be observed from Table 9-1 to Table 9-3 that 57%, 50% and 29% of screenlines have a difference of less than 5% between modelled and observed flows for the AM, Inter-Peak and PM peak hours, respectively. However, 79%, 64% and 71% of the screenlines have a GEH less than 4 for the AM, Inter-peak and PM peak hours, respectively, which indicates that a number of screenlines are close to passing. It is noted that out of the 14 screenlines, 10 are outside MIA's where model calibration was performed. Table 9-4 and Table 9-5 present the screenline validation results for total vehicles and cars respectively in MIA's.

Table 9-4 - Post ME Screenline Validation - Total Vehicles in all model improvement areas

Area	SL	AM	Peak			Inter	Peak			PM	Peak		
		Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4	Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4	Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4
Aylesbury	2	0%	50%	100%	50%	100%	100%	100%	100%	50%	50%	50%	50%
High Wycombe	2	100%	100%	100%	100%	0%	50%	50%	50%	50%	100%	100%	100%
Outside MIA	10	60%	70%	90%	80%	50%	50%	60%	60%	20%	60%	70%	70%
BSTM2 Area (all)	14	57%	71%	93%	79%	50%	57%	64%	64%	29%	64%	71%	71%

Table 9-5 - Post ME Screenline Validation - Cars in all model improvement areas

Area	SL	AM	Peak			Inter	Peak			PM	Peak		
		Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4	Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4	Flow Diff <5%	Flow Diff <7.50%	Flow Diff <10%	GEH<4
Aylesbury	2	50%	100%	100%	100%	100%	100%	100%	100%	50%	50%	50%	50%
High Wycombe	2	100%	100%	100%	100%	0%	50%	50%	50%	50%	100%	100%	100%
Outside MIA	10	50%	90%	100%	100%	50%	50%	50%	50%	30%	30%	40%	40%
BSTM2 Area (all)	14	57%	93%	100%	100%	50%	57%	57%	57%	36%	43%	50%	50%

The following is noted:

- For Aylesbury, 100% of screenlines pass for a flow difference of less than 10% in all AM and Inter-Peak time periods for both cars and total vehicles.
- For Aylesbury, 50% of screenlines pass for a flow difference of less than 7.5% in PM Peak time period for both cars and total vehicles
- For High Wycombe, all screenlines pass for a flow difference of less than 5% in AM peak hour for cars and total vehicles.
- For High Wycombe, all screenlines pass for a flow difference of less than 7.5 % in PM peak hour for cars and total vehicles.



It is to be noted that many of the screenlines have less than 5 counts which makes the TAG criteria difficult to achieve. Accordingly, model validation at screenline links individually can provide better evidence about the model validation.

9.2 Link Flow Validation Results

Historically TAG advised that traffic count data be divided into a set used for calibration and an independent set for validation. However, recent guidance suggests that using more data for calibration has the advantage of the development of a better trip matrix. For example, DfT Technical Report 'Provision of Technical Advice and Support for Matrix Building Guidance, 19 December 2016' states that "Generally, all relevant available data should be used in developing the matrix with concurrent calibration and validation. It is not recommended to hold data back specifically for the purpose of what is sometimes referred to as independent validation, except in special circumstances, but rather to concentrate on how well the model fits all of its inputs, recognising the mutual inconsistency that usually exists among the data sources..."

More recently TAG M2-2 para 6.4.2 states "...use of count data to refine matrices should be through a staged approach.." and para 6.3.13 states "...A staged approach to using ME should be considered, where a subset of count data is used progressively to refine the matrices, and the performance of matrices are validated after each stage of matrix refinement..."

Accordingly, It was thus decided to incorporate as much of the traffic count data on screenlines into the calibration process and leave some ad-hoc counts for link validation. The locations of the counts used in the link flow validation are shown in Figure 9-2. The link validation results for total vehicles and cars only are summarised in Table 9-6 and Table 9-7 respectively. The tables show the number of links which meet the TAG criteria (refer to Table 7-2) stating that all the links should have:

- Individual flows within 100 veh/h of counts for flows less than 700 veh/h;
- Individual flows within 15% of counts for flows from 700 to 2,700 veh/h;
- Individual flows within 400 veh/h of counts for flows more than 2,700 veh/h or;
- GEH<5 for individual flows for at least 85% of count links.

Details of individual link validation are provided in Appendix K.

Table 9-6 - Post-ME Link Validation (Total Vehicles)

	AM	IP	PM
Validation links	75% (60 out of 80)	81% (65 out of 80)	75% (60 out of 80)

Table 9-7 - Post-ME Link Validation (Cars)

	AM	IP	PM
Validation links	75% (60 out of 80)	81% (65 out of 80)	71% (57 out of 80)

Figure 9-2 – Validation Count Locations

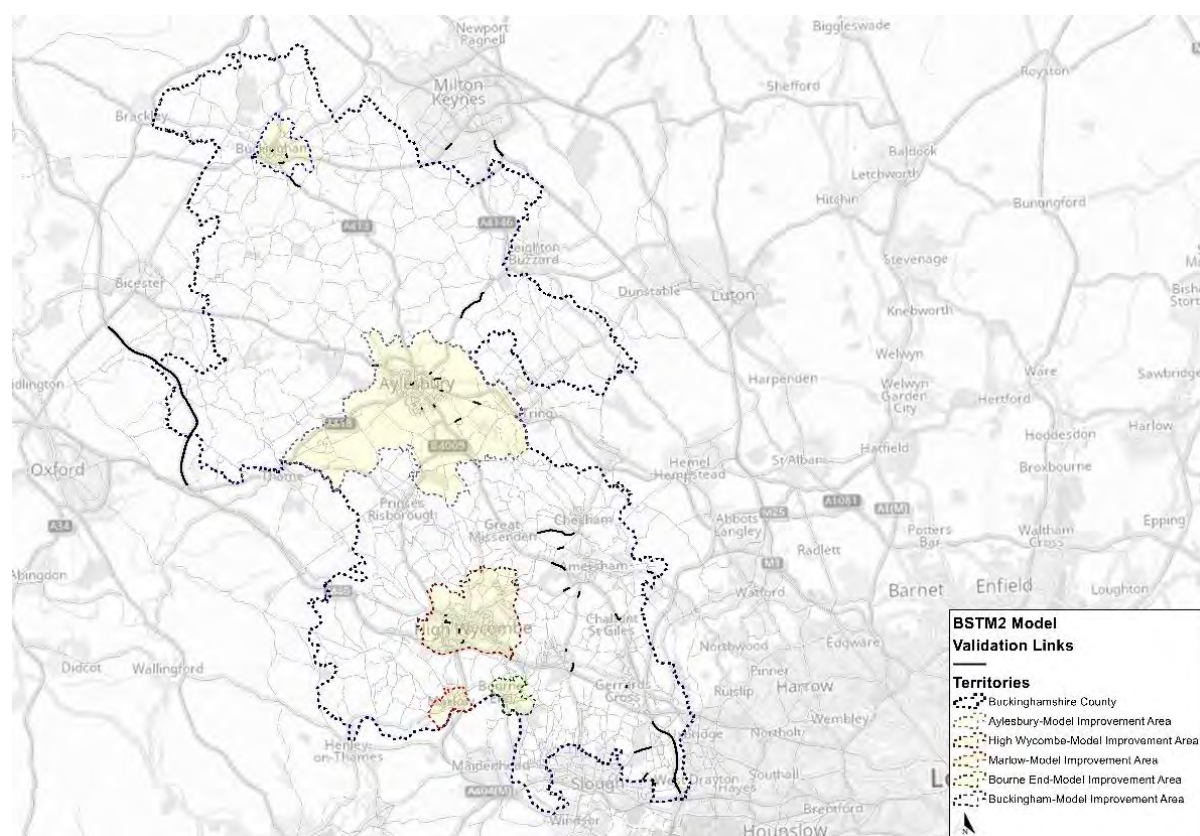


Table 9-6 and Table 9-7 show that 75%, 81% and 75% of links meet the TAG criteria for total vehicles for the AM, Inter-Peak and PM peak hours, respectively. For cars, 75%, 81% and 71% of links meet the TAG criteria of flow differences or GEH<5 for more than 85% of count links for the AM, Inter-Peak and PM peak hours, respectively. Given the size of the model this demonstrates a good level of correlation between modelled and observed flows throughout the model.

Figure 9-3 to Figure 9-14 show the link validation of the full model and the model improvement areas for each of the time periods. It should be noted that due to a smaller number of counts in Bourne End and Marlow, all the counts were used for calibration and as a result there were no counts for independent validation in these two areas. Table 9-8 and Table 9-9 present the link validation for total vehicles and cars respectively in all model improvement areas.

Table 9-8 - Post ME Link Validation – Total Vehicles in all model improvement areas

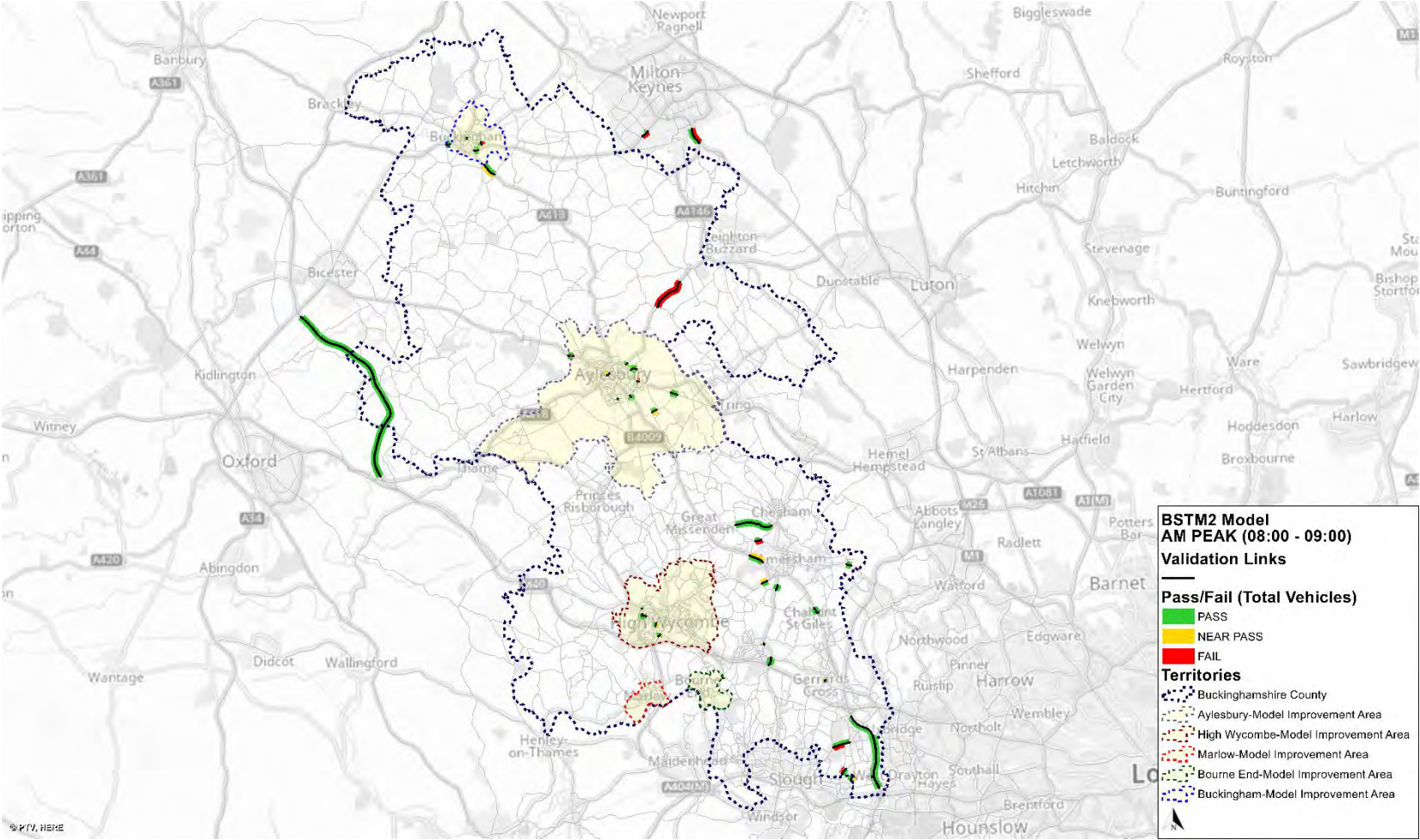
Area	Counts	AM Peak	Inter Peak	PM Peak
		GEH (<5)	or	Flow Diff
Aylesbury	18	83%	100%	78%
High Wycombe	10	90%	80%	80%
Buckingham	10	90%	90%	90%
Outside MIA	42	64%	71%	69%
BSTM2 Area (all)	80	75%	81%	75%

Table 9-9 - Post ME Link Validation - Cars in all model improvement areas

Area	Counts	AM Peak	Inter Peak	PM Peak
		GEH (<5)	or	Flow Diff
Aylesbury	18	83%	94%	67%
High Wycombe	10	90%	80%	80%
Buckingham	10	70%	80%	90%
Outside MIA	42	69%	76%	67%
BSTM2 Area (all)	80	75%	81%	71%

Table 9-8 shows that there is a higher proportion of links meeting the TAG criteria for total vehicles in the MIA's than the wider BSTM2 area, with all areas close to or meeting the TAG criteria of 85% passing. It is noted that the validation counts form a small proportion of the overall counts used for calibration and validation of the model.

Figure 9-3 – Link Flow Validation AM Peak- Model Extent



**BSTM2 Model
AM PEAK (08:00 - 09:00)
Validation Links**

Pass/Fail (Total Vehicles)

- PASS
- NFAR PASS
- FAIL

Territories

- High Wycombe-Model Improvement Area

Figure 9-6 – Link Flow Validation AM Peak- Buckingham

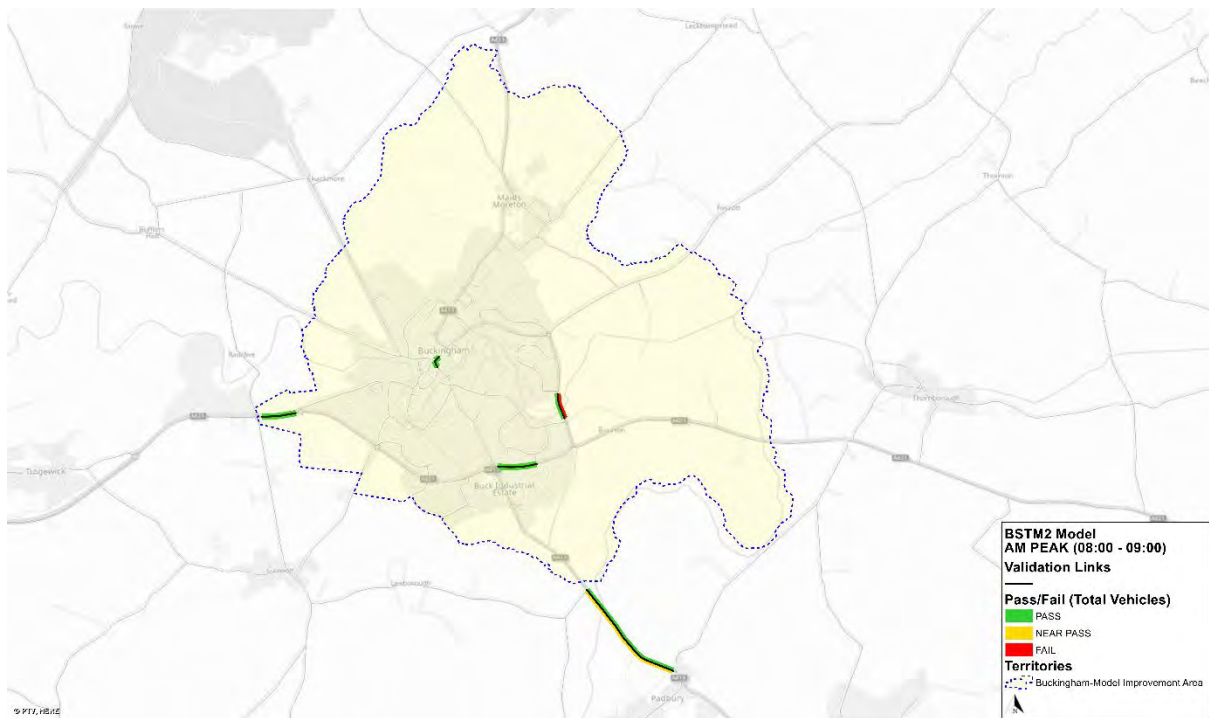
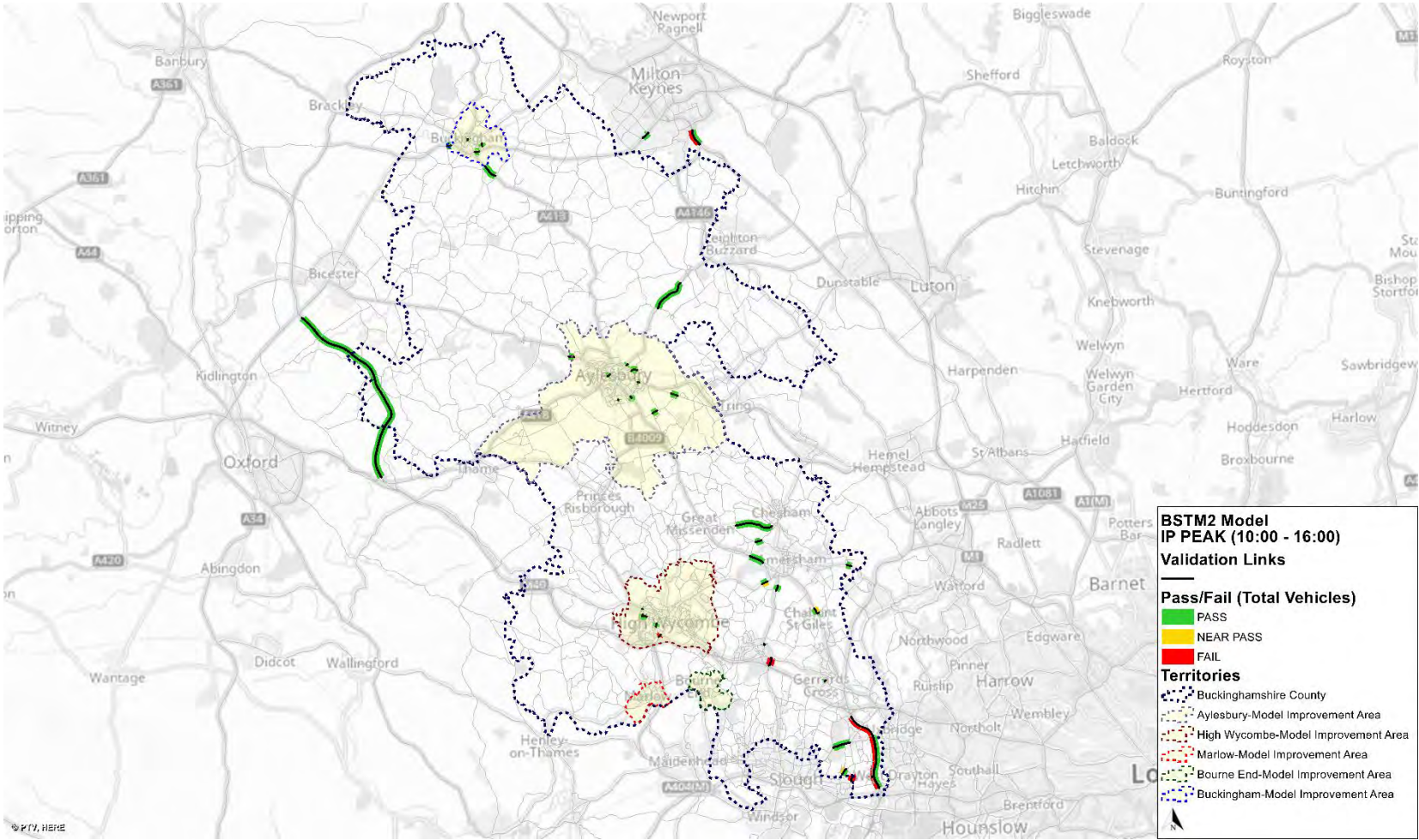


Figure 9-7 – Link Flow Validation Inter-Peak- Model Extent



**BSTM2 Model
IP PEAK (10:00 - 16:00)
Validation Links**

Pass/Fail (Total Vehicles)

- PASS
- NFAR PASS
- FAIL

Territories

- High Wycombe-Model Improvement Area

Figure 9-10 – Link Flow Validation Inter-Peak- Buckingham

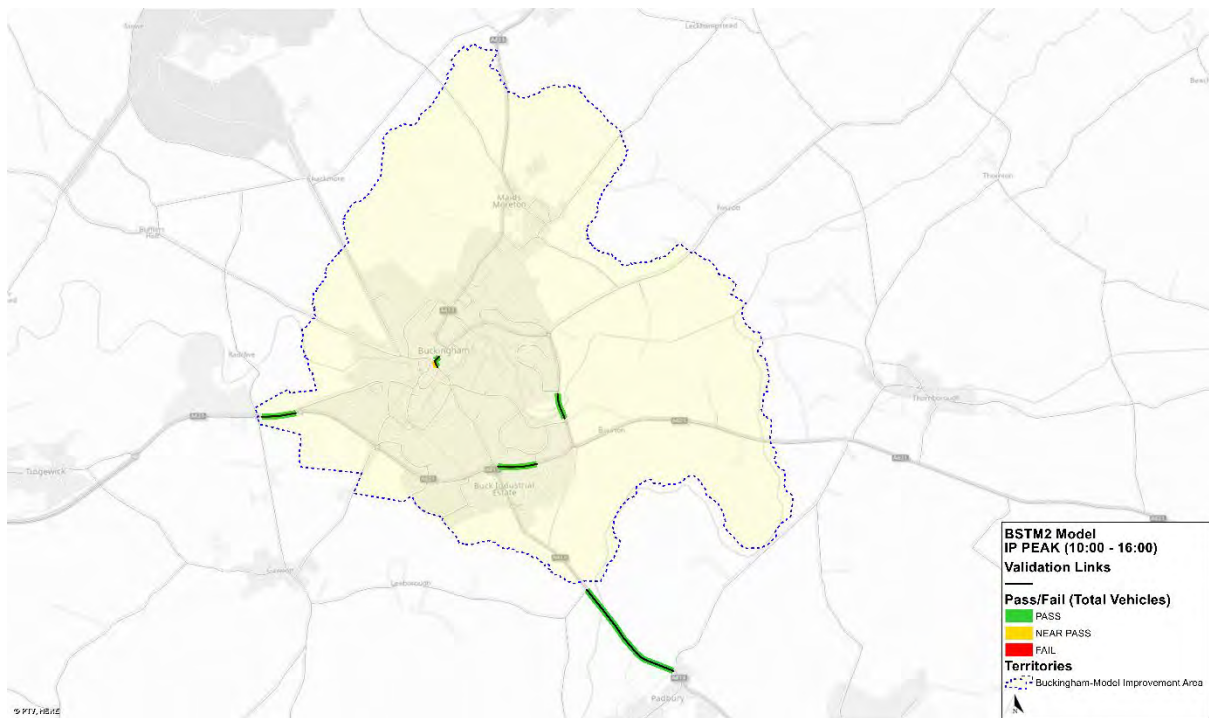


Figure 9-11 – Link Flow Validation PM Peak- Model Extent

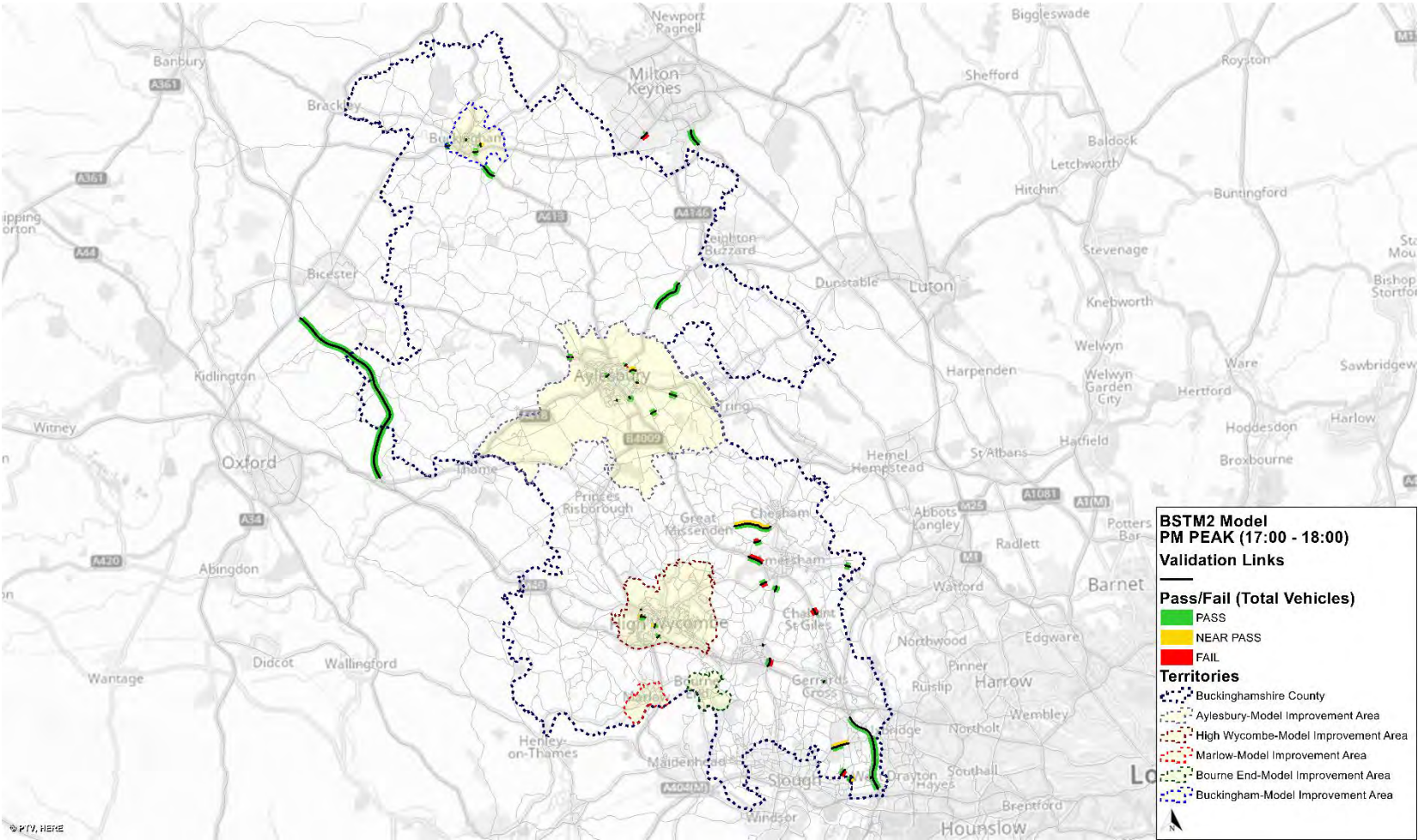


Figure 9-12 – Link Flow Validation PM Peak- Aylesbury

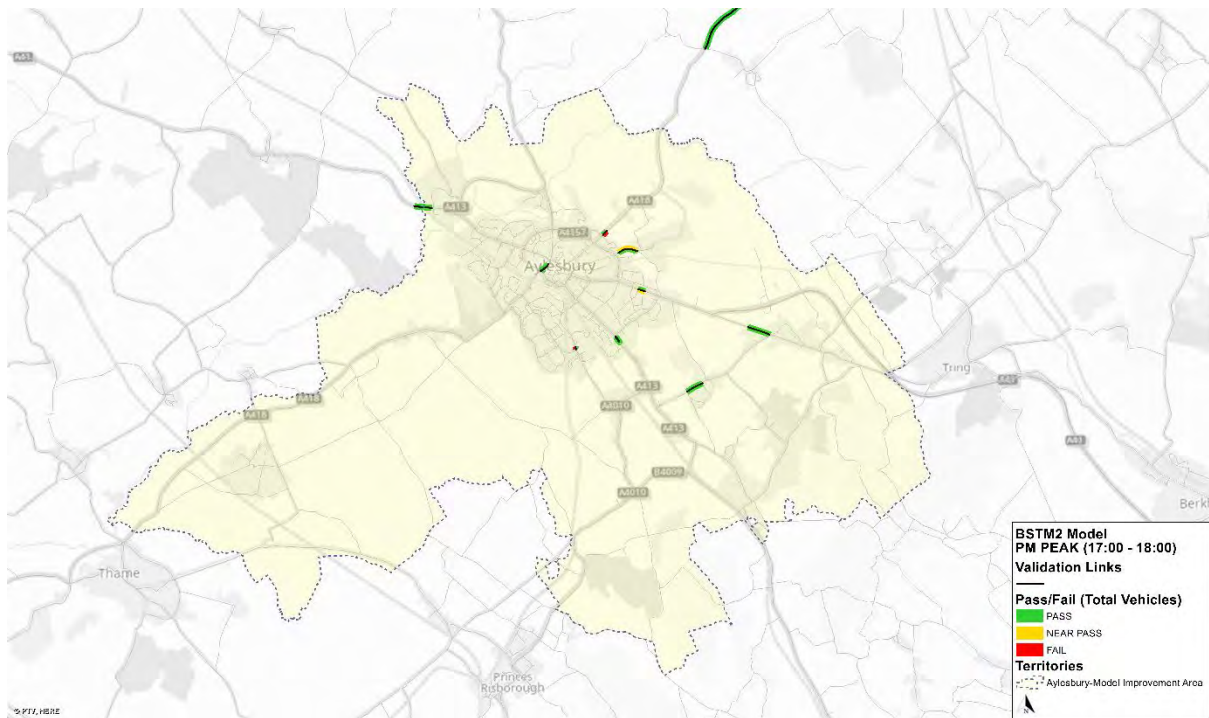


Figure 9-13 – Link Flow Validation PM Peak- High Wycombe

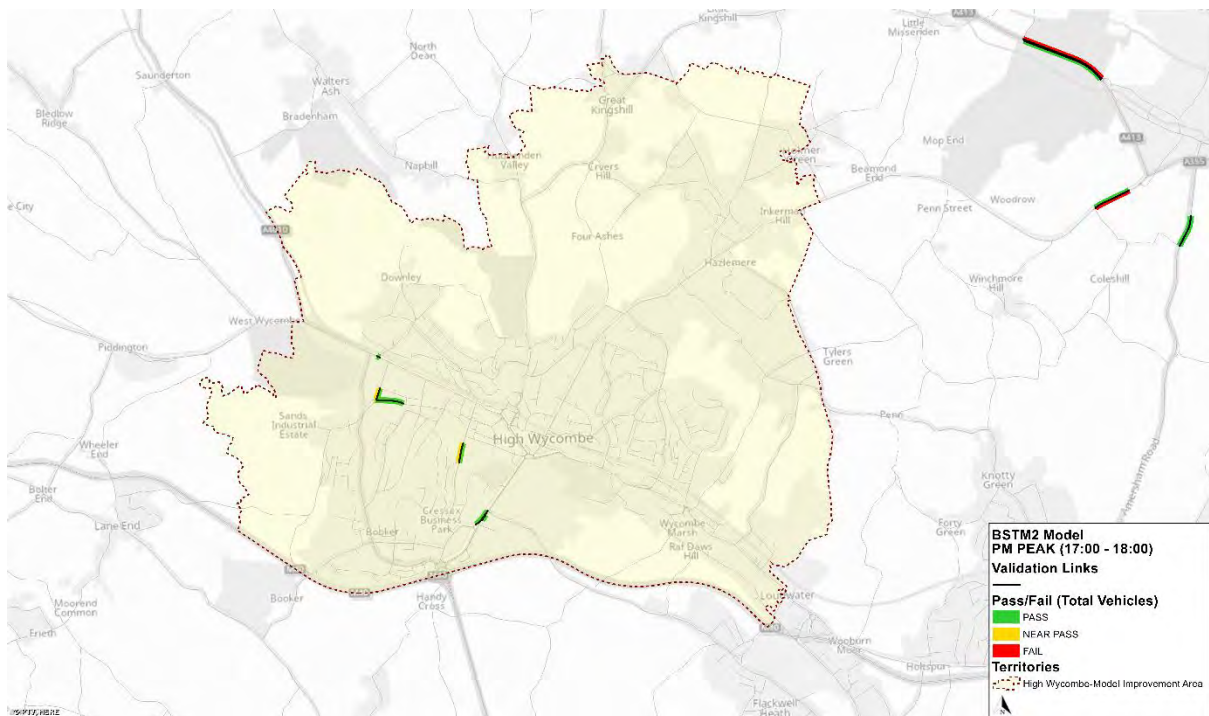
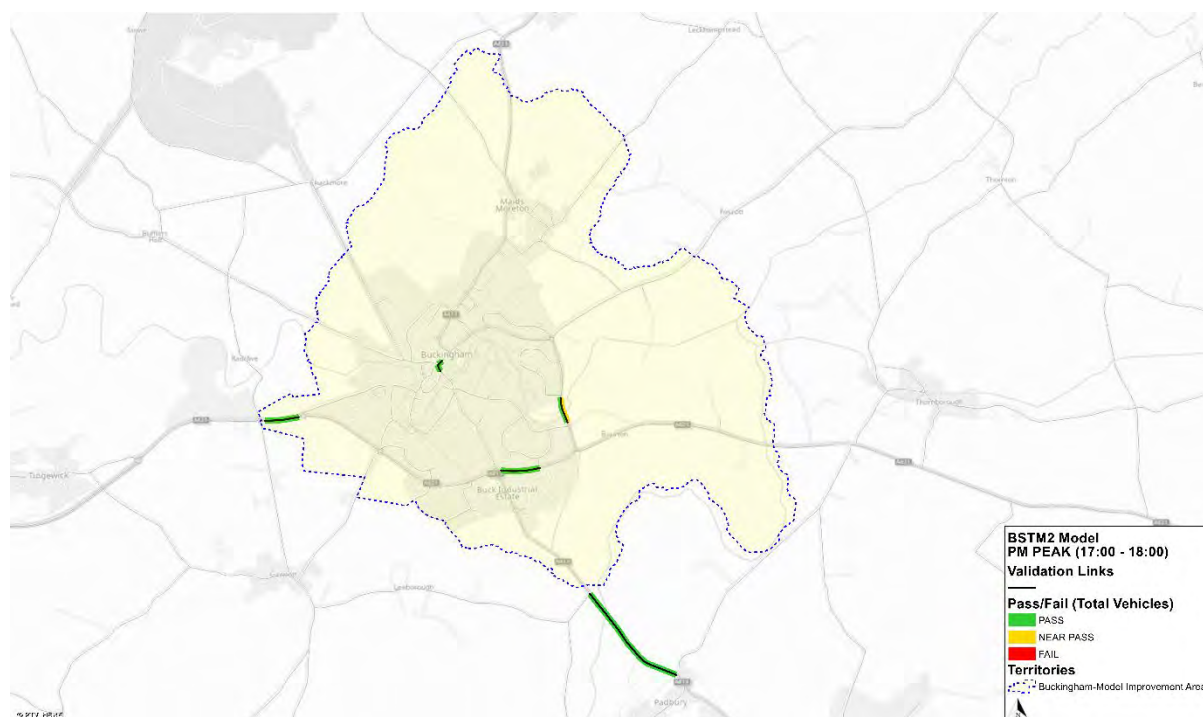


Figure 9-14 – Link Flow Validation PM Peak- Buckingham



9.3 Journey Time Validation

Journey time validation was undertaken to ensure that travel times and delays along links and at junctions across the study area are accurately represented in the model. The validation was based on a comparison of modelled and observed journey times along the 84 survey routes (in both directions) shown in Figure 9-15.

A summary of the journey time validation for each time period is presented in Table 9-10.

Table 9-10 - Journey Time Validation

	AM	IP	PM
Total	86% (72 out of 84)	92% (77 out of 84)	87% (73 out of 84)

Table 9-10 shows that 83%, 92% and 87% of the journey time routes are within the 15% or 60 seconds TAG criteria of achieving for more than 85% routes in the AM peak, Inter-Peak and PM peak hours respectively. This demonstrates a high level of journey time validation.

A summary of the journey time validation for each time period within each MIA is shown in Table 9-11, with full details of all 84 routes found in Appendix L.

Table 9-11 - Journey Time Validation in each of MIA

Area of model Improvement	No. of Routes	AM	IP	PM
Aylesbury	18	94%	100%	94%
High Wycombe	10	70%	80%	80%
Marlow	4	75%	100%	75%
Bourne End	2	100%	100%	100%
Buckingham	14	100%	100%	100%
Outside MIA	36	81%	86%	81%
BSTM2 Area	84	86%	92%	87%

The following can be observed from Table 9-11:

- In Aylesbury, Bourne End and Buckingham a very high level of journey time validation has been achieved;
- In High Wycombe, 2 routes which fail in the AM peak hour have modelled journey times within 16% of observed which when considered would raise the level of validation to 90%; and
- In Marlow, 1 route which fails in the AM peak hour has a modelled journey times within 24% of observed which when considered would raise the level of validation to 100% whereas 1 route which fails in the PM peak hour has a modelled journey times near to 15% of observed which when considered would raise the level of validation to 100%.
- Outside MIAs, if the within 18% of observed journey time criteria is considered, the level of validation will increase to 94% in AM PEAK, 97% in Inter-Peak and 83% in PM peak.

Therefore, it considered that is a good level of journey time validation in the whole BSTM2 area.

Figure 9-16 to Figure 9-18 show the individual route validation and shows how the model compares to observed journey time data for each time period. It can be observed that the majority of routes that are failing lie in the south-east of Buckinghamshire away from the MIA's.

Figure 9-15 – Journey Time Routes in BSTM2

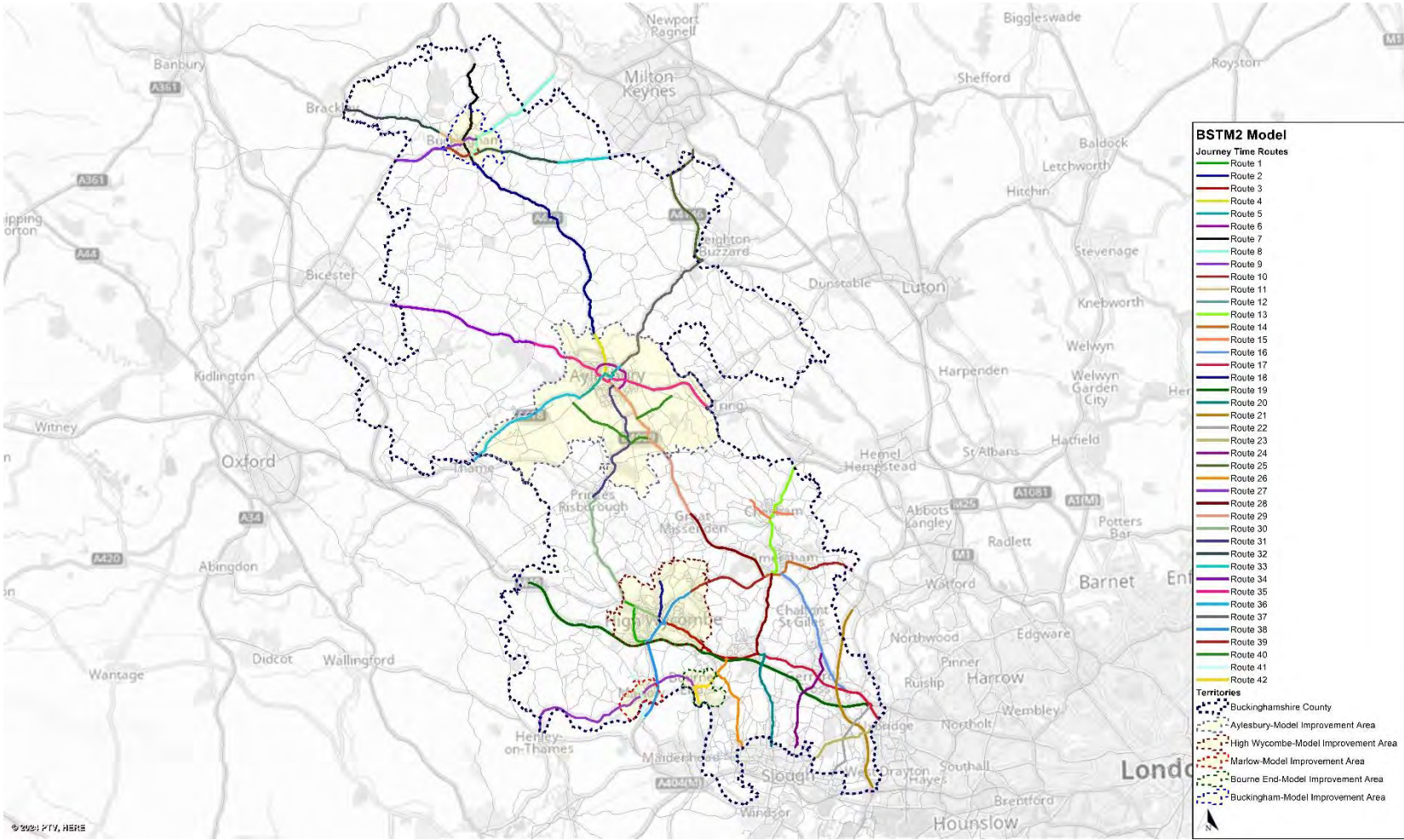


Figure 9-16 – Journey Time Validation – AM Peak

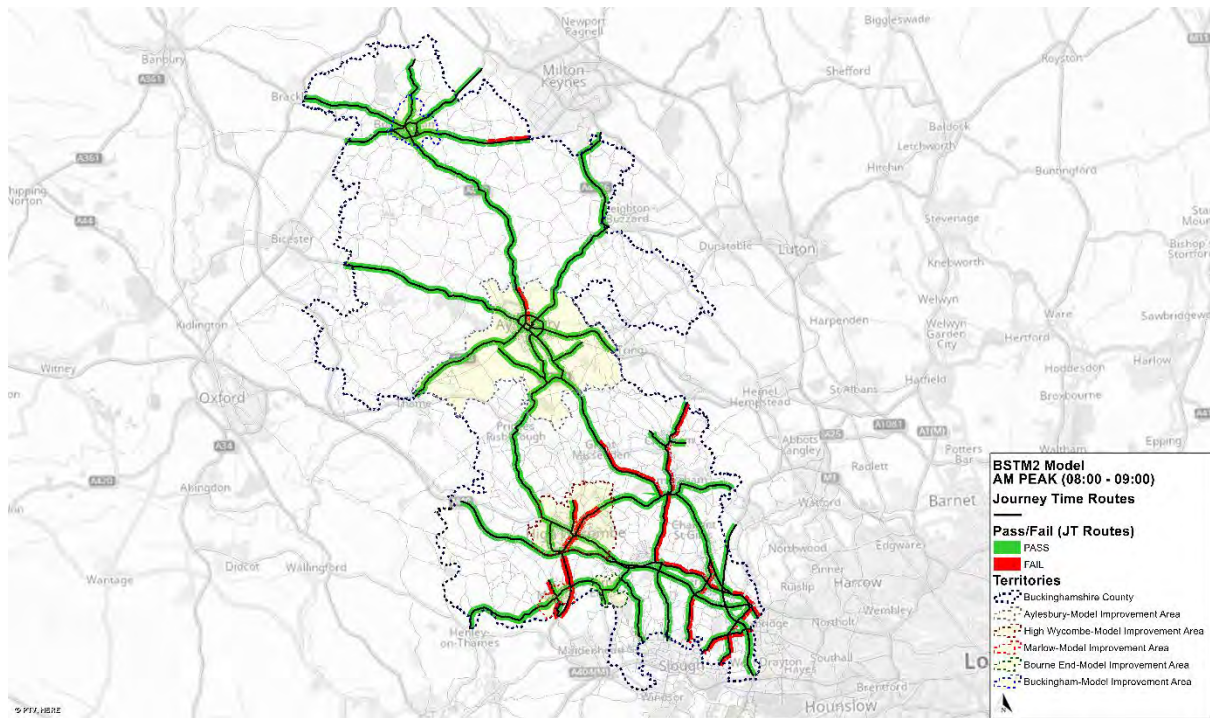


Figure 9-17 – Journey Time Validation – Inter-Peak

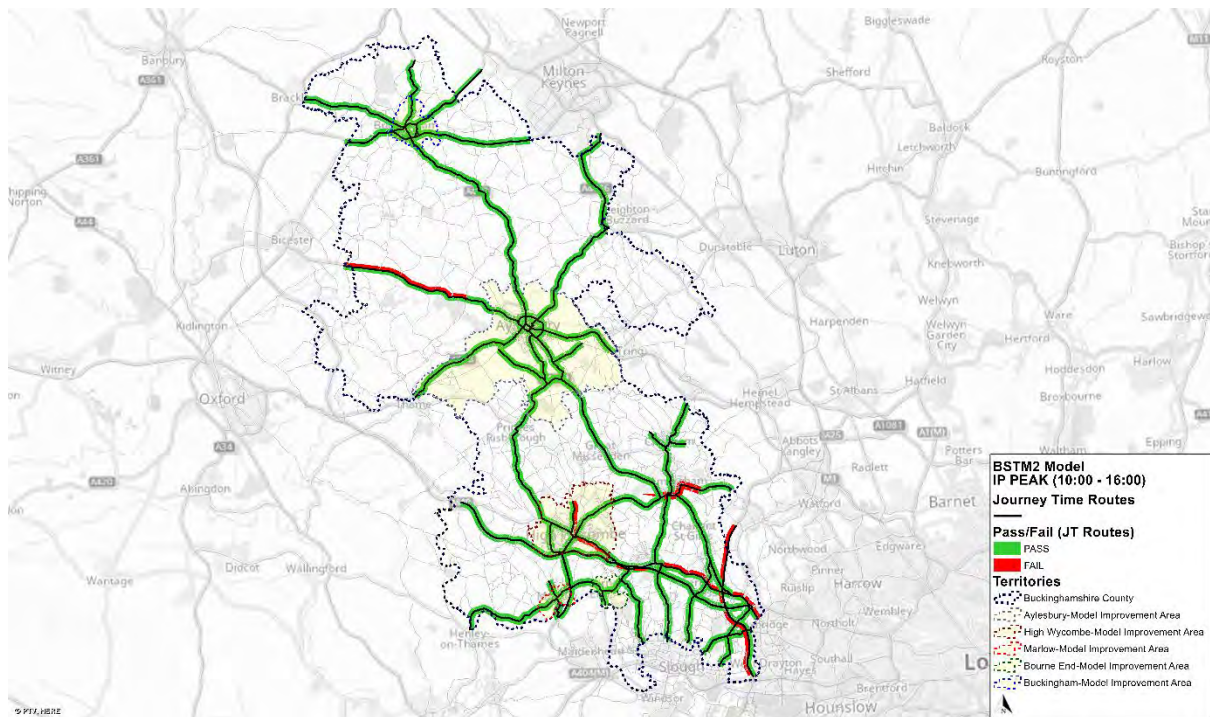
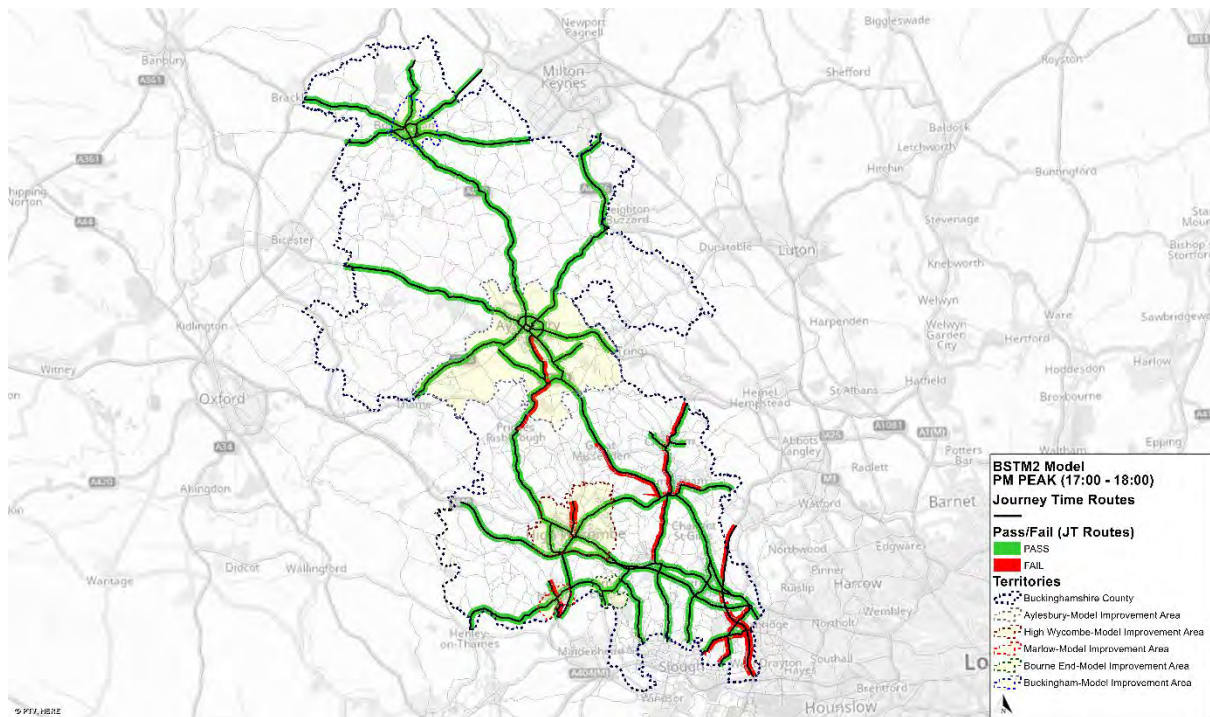


Figure 9-18 – Journey Time Validation – PM Peak



The journey time validation plots in Appendix M show that for the majority of the routes there is a good correlation between modelled and observed times for the length of the route with appropriate levels of delay at key junctions.

The journey time routes provide coverage of all key roads across the model area and show a high level of validation providing confidence in the model's representation of capacity and delays throughout the model area.

9.4 Routing Validation

The validity of route choice was also checked in the model by examining modelled routes between selected origins and destinations. The selected routes focus on important strategic movements or movements through key areas of the model.

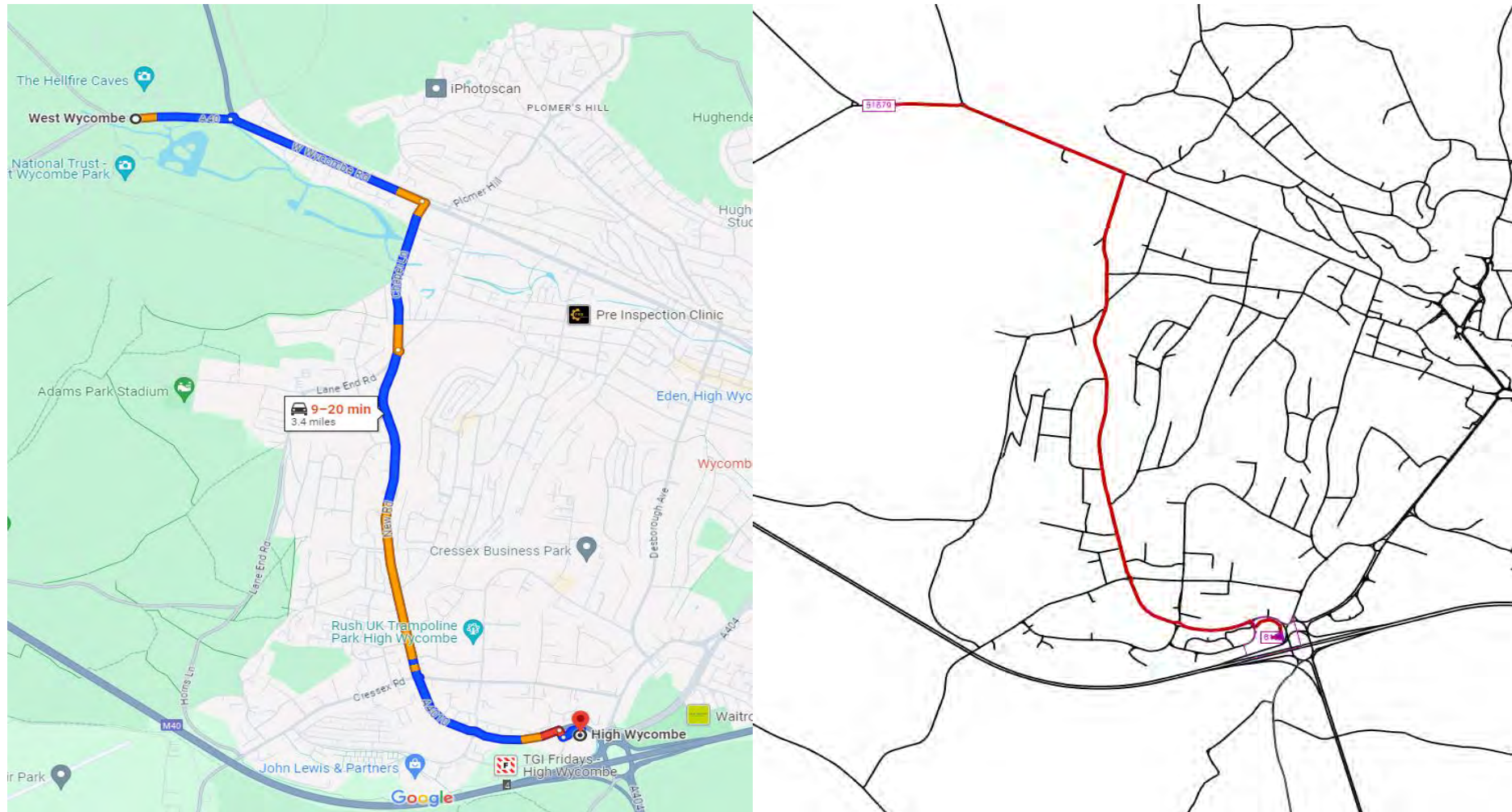
TAG M3.1 states in para 7.3.2 that "The number of pairs of zones which should be examined and displayed will be dependent on the size of the model. The following rule of thumb should be used:

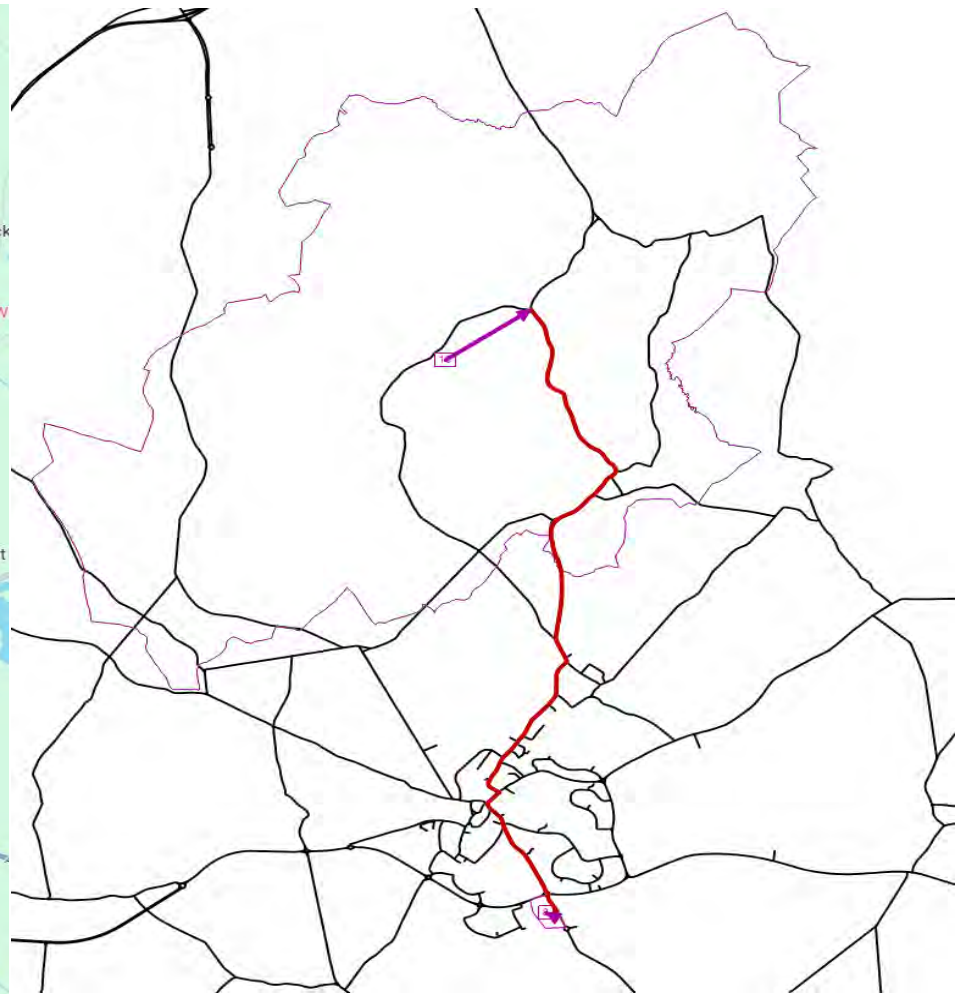
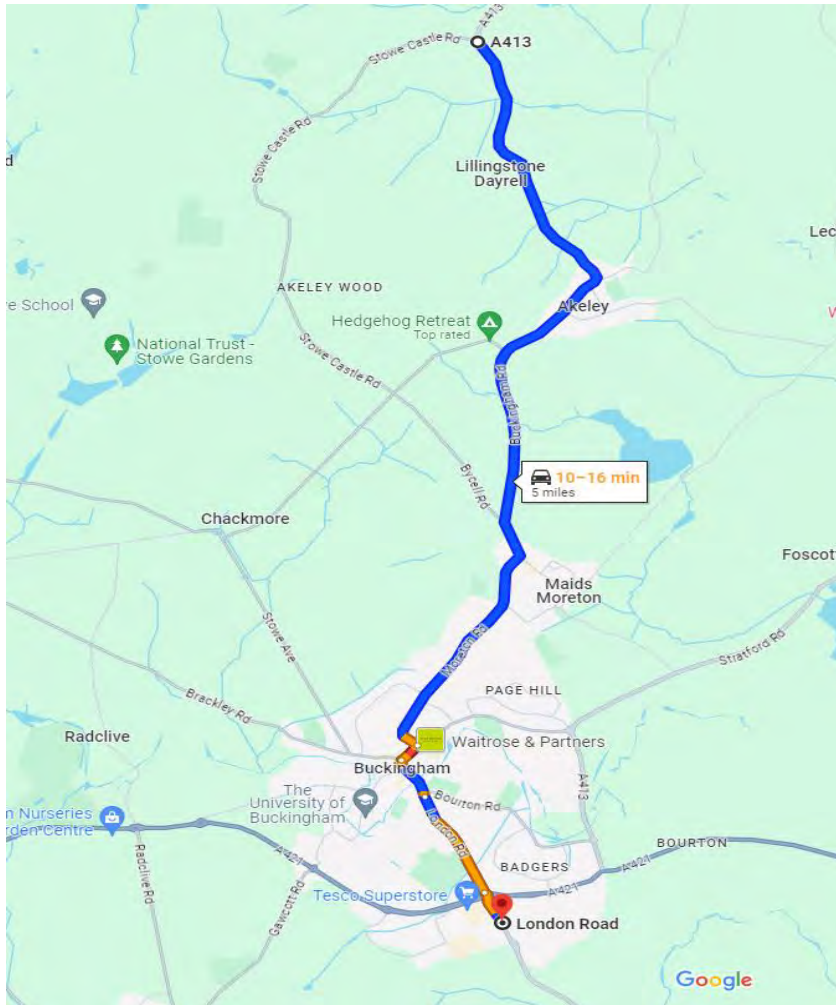
$$\text{Number of OD pairs} = (\text{number of zones})^{0.25} \times \text{the number of user classes.}$$

Given that there are 912 zones and the assignment has five user classes, this means that about 27 OD pairs need to be checked as a minimum.

A few sample route choice validation are shown in Figure 9-19. The remaining routes are shown in Appendix N and are all logical.

Figure 9-19 – Sample Route Choice Validation





10. Summary

10.1 Need for the new model

The BSTM is a highway assignment model (HAM) with fixed demand adopting the base year 2019. It was built following the Department for Transport's (DfT) Transport Appraisal Guidance (TAG) but does not fully comply with its requirements for link validation, screenlines or journey times with enhancements needed in several key urban areas. In addition, the BSTM doesn't have components of public transport modelling and variable demand modelling.

Following the review of the BSTM by AtkinsRéalis, the below list of improvements were suggested:

- The addition of variable demand modelling (VDM);
- The addition of public transport elements; and
- The enhancement of the model validation in selected urban areas (Aylesbury, High Wycombe, Marlow, Bourne End and Buckingham).

The purpose of the BSTM2 is to provide a model that better meets the relevant TAG standards in the above-mentioned urban areas and includes the provision of a VDM component.

10.2 Model Build and Calibration

Highway assignment models have been developed to represent the AM peak hour (08:00 – 09:00), the average Inter peak hour (10:00 – 16:00) and the PM peak hour (17:00 – 18:00) traffic conditions.

Traffic count data was collated from a variety of sources: BSTM counts at 354 sites, SEALR(ATM) counts at 34 sites, new ATC data at 38 sites and 58 CTC sites. Adjusted prior matrices from BSTM were taken as a starting point and then further calibrated to overcome demand gaps at key points of divergence from observed traffic flows. Matrix estimation (ME) was then employed to adjust the prior trip matrices to observed traffic counts. The output matrices were compared to pre-ME for changes in trip totals and trip length distributions.

Table 10-1 show the screenlines pass/fail results for the AM, Inter-Peak and PM peak hours, both for the model extent and the areas of model improvement. Here, 'pass' is considered if the TAG criteria are fully met (i.e. flow difference<5%), 'near pass' if the TAG criteria is not met but flow difference<10% and 'fail' if the TAG criteria are not met and flow difference>10%.

Table 10-2 and Table 10-3 show the link pass/near pass/fail results for the AM, Inter-Peak and PM peak hours, both for the model extent and the areas of model improvement. Here, 'pass' is considered if the TAG criteria are fully met (i.e. GEH<5 or the flow difference criteria is met), 'near pass' if the TAG criteria are not met but GEH<7.5 and 'fail' if the TAG criteria are not met and GEH>7.5.

The calibration at the screenline level showed that if a pragmatic approach (GEH< 4) is adopted, 97%, 88% and 85% of screenlines in the AM, IP and PM peak, respectively, were within TAG guidance thresholds for total vehicles as shown in Table 10-1. At the individual link calibration level, over 90% of the links passed the TAG criteria in all peaks, the high-level results are summarised in Table 10-2.

Table 10-1 - Highway model screenline calibration results (Total Vehicles)

Area	Counts	AM	Peak				Inter	Peak				PM	Peak			
		Flow Diff <5%	GEH<4	Pass	Near Pass	Fail	Flow Diff <5%	GEH<4	Pass	Near Pass	Fail	Flow Diff <5%	GEH<4	Pass	Near Pass	Fail
Aylesbury	14	86%	93%	86%	14%	0%	86%	100%	86%	14%	0%	86%	93%	86%	14%	0%
High Wycombe	10	90%	100%	90%	10%	0%	90%	100%	90%	10%	0%	70%	90%	70%	20%	10%
Marlow	2	100%	100%	100%	0%	0%	100%	100%	100%	0%	0%	100%	100%	100%	0%	0%
Bourne End	2	50%	100%	50%	50%	0%	50%	100%	50%	50%	0%	100%	100%	100%	0%	0%
Buckingham	2	100%	100%	100%	0%	0%	50%	100%	50%	50%	0%	100%	100%	100%	0%	0%
Outside MIA	44	84%	98%	84%	14%	2%	45%	80%	45%	41%	14%	52%	80%	52%	30%	18%
BSTM2 Area	74	85%	97%	85%	14%	1%	61%	88%	61%	31%	8%	65%	85%	65%	23%	12%



Table 10-2 - Highway model link calibration results (Total Vehicles)

Area	Counts	AM	Peak				Inter	Peak				PM	Peak
		Flow Diff <5%	GEH<4	Pass	Near Pass	Fail	Flow Diff <5%	GEH<4	Pass	Near Pass	Fail	Flow Diff <5%	GEH<4
Aylesbury	102	98%	98%	1%	1%	97%	97%	3%	0%	95%	95%	2%	3%
High Wycombe	60	83%	83%	17%	0%	95%	95%	3%	2%	95%	95%	5%	0%
Marlow	12	92%	92%	8%	0%	100%	100%	0%	0%	92%	92%	8%	0%
Bourne End	16	94%	94%	6%	0%	94%	94%	6%	0%	88%	88%	13%	0%
Buckingham	32	100%	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%
Outside MIA	182	96%	96%	3%	1%	96%	96%	3%	1%	89%	89%	8%	3%
BSTM2 Area	404	95%	95%	5%	0%	96%	96%	3%	1%	92%	92%	5%	2%

It is noted that a good level of link and screenline calibration has been achieved for all the MIA's.



10.3 Model Validation

The highway model validation results are presented in Table 10-3. Link flow validation results show a good level of validation against the GEH<5 or flow difference criteria in the three model periods respectively. The journey time validation meets the TAG criteria in the three model time periods showing good level of validation.

Table 10-3 - Highway model validation results (Total Vehicles)

	Area	Counts	AM				Peak				Inter				Peak				PM				Peak			
			GEH (<5) or Flow Diff	Pass	Near Pass	Fail	GEH (<5) or Flow Diff	Pass	Near Pass	Fail	GEH (<5) or Flow Diff	Pass	Near Pass	Fail	GEH (<5) or Flow Diff	Pass	Near Pass	Fail	GEH (<5) or Flow Diff	Pass	Near Pass	Fail	GEH (<5) or Flow Diff	Pass	Near Pass	Fail
Validation	Aylesbury	18	83%	83%	11%	6%	100%	100%	0%	0%	78%	78%	11%	11%												
link	High Wycombe	10	90%	90%	10%	0%	80%	80%	0%	20%	80%	80%	20%	0%												
counts	Buckingham	10	90%	90%	0%	10%	90%	90%	10%	0%	90%	90%	10%	0%												
	Outside MIA	42	64%	64%	17%	19%	71%	71%	10%	19%	69%	69%	7%	24%												
	BSTM2 Area	80	75%	75%	13%	13%	81%	81%	6%	13%	75%	75%	10%	15%												
Journey time routes	All vehicles	84 Routes		86%		14%		92%		8%		87%		13%												

The overall model link calibration and validation (combined) for different areas is presented in Table 10-4.



Table 10-4 - Model performance in different areas

Area	AM		IP		PM		Number of counts
	Car	Total	Car	Total	Car	Total	
Amersham	89%	89%	89%	93%	79%	75%	28
Aylesbury	96%	96%	98%	98%	92%	93%	120
Beaconsfield	92%	92%	88%	85%	81%	77%	26
Bicester	100%	100%	100%	100%	100%	100%	8
Bourne End	94%	94%	94%	94%	94%	88%	16
Buckingham	93%	98%	95%	98%	98%	98%	42
Chesham	100%	100%	100%	100%	100%	92%	12
Gerrards Cross	100%	100%	100%	100%	80%	80%	10
Great Missenden	100%	100%	100%	100%	88%	100%	8
High Wycombe	87%	84%	93%	93%	91%	93%	70
Iver	88%	86%	90%	83%	83%	88%	42
Leighton Buzzard	88%	75%	100%	88%	75%	75%	8
Marlow	92%	92%	100%	100%	92%	92%	12
Milton Keynes	93%	79%	93%	93%	79%	86%	14
Princes Risborough	100%	100%	100%	96%	92%	92%	24
Slough	83%	83%	94%	94%	78%	72%	18
Tring	100%	100%	83%	83%	100%	100%	6
Winslow	100%	100%	100%	100%	100%	100%	6
Rest of Modelled Area	79%	79%	93%	86%	86%	93%	14
Total	92%	92%	95%	94%	89%	89%	484

There is a good level of calibration and validation across the BSTM2 model area.

10.4 Conclusion

Whilst it can be argued that model validation falls short of TAG thresholds in certain areas, as the name implies, TAG provides “guidance” as opposed to strict requirement. The DfT confirms this position in M3.1 #3.2.2 where it states the following:

“The achievement of the validation acceptability guidelines specified ... does not guarantee that a model is ‘fit for purpose’ and likewise a failure to meet the specified validation standards does not mean that a model is not ‘fit for purpose’. A model that meets the specified validation standards may not be fit for particular purposes and, conversely, a model that fails to meet to some degree the validation standards may be usable for certain applications. Local Model Validation Reports should therefore not include statements to the effect that, because the validation standards have been (largely) achieved, the model is necessarily fit for purpose”.

Moreover, M1.1 #4.9.5 states: “Even when a model performs well against these tests, there is no guarantee that it will not produce misleading forecasts, but the risk of this happening is considerably reduced. Conversely, a model which does not perform particularly well against these tests may still be useful for some purposes (e.g. relatively minor schemes or early stage option sifting), providing the risks are understood and managed. However, even at these early stages, models should only be used if their response is plausible”.

It is therefore not uncommon for large strategic models not to be fully compliant with the guidance in every respect. Pragmatism and proportionality should therefore be applied to assess how good the model fit is and how much impact this has on the testing of Use Cases. Where there are differences between the model and TAG guidance, we need to demonstrate this does not undermine the quality of the model for specific applications.

Given the above, we believe that in terms of link, screenline and journey time validation the BSTM2 is a significant improvement on the BSTM, with a good level of validation in the MIAs and is therefore suitable for use in a predictive mode for the intended purposes.

APPENDICES



Appendix A. Link Types



Appendix B. VDF Curves



Appendix C. Correspondence of BSTM2 Zones to BSTM Zones



Appendix D. Location of Connectors in model improvement area



Appendix E. Screenline Calibration with Prior Matrices



Appendix F. Comparison of trip length distribution for all user classes and for all time periods.



Appendix G. Percentage change in trip levels between sectors, prior to post matrix estimation



Appendix H. Screenline calibration by vehicle type



Appendix I. Link Calibration by Vehicle Type



Appendix J. Screenline Validation by Vehicle Type



Appendix K. Link Validation by Vehicle Type



Appendix L. JT Route Validation Statistics



Appendix M. Journey Time Validation Plots



Appendix N. Route Choice Validation



Appendix O. Local Model Validation Report - BSTM



Appendix P. Local Model Validation Report - SEALR



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